SOCIOECONOMIC PERSPECTIVE OF DEFORESTATION AND FOREST DEGRADATION IN NEPAL

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ABSTRACT

SOCIOECONOMIC PERSPECTIVE OF DEFORESTATION AND FOREST DEGRADATION IN NEPAL

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Deforestation and forest degradation are the major ecological problems in developing countries. It is a dynamic process which can be attributed to various socioeconomic and biophysical factors, resulting in the conversion of forest area into a mosaic of mature forest fragments, pasture and degraded habitat.

In this research, a multi-agent analysis of social and economic complexity of deforestation was developed for Nepal at two different scales. We offered the temporal analysis of forest changes, people's livelihood and forest dependency at local scale, and the spatio-temporal extent of various proximate and underlying causes of forest changes at regional scale in an attempt to explore the socioeconomic perspective of deforestation and forest degradation in Nepal. At local scale, we quantified the major forest types and forest cover changes in Chitwan distict, where except for riverine forest, forest areas of all other forest types were reduced. Terai Shorea robusta forest, which has high commercial value, showed a loss of 23% between 1976 and 1989, and an overall forest cover loss of 15% between 1976 and 2001. An artificial neural network predicted in five classes of forest canopy density using Landsat image of 2001 with overall accuracy of 82%.

A household survey in Chitwan revealed that 82% of all households still collected firewood and 81% gathered fodder from the forest and 42% of all households used forest fringe for grazing. The Forest Product Availability Index showed a sharp decline from 0.781 to 0.360. Timber wood was noticeably lower than the other forest products. These findings showed people's high forest dependency in

the district. These support the hypothesis that forest land has been excessively converted to farm land, or the forests resources were heavily extracted in the past.

Similarly, population factors, growth of arable land and food insufficiency could be a main cause of high forest degradation and deforestation in Terai. Pearson's correlation coefficient significantly showed (r = - 0.750 and r = - 0.788, p = 0.01) a negative association between population and forest area loss for 1958 and 1978 respectively. Moreover, pressure on forest significantly increased from about 2.4 people/ha to 17 people/ha during the same period. Similarly, forest area lost and growth in arable land showed a strong negative correlation association significance (r = -.745, p = 0.01) between 1958 and 1996 while association negatively correlated and significance (r = -.485, p = 0.05) for 1958-2001. Further, forest area and food insufficiency in 2001 in Terai showed also a strong negative association with significance of correlation coefficient (r = - .492, p = 0.05).

Landuse/land cover analysis of the whole Terai region showed that agricultural land increased by 542,481 ha (47%) in 2001 from 1,150,196 ha in 1963/64. Area covered by food crop increased by 19% in between 1986/87-2005/06. There was an increase of 104,800 ha of crop land and a decrease of 71,600 ha of wood and forest land between 1991/92-2001/02. Food security results based on Food Supply to Demand Ratio showed that more than half of the districts were classified under potentially food secured and unsecured category. Seven districts out of 20 had food deficit of 8-16 times during the study periods. The productivity of major food crop was not promising and below the production potential. About 60% of holdings found to be unable to survive from their own agriculture production. This indicated that Terai was also not a food secure region considering 20% excess food production for unforeseen food shock.

We integrated GIS, RS and socioeconomic data and recognized a wide variety of factors impacting on forest conditions. The integration of socioeconomic data in GIS and RS was capable of mapping and analyzing complicated relations between socioeconomic and biophysical forest parameters. The perspective presented in this study was promising in that these applications and demonstration of socioeconomic data could be a useful indicator in forest management processes. There are

significant differences in socioeconomic structures, forest resources, and historical processes in the use and management of forest resources between the districts as Nepal shows a diverse topography and socioeconomic differences.

Therefore, further studies on forest resource monitoring integrated with better understanding of socioeconomic factors considering the location specific problem is needed in Terai to sustain the tropical forest management system. These results suggest that some of the agent's behaviors and forest management plans should change to promote sustainability of the forest reserve such as broadening government's role to improve management plans and monitoring, and to prevent encroachment of forest land by improving living conditions of potential settlers outside the forest. In addition, other alternatives for instance changes in temporal interdependency could be potential research field to be explored in future work.

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CHAPTER 1 INTRODUCTION

1.1 Background

Forest types and their spatial coverage offer a proxy indicator that aids better understanding and monitoring of the dynamics of quality, quantity and condition of forest resources. Forest resources are crucial for the wellbeing of humanity with their economical and environmental value (Sati, 2006) and foundation for life on the earth through ecological function (FAO, 1999). More than 1.6 billion people worldwide depend on forests for some part of their livelihood (USAID, 2007). Forest area and its changes are important and supposedly easily measurable indicators for sustainable resource management in larger areas to improve environmental and economic health (Kleinn, 2001; Morrow et al., 2001). Forest cover and density are important indicators of ecological stability and vestiges of forest play a significant role in conserving the natural world (Valente and Vettorazzi, 2008) while fragmentation of it enhances the isolation of forest patches and decrease in their size (Geneletti, 2004). However, human influences to transform forested lands are one of the great forces in global environmental change where 13.5 million hectares of tropical forest is cleared annually for agriculture, timber products and infrastructure development (FAO, 2001; Geist and Lambin, 2002). Moreover, the pace of tropical forest deterioration signifies the risk of our quality of life, threat in stability of climate, and undermines the valuable services provided by biological diversity (Butler, 2001).

In spite of an increased recognition of the value of tropical forest resources at national and international levels, most of the forests are continuing to be seriously threatened and disappearing at an alarming rate. In tropical regions, deforestation and forest degradation are progressive processes that are advancing at an alarming rate (Verolme et al., 1999; Rudel and Roper, 1997; Laurance, 1999), resulting in the conversion of forest area into a mosaic of mature forest fragments, pasture and degraded habitat. Deforestation is one of the major environmental problems in developing countries (Araya et al., 2003) and rapidly depletion of forest resource is

resulting into other various social and economic problems. Deforestation and forest degradation are the consequences of the interaction of the various environmental and socioeconomic forces at work in any given region. It is a dynamic process which can be regulated by complex biophysical and socioeconomic factors (Namaalwa et al., 2007). These factors play a significant role in forest fragmentation and can have large degrees of variation across the landscapes. Natural or anthropogenic, impacts of disturbances are always complex in the dynamics of forest ecosystems (Barren˜ada Sanz, 2001; Kuuluvainen, 2002 cited in Kangur et al., 2005), they will affect forest structure, composition and ecological processes (Stanturf, 2004; Kangur et al., 2004 in Kangur et al., 2005). People and their livelihood security are often susceptible, particularly those who live in and around the degraded forest's frontiers. While deforestation happens, environmental degradation severely degenerates (WCC, 2000; SOE, 2001) and various natural phenomena as well as socioeconomic circumstances of a particular geography are affected (USAID, 2007; FAO, 1998).

Forest land covers the 29% of the total land area of Nepal (HMG/Nepal, 1999) which is considered as the second largest natural resource (SOE, 2001) and important assets from a socioeconomic point of view (Acharya, 2002). About 83 % of the rural population in Nepal depends mainly on forest resource for cooking and house heating (SOE, 2001, FAO, 1999). Since the beginning, Nepal has long experienced various forest management approaches and the history of forest resource has been summarized by various authors (Hobley, 1996; Pokharel, 1997; Acharya, 2002; Sinha, 2003). Accordingly, during the Rana dynasty in 1924, forests were managed through the central forest management system from the national level (Palit, 1996). Later, traditional and indigenous forest management systems were practiced until the mid-1950s (Messerschmidt, 1987; Thapa and Weber, 1995) and it was based on long historical experience that spontaneously reflected in the dynamics of particular forest ecosystem. Therefore, systematic forest management systems barely existed until the 1950s (Mahat et al., 1986) and concern about deforestation did not begin until 1975 (Shrestha and Britt, 1998).

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 (Petheram et al., 2002 and Kanel, 2004; Kanel and Niraula, 2004 in Gilmour et al., 2004). However, some comments despite a few attempts and successess, 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, 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.

Regardless of various policies, rules and effort have been contributed from different sectors in forest management process, deforestation and forest degradation has not been stopped yet and a persistent rate of forest degradation is still observed in Terai (Joshi, 2006). Systematic assessment, intensive monitoring and sound management plan for forest resource have not been fully implemented throughout the region. Therefore, the analysis of actual deforestation and forest degradation and its socioeconomic impact is essential in the Nepalese context.

1.2 Problem statement

Nepal is still in quest of capacity development in terms of human resources and technology enhancement for proper and systematic forest resources management. Natural resource management strategy has been initiated across the country to pursue better management in forest resources (WWF, 2004/05). However, effort is far less

than satisfactory yet. Due to some conceptual and practical difficulties in forest resource planning and management processes, there are still challenges in data updating and managing with limited ease of use in spatial data. Further, the adaptation of new technology, expertise, research potentiality and significance are also limited. It requires undertaking the socioeconomic and technical issues with the cooperation of all stakeholders involved for the inclusion of those approaches in decision-making level. However the sustainable forest resource planning and management with integration of socioeconomic and technological concerns are still missing across the region.

Although it is widely known that deforestation and forest degradation are a significant problem in the Terai of Nepal, a thorough understanding of the specific human and socioeconomics consequences by which it occurs is considered deficient. Much is known about the problems associated with, but very little is known on the proximate and distant cause and underlying forces behind such processes in Nepal. Another challenge is how to assess the forest quality, quantity and develop approaches to reduce such processes.

With this fact, about 182,770 ha forest has been cleared from 1956 to 1985 (FAO, 1999) and 5.8 to 4.6 million ha between 1985 and 1993 (CBS, 1998). Crown density of forest has severely degraded in Terai (Regmi, 1988). Growing stock of Shorea robusta has also declined from 101 to 72 m^3/ha and other hardwood forests 76 to 58 m^3/ha (FINIDA, 1993). Most of the forest has a thin over storey canopy of trees with virtually no regeneration (SOE, 2001) hence the traditional forest management system has disrupted. Recently, about 70, 256 ha area has estimated under forest encroachment in Terai and inner Terai districts (Acharya, 2003; GIDA, 2003 in Bampton and Cammaert, 2006). Similarly, about 8,821 ha forest land has lost during 1990/91-2000/01 (MFSC/DOF, 2005). More recent research has been summarized by Joshi (2006) indicating that forested area was reduced from 21,774 km^2 in 1958 to 12,649 km^2 in 2000 in Terai. It proves the magnitude and spatial extent of forest resource depletion is growing rapidly (WCC, 2000). Nevertheless, factors which could accelerate the deforestation and forest degradation process have not been well understood in the Nepalese context yet.

Some authors have focused on the issue of monitoring deforestation and forest degradation (Achard et al., 2002; MFSC/DOF, 2005, Joshi, 2006) while others focused on socioeconomic phenomena and forest degradation (Namaalwa et al., 2007). However, studies have rarely focused on the remotely sensed deforestation and forest degradation at forest type's level combined with GIS and socioeconomic data. Confronted with this, we argue that a thorough understanding of socioeconomic prospects in a spatial and temporal context by which forest condition has been deteriorating need to be analyzed. The analysis of spatial and temporal perspective of deforestation in association with socioeconomic factors could resolve this knowledge gap and provide a basis for the sustainable management of Terai forest and similar areas elsewhere in Nepal. Understanding of these processes needs an integrated approach linking a wide range of socioeconomic data in the forest biometry at different scales.

1.3 Significance of the study

Monitoring the forest status and assessing impacts caused by various human induced activities are important in assessing the planning process, effectiveness of forest management (Nagendra et al., 2005) and the changes brought by them (Schweik, 1998). With the advent of spatial data acquisition using GIS and remote sensing technology, the assessment of forest resources are now becoming more accurate and sophisticated. These technologies are creating the possibility to build spatial knowledge of biophysical and socioeconomic aspects of forest resources. This potential has been extensively used in mapping resources, land cover and land uses. Furthermore, it also allows us to develop spatial models that are useful in predicting impacts. These characteristics facilitate in conceptualizing the situation and help in translating impacts prediction results into appropriate management plan and policy measures.

We studied the socioeconomic perspective of tropical forest degradation and emerging scientific challenges by combining the remote sensing, GIS and socioeconomic data. Remotely sensed deforestation and forest degradation

information integrated with those of socioeconomic studies could provide a good reference for planning future forest management projects. The detailed analysis undertaken here aims to provide a basis for the future management of Terai forest and similar areas elsewhere in Nepal. 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. Maps and results that are executed by this study could be useful for the government and non - governmental authorities for conservation and sustainable management of natural resources in Nepal. This could also bring overall ecological benefits to take up proper assessment and legislative processes to address existing disputes across the region.

1.4 Research objectives

The two main objectives of this research are as follows. The first is to quantify and map the spatio-temporal patterns of deforestation and forest degradation processes. The second is to explore the promising proximate cause and underlying forces behind those processes.

To achieve the first goal, we quantify and map the forest cover changes and compare the conditions of all major forest types in Chitwan district using remote sensing and GIS technology from 1976 to 2001.

To achieve the second objective, we realized that there could be diverse socioeconomic causes behind such deforestation and forest degradation; hence analysis of those complex causal factors is essential.

To accomplish these objectives, three sub-objectives are defined. Firstly, we analyzed the livelihood strategy of the rural people and the historical processes of forest use and management in and around at the local scale in Chitwan district. Secondly, we explored and analyzed the demographic factors, poverty, land tenure, dependency on forest and forest resource statuses in an attempt to link and visualize the information needed to assess the present circumstances hindering forest resource management in Terai as regional scale. Thirdly, we analyzed land use change, major food crops production and map the food security status to link with other

socioeconomic indicators and forest degradation and deforestation processes in Nepalese Terai.

1.5 Organization of the dissertation

The remainder of the dissertation is organized as follow. Chapter 2 provides a broad overview of the core theme of the thesis. It highlights the linkages between tropical forest resources, human well-being, socioeconomic factors and forest resources depletion. It reviews the research works that has been carried out on the concerns of major casual factors of forest degradation and deforestation. Socioeconomic factors are the predominant underlying forces, which has greatly influenced forest resource phenomena that are frequently mentioned in most of the literature. Previous work related to these topics and the various forest management related issues considered in thesis are reviewed. It reviews mapping methods and demonstrates how the modern tools can be used to enrich our understanding of forest resource management.

In Chapter 3 we mainly focus on the clarification about study area, data sources and data uses and methodology derived and uses for the whole analysis. Thus, detail about the data, data sources and methodology used for the corresponding chapters are described in subsequent sections of Chapter 3.

In Chapter 4 we analyzed spatial and temporal trends of forest degradation and deforestation in Chitwan district of central Nepal using remote sensing and GIS tools. We calculate the forest cover changes using multi-temporal satellite dataset, map the forest canopy density to assess the forest health and degradation, and compare the conditions of all major forest types in the region. Our finding showed that the forest and area of major forest types were disproportionately reduced in Chitwan. In this situation forest dependency could be higher and availability of forest products which can be extracted from the remaining forestlands could be in a decreasing trend. Further, the livelihood options of rural people might be limited rather than the dependency on forest and forest services. Therefore, we further analyzed the livelihood strategy of local people and their dependency on forest resources in the

same area. It provides clearer portrait on current status of rural livelihood, degree of their dependency on forest which can have an effect on the forest degradation process in Chitwan. This analysis focused on the historical processes in the use and management of forest resources and livelihood strategies of rural people in Chitwan. The results of this study are intended to aid in the planning of future actions concerning forest restoration, tropical forest ecosystem management and better management of rural livelihood in the region.

Chapter 5 described an overview of socioeconomic consequences in forest depleting process in Terai at regional scale. Human dimensions such as demography, poverty, and agricultural expansion are some of the factors that could persistently influence forest loss. Therefore, we realized to explore and analyze spatio-temporal extent of population factors (growth, size and density), migration, poverty incidence, and forest resources dependency from larger area could provide imperative information regarding planning and management of forest resources and mitigate the human pressure on it.

Similarly, we analyzed basic food production and the productivity trend of major food crops to examine whether the Nepalese Terai coped with the entire demand of food for growing population or not. This situation could either manage the food ease of use or increase hunger and rural poverty at household level. In later case, hunger and poor are mainly depend on forest resources and prone to the deforestation and forest degradation due to satisfying their basic needs, where livelihood options are very limited from other sectors in the country such like Nepal. Therefore, information on crops productivity and food security status could be supplementary to minimize poverty, hunger and vulnerability against the forest lost. Hence, the situation of land use change, food security and other socioeconomic indicators were analyzed in detail and try to link with forest resources degradation in Chapter 5.

Chapter 6 combines the findings and conclusions of previous chapters. We try to evaluate possible pathways and dissemination of practical, implementable strategies for forest resources management in Nepal. We attempted to acquire a wider socioeconomic view of some of underlying forces of forest degradation and deforestation to better understand the reasoning and explore the possibility of

sustainable forest management in Nepal. Moreover, the Nepalese forest resource management system follows a traditional system of resource management. The traditional information system didn't satisfy the modern needs of forest resource monitoring and management systems. Therefore, this research which combines remote sensing and GIS technology with various socioeconomic data could potentially provide a foundation for decision making processes.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Forest resources are altered either by natural or by human-induced factors. However, human-induced activities are more aggressive and have influenced forest depletion in a variety of ways. Forest management requires up to date technology to ensure the sustainable resource utilization. Recently, technological development and scientific advances have been moving at an incredible pace, providing significant challenges to the forest conservation movement. Nevertheless, a growing body of knowledge and scientific literature has been raised to develop the ecological and economic criteria for forest management. But, relatively little attention has been paid by the forest science communities to the social dimensions of forest.

Deforestation and forest degradation are the human impediments to the forest's biological ability to reproduce itself. In the tropics it involves a complex system because of inter-relation between various driving forces. Due to increasing pressure on tropical forests, the importance in assessing socioeconomic and biophysical constraints on the deforestation process is emerging (Prasad and Badarinath, 2005). Recently, concern has been shifted in developing techniques, for instance landscape structure indices (Peralta and Mather, 2000), socio-economic and biophysical indicators (Prasad and Badarinath, 2005), and modality to comprehend the socioeconomic demolishes on tropical deforestation. This chapter describes a comprehensive review of literature analyzing the socioeconomic prospective of deforestation and forest degradation linking recent technology in the tropical region around the globe.

2.2 GIS and RS in forest resources monitoring

Satellite data have been used in natural resources management including forest mapping since the Landsat program was launched in 1972 (Brockhaus and Khorram, 1992; Joffre R, 1991; Rafieyan et al., 2003; Kellenberge, T., 1998). Remote sensing,

which is regarded as a promising data source for multi-temporal vegetation monitoring, is advantageously aligned to provide maximum benefit from resource expenditure (NCAS, 2002). Deforestation is the conversion of forest to another land cover type (Allen and Barnes, 1985). Satellite remote sensing has been widely used to detect forest change, assess rates of deforestation, and update existing forest maps (Myers, 1980; Defourny et al., 2006). Achard et al. (2002) reported a rate of decline of humid tropical forest of 4.9 million ha per year, a statistic that is 23% lower than the FAO (2001a) estimate of 6.4 million ha per year.

Remote sensing has been also used to gather information on biophysical i.e. vegetation cover and other terrain, and physical parameters, that could have a vital role in decision-making or livelihood options (Sherbinin et al., 2002). However, literature review shows that there are relatively a fewer examples of remote sensing applications in social science research (Rindfuss and Stern, 1998 cited in Sherbinin et al., 2002). Even so, Sherbinin et al. (2002) stated that remote sensing has been initiated since the late 1980s to apply to understand the social process behind deforestation and desertification. Similarly, GIS which is a spatial informatics technology and also equally important for social science analysis, has largely applied to both demographic databases and environmental factors (Guebas, 2002).

Remote sensing technology is a potentially useful mapping tool for providing a spatial synoptic view of changes in forest condition, type and cover over time (Millette et al., 1995; Schweik and Green, 1999). Due to the capability of massive spatial data gathering, the use of GIS in the forestry sector is becoming very important (Hamzah, 2001). Remote sensing and GIS has been efficiently and widely used much in single thematic analysis such as landuse and land cover change mapping (Lambing, 1997; Skole and Tucker, 1993), forest monitoring (Joshi, 2006; Coppin and Bauer, 1994; Rogan et al., 2002), watershed management (Pahari et al., 1996), forest fire management (Kachmar and Sánchez-Azofeifa, 2003) forest policy evaluation (Nagendra et al., 2005), ecological modeling (Tueller, 1989) while yet to be little used in integration of socioeconomic data in GIS and remote sensing for forest management purpose.

It is an important tool in interdisciplinary study of tropical forests (Trigg et al., 2006) for analyzing data and communicating the results (Turner et al., 2001) which provide continuous monitoring of forest developments by detecting changes and integrating the outcome into the databases to ensure sustainable management (Hamzah, 2001). However, uses of remotely sensed data are still limited in GIS, land and natural resources management (Zhou, 1991) and expensive in developing countries. Intensive monitoring and sustainable management of forest resources are essential (Zawadzki et al., 2005) which require systematic information. Nevertheless, limited, scattered and state forward application of remote sensing and GIS technology in forestry in Nepal has been established (Joshi, 2006; Nagendra et al., 2005; MFSC/DOF, 2005; Panta and Kim, 2006; Panta et al., 2008; Joshi et al., 2006). Accurate assessments of forest cover, rates of forest loss and a clear identification of its proximate sources need to be comprised at the first step to analyze the deforestation process. Moreover, it further requires a deeper understanding of the primary mechanisms and driving factors behind forest change.

2.3 Demographic, poverty, deforestation and forest degradation

Deforestation is driven partly by natural disturbances and ecological process (Dunning et al., 1992) and however, human induced activities (Foster, 1992) bear responsibility. It could be either exaggerated by proximate causes that directly result in a conversion of land use/land cover or driving forces that amplify the actions for proximate causes (Chowdhury, 2006). Some authors have mentioned that wood extraction, agricultural expansion, urbanization and infrastructure development are proximate cause of deforestation (Shukla et al., 1990; Burgess,1993; Ojima et al., 1994; Lambin et al., 2003) that could have direct impact in ecosystem, food production mechanism and local livelihoods in the tropics (Foley et al., 2005). While others have mentioned those biophysical factors, population growth, land tenure system and other sociopolitical and economic policies for development are also responsible for accelerating the deforestation process (Kasperson et al., 1995; Ostrom et al., 1999; Geist and Lambin, 2002; Leemans et al., 2003).

In most cases, increasing population growth, poverty and agricultural expansion are the main forces that facilitate deforestation in the short term while wood harvesting and export aggravates over the long term (Allen and Barnes, 1985). Population pressure exerts various socio-economic burdens (Tole, 2002) and other political, social instability and economic development activities could significantly affect the forest cover change and forest degradation (Achard et al., 2002; Hussin and Sha, 1996 in Panta, 2003). Forest degradation often endorsed to population growth, poverty and open access in developing countries (Dayal, 2006) and correcting these factors is difficult (Bluffstone, 1998). Similarly, population growth affect directly or indirectly (ADB, 2004) on natural resources and threatens not only forest and biodiversity but also equally raises concerns regarding food, water security and livelihoods because the poor often depends on them (UNDP, 2002). Population density may increase while communication networks improve (Bampton et al., 2004) and population together with settlement intensification could contribute to rapid deforestation in Terai (Conway et. al., 2000). Similarly, lack of off-farm opportunities, low levels of welfare and limited access to the land resulted pressure on natural resources (Tole, 2002).

Population growth plays an important role in triggering tropical deforestation (Butler, 2001) and there is a strong connection between them (Weese, 2003). Due to a rapidly growing population, dependency on forest and arable land, Terai forest of Nepal possess under a heavy pressure in recent decades (Rautiainen, 1999). But, we argue that the effect of population pressures is a predisposing condition for deforestation and is dependent on the other socioeconomic factors. The dynamics of rural land use is very complex and deforestation is rarely the consequence of one single cause, it is the product of the interaction of many other driving forces. In some cases, rising population pressure and a prevailing climate of rural poverty could be important conditions that facilitate deforestation. Poverty limits the basic aspects of human life but is itself not a direct cause of deforestation. However, it is an underlying condition that could facilitate deforestation and forest degradation (NLSS, 2003; ADB, 2004). Poverty, deforestation and forest degradation are mutually reinforcing and unless proper understanding of these factors in an integrated manner,

environmental protection and poverty reduction could impossible in any geography (ADB, 2003).

In Terai, deforestation has predominantly been caused by the demand for agricultural land and forest products for settlers who migrated to the region from the mountains or hills or from the Indian part of the Gangetic plain. Some literature suggested that migration is also a major factor in forest encroachment in Nepalese Terai (SOE, 2001) and recent increments in forest encroachment could be the result of approximately 300,000 internally migrated people in Nepal (WWF, 2004/05). Deforestation and forest degradation in Terai has stirred with migration (MPFS, 1988) where >90% population were from hills which also play an important role in raising population pressure in Nepal. Various studies confirmed that the cause of Terai deforestation is also associated with the commercial logging and agriculture land expansion to meet the food requirements of the growing population and migrants (UNDP, 1997; UNCED 1992; DFRS, 1999).

The most significant emerging impact of deforestation with its massive loss of ecological services is occurring at local level (Butler, 2001). It is also stated that, a high degree of poverty and rapid population growth in Terai might exert pressure on the natural resources and accelerated deforestation and forest degradation (FAO, 1997). A few studies have been carried out to assess population pressure on natural resources (Gurung, 1989; Shrestha, 1990; Shrestha, 1999) however those studies are mainly concentrated in population density and arable land only (Silwal, 1995).

Thorough research summarized by Geist and Lambin (2002) on the causes of tropical deforestation concluded that populations virtually never work in isolation; rather, other socioeconomic factors mediate between population attributes and agricultural systems. Dasgupta (2003) explained that among the ecological and socioeconomic pathways there could be positive involvement between poverty, population growth and degradation of the local natural-resource. Therefore, neither poverty, nor population growth, nor environmental degradation is the prior cause of the others: over time each influences and is in turn influenced by the others. So, we need to analyze the existing status of various socioeconomic factors with their multifaceted interaction with respect to forest resource degradation in Terai, Nepal.

2.4 Food security, agriculture expansion and deforestation

Terai's flat low land uses both subsistence as well as commercial farming and occupies by valuable forest species Shorea robusta (Hobly, 1996; Webb and Sah, 2003; Siwakoti, 2006). An empirical study carried out by Culas (2007) indicated that deforestation has been positively linked with agricultural production and the effect of agricultural production on deforestation could be halted by strengthening institutional factors. At the same time excessive deforestation also jeopardizes the agricultural productivity (Maertens et al., 2006). Gilmour and Fisher (1991) also recognized that forests, farmers, livestock and agriculture are symbiotically interacted in Nepal. Out of the total land, agriculture, forestry, and pasture account for 97% of the area. The importance of land resource is further warranted, since the overwhelming majority of the population i.e.>85% live in rural areas and >60% of the economically active population is primarily reliant on agriculture occupation (CBS, 2003). However, it is widely recognized that human intervention in land utilization has changed forest cover over time (Kammerbauer and Ardon, 1999; Millington et al., 2003; Van Laake and Sa´nchez- Azofeifa, 2004). Land use change by human activities has become a proximate factor that catalyses deforestation and forest degradation (Tole, 1998; Koop and Tole, 2001; McMorrow and Talip, 2001; Uusivuori et al., 2002).

In Nepal, about 3.2 million ha or 21% of the total land area is cultivated, where rice, maize, wheat, millet, and potatoes are considered the major crops (HMGN/MFSC, 2002). Terai plain compose less than one-third of the total land of the country, however posses the largest proportion i.e. 40% of cultivated area. Similarly, expansion of agricultural land is also a major threat in many developing countries including Nepal, as expansion proceeds to meet the growing demands of the population (LRMP, 1986; JAFTA, 2001). The most widely studied of causal factor in agricultural change literature is population growth, which explicitly set out to resolve the dispute about the effects of population growth on agricultural production (Barlett, 1976; Shorr, 2001; Tiffen et al., 1994; Turner and Ali, 1996 in Keys et al., 2005). Population density is also a driving force to shape long-term

agricultural development (Boserup, 1965; Pingali et al., 1997 cited in Stoop et al., 2002).

A high population growth and low agricultural productivity does not cope with the food demand and supply ratio, hence, resulting in a food security problem. It is stated that population growth in Nepal is higher than food grain production by 2.2 % (FES, 2007). Increasing population and decreasing agricultural productivity is threatens the forest resources where 80% of population mainly depends on agriculture. However, the majority of farmers are unable to produce sufficient food from their own land due to small landholding size (FES, 2007).Therefore, such types of small holder and marginalized people highly motivated to turn to the forest frontier for their survival.

Similarly, poverty and food security are also closely related in rural Nepal and the poorest and hungriest groups of people mainly depend on arable and forest land. Hunger mainly tends to be concentrated among the landless or among farmers with insufficient land to afford their basic needs (FAO, 2005). NLSS II (2003/04) reported that the percentage of farm holdings having <0.5 ha were 40.1% in 1995/96 but it increased at 44.8% in 2003/04. Similarly, Joma (2007) also found the highest level of food deficiency (97%) within the population of the lowest income group which is linked with poverty.

About 852 million people living under an insecure food supply (FAO, 2007a) worldwide. Food security is a major concern in the developing world's cities, while demographic and household structures rapidly changes (FAO, 2005) and the rate of poverty is frequently excessive (FAO, 2007; FAO, 2006). Efforts to promote food security and environmental sustainability must be reinforce each other (FAO, 2005a). Nevertheless, adequately food supply is necessary and basic condition for reducing hunger and poverty (Pretty et al., 2003).

Biophysical constraints such as limited arable land and poor soil could also severely limit the food crop production (Gurung and Gurung, 2002) and control the intensities, patterns, production, and yields of the crops (You and Wood, 2004). Similarly, environmental and climatic factors also could play an important role in land productivity and food production. Various authors (Selvaraju, 2003; Kumar et

al., 2004; Aggarwal et al., 2000; Mall and Srivastava, 2002; Pathak et al., 2003 and Singh et al., 2003 in Prasad et al., 2007; Geerts et al., 2006) have analyzed the relationships between climatic factors and agricultural crop productivity. The monsoon often leads to severe flooding and landslides, worsening the food security situation and bringing about a wide annual variation in food production (NPC/HMGN, 2003; FAO, 2007b).

You and Wood (2004) emphasized that an agro-ecological zone's information should include crop production, farming system, land cover data, biophysical crop suitability, and population density, while agricultural statistics should be reported on a national basis. A number of researches have been carried out on agriculture production, food security mapping and other same as Fischer et al. (2005) computed the extent of potential agricultural land and related crop production in other parts of the world. However, yet little of this type of study has been carried out in Nepal.

2.5 Forest resources and livelihoods of the people

Forest resources play an important role in people's livelihoods throughout the globe (Arnold, 1992; Beck and Nesmith, 2001; Dev et al., 2003; Metz, 1998; Smith et al., 2003 cited in Shackleton et al., 2007; Quang and Noriko, 2008). Thoms (2008) also mentioned that forest products and services are important in that they provide indirect livelihood benefits for the well-being of people. Sunderlin et al. (2005) explained that most of the rural livelihood is maintained with diversified sources while sufficient income could not be obtained from any single occupation to survive. The reason is that farmer's livelihood systems also couldn't be entirely reliant on agriculture but rather should involve the forest. Livelihood opportunities are determined by various socioeconomic and development factors (Wunder, 2001; Sunderlin et al., 2005; Shackleton et al., 2007), therefore, communities living in and adjacent to savannas and forests are characterised by seemingly high levels of poverty. There is always a strong relationship among the natural resources, people's livelihoods and socioeconomic consequences in particular.

FAO (2001) stated that forest resources contribute directly to livelihoods and combine with other key components of poverty reduction through food production, food security, provide commercial opportunities and employment for the poor. Sunderlin et al. (2005) mentioned that household surveys and case study research demonstrated that the rural poor tend to be disproportionately dependent on forest resources in the sense that a higher proportion of their total income comes from forest resources. Wunder (2001) noted that in the tropics, extensive forest areas has occupied with large number of poor people that depend on forest for their livelihoods. Poverty and other socioeconomic factors could limit various social and physical conditions of rural poor that could also play an important role in forest destruction process. Therefore, forest loss can have adverse effects in livelihood directly (Brosius, 1997; Maruyama and Morioka, 1998; Poore, 1986 cited in Sunderlin et al., 2005) and indirectly.

For centuries, forests have been a key component of rural livelihood and important for both socially and economically in Nepal. Nepalese livelihood still largely relies on forest resources for fodder and grazing, fuelwood for cooking, and construction material thereby forest cover change and degradation have consequently continued. Human dependence on forest resources has had adverse impact on flora and fauna and undue pressure on it has led severe deterioration (FAO, 1999). Similarly, livestock raising is an essential component of the rural farming system in Nepal. However, over-grazing is one of the primary factors responsible for the rapid depletion of the forests (HMG/ DOF, 1997).

Terai forest is recognized as one of the major sources of national revenue for the country (Hobley, 1996; Rautiainen et al., 2000). However, deforestation process in Terai assumed 1.3% higher annually than in the hill regions during recent decades (DFRS, 1999; Pokharel and Amatya, 2000). It was also widely assumed that the poor and marginalized farmers are also the main cause of deforestation (UNCED, 1992) in Nepal. It has been also reported that 42% of people were below the recommended nutrition-based poverty line while 53% had daily income below 1 US$/day (UNDP, 1997) in 1996. These people were assumed to be heavily relying on natural resources

for their livelihood and are frequently blamed as the root cause of forest and environmental degradation (UNCED, 1992).

A huge method has been already practiced by various authors for livelihood strategy and forest dependency assessment throughout the world. Stakeholder analysis is also useful tool to design satisfactory forest management systems which could meet the requirement to assess the local livelihood approach relying on forest resources. However, such kind of study needs detailed information on livelihood strategy and natural resources as well to understand the holistic approach in forest dependency.

2.6 Summary

The main objective of this research focuses on the consequences of socioeconomic interaction in tropical deforestation and forest degradation in Nepal. The research and literature that explained the casual factors of tropical deforestation and forest degradation, techniques and tools that have been previously used by various authors has been extensively reviewed. At the same time, some study mentioned that the proximate cause of deforestation i.e. agricultural expansion, logging for infrastructure development and forest clearing, encroachment that have direct impact on forest resources depletion. While others commented that demography, poverty, land tenure, forest dependency, low agricultural productivity, food insecurity, and livelihood strategy of local people were underlying forces that ultimately acted on and accelerated the forest degradation and deforestation processes. But, the process of deforestation and forest degradation that have taken place throughout the tropics appeared to be similar in nature though it differ in magnitude. Moreover, various research endeavours have been already initiated to understand the complex system of tropical deforestation in different part of the world. Nevertheless, the government of Nepal has not been able to develop adequate mechanisms to comprehend such process. Except few scheduled forest inventory programs and individual studies (HMGN, 1993; MFSC/DOF, 2005; Joshi, 2006;

Panta et al., 2008) research motivation have been rarely found to examine the patterns and process of deforestation and forest degradation in Nepalese context.

CHAPTER 3 STUDY AREA AND ANALYSIS

3.1 Study area

Nepal (latitude of 26° 22' N and 30° 27' N and longitudes of 80° 04' E and 88° 12') covers an area of 147,181 sq.km, with a length of about 885 km, and an average width of 193 km (Figure 3-1). Its physiography extends from the Terai plains with a minimum altitude of 60 meters above sea level in the south, through to the Siwalik hills, Middle mountains and Himalayas up to Mount Everest 8,848 m above sea level (ADB, 2004). The Terai region is tropical lowland and a subtropical belt of flat, alluvial land cover accounting for 14% of the total land area in Nepal where 40% of its land area is under cultivation and extends from east to west along the southern side of the country (MPFS, 1988).

Population in this region has increased day by day due to high population growth rate and internal migration from hills and mountains, where >48% of the total population of the county has existed in 2001 (CBS, 2002).Terai region is the preferred destination for inhabitants from both social and economic aspect of human life owing to accessible terrain, infrastructural development (east-west highway, communication and other social overheads), and valuable forest resources. Moreover, this region is also regarded as the "grain basket" due to high productive agricultural land (Ghimire, 1998; Blaikie et al., 2000). Thus, the importance of Terai for Nepalese economy is undoubtedly significant. Conversely, continually migration from hills, mountains and India and high demand of timber products and agricultural land has had negative impact on the forested land (Blaikie et al., 2000). The lower slopes of the Himalayas in eastern part of Nepal have been identified as a biodiversity "hot spot," a region of the world that is rich in endemic species and is also environmentally threatened. Terai contains an array of varied socioeconomic structure with extremely diverse flora and fauna, including widespread multiple species that not found elsewhere in Nepal. Similarly, the largest natural forests with commercially exploitable species of Sal (Shorea robusta), Sissoo (Dalbergia sissoo)

and Khair (Acacia catechu) further add value to the region (Hill, 1999). But, forest resource is profoundly vulnerable and deforestation and forest degradation has perceived constantly higher in the recent decades owing to various human activities and socioeconomic burdens. That makes an ideal setting for the regional scale study, which consists of 20 districts, out of 75 districts of the country.

Whilst forest resource and people's livelihood assessment limits the Chitwan district due to high forest dependency, National Park and national forest, while both forests have controlled and managed by the government for preservation of flora and fauna. Greater understanding of the influence of socioeconomic consequences on forest degradation process at local scale will thus provide important information for conservation efforts in both this and similar area elsewhere in Nepal. Beside this, there are four specific reasons.

The first is its geographic insularity: the district is located between 27° 00' -27° 45' N latitude and 84°15'- 85°15'E longitude. Situated at the foot of the Himalayas, it covers the total area of 2218 sq km and extends from 244m to 1945m altitude. It is one of the few remaining undisturbed vestiges of the Terai region, which formerly extended over the foothills of India and Nepal. One of the last populations of single-horned Asiatic rhinoceros (Rhinoceros unicornis) lives in this region. Moreover, it is world renowned for its unique biodiversity of flora and fauna and outstanding natural resources, with more than 600 flowering plants, 50 species of mammals, 526 species of birds, 49 species of reptiles and amphibians and 120 species of fish (DNPWC, 2000). Second, since 1960 land cover has been heavily disturbed by humans -. It was one of the resource rich districts of the country having immense natural and commercial forests and agricultural commodities which, covered by virgin forest, had been preserved for centuries and an undisturbed wildlife habitat. A heavily degraded narrow forest passage in the middle of the district is the last remaining forest corridors linking Chitwan National Park with wider mountain ecosystem of Nepal. It has also evergreen and semi-deciduous tropical forests as climax vegetation (Dobremez, 1976). Almost 70% of the forest in Chitwan district has dominated by Sal (Shorea robusta) while it is the most valuable commercial tree species in Nepal that also dominates most of the other tropical forest area. Similarly, largest

percentage of area outside the protected area belongs to the Shorea robusta forests which further added its important value for both biological conservation and supporting local livelihood. The district has the comparatively good shape of forests compared to the other nearby districts but this is also deteriorating very rapidly. It covers tropical, subtropical and temperate areas within a short vertical distance representing some of the common Nepalese ecosystems and forest species which could have a wide range of economic and social use.

Third, the district is divided into 2 municipalities, and there are 36 Village Development Committees as the lowest administrative unit. A high population growth rate directly influences the existing forest resources in the district. Land under heavy agricultural and residential use is often favourable for a variety of socio-economic activities. The average size of agricultural holdings is 1.26 ha in the Chitwan district, which is the highest in Nepal (Hills: 0.77 ha, Mountains: 0.68 ha, Nepal: 0.96 ha). It is difficult to obtain data on migration into the Chitwan. However, the population growth rate of the Chitwan (as compared to other district) is indicative of the fact that in-migration has occurred on a large scale. Hence, the ethnic diversity of the district is largely a result of recent migration. Moreover, Chitwan's forest is surrounded by a large number of poor farmers; landless and indigenous communities who depend on the natural resources (mostly forest) in and around it. The demographic composition is formed with several socio-ecological groups having unique relationship with the local natural environment. The nature of their livelihoods heavily interacts with existing resources such as forest and land. Therefore, land use and land cover pattern has been heavily disturbed by humans here (Guneratne, 1994; Isaacson et al., 2001).

The fourth reason is that part of the district covers the Chitwan National Park (IUCN category II Protected Area and UNESCO World Heritage Site) (BPP, 1995). In the recent years, the National Park also has been increasingly encroached upon by the local people for firewood, fodder, non timber forest product, thatching materials, poaching, etc making it an ideal site for local scale study at Chitwan.

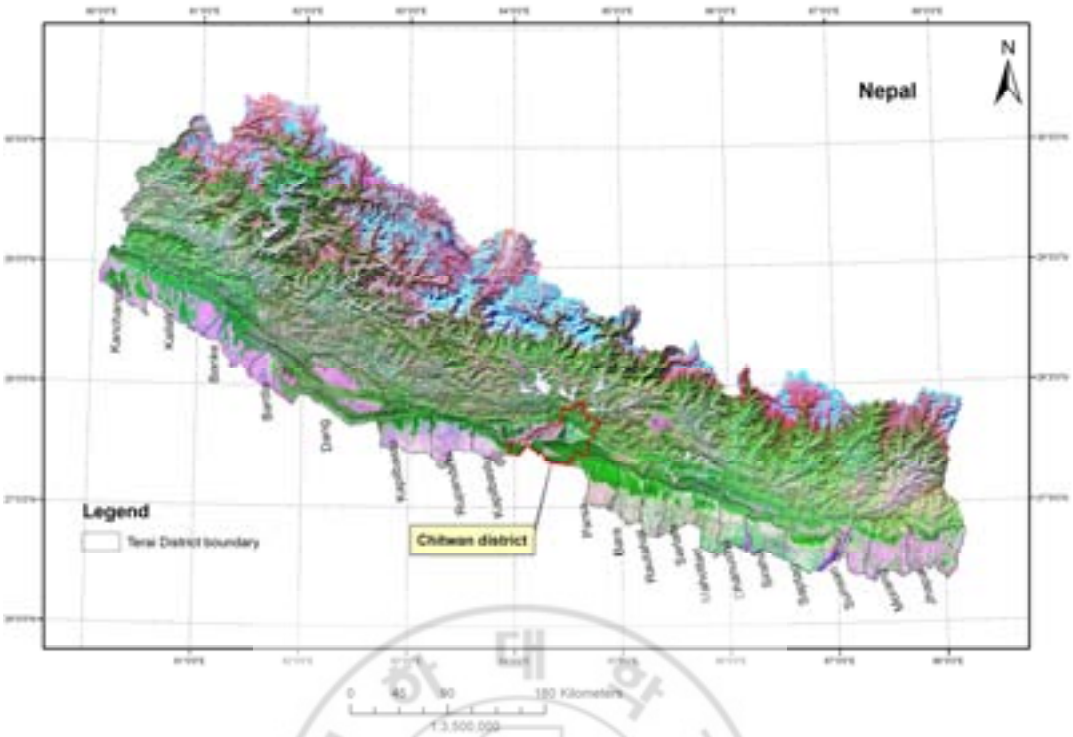


Figure 3- 1 Nepal physiographic, study area: Chitwan and Terai districts.

3.2 Data used and data sources

3.2.1 Mapping deforestation and forest degradation processes

To perform this analysis we mainly used remote sensing data which were collected from different sources. Only Landsat MSS of 1976 image covers the whole Chitwan district. But, images of 1989 and 2001 with single scene could not cover the whole district, we therefore, mosaic the images acquired from two different dates however with almost same seasonality for 1989 and 2001. The details of remotely sensed images, including path and row number, acquisition date, source and other secondary data used in this study are given in Table 3-1. And FCC satellite images of 1976, 1989 and 2001 are given in the Figure 3-2, 3-3 and 3-4.

Table 3- 1 Images path and row number, acquisition date & sources.

Image/ Maps/Data	Path	Row	Date of acquisition	Sources	Purpose of use
Landsat MSS	152	041	28th Oct 1976	GLCF	Image classification
Landsat TM	142	041	07th Nov 1989	GLCF	‘’
Landsat TM	141	041	31th Oct 1989	GLCF	‘’
Landsat ETM+	142	041	13th Dec 1999	GLCF	‘’
Landsat ETM+	141	041	27th Dec 2001	GLCF***	‘’
Aerial photo			1976	DoS, Nepal	Training sample
Aerial photo			1989	DoS, Nepal	’’
Forest types maps			1976-1982	Dobremez et al	To compare forest type map
Forest types map			2003-2005	Joshi	”
Topographic maps			1996	DoS**, Nepal	GCP transformation
Land use/Land Cover map			1958-1996	CBS*, Nepal	Field survey

* Central Bureau of Statistics, **Department of Survey, *** Global Land Cover Facility

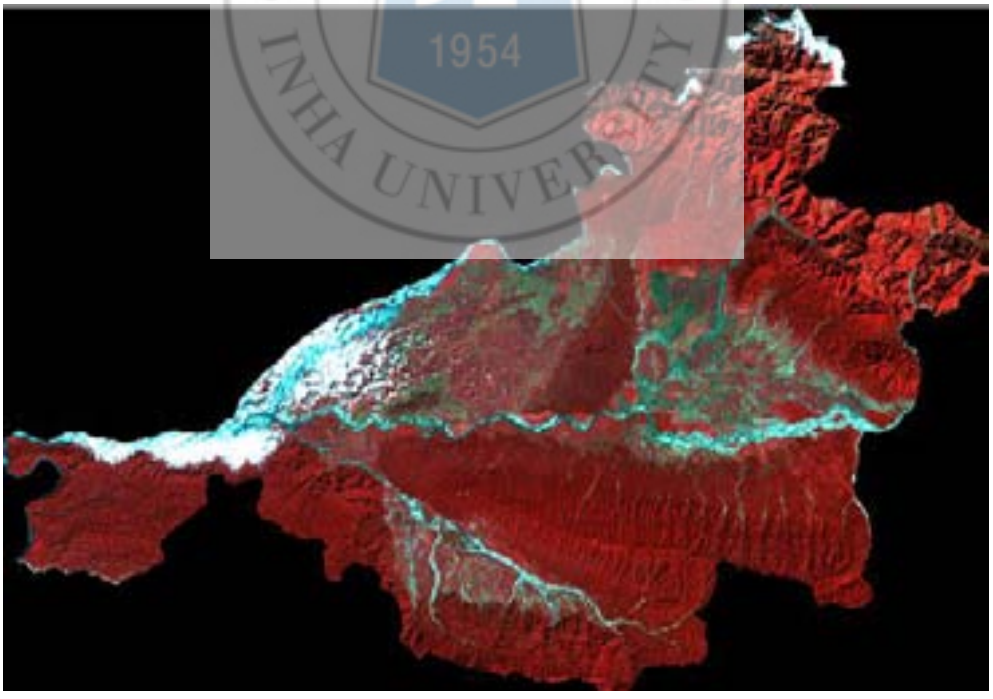


Figure 3- 2 FCC Landsat MSS satellite image of 1976.

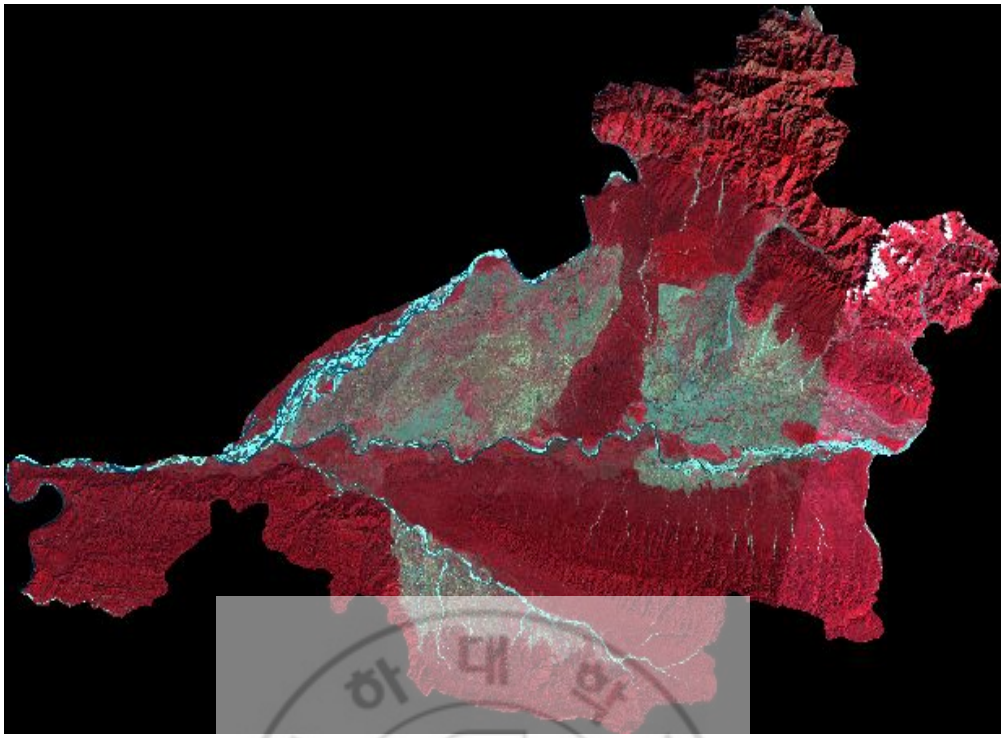


Figure 3- 3 FCC Landsat TM satellite image of 1989.

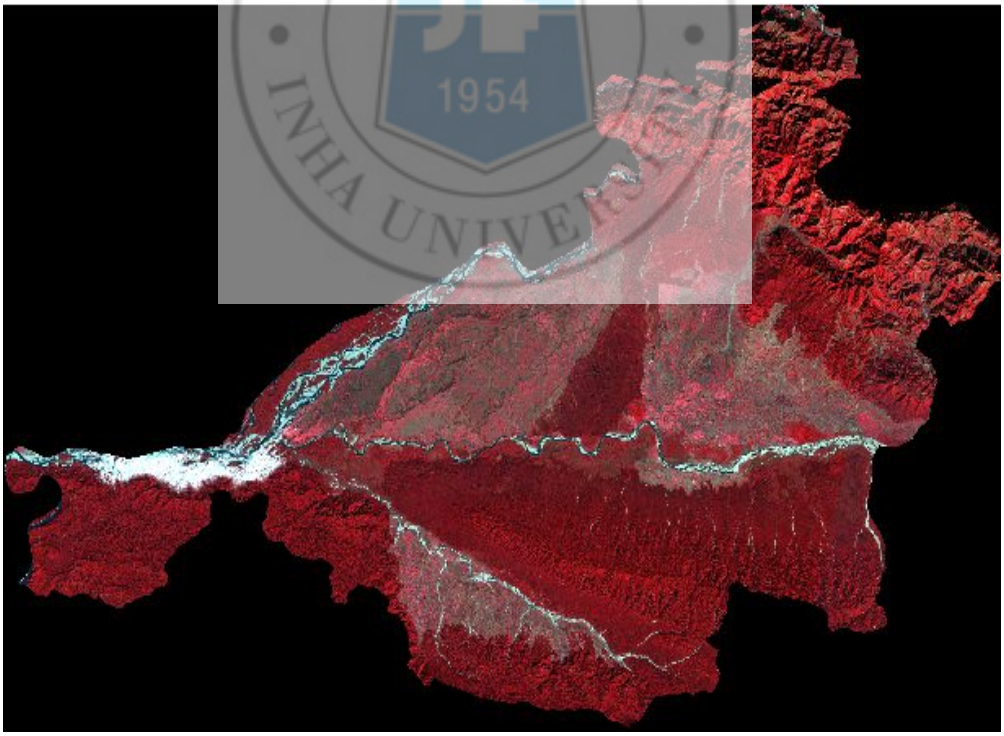


Figure 3- 4 FCC Landsat ETM+ satellite image of 2001.

High-resolution aerial photographs of 1976 scale (1:10000) and 1989 (1:25000) covering part of Chitwan district were obtained from the Department of Survey and Forest Survey and Research, Government of Nepal and scanned and georeferenced. Chitwan valley lies between the Mahabharat mountain range in the north and the Siwalik or Churia Hills in the south. The climatic condition varies according to the differentiation in heights from subtropical to temperate type. The northern mountainous parts of the district with Mahabharat range are consisting of steep elevation and dense forest. Thus, a few shadow and ridges appears in the satellite images of the north side is because of mountains and in the south side is also caused by Siwalik Hills. Similarly, the white covering in 1976 Landsat MSS and 2001 ETM+ images of the same area is caused by cloud in the Narayani river which is one of the biggest river for the Chitwan district.

3.2.2 People's livelihood strategy and forest resources dependency

Household Survey (semi-structured questionnaire), Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) methods were used to collect the primary information of the study area. Secondary information was collected from the concerned offices such as Village Development Committee (VDC) and Municipalities, previous study/research documents and other publications. A household survey of important stakeholders (local people around the forest corridor who are mostly dependent on forest for their livelihood) and key informants involved in forest resource management was conducted to collect data on forest resources availability, the extent of forest dependency and livelihood strategy in Chitwan district of Nepal. Holt et al. (2002) mentioned that unavailability of quantitative cause-effect data could be substituted by qualitative information to transfer knowledge from local level. Therefore, we collected data from households based on questionnaires relating the qualitative as well as quantitative information on the people's livelihood including demographic, sources of income occupation and households consumption, forest resources uses and their monetary value.

3.2.3 Population factors, poverty and forest degradation processes

We used secondary data sources to analyze the socioeconomic factors and forest depletion process. The Government of Nepal, Central Bureau of Statistics, Nepal (CBS); Ministry of Forest and Soil Conservation (MFSC); Department of Forest; Department of Forest Survey and Research are the main institutions serving as our data source. Over a period of few decades, the numbers of research initiatives and measures regarding various data such as socioeconomic, demographic and other specific fields (forest, agriculture and livestock) management have increased. However, consistency in data, reliable documents and factual evidence are still inadequate. In this study, available data was the optimum level of survey data. However, a lack of detailed information at household and district level, and time series data on various categories posed a major constraint in this analysis. The details of the data, types and their sources are outlined in Table 3-2.

Table 3- 2 Data types and data sources

Data type	Period	Source
Population, population size, distribution and migration	1971-2001	CBS, Nepal Population monograph , Census 2001
Agrihousehold & landholding	2001	Agriculture census, 2001 CBS*
Other social data (Fuel types & collection)	1995/96-2002/03	NLSS I, 1995/96 –NLSS II 2002/03, Poverty trends in Nepal, 2005, CBS
District boundary		Department of Survey, Nepal
Forest area (Ha)	1958	WWF**, Nepal
Forest area (Ha)	1978	Joshi, 2006, CBS (various census year)
Forest area (Ha)	2001	Department of Forest, MFSC***, 2005

*Central Bureau of Statistics, **World Wildlife Fund, *** Ministry of Forest & Soil Conservation

3.2.4 LULC change, food productivity and food security mapping

Most of the data used for this analysis were collected from authorized sources. Government of Nepal Central Bureau of Statistics, Ministry of Agriculture and Cooperatives, Department of Agriculture; and Department of Survey are the main

institution of data source in this analysis. Some of the data that we used are outlined in below.

- District population, growth rate: population census 1981,1991 and 2001
- Time series data of crop area, production : CBS: http://www.cbs.gov.np ; CBS publications (Agriculture Census 1981/82, 1991/92, and 2001/02; Statistical Year book and Pocket Book (various series); Statistical Information of Nepalese Agriculture, Ministry of Agriculture and Cooperative, Nepal
- Other authorised secondary sources for socioeconomic data
- District boundary (Spatial data) – Government of Nepal, Department of Forest Research and Survey.

3.3 Research approach

Once the research objectives were identified, a comprehensive background study on deforestation and forest degradation and their apparent proximate causes and underlying forces were reviewed. In order to address the research approach and methodologies, the following steps were performed subsequently as illustrated in Figure 3-5. Importantly, not all socioeconomic factors are equally responsible for the deforestation and forest degradation process. Thus, we try to conceptualize how to identify the major factors that accounted for the deforestation and forest degradation process in reality. Therefore, we first propose a problem tree which can properly explain the cause and effect relationship of deforestation and forest degradation process in overall (Figure 3-6). However, the vital question is how to develop the appropriate tools and techniques to quantify and map such issues for dealing of proper forest resources management approach? Then, we define simple measurable socioeconomic, ecological and environmental parameters of deforestation and forest degradation indicators to produce further information for assessment of forest quality and quantity as well. Finally, these parameters were linked with remote sensing and GIS technology to visualize and correlate the relationship between most apparent socioeconomic factors and deforestation and forest degradation in Nepalese Terai.

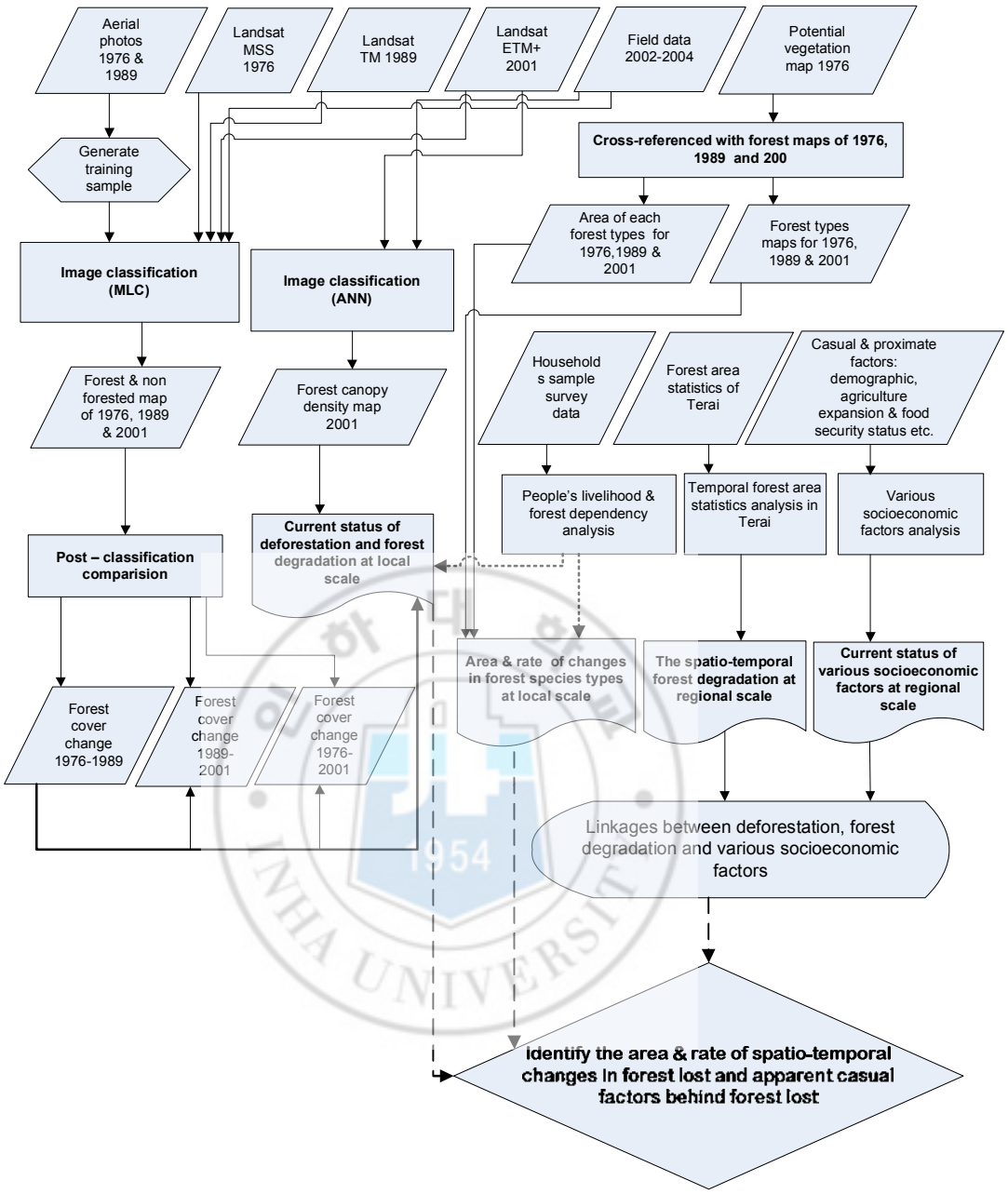


Figure 3- 5 Workflow of the research.

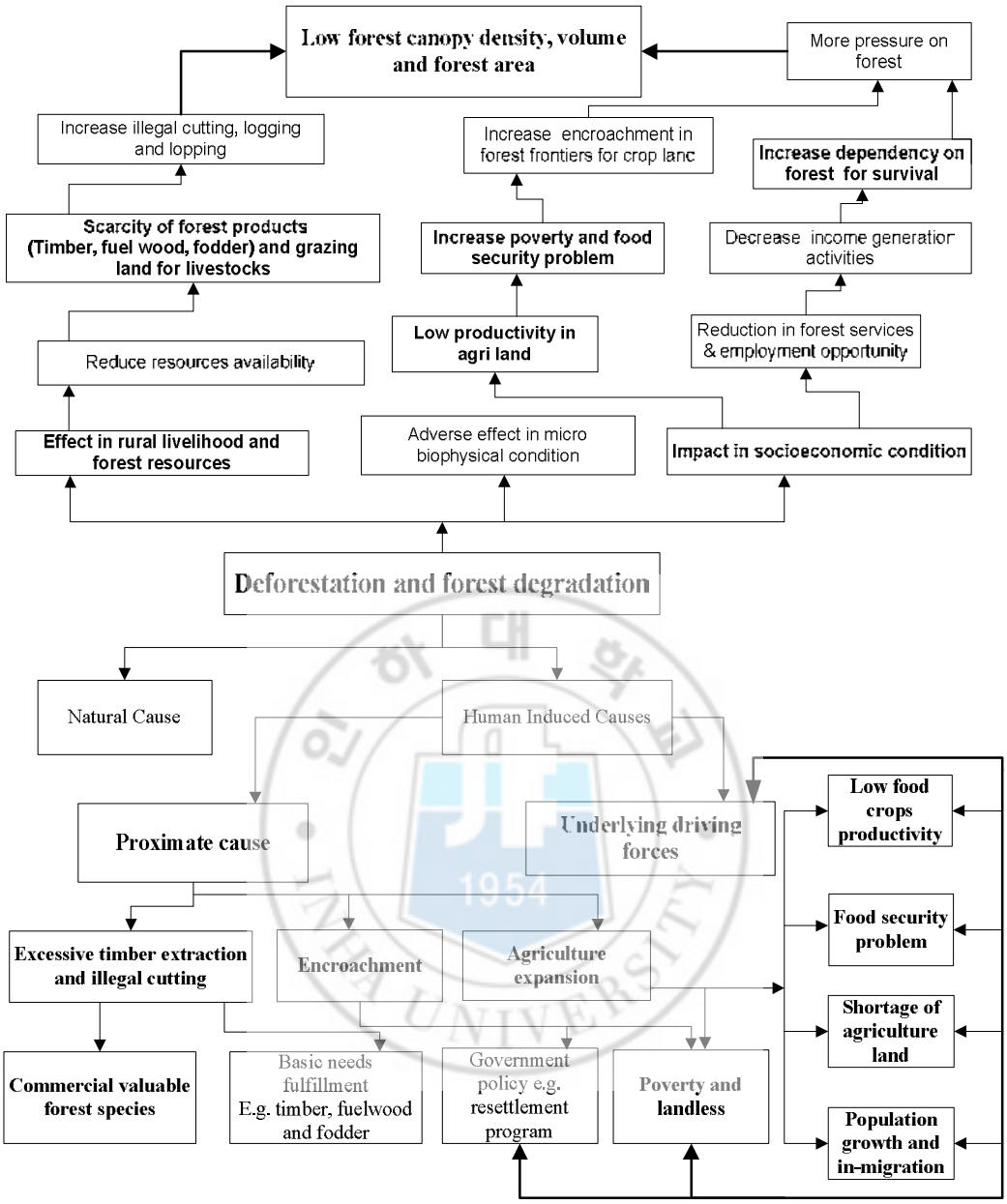


Figure 3- 6 A problem tree- cause and effect relationship.

Going through the mechanism mention in the figure 3-7, food security largely depends on various agricultural farm management systems and it can also intangibly affects on the deforestation process. Forest clearing could be initiated while farmers are marginalized and do not sustain with their existing farms' productivity. Then they could either turn to land use change or migrate in search of new crop land. Finally both systems would support to accelerate the deforestation and forest degradation processes.

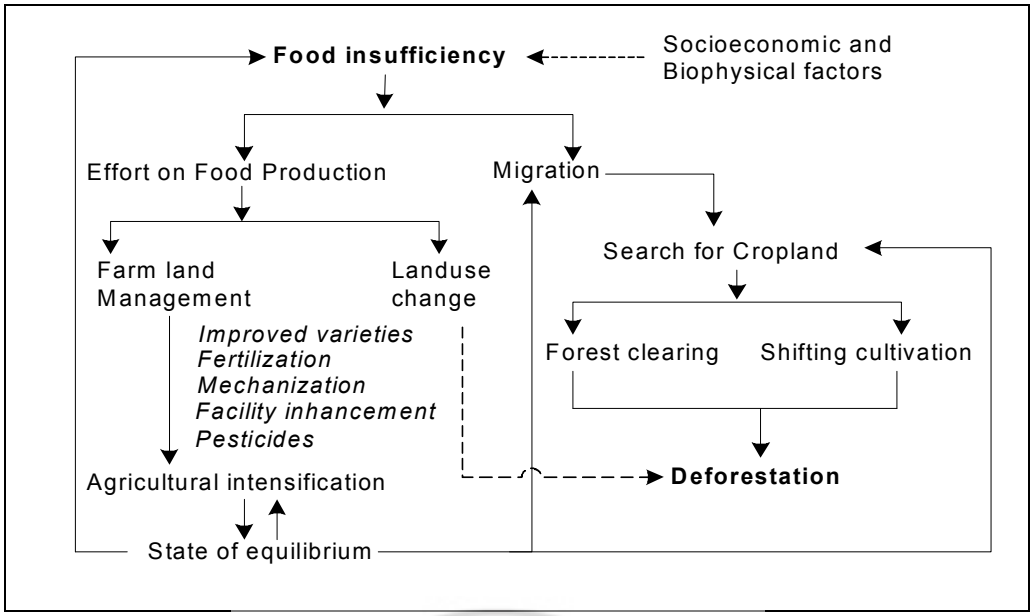


Figure 3- 7 Food security mechanism and deforestation.

Still socioeconomic data as spatially explicit information is rarely available in Nepal, which results in preventing the execution of spatial analytical approaches in linking the socioeconomic realities with the local environment. Hence, this analysis also seeks to understand the spatially explicit information to link the spatial analytical approach in forest resource management. Some literature suggested that population; poverty, land scarcity and low productivity are the drivers which stimulated the pace of deforestation in Terai. While others suggested that heavy grazing and illegal logging has also led to diminish the forest (Pradhan, 1982). But, we argue that deforestation and forest degradation process is multifaceted and acted in various ways. So, analysis of multidimensional interaction of various socioeconomic factors on it is crucial (Figure 3-8).

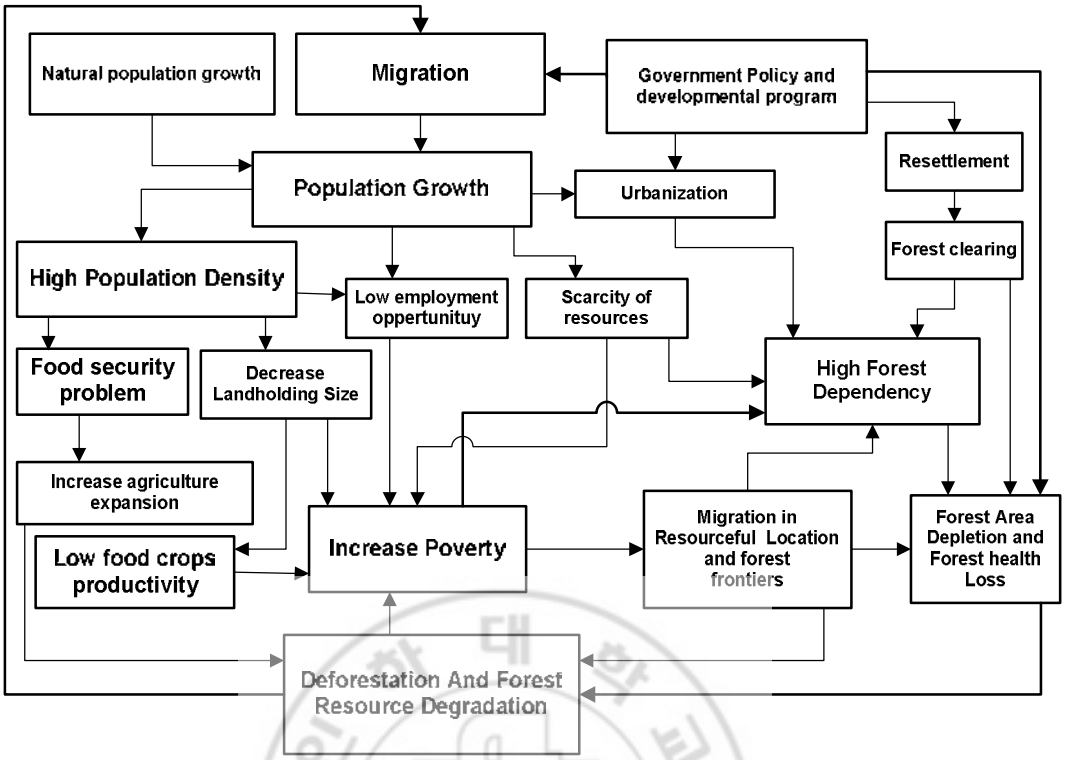


Figure 3- 8 Interaction of socioeconomic factors in forest degradation.

In conclusion we realized that to describe and understand the interactive socioeconomic processes that influence the total earth system, the changes that are occurring in this system and the manner in which they are influenced by human activities need to be analyzed. A research base contribution to food security, poverty eradication and promoting sustainable agricultural development based on the environmentally sound management of forest resources is also important. Hence, we proposed a forest resource management research approach that can be used to bring together the objectives of farmers with those of forest land use change research in this study. The overall purpose is to meet farmer needs for food security

and poverty reduction while satisfying societal objectives for forest protection. The approach and its components are illustrated in Figure 3-9.

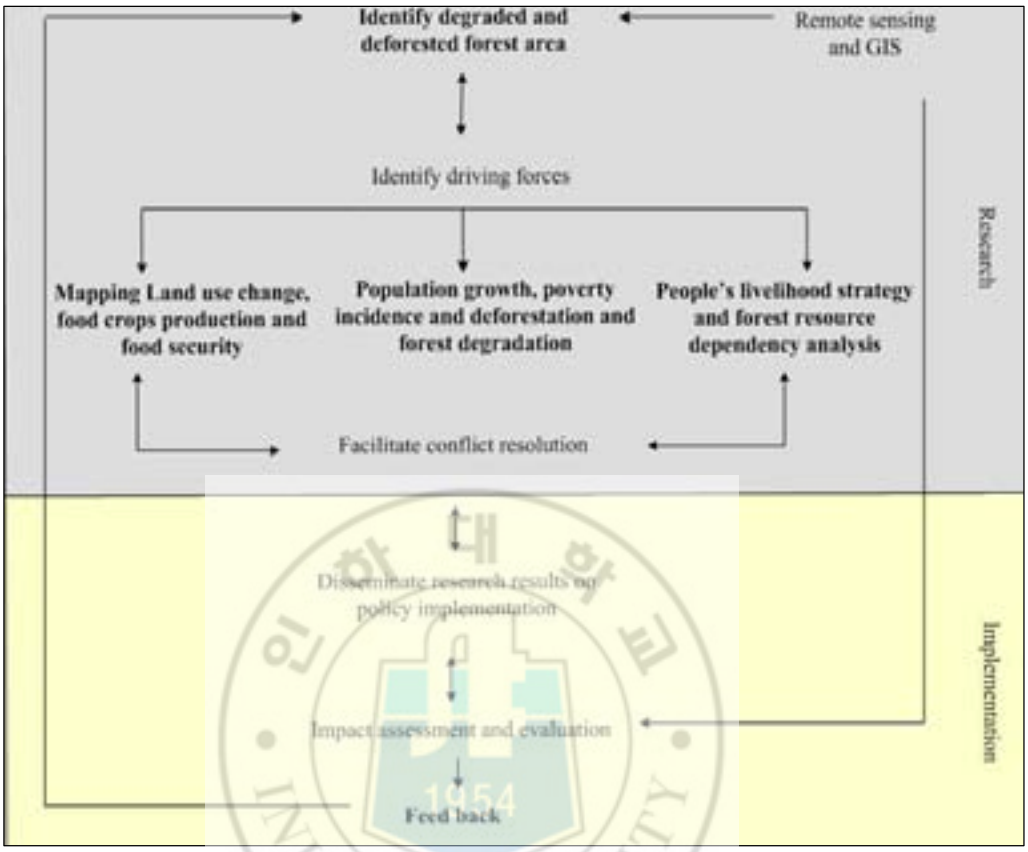


Figure 3- 9 Research agenda and its components for forest resource management.

3.4 Methodology

3.4.1 Mapping deforestation and forest degradation

3.4.1.1 Satellite images and aerial photo analysis

Shorea robusta (Sal) is a light-demanding, semi-deciduous tree and frequently forms a nearly monotype canopy (Rautiainen and Suoheimo, 1997; Pandey and Shukla, 2001 in Timilsina et al., 2007). Shorea robusta dominated forest types show considerable phenological variation over the year due to shedding of Shorea leaves in March (Singh and Kushwaha, 2006). This changing forest conditions could reduce the classification ability of an image classifier algorithm. Furthermore, phenological variation could complicate consistency in image classification between scenes. We

therefore selected satellite images of 1976, 1989 and 2001 from approximately the same season (October, November and December, shortly after cessation of the monsoon but before leaf fall) to analyze the spatial and temporal degradation and deforestation status of forest covers and different forest types in the district. Landsat ETM+ data were acquired from seven spectral bands. Except thermal band we used six bands for this analysis. These bands of each image sets of each year were georeferenced and resampled to 30m pixel size using Erdas 8.7 image analysis software.

By visual observation, training samples of forested and non forested area were generated from aerial photographs of 1976 and 1989 to classify MSS and TM images of 1976 and 1989 respectively. Forest cover maps for 2001 were generated from an ETM+ image of 2001 using field observation data from 2002 and 2004. Potential forest type map of 1976 (Dobremez, 1976) were cross-referenced with forest maps of 1976, 1989 and 2001 and the area of forested land and forest types of for each year was calculated.

3.4.1.2 Field observations, images classification and analysis

The geometrically rectified image was subjected to classification via unsupervised and supervised classification techniques for the generation of forest types and a cover map of the district. Initially, a given image was classified by an unsupervised isoclustering method all together in 10 classes to separate the pixels of the image into different spectral clusters representing various land use and land cover types. A hardcopy of the spectral cluster map was generated for a reconnaissance field survey in order to become familiarized with the general pattern of vegetation of the area and to identify spectral clusters representing different features on the ground. Existing forest and vegetation maps were compiled to form a knowledge base. During the field survey, the geographical coordinates of the predominant vegetation types and other land cover classes were marked on the cluster map using a Garmin GPS instrument. LU & LC and forest canopy density in % were recorded from 329 plots.

Later, images were classified by a supervised classification technique using a maximum likelihood classifier (MLC), with appropriate signatures or training sets generated from half of the ground control points collected during field inventory, for corresponding land cover and vegetation classes. MLC can spectrally segregate two distinct classes (forest and non-forest) with high accuracy. For forest cover change in terms of area, we looked at temporal image analysis using MLC from 1976, 1989, and 2001 periods. Forest cover (presence and absence), forest types, degradation status of forests (none, low, moderate, high and very high) and canopy density (%) were visually estimated at 329 plots in Sept-Oct 2002 and 2004. Since our main objective is to assess and map the forest degradation and deforestation, thus, we calculate the forest canopy density in the whole district, Landsat ETM+ image of 2001 was classified using Artificial Neural Network (ANN) classifier, which was experienced, the best classification method in classifying forest canopy density (Joshi et al., 2006). However, we were unable to use other two years images data for forest degradation analysis due to the lack of training sample for classification. ANN is more capable in classifying even homogenous object using its capability of back propagation. Neural network classifiers tend to be accurate and use a powerful learning algorithm that can give better classification results and forest mapping (Atkinson and Tatnall, 1997; Boyd et al., 2002; McClelland et al., 1989; Linderman et al., 2004).

The canopy density estimates were classified into five classes: “1-20%”, “21-40%”, “41-60%”, “>60%” density and “0% or Other” referring to classes other than forests. From this large sample of 329 sites, one sub-sample of 50% (n = 165) of the sites was randomly selected to train an artificial neural network to predict canopy density. The neural network was trained with the canopy density and DN values for the six ETM+ bands for the sub-sample of 165 sites. The remaining sub-set of 164 sites was used to validate the predictions of the neural net. Finally, a standard majority filter (ILWIS, 2005) was run through the classified image for smoothing. The validation data set was used to compile a confusion matrix. Accuracy and associated errors of commission and omission were calculated according to Congalton and Green (1999).

3.4.2 Livelihood strategies and forest resources dependency

3.4.2.1 Sampling design

Due to time constraint only 100 households were selected from study area. For the selection of sample households the Bharatpur Municipality having large demand of local level industrial wood, Gitanagar VDC, Patihani VDC, Jagatpur VDC, Kabilas VDC, Padampur VDC (a newly resettled village), Ratna Nagar Municipality and Jutpani VDC were selected purposely considering the location advantage. Later, we were only selected five VDCs out of eight where forest corridor is the one border of these administrative units. In Nepal, Village Development Committees, in rural areas and Municipality in urban area are the grass root level administrative boundary, and each is further divided in to smaller units called Wards. A VDC constitutes 9 wards and a Municipality constitutes more than 9 wards. Three wards from each VDC and Municipality were selected purposely giving consideration to sharing a boundary and located nearest to the forest corridor to select sample households. In such a way, 15 wards were selected and then 5 wards were selected randomly for the purpose of field survey for this study. From each selected wards 20 households were selected for interview. Such types of ethnography, interviews, household surveys and other methods aid to gather the local people's perception and understandings about the natural resources. Sampling, e.g. transect walks, wealth ranking, social mapping and interviewing, e.g. focus group discussions, semi-structured interviews, triangulation are some of types that we were also use during the field work.

In each VDC/Municipality, the household profile register was collected and the entire population (households) list was recorded assigning numbers 001 to 002, 003 and so on for each selected wards. Then, random sampling method was used to select the samples from this entire population list. The sample from the population was selected by using the following equation and random numbers were generated by using Random Number generating calculator.

$S_i = Rn * N$ ……(1)

Where,

S: is the selected sample from the entire population

Rn: is the random number that was generated from random number generating calculator

N: is the total number of households in selected ward

3.4.2.2 Participatory Rural Appraisal (PRA)

PRA is a reciprocal process that emphasizes local knowledge and involves rural people in the inventorying, monitoring, and planning of local forest management. It basically empowers the marginalized people and helps to identify their resource needs and sustainable use systems. The PRA method can provide information to outsiders who wish to understand how the rural people use and manage its resources in a particular location. And it itself is a kind of information source to the rural people because it can help them to evaluate their current resource status and management practices (AFN, 2002).

In this process, stakeholders (who are using those resources) are usually invited and representatives from different groups and ranks. Such mechanisms could challenge research and institutional objectives and implementation process as well. So, it is important to be aware of the true representation of stakeholders from multi-ethnic and various groups in the process (Johnson and Wilson, 2000). A participatory approach was employed to evaluate the historical uses and current status of forest resource, forest dependency and rural livelihood strategy in the study area. During the small meeting and discussion, each of the participant stakeholders was allowed to put his or her perception and knowledge towards livelihood strategy, forest resources availability and their uses.

The reconnaissance survey is a PRA tool and this survey is widely used for the ad hoc assessment of the natural resources principally by research teams to gather preliminary information about the study area before conducting the detailed survey. While conducting a reconnaissance survey, we take account of the main components of the land use, vegetation, crops grown, forest etc. and human activities and their

interrelation with these resources focusing on livelihood strategies. Structured and unstructured questionnaire were used for interviewing the selected households of the survey area. Similarly, focus group discussion, meeting with elderly people, discussion with key informants were carried out in the village to understand the forest changes over time, availability of resource services and resource management. Direct observations were also made to achieve an overall impression of geographical conditions, land use, and the forest situation of the study area.

3.4.2.3 Poverty and inequality assessment among households

Principally, poverty and inequality has greater influence in resource management in the aspect of natural resource management. Most of the rural people in the third world primarily depend on the natural resources such as agriculture, forest and water resources. Thus, addressing poverty and inequality for the betterment of livelihood of poor rural is the key issue of the natural resources management in the developing country like Nepal. Hence, in this study we were also trying to explain the status of poverty level and inequality in the study area to relate such information on forest resources dependency and foresee the aspects of the forest resource management. We use Foster-Greer-Thorbacke (FGT) indices for poverty analysis recommended by World Bank (http://www.worldbank.org/). These are given below.

(a) Head Count Poverty Index

It is defined as the proportion of units (households or Individuals) below poverty line and this index is calculated as:

$$HCI = \frac{Np}{N} x\ 100\ \%$$

Where, HCI= Head count poverty Index
Np= Number of units below poverty line
N= Total population

(b) Poverty Gap Index

The Poverty Gap Index is based on total economic deficit of the poor and it explains the depth of the poverty and calculated as:

$$P_i = \frac{1}{N} \sum_{i=1}^{N_p} \frac{Y_p - Y_i}{Y_p}$$

Where,

P = Poverty Gap Index

N= Total Population

Np= Number of people below poverty line

Yp= Poverty Line Income ($1 per day of 14942 NRs per annum considering, household available only 210- 215 days of working day/ year)

Yi= Individual income

∑= Summation

(c) Gini-coefficient and Lorenz Curve

Gini coefficient is a measurement of statistical dispersion most commonly used as a measure of inequality of income or wealth distribution. The Gini coefficient was developed by the Italian statistician Corrado Gini and published in his 1912 paper "Variability and Mutability''. It can be easily represented by the area between the Lorenz curve and the line of equality. The Gini coefficient is the ratio of the areas on the Lorenz curve diagram. The coefficient is defined as a ratio with values between 0 and 1 and a low Gini coefficient indicates more equal income or wealth distribution, while a high Gini coefficient indicates more unequal distribution and ratio, 0 reflects complete equality and 1, which indicates complete inequality (one person has all the income or consumption, all others have none) (Source: www.wikepedia).

3.4.2.4 Forest Product Availability Response Index

We generated the forest product availability response index to reflect the households' perception towards the concentration of forest resources in Chitwan.

This index is calculated on the basis of response of sample households on availability status of forest product over time (20 year before, 10 year before and currently). Score number is assigned to measure the availability status over time (abundant = 1, as required = 2, less than require = 3, and scarce = 4). Then, the average household score is decoded into scale between 0 -1 (where 1 is perfect) and interpreted the results.

3.4.3 Population factors, poverty and forest depletion processes

In the recent decades Nepal has collected a large amount of data about population characteristics and agriculture data by census. Though these data have been analyzed and made partially available in aggregated tabular form, the representation of these data in GIS and remote sensing technology to translate them into more readily accessible form to users has thus far been largely unexploited.

We used body of census data published from CBS (Central Bureau of Statistics), Government of Nepal and other secondary sources for this analysis. The available data were collected for a different purpose which has severely influenced the analysis. However, those data were optimally integrated and analyzed with GIS software and simple descriptive statistics. ArcGIS 9.0 was used to map and visualized the spatio-temporal extent of forest resource status and socioeconomic consequences in Terai region of Nepal. Dynamic fluctuation of others parameters over time were analyzed using simple pie chart and bar graphs.

Moreover, Pearson's correlation analysis has been carried out to explore and visualize the effects of population factors on forest area lost over time. Similarly, regression analysis and curved estimate model has been also applied to see the effect of population growth in forest area lost pattern. Those statistical analyzes were performed in SPSS. As Chowdhury (2006) emphasized, the modelling techniques used in evaluating the socioeconomic and biophysical forces driving deforestation are important. Various authors also proposed numerous methods and modelling techniques to evaluate the tropical deforestation over the different parts of the world. However, formulation of a deliberate plan and appropriate modality in due course is complex unless there is a detailed understanding of the entire process and a clear

recognition of those causes and forces behind deforestation in a particular locality. So, we argue that a clear identification of the most probable proximate cause and driving forces comprise at the first step could be more prolific to precede the deforestation and forest degradation analysis.

3.4.4 Mapping LULC change and food security status in the Terai

The spatial extent of food security is depicted by measuring Food Supply to Food Demand Ratio (FSDR). The food supply or availability at spatial unit is the total edible food production in a given year including food that was produced from animal origins and other sources, but ignoring the effects of food import and export. Food import and export has no significant role in the case of Nepalese Terai. Thus, local food production and the total number of population that live in the given spatial unit was the basis of this analysis. However, we also tried to link this food supply measure with other indicators of food insecurity to discover the relationship between the existing level of food crops production and food availability. It can influence not only food consumption but also can affect the land use change and natural resource deterioration including forests. In this study, we also consider some household socio-demographic variables that affect food demand, consumption, and/or purchasing ability.

Various methodology and data for agriculture crops productivity have been proposed by numerous authors. However, Lobo et al (1996) commented that the environmental and social circumstances in a complex landscape could be better analyzed with integration of GIS data. Therefore, in the present analysis, we used GIS and some descriptive statistics to develop the logical concept to compute and map the crop productivity trends and food security status in Terai.

Another important aspect to consider mapping food security is food accessibility. Food security should be examined at the local level to encompass household. Food security must be viewed in terms of availability or production, access and utilization. In this context, the mapping of food security and the stability (frequency of food deficit over time) since 1986/87-2005/06 in Terai has been accomplished by adopting the food availability approach (Food Supply to Food Demand Ratio). This

information is subjectively linked with other indicators such as population growth, poverty, land access, and child malnutrition to establish the status of food access utilization. The aggregate data is used to depict the regional level trends of food production and supply. The details of the data analysis approaches and mapping methods of the food security status at a district level are described below.

3.4.4.1 Food Supply to Demand Ratio

(a) Determining the Food Supply

Paddy, wheat, maize, barely, millet, and potato are the major food crops of the Nepalese Terai. We developed a simple logical equation considering the underlying variables of food production to assess the temporal status of food security in Terai districts. Thus, following equation was used to calculate the calories produced in the districts on the basis of Table 3-3.

$$Xi\ (cal) = [\{Y - (S+L_1+L_2+O)\} * E] * (Rcal/100) \quad \ldots\ldots (1)$$

$$Tcal = \sum Xi\ (cal) \quad \ldots\ldots (2)$$

Where,

Xi (cal) = Calorie from crops production those are grown

Y= Output produced from single crop

S= Parts of crops that are used for seed

L_1= Loss before processing

L_2= Loss after processing

O= Parts of the crops that are used for other purposes

E= Extraction rate (Milling Rate)

R Cal= Calorie conversion rate per 100 grams

Tcal= Total calories produced in the district

(b) Estimation of Calorie/Food Demand

Food Demand (FD) is estimated on the basis of individual calorie requirements from cereals and tuber crops. The calorie consumption is the product of the Total

Population (TPOP) and the Minimum Dietary Energy Requirement (MDER). MDER = Recommended calories per person per day i.e. 2,144 calories/person/day.

$$FD = TPOP * MDER \quad \ldots\ldots (3)$$

An individual receives calories from different sources such as cereals, animal products, vegetables, and fruits and other food stuffs. Due to unavailability of data from all sources at the district level for the entire study period, only cereals and potato are considered. Similarly, the NLSS (2003/04) recommended that 2,144 calorie/person/day is needed. In Nepal, an individual receives a share of >87.3% of the total average calorie from cereal crops (CBS, 2003). Thus, in this analysis, the basis of minimum threshold calorie required per person per day from cereal is considered by adopting 1,872 calories/person/day. Population level for the entire study period at the district level was not available, and thus the population for the study period is projected on the basis of census taken in 1991 and 2001. Population at the district level for both census and the annual population growth rate from 1991-2001 are available. Therefore, the population growth rate during 1991-2001 by districts is used to project the district level population between 1991 and 2001 and from 2002 to 2006. The population determined by the 1991 and 2001 census is used at the district level. Similarly, to depict the district level population for the period 1986-1990, a backward projection method was used by using the district level population of the 1991 census and population growth rates from 1991-2001.

Table 3- 3 Seed rate, losses, and calorie conversion rate

Crops	Seed rate (Kg)/ha	Loss before processing (%)	Loss after processing (%)	Other usage (%)	Calorie conversion rate (100gm) after extraction	Extraction Rate (%)
Paddy	50-60	10	1	0	345	61.75
Wheat	110-120	10	1	0	346	96
Maize	20-25	10	1	15	342	97
Millet	5-10	10	0	10	336	93
Barely	90-100	10	0	0	309	32
Potato	1000-1500	15	0	0	097	N/A*

Source: Ministry of Agriculture and Cooperatives, Department of Agriculture, Marketing Directorate Harihar Bhawan, Nepal. * Not Applicable

- **Loss:** Before processing loss includes losses from transportation, losses during threshing, losses from storage pests, and any type of loss after harvest losses. Loss after processing includes losses during transportation of processed food, storage loss after processing, and other loss before consumption.
- **Calorie Conversion**: For calorie conversion, equations 1 and 2 are used. First, the caloric levels for single crops are calculated and the caloric levels from all 6 crops are added to obtain the total calorie supply (Food Supply) in each year in each district.
- **Limitations**: Due to unavailability of all data pertaining to food stuffs at the district level, only cereals and tuber are considered to calculate the food demand at the district level.

3.4.4.2 Food productivity trend and future food production

Similarly, moving average analysis has been applied to depict the productivity trends of food crop where projects values in the forecast period, based on the average value of the variable over a specific number of preceding periods. A moving average provides trend information that a simple average of all historical data would mask. Moving average can be applied to any data set, but is most commonly used with time series data to smooth out short-term fluctuations and highlight longer-term trends or cycles. Mathematically, a moving average is a type of convolution and so it is also similar to the low-pass filter used in signal processing.

Moving average is explained as.

$$MA = \sum_{i=1}^{3} \frac{y_{t-1} + y_t + y_{t+1}}{N}$$

Where,

y_{t-1} = Production of preceding the t year

y_t = Production of t year

y_{t+1} = Production of following the t year

N = Number of periods

And, ordinary least square method has also applied to predict the future food crop production in Terai. Ordinary least square express as:

$$Y_t = \alpha + \beta X_t$$

Where, Y_t is dependent variable explained by exogenous variable X_t,

α and β are parameters.

3.4.4.3 Assumptions

Mathematically, the FSDR 1 is a balanced situation in any geographical boundary; however, this is not a sufficient condition for food security. Practically, we assume that:

- 20-25% of excess food production in a district represents a secure food situation, considering the unforeseen shock of a potential food deficit.
- Share of cereals to total energy consumed by person is the basis of this analysis.
- Potato is also included to calculate the energy supply.

CHAPTER 4 FOREST MONITORING AT LOCAL SCALE

4.1 Introduction

4.1.1 Mapping deforestation and forest degradation

Deforestation and forest degradation are associated and progressive processes resulting in the conversion of forest area into a mosaic of mature forest fragments, pasture and degraded habitat. It reduce the area, quality and quantity of woody vegetation cover and alter the spatial structure of landscapes through the process of fragmentation which is also related to deforestation and loss of forest cover (Noss, 1999; Fitzsimmons, 2003; Nagendra et al., 2004). In both processes forest land is cleared and opened up to supply large and small scale industry with various wood products and to provide rapidly growing populations' space for cultivation and settlement.

Account of widespread degradation and deforestation in Nepal has been found in the management plans developed by forest authorities in Nepal. We argue that not all the forest types experience similar rates of deforestation and degradation. In other words, forest with high commercial value species would be degraded more than the forest having low value species. Therefore, there is an urgent need to develop strategies and remedies for this threatening problem. In this endeavour, the first task is to provide accurate spatial information and progression about the degradation and deforestation trend of each forest type. The range and variation in forest types or coverage of forest area can be quantified from many sources. The best source is a sequence of maps of one landscape from many time periods or time series data. In this scenario, available remote sensing satellite data at different spatial, spectral, and temporal resolutions have shown good potentialities for detection and mapping of forested area, forest types and deforestation and degradation status of each forest types. Thus, in this study we utilizes the different remote sensing sensors and GIS data to quantify spatial and temporal patterns of degradation and deforestation of

forests in Chitwan district of Nepal and to map and compare the conditions of all major forest types in the region. The results of this study are intended to aid in the planning of future actions concerning forest restoration and ecosystem management in Nepal. This information will help the forest authorities and decision makers in developing and planning a suitable strategy to control deforestation and forest degradation processes. We used times series satellite data and aerial photos to analyze and classify the satellite imagery to separate forest and non- forest area in the region. Forest canopy density has also quantified to assess the rate of forest degradation. Detailed procedure has described to map and quantified the forest cover and major forest type's changes in Chitwan district in methodology section 3.4.1.1 and 3.4.1.2 in Chapter 3.

4.1.2 People's livelihood and forest resources dependency

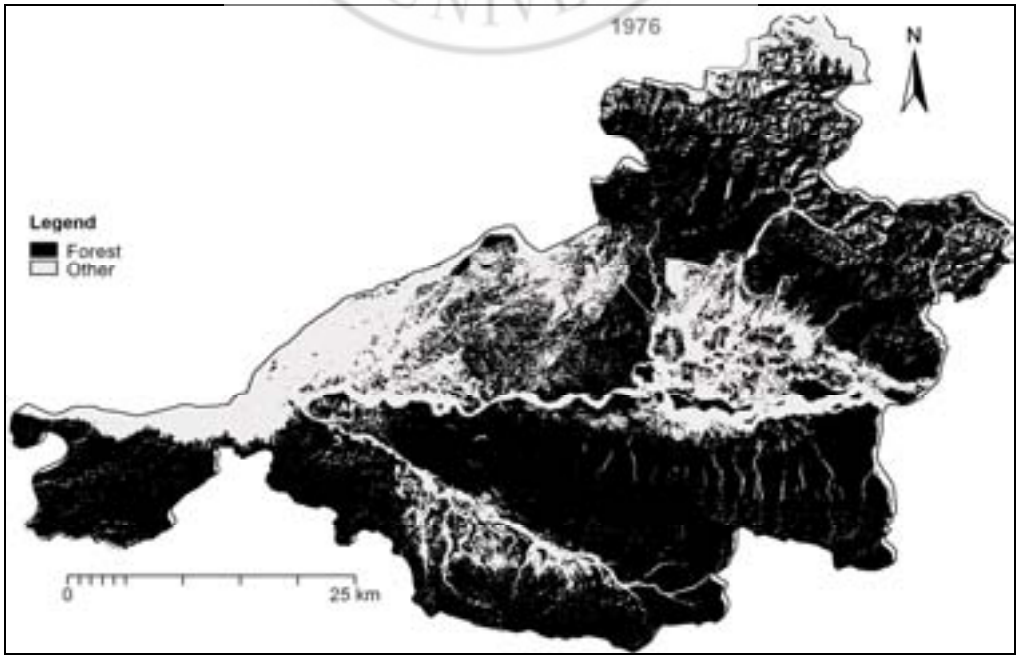
Forest resources are crucial for the human well-being by providing foundations for life on earth through ecological functions, regulating the climate and water resources. Additionally, forests also endow a wide range of natural assets such as goods, cultural values, physical and biological function and other services that vital for the people's livelihood (USDA, 2007; NRC, 2008). In Nepal, forest are closely related to the basic needs and survival of rural poor livelihood where dependency on fuel wood for cooking and house heating represents 83% of the energy consumption (SOE, 2001; ADB, 2004). While fodder collection and grazing are traditionally practiced for livestock production, a major food resource for the people of all regions (FRA, 2000). The national policies of government mainly focus on the activities like commercial forest production and agricultural development, however, ignoring the local resources potential and requirements of rural poor. Major conflict thus exists between the local and national desires either for protection of such areas/forest resource or for exploitation. The focal point of national policy could always on tourism promotion and economic development while local people seek for the maximum utilization of resources such as forest to meet their basic needs. The responsible government body however, could not pay adequate attention to future required negotiations regarding equitable access to knowledge and means for the

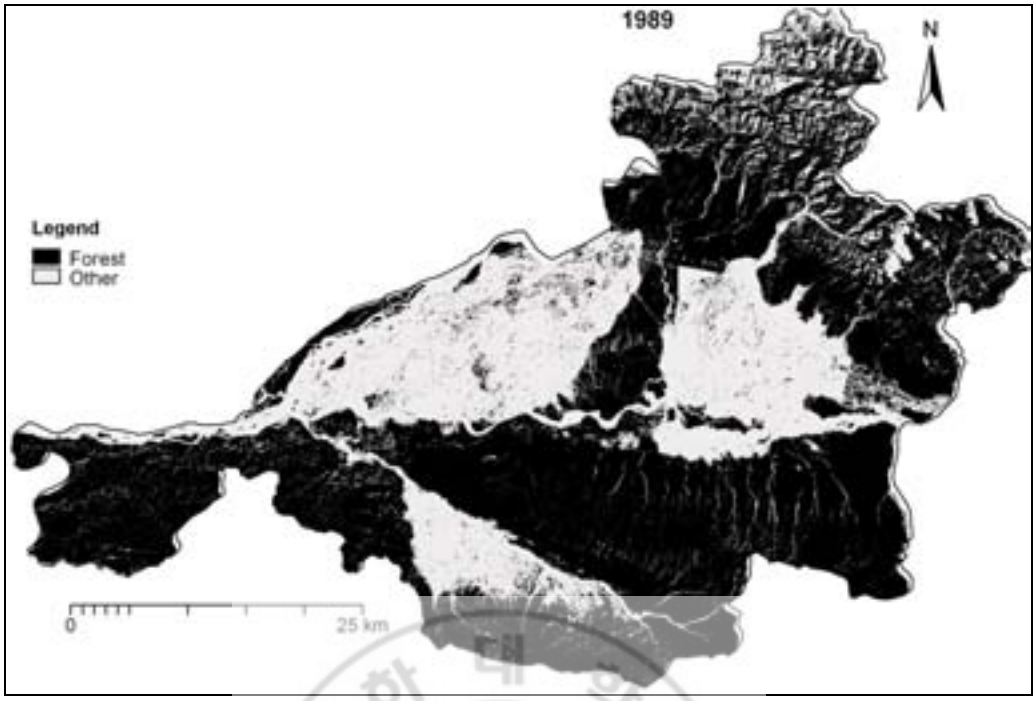
sustainable resource management. Such negotiation processes must balance local entitlements, national developmental interests and environmental concerns with sustainable utilization strategy. A fundamental premise is, therefore, that existing constraints at different scales need to be addressed simultaneously as to increase the awareness in local responses. This analysis tries to identify the livelihood strategies of rural people and their degree of dependency on forest resources around the forest corridor of Chitwan based on information gathered from field visit during the household survey. Detail procedure for whole analysis is explained in the sections 3.4.2.1, 3.4.2.2, 3.4.2.3 and 3.4.2.4.

4.2 Deforestation and forest degradation analysis and results

4.2.1 Forest covers changes analysis

Satellite images of different years such as 1976, 1989 and 2001 were analyzed to investigate the spatio-temporal change in forest covers in Chitwan district. Most of the land of Chitwan district was covered with dense forest vegetation in 1976. Forest area started to decrease and converted into other land in subsequent years. Our analysis reveals a considerable decline in forest area and forest vegetation in the Chitwan district between 1976 and 2001 (Figure 4-1).




1989
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Legend
Forest
Other
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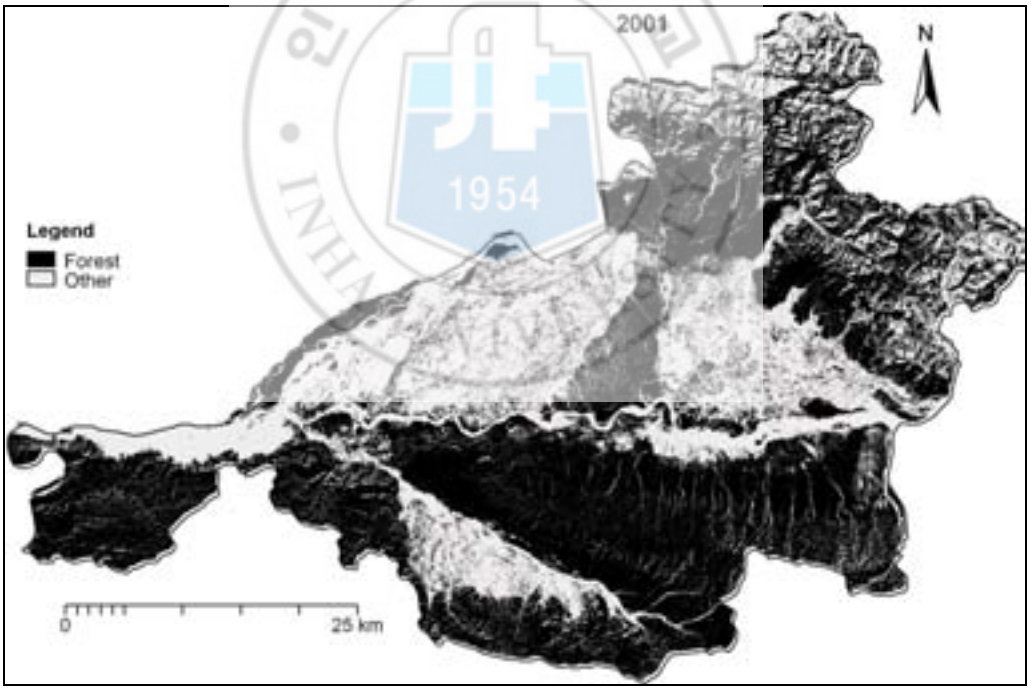
25 km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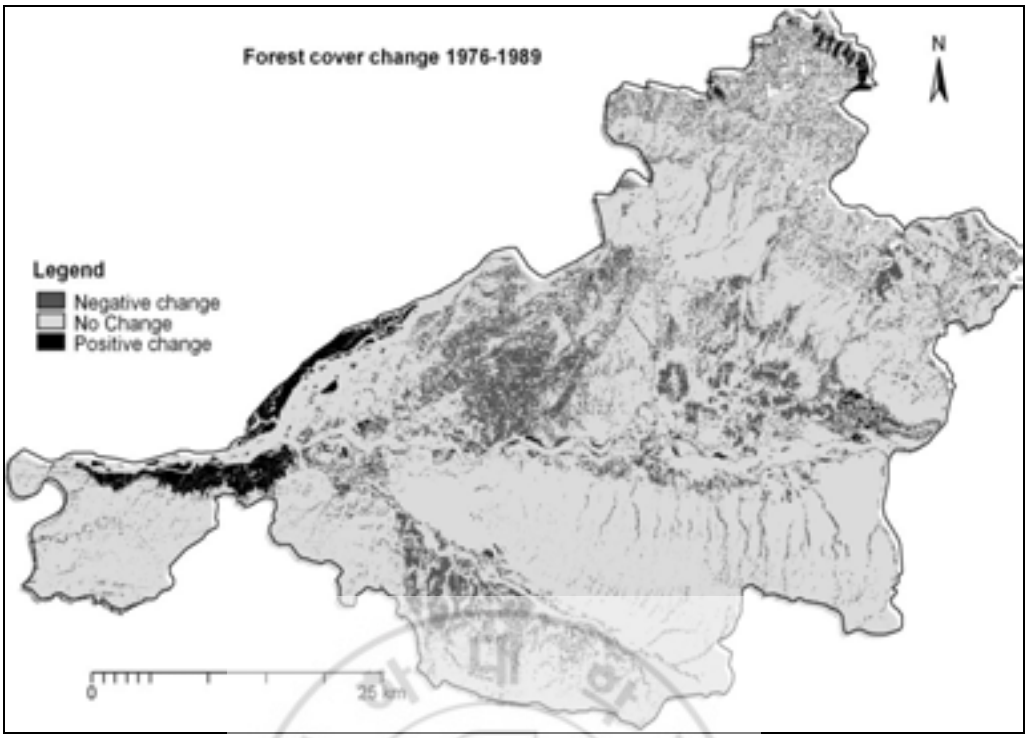

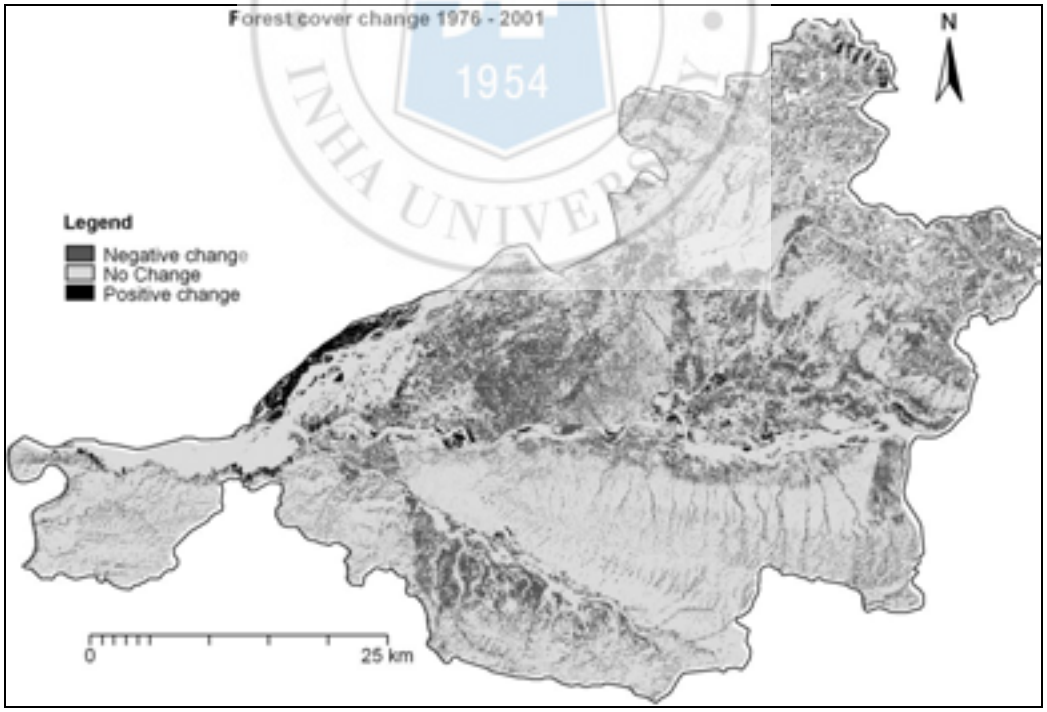

Figure 4- 1 Forest covers of ´76,´89 &´01 and change between´76 -´89 &´76 -´01.

This analysis reveals that the forested area in Chitwan district was reduced by 15.3 % between the year 1976 and 2001 with an annual rate of decline of about 0.6% (Table 4-1).

Table 4- 1 Forest covers changes between 1976-1989, 1989-2001 and 1976-2001.

Percent change 1976 - 89	Percent change 1989 - 01	Percent change 1976 - 2001	Annual rate of change percent
-7.99	-7.95	-15.31	-0.61

A historical data analysis revealed similar trends in forest area depletion in the Chitwan district. Figure 4-2 further shows that the arable land of the district significantly increased and forest area decreased between 1958 and 1996.The forest area was about 69 % in 1958 and remained at nearly 42 % in 1996 while arable land area increased from about 31% to 58 % between 1958 and 1996.

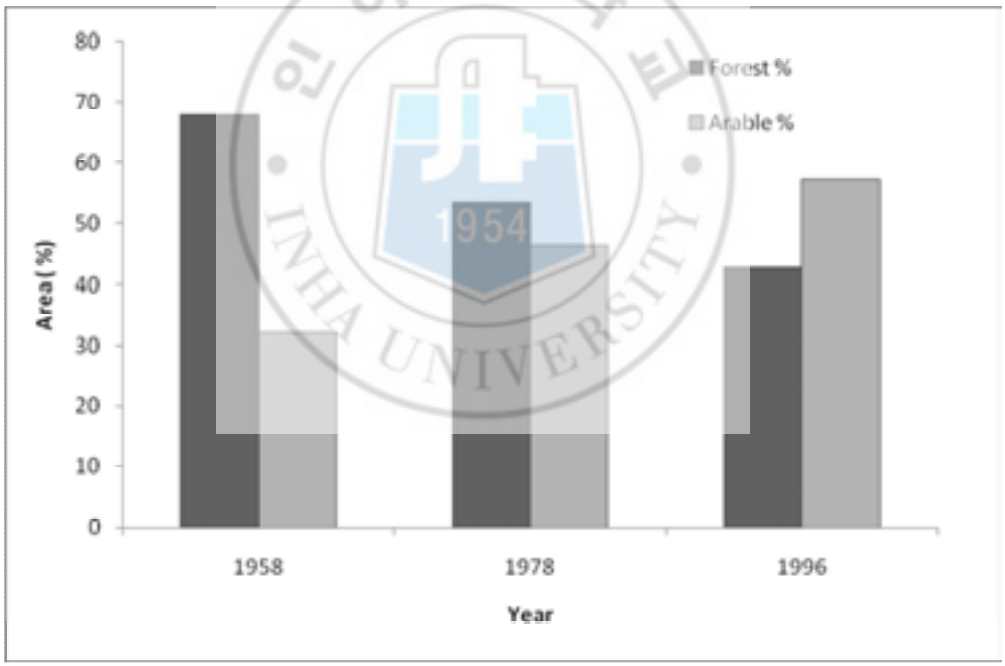

Figure 4- 2 Forest and arable land area of Chitwan in 1958, 1978 and 1996.

4.2.2 Forest canopy density and conservation status

Figure 4-3 presents the status of the forest canopy density within and outside the protected areas. A confusion matrix (Table 4-2) reveals that the canopy classes were mapped with high accuracy. 135 out of 164 observations were correctly classified.

The confusion matrix analysis yielded an overall accuracy of 82 %. It further shows that the <20% and 21-40% canopy density classes were classified with a producer's accuracy of more than 77% and 67%, respectively, with much of the error attributed to confusion with the "0 % or other" and 40-60% canopy density class. The highest canopy density class (i.e.>60%) was classified more accurately than the other canopy classes with a producer's accuracy of 98%.

Visual interpretation of the classified canopy map (Figure 4-4) reveals that dense forest of over 60% canopy density in the Chitwan district in 2001 remained only within the confines of the Chitwan National Park boundary and some high mountains in the northern part of the district. But, forest canopy density in all other areas in the district remained below 40%.

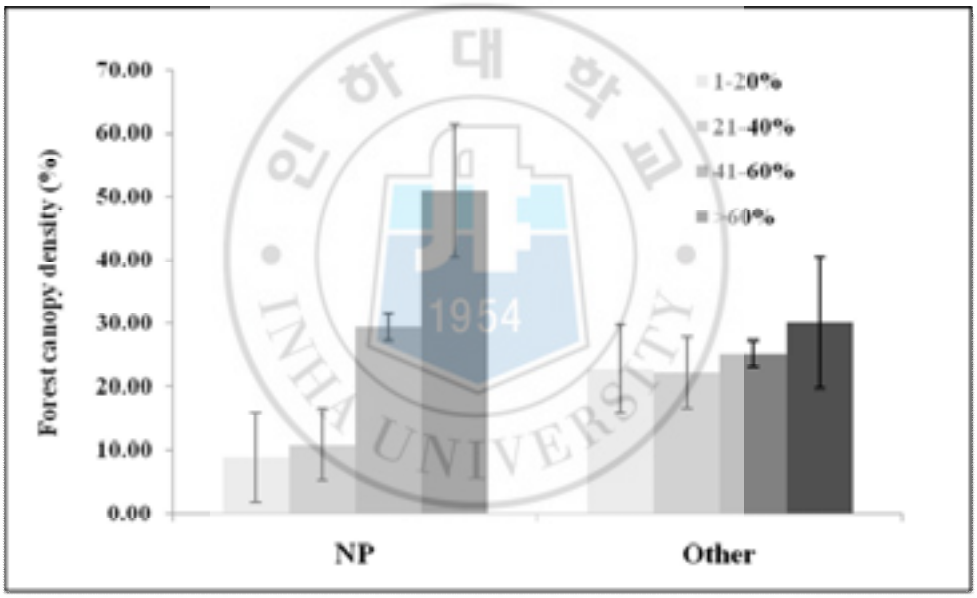

Figure 4- 3 Forest canopy density within and outside the National Park (NP).

Table 4- 2 Confusion matrix for observed vs. predicted forest canopy density classes.

Forest canopy density	0%	<20%	21-40%	41-60%	>60%	Total	Omission error	Producer's accuracy
0%	26	4	2	0	0	32	18.75	81.25
<20%	2	14	2	0	0	18	22.22	77.78
21-40%	1	2	21	7	0	31	32.26	67.74
41-60%	0	1	1	23	6	31	25.81	74.19
>60%	0	0	0	1	51	52	1.92	98.08
Total	29	21	26	31	57	164		
Commission error	10.34	33.33	19.23	25.81	10.53		135	
User's accuracy	89.66	66.67	80.77	74.19	89.47	Overall Accuracy		82.3%

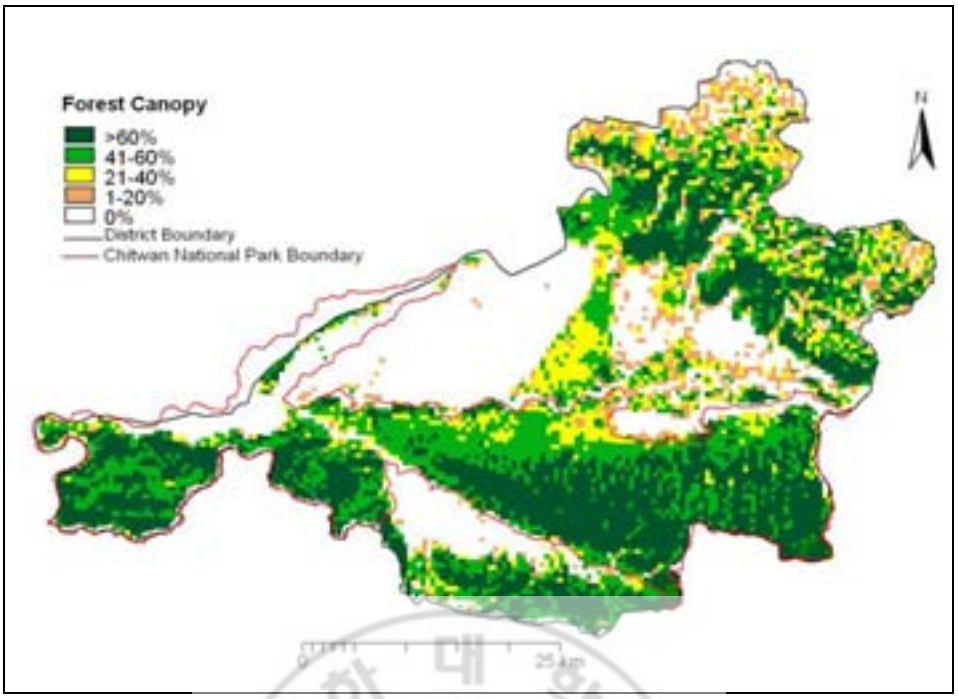

Figure 4- 4 Forest canopy density map of Chitwan district in 2001.

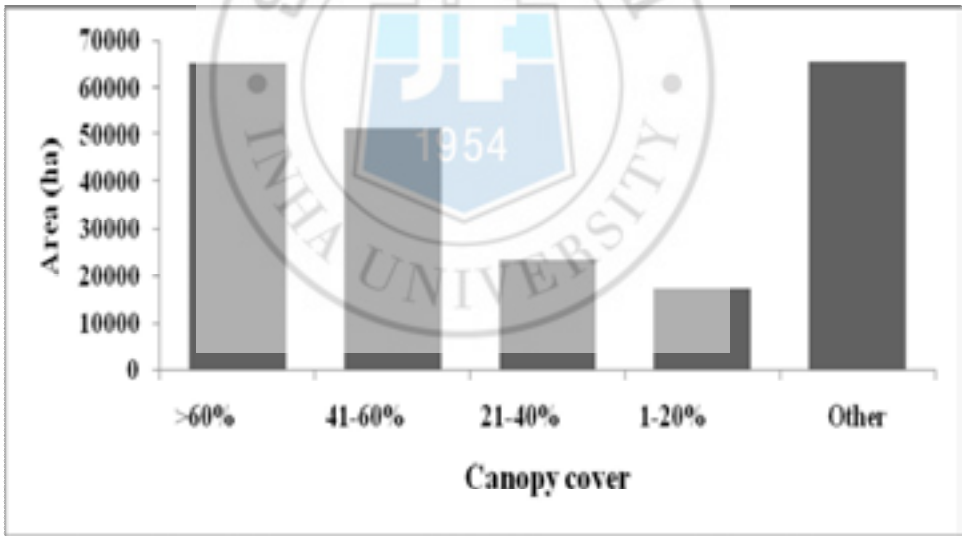

Figure 4- 5 Total area under different forest canopy density classes.

A narrow forest patch in the middle of the district had the lowest canopy cover, which indicates a heavily degraded forest corridor connecting the protected area (the Chitwan National Park) with the remaining forested area in the district. The total area in the district under forest canopy densities classes is given in Figure 4-5.

4.2.3 Depletion of area of forest types

Forest types map of 1976 (Dobremez, 1976) identified five forest types found in the Chitwan district. They were: 1) Chir pine (Pinus roxburghii) with Broad Leaved, 2) Hill Shorea (Hill Shorea robusta), 3) Terai Shorea (Plain Shorea robusta), 4) Riverine Acacia (Acacia catechu) with Dalbergia (Dalbergia sissoo) and 5) Riverine Broad leaved forest.

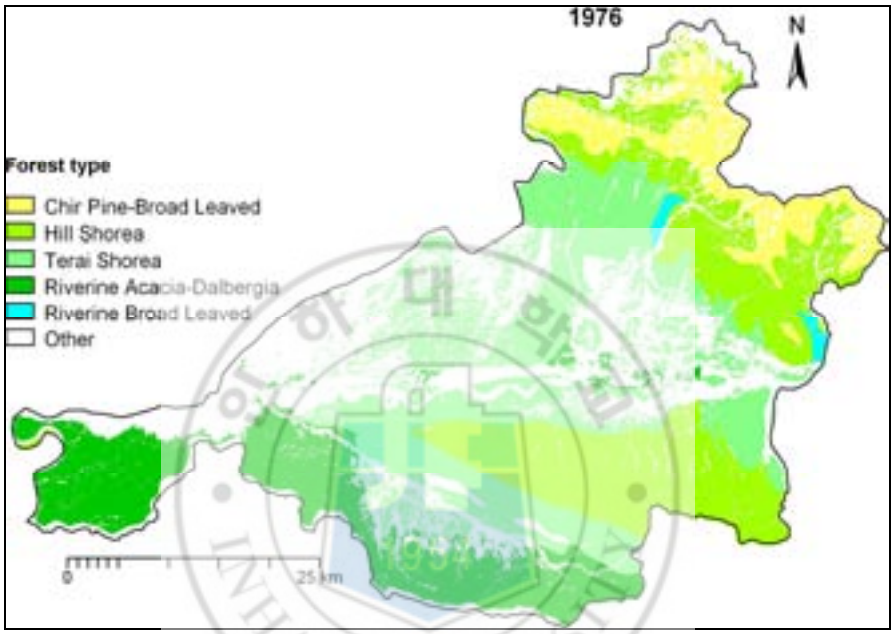

Figure 4- 6 Forest type's map of 1976.

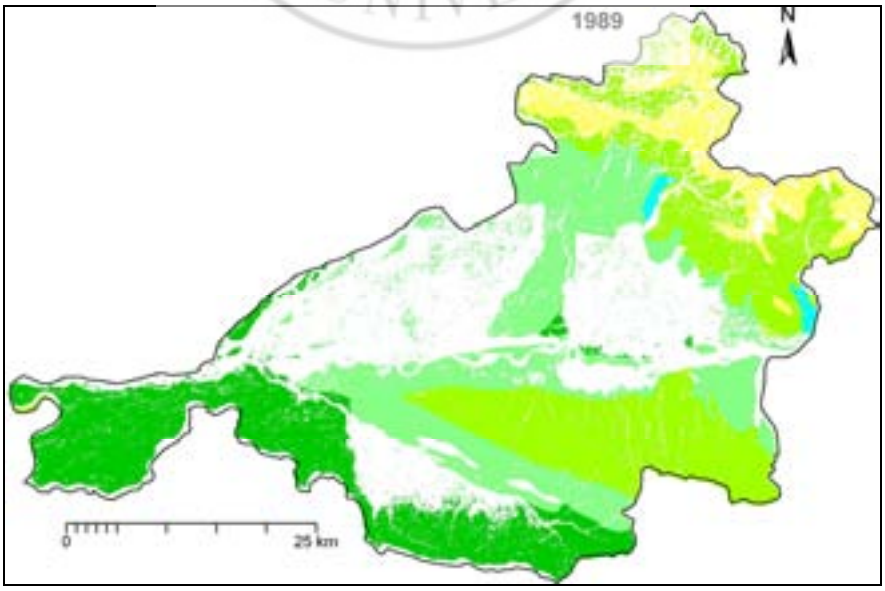

Figure 4- 7 Forest type's map of 1989.

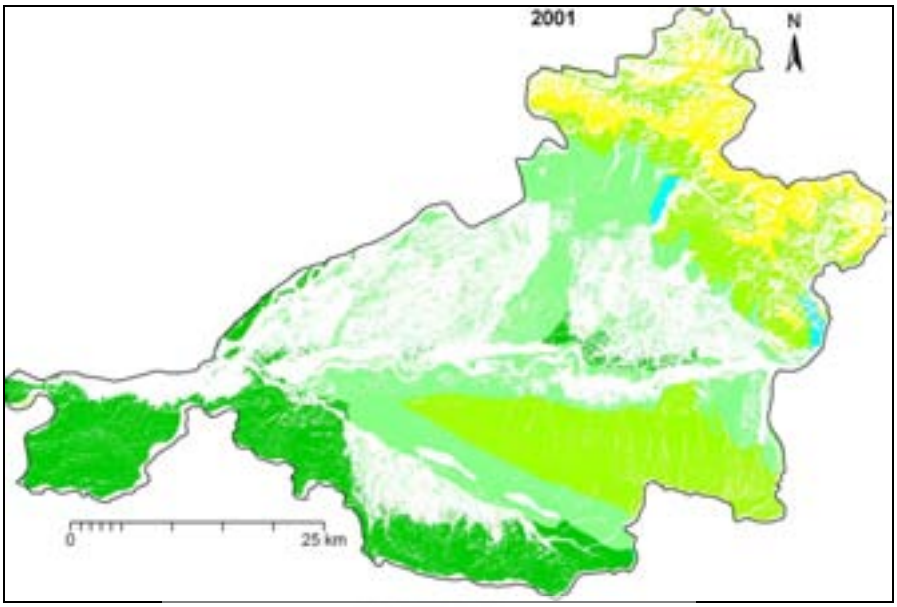

Figure 4- 8 Forest type's map of 2001.

Our data analysis of the forest area of the five major "forest type" and "0 % or other" (land cover other than forest) in 1976, 1989 and 2001 reveals a maximum decline for the area of Chir pine (Pinus roxburghii) with Broad Leaved and Terai Shorea forest (Figure 4-6, 4-7 and 4-8). Except for Terai Shorea forest between the periods of 1989 - 2001, the area of all other forest types was reduced (Table 4-3).

Table 4- 3 Change in different forests cover types.

	Forest cover change (in %)		
Forest type	1976 - 989	1989 - 2001	1976 - 001
Chir Pine with Broad Leaved	-9.80	-12.10	-20.71
Hill Shorea robusta	-0.37	-12.64	-12.97
Terai Shorea robusta	-23.04	5.22	-19.03
Riverine Acacia with Dalbergia	4.06	-9.31	-5.63
Riverine Broad Leaved	-0.93	-17.38	-18.15
Other	20.20	14.57	37.71

4.3 Analysis of livelihood strategies at local level

4.3.1 Demographic characteristics

The total population in sample households was 607 with average household size of 6.07.The population constitutes 51% of male and 49% of female. The economically active population (>15 years and <60 of age) in sample households was about 51.24 % with dependent population about 48.76 % (children 37.56 and old aged 11.20%) (Table 4-4).

Table 4- 4 Demographic characteristics

S.N	Description	Count	Percent
1	Population		
1.1	Male	310	51
1.2	Female	297	49
1.3	Total Population	607	100
2	Population characteristics		
2.1	Adult (including above 60 years)	379	62.44
2.2	Economically active population	311	51.24
2.2	Children	228	37.56
2.3	Old aged	68	11.20
2.4	Average Household Size	6.07	
3	Respondents		36
3.1	Female	36	74
3.2	Male	74	
4	Education of respondent		
4.1	High School Graduate and Above	29	29
4.2	Some Secondary Education	7	7
4.3	Some elementary Education	34	34
4.4	No Education	30	30
4.5	Literacy rate		70

4.3.2 Livelihood sources

It was observed that most of the villagers had multiple livelihood sources and basically reliant on the agriculture based occupation such as food crops, livestock farming and vegetables. Out of total sample households, about 98% of households fall under food crops, and 92% under livestock husbandry. Similarly, response on wage labour, service sector (employment on private and government sector) and

petty shop are 33% , 29%, 23% respectively but fire wood collection accounts only 20% for their livelihood (Figure 4-9).

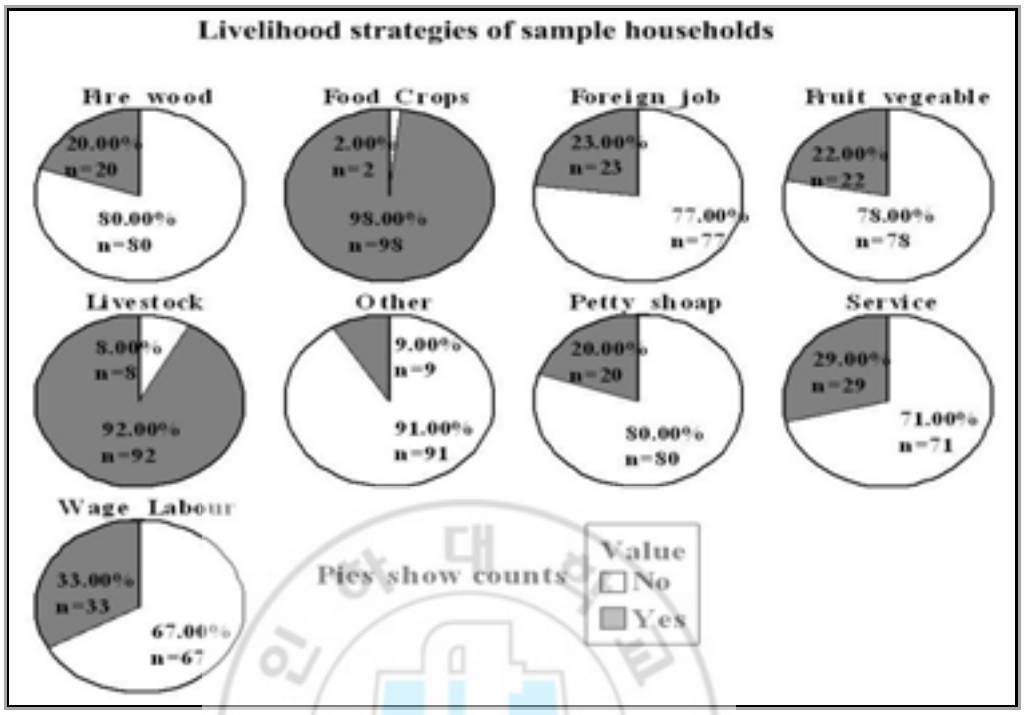

Figure 4- 9 Responses of households on their livelihood strategies.

Mostly, food crops, vegetables and livestock are raised together. The response over multiple categories of the livelihood strategies are depicted in figure 4-10. Data explores the facts that the dominate livelihood strategy is crop and livestock farming which is directly associated with forest resources in terms of grazing, fodder collection. The crop, livestock and service category accounts for 29% responses. Similarly, crops, livestock and wage labour; crop, livestock and foreign labour; crop livestock and petty shop accounts for 26%, 23%, and 20% of responses respectively.

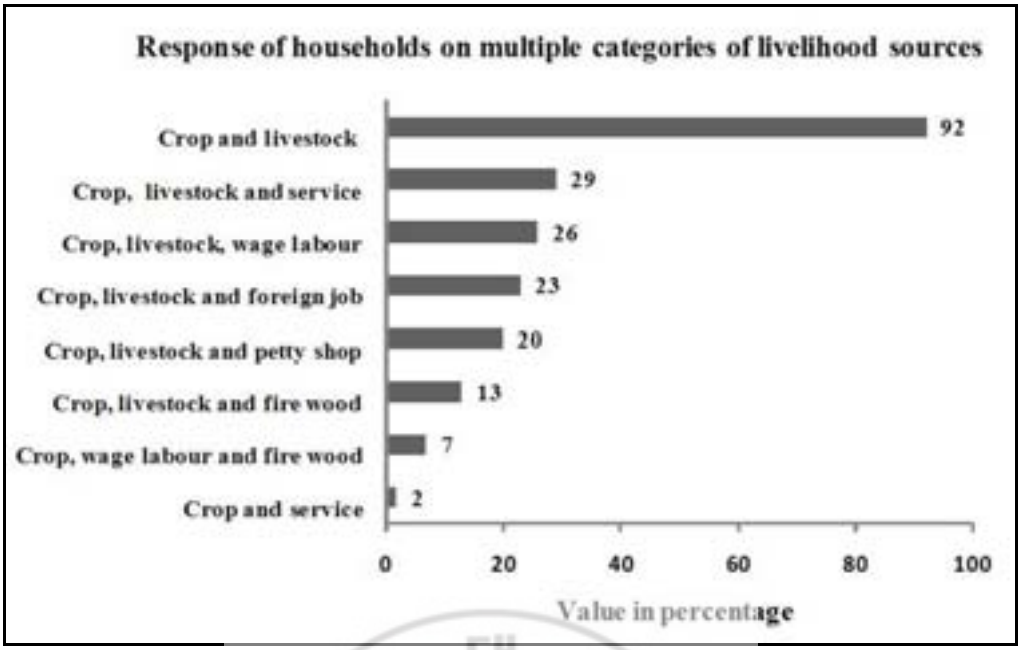

Figure 4- 10 Response of households on multiple livelihood sources.

4.3.3 Production and productivity of food crops

A sum of 65.74 ha arable land with 0.656 ha of average landholding size was in the study area. Paddy is the principle food crop followed by maize and oilseeds. The total cropped area was 136.60 ha and out of which paddy shares highest share in both total cropped area (about 35%) and total production (about 56%). Similarly, maize and oilseeds shared about 32% and15 % respectively in total cropped area and about 23% and 5% in total production. Vegetables shared about 5% of total cropped area where as it shared almost more than 10% in total production. The productivity of paddy is considerably good and it yields 3.3mt/ha. The productivity of maize, wheat and vegetables and oilseeds were very low indicating that agriculture alone is not a sufficient occupation for their livelihood in the study area (Table 4-5). Additionally, Table 4-6 reveals that 63% of the sample households responded their production did not yield enough to feed their family and among them about 74% (47.6% for <3 months and 26.89% for 3-6 months) of household responded their production did not supported their family more than 6 months.

Table 4- 5 Area, production and productivity of major food crops

Crop	Area (ha.)	Production (MT)	Percentage share of total cropped area	Percentage share in total production	Productivity (Kg/ha)
Maize	44.46	63.69	32.55	22.62	1432
Paddy	48.48	158.41	35.49	56.27	3268
Wheat	12.16	14.71	8.91	5.23	1209
Vegetables	7.09	28.70	5.19	10.19	4049
Pulses	4.12	2.85	3.02	1.01	691
Mustard /Tori	20.28	13.18	14.85	4.68	650
Total	136.60	281.54	100	100	
	Per capita land holding:		0.656 ha,		
	Cropping Intensity:		208 %		

Table 4- 6 Households response on their production to feed their family

Description	No. of households	Percentage
Supporting their family	37	31.00
Not supporting their family	63	63.00
Period of sufficiency among 63 households		
< 3 month	30	47.61
3-6 months	17	26.89
6-9 months	12	19.04
> 9 months	4	6.35

4.3.4 Income sources of households

Arable farming constitutes the highest share of NRs. 28,769.00 (about 24%) in average annual household income followed by remittance NRs. 23,775.00 (about 20 %). Service sector, petty shops and livestock shared almost 19 %, 13% and 10% in total average households' income respectively. Similarly, other sources such as pension, wage labour etc shared 5 or < 5% in total household income where as fire wood collection and sale shared about 3% of the total house hold income. The data reveals that almost 34% of annual household income shared by agriculture (crop and livestock) and remittance (20%) is another important source of income in the study area. The largest share of income in agriculture explores the fact of dependency on agriculture and forest resources because forest and agriculture sector together accounts almost 37% of share in total annual household income in the study area.

The average per capita income of sample households is NRs. 21,117.00 (about US $ 293.00) which indicates the lower income than the National per capita GDP (US $ 383.in 2006/007) (Table 4-7). Source (National Accounts of Nepal 2006/07, CBS, 2007).

Table 4- 7 Income sources and share in total annual household income

S.N.	Income Sources	Mean Income (per household/year)	Percent
1	Arable Farming	28,769	23.92
2	Livestock	11,500	9.56
3	Petty shops	15,603	12.97
4	Wage labor	6,585	5.48
5	Pension	5,142	4.28
6	Remittance	23,775	19.77
7	Services	22,595	18.79
8	Fire wood sale	3,580	2.98
9	Others	2,714	2.26
Total		120262	100
Per capita income		NRs. 21,117.00 , in US $293.00 (1 $= about 70-72 NRs)	

4.3.5 Land and income distribution

The individuals or households perceive their position in society is an important aspect of their welfare. The relative poverty line may not guarantee to capture the dimension of welfare by classifying as 'poor' those who have less than some societal norm. The overall level of inequality in a specific population group is also an important dimension of welfare in that group. Lorenz curve and Gini coefficient is commonly used to measure inequality of some specific distributions such as consumption pattern, income or land and other continuous and cardinal variables. Thus, we also adopted this statistical tool to assess the income and land property distribution of the study area. The distribution of the income and the land property in the study area clearly has greater impact from the perspective of the forest resource management.

The distribution pattern of the income and the land holdings in the sample population is depicted in Figure 4-11. Data reveals that income is not equally distributed among the sample population but the Lorenz curve shows distribution is

nearer to the perfect line with low Gini coefficient 0.25 (Figure 4-11 in left). The income distribution is somehow more equal than the distribution of landholdings; this is possibly being the outcome of remittance because some of households reported that their family member migrated temporally to seek the job outside the country i.e. India and other foreign countries which make considerably higher income for them even though they have very small size of land to cultivate and no job in the village or outside the village in home country. The Lorenz curve of land holdings demonstrates that there was moderately unequal distribution of arable land within the sample population with Gini coefficient 0.37 (Figure 4-11 in right).

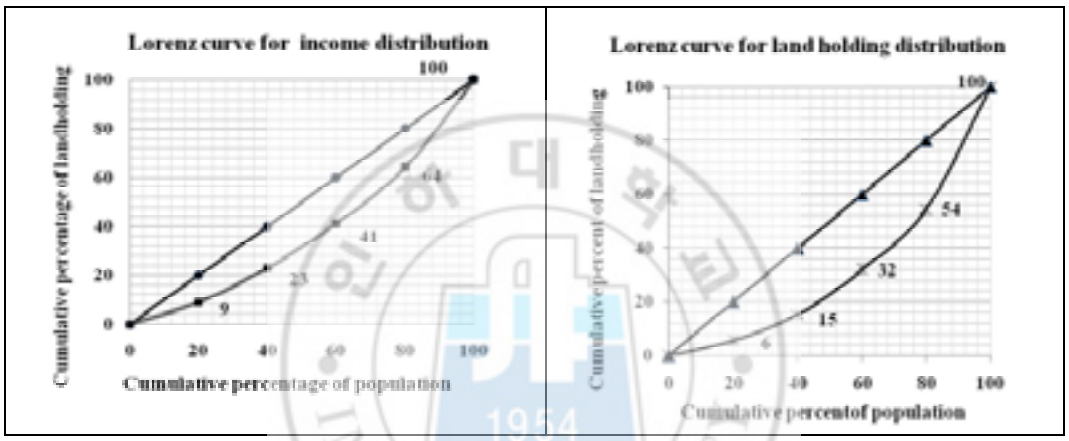

Figure 4- 11 Distribution of the household's income (left) & land (right).

4.3.6 Household consumptions

The largest share of average annual households' income was spent on food consumption (about 53%) followed by education 13%, cultivation about 5%, and in religious, health and clothing were 8%, 6% & 5% respectively. Only 3.2 % & 2.6% of their total annual income was spent for transportation and energy (Table 4-8). The share of firewood purchase in total energy consumption was only 2.62 % (NRs 234/hh) and out of 100 households, 98 responded they were using firewood for cooking and other purposes except light. Out of 100, 20 responded they were also using Biogas and firewood. 50% of the cooking energy is shared by firewood even though they have a Biogas plant the gas may not sufficient in winter and quite low so they depends on firewood. This indicates the largest volume of firewood is extracted from the forest.

Table 4- 8 Allocation and consumption of average annual household income

S.N.	Items	Average Consumption (Household per month)	Percent of total income
1	Food	4,781.00	53.37
2	Health	551.00	6.15
3	Education for Children	1,140.50	12.73
4	Clothing	452.50	5.05
5	Religious functions	684.00	7.64
6	Transportation	291.00	3.25
7	Energy Total	234.50	2.62
7.1	Electricity	106.80 (45.54)*	(1.19)**
7.2	Kerosene	30.90 (13.18)*	(0.34)**
7.3	L.P. Gas	67.50 (28.78)*	(0.75)**
7.4	Fire Wood Purchase	29.30 (12.49)*	(0.33)**
8	Cultivation	455.50	5.08
9	Others (Water, Telephone etc.)	368.25	4.11
	Total	8,958	100

*, ** figures in parentheses denotes the percentage of subtotal and total consumption respectively

4.3.7 General poverty in the study area

The poverty in the study area was expressed based on the income assessment of the sample households during the field survey. Income from different sources was calculated based on the local price of the products produced by the villagers. Head count poverty index (see methodology) and poverty gap was calculated to explore the poverty status of the sample population considering threshold poverty line NRs, 14942.00/yr based on the per capita income US $ 1 per day and assuming 210- 215 working days available for them. This was generalized in the whole study area.

Our result revealed that almost 33% of population was below the poverty thresholds (Nrs.14942.00) with poverty gap index 0.0945 (about 10%). It is considerably higher than of NLSS II which explained almost 28% of head count poverty in rural Terai in 2003/2004 but somehow similar to 31% of National poverty line in 2003/04.

4.4 Forest resource dependency at local level

4.4.1 Forest products use and their availability

Forest products contribute an important role on village as well as urban life. Fire wood and fodder are the basic forest harvest extracted daily or weekly basis in the village life. Out of 100 sampled households, 82% households responded they collect fire wood from the forest and 12% responded they collect fire wood both from their own land and forest, 81% households collect fodders from the forest and about 58% households use forest or forest fringe for grazing their animals. Quantities of various forest products extracted from the forest are presented in Table 4-9. Data explores the fact that there is high dependency on forest products in the study area for their livelihood. The dominant forest products that extracted in the study area were fire wood and fodder and an average about 104 kg of fire wood and 66 kg of fodder were extracted by single household in weekly basis. About 1.21 hr/day was spent for animal grazing in the forest or forest fringe. Additionally, almost 6 cubic feet of timber, 4 kg of fibers, 0.7 kg of mushroom and 0.5 kg of medicinal herbs are annually extracted from the forest.

Table 4- 9 Type and quantities of forest products use

S.N.	Description	Households		Average Quantity Used(per household)	
		Number	Percent	Local Unit (Bhari /Week)	Standard Unit/week
1	Fire wood only from the forest	82	82	3.46	103.8kg/week
2	Fire wood both from the forest and own land	12	12	-	-
3	Fire Wood only from own land	5	5	-	-
4	Timber	12	12	-	5.970cf/year
5	Fodder from Forest	81	81	2.19	65.7kg/week
6	Medicinal Plants	21	21	-	0.5kg/year
7	Mushroom	10	10		0.7kg/year
9	Fiber and other Products	5	5	-	3.99kg/year
10	Grazing	42	42	-	1.21 hr./day

4.4.2 Monetary value of forest products use

Moreover, Table 4-10 explores that the annual extraction of forest products and services that used by local people in monitory term. A sum total of NRs. 10223.28 is the total annual value of the forest products and services that consumed by the individual household. Among forest products, fire wood constitutes the largest value (NRs. 4318.08) followed by timber wood (NRs. 3880.8). Likewise, the value of fodder is the NRs.1708 and fiber constitute about NRs.200.0 per year. The medicinal plants as well as mushrooms are also extracted from the forest. It is also obvious that income from livestock is also positively correlated with fodder that extracted from the forest which constitutes almost 10% of total household income.

Table 4- 10 Forest services used by a household (based on local price)

S.N.	Product	Unit	Annual Extraction	Per unit local price (NRs.)	Total Value
1	Fire wood	Kg	5397.6	0.8/kg	4318.08
2	Timber	cf	5.97	650/cf	3880.5
3	Fodder	kg	3416.4	0.5/kg	1708.2
4	Medicinal Plants	kg	0.5	150/kg	75
5	Fiber and other	kg	3.99	50/kg	199.5
6	Mushroom	kg	0.7	60/kg	42.0
7	Average Herd size	No.	6	-	-
8	Grazing	day	58.40	-	-
9	Total Grazing	animal day	350.40	-	-
10	Total value of forest product				10,223.28

4.4.3 Type and purpose of energy use

The Table 4-11 demonstrated the type of energy used, source and purpose for energy use reveals that electricity and kerosene is used for light during night. Out of 100 sample households 95% of household responded, Electricity was mainly used for light and for electronic house wares. Only 34% of household use Kerosene for burning lamps during power cut offs by the electrical authority.

Similarly, the LP gas, Biogas, and firewood are used for cooking. Based on the responses of the sample households a total of 82% of households are using firewood for cooking but only 23% and 20% of households are using both fire wood and LP

gas and both fire wood and Biogas for cooking. The households using LP gas and Biogas with arrangement of fire wood responded more than 50% of cooking energy is used from fire wood because of high cost of LP gas and the Biogas produced in their plant is not sufficient as their demand as well as during the winter, the production of Biogas is considerably very low. This result, explores the fact that a large volume of population is still depends on the firewood for cooking, and that it is collected from the forest.

Table 4- 11 Types and purpose of energy use

S.N.	Description	Household No	Purpose	Percent
1	Electricity	95	light, radio, television ironing	95
2	Kerosene	34	light during electric power cut off	34
3	Fire wood from the forest	82	cooking	83
4	Fire wood both from the forest and own land	12	cooking	12
5	Both firewood and Biogas	20	cooking	20
6	Both Fire wood and LP gas	23	cooking	23
7	Biogas and LP gas	2	cooking	2

4.4.4 Forest products availability

Present availability of forest product is analyzed by the responses of the households with temporal comparison of 20 years time horizon. Responses of the sample dwellers are recorded by assigning rank score for high availability to low availability of the forest products. We believed that, to explore the forest resource availability over time, opinion of the villagers could be one way which can demonstrate the status of resources on their experiences within time frame. Thus, to extract the fact, qualitatively response index were develop and response of sampled households were recorded assigning by scores as 1- 4 (1= abundant and 4 = scarce) for these responses (also see in methodology). The response about the forest resources was decoded to make ratio between 0-1 (1= abundant and 0 = no availability). We set 10 years period for time lag. A response index is constructed based on their ranking and the response index, reveals that there is a continuous decline of availability of forest products in the study area.

Based on the responses of the villagers it is concluded that even in the 20 years prior to now, the availability of the forest products and services might be not perfect but the response ratio reveals that the availability was quite good (0.781). The response ratio declined slightly for the previous 10 year period from 0.781 to 0.621 but it was sharply declined from the previous 10 year period to current year (0.308 - just half) (current year denote 2007 the year we collected sampled household survey data for this analysis) (Figure 4-12).

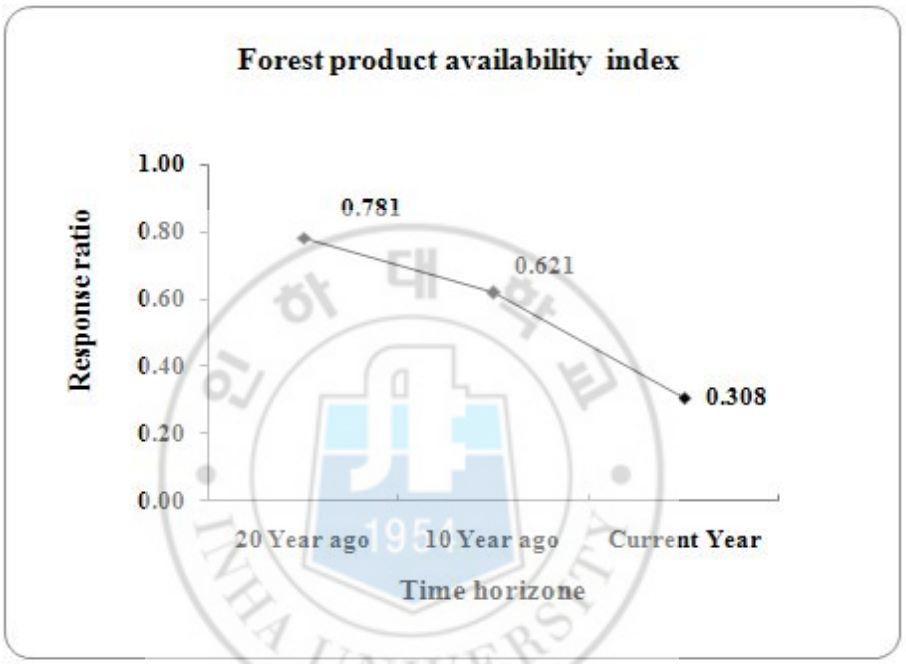

Figure 4- 12 Forest product availability response index.

Moreover, the response index for some of the key forest products are also constructed, and the results are also depicted in the figure 4-13. Figure 4-13 reveals that there is sharp loss of timber wood availability as compared to fire wood and fodder since 20 year ago. However, in case of fodder and fire wood there is slightly decline of availability from 20 year ago to 10 year ago and it was accelerated to decline from the similar pattern of timber wood from 10 year before to current year 2007.

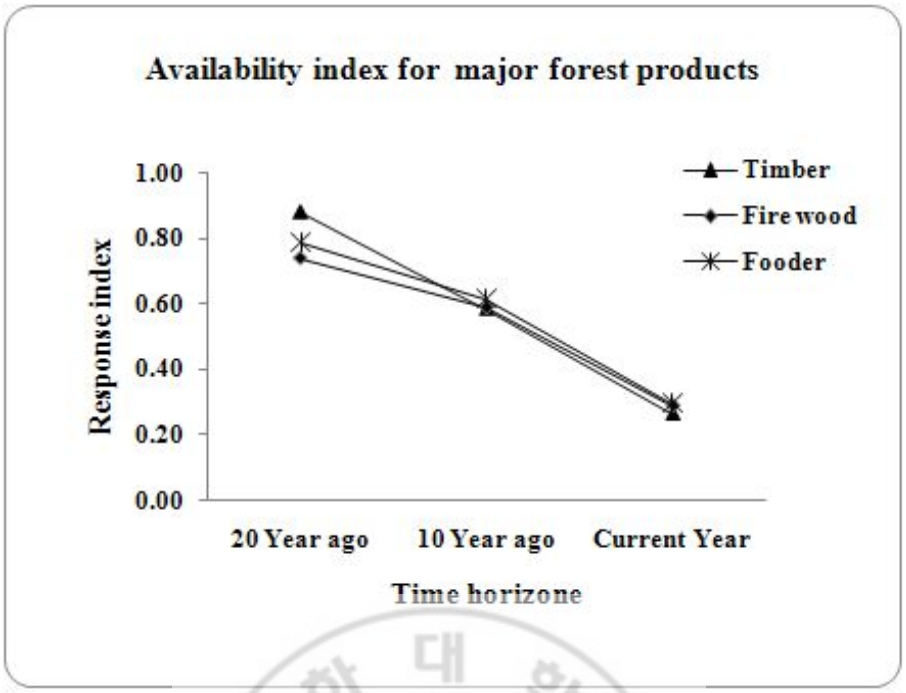

Figure 4- 13 Major forest products availability response index.

4.5 Forest management and local people's perception

4.5.1 Stakeholder identification and categorization

Stakeholder analysis is a tool for the identification of stakeholders, the assessment of their interests and other relevant attributes, and their relationships within or outside the every spatial system (if they are related to the specified system) which describes human and their relationship with natural resources. Stakeholders are all actors or groups who affect, and/or are affected by, the policies, decisions, and actions of resource management projects. This analysis seeks to differentiate and study them on the basis of their attributes and criteria appropriate to the specific situation (Table 4-12). These may include the interest of each stakeholder, their influence and importance, and the networks and coalitions to which they belong.

The forest of the study area is belongs to the protected area. Protection is an essential part of forest management. However, the quality aspects of the forest corridor have been depleted over time. The main threats which cause forest degradation are biotic (human) causes. Some of them are grazing, encroachment,

illicit cutting and fire. Forest protection is not the same as forest management and needs effective participation of the local people and other stakeholders considering their needs and interests. Forest resource management is not just about trees and it should also include management of the grass, fodder and NTFP resources in the forest. The quality and sustainability use of forest is the prime concern of all level of the stakeholders in the concerned spatial unit. Thus the key objectives for Stakeholder analyse are given below.

- ❖ It can improve the effectiveness of policies or projects, consider by stakeholders' interests and the challenges.
- ❖ It can better address the distributional impact of policies and projects to assess the interests and impact of intervention on different stakeholders.
- ❖ It can assure the involvement of minority groups in participatory methods.
- ❖ It can strengthen the implementation of projects and accelerate the operations involved.
- ❖ To better understand complex, multi-stakeholder situations on forest resources and existing consequences.

Table 4- 12 Stakeholder categories, their interest and potential impact

Stakeholders Category	Interests	Potential impact on forest resource management	Relative priorities of interests
Primary Stakeholders			
a. Local People			
b. Landless	Gathering fire wood for house and sale in local market, collecting grass, fiber and herbs, Timber wood	-/+	=1
c. Farmers	Gathering fire wood for house, collecting grass, fiber and herbs, Timber wood and grazing, Forest Management	-/+	=1
d. Service holders (Teachers and others)	Gathering fire wood for house, collecting grass, fiber and herbs, Timber wood and grazing, Forest Management	-/+	=2
e. Poacher and Illegal wood cutter	Hunting Rhino, Illegal timber wood cutting for sale	--?	=2
Secondary Stakeholders			
a. Urban dweller nearby Forest	Regular supply of timber, firewood and medicinal plants	-/ +	=2
b. Local Government (VDC or Municipality)	Regular supply of forest products, Sustainable forest management, Empowering local people and forest protection	+	=2
c. Local NGOs	Regular supporting by various micro-credit services in people's livelihood, Technical and financial support for forest resource management, and Awareness program etc.	+	=2
Tertiary Stakeholders			
a. Central Government	Sustainable forest management, Empower local people through various forest management modality and policy, Forest and biodiversity conservation and Tourism promotion	+	=3
b. National NGOs or INGOs	Sustainable forest Management, Empower local people through Community Forest Management, Forest management and biodiversity conservation and Tourism promotion	+	=3
c. Tourist	Enjoy with nature and natural heritage through visit, sight scene, Rhino and bird watching etc.	+	= 4

4.5.2 Forest resource management: aspect and problems

To observe the problems of forest resource management we collected the response of the sample households which is presented in the Table 4-13. On the basis

dwellers responses, the grazing in the forest was uncontrolled before 20 year (95% response) as well as 10 year before (75%), but 80% of the dwellers responded that currently (2007) grazing is controlled. Similarly, 85% of the respondent argued that the present status of the forest is degraded. The main reason behind the forest depredation are; i) over exploitation (100%), ii) socioeconomic factors (migration, population growth, poverty, no employment opportunity -95%), iii) low awareness of villagers about forest management (82%) and inability and in some cases involvement of the forest officials and illegal cutting (75%). Thus we can conclude that over exploitation, low awareness, ineffective law enforcement, poverty and other socioeconomic variables are the main cause of the forest degradation. Poverty, participation of villagers and resource right and access to the local people are the key issues that should be addressed for forest manage management program because 60% of the respondent think that if the forest is managed effectively it meets the local people needs.

Table 4- 13 Response of sample households on forest management.

S.N.	Some questions that inquired		Response (%)
1	What do you say about the grazing of animal in the forest?		
	1.1	Before 20 Years	
	a.	Controlled	0.00
	b.	Uncontrolled	95.00
	c.	Can't say	5.00
	1.2	Before 10 years	
	a.	Controlled	0.00
	b.	Uncontrolled	75.00
	c.	Can't say	25.00
	1.3	Currently (within 3 years)	
	a.	Controlled	80.00
	b.	Uncontrolled	8.00
	c.	Can't say	12.00
2	What do you say about the current status of forest?		
	2.1	Degraded	85.00
	2.2	Moderately degraded	15.00
	2.3	Slightly degraded	0.00
3	What are the main causes of forest degradation?		
	3.1	Low awareness	82.00
	3.2	Over exploitation of forest products	100.00
	3.3	Inability of forest officials to enforce the present law	75.00
	3.4	Forest staff also involved in illegal forest product transaction	75.00

	3.5	Socio-economic factors(migration, population growth, poverty, no employment opportunity)	95.00
4	Do you participate in forest management practices or activities?		
	4.1	Plantation on bare land	
		Yes	13.00
		No	87.00
	4.2	Enrichment planting	
		Yes	0.00
		No	100.00
	4.3	Protection against illegal cutting	
		Yes	75.00
		No	25.00
	4.4	Forest management operation (Thinning, Pruning etc)	
		Yes	30.00
		No	70.00
5	Does this forest fulfill the local people need if it manages effectively?		
		Yes	63..00
		No	22.00
		Can't say	15.00

Note: After hand over of the forest to the community there is mechanism of control the animal grazing; however, people are still grazing the animal illegally in the forest fringe and forest.

4.6 Discussion

4.6.1 Mapping deforestation and forest degradation

Spatial and temporal mapping of forest conditions in the Chitwan district in Nepal suggests that the forest cover and forest types have been continuously modified due to forest degradation and deforestation. One important finding of this study was that not all the forest types experienced similar rate of deforestation and degradation, which can be monitored on different spatial and temporal scales. Such changes have direct implications for forest resource management since Shorea robusta is one of the most valuable timber trees in Nepal that was legally and illegally logged in the past. A huge decrease by 23% in the area of Terai Shorea forest type between 1976 and 1989 confirms this (Table 4-3). The reasons of heavily degradation of this forest type could be high deforestation rate in Chitwan. During 1978–1991, deforestation continued at an annual rate of 1.25% comparatively higher

than the later decades (HMGN, 1993). Beside these, Chitwan's largest town Narayanghat was started to link with the other cities in Eastern Nepal, India and Kathmandu, Nepal's capital city shortly after 1979. Due to the central junction Chitwan's Narayanghat, this once isolated town was transformed into the transportation hub of the country by the mid-1980s. It ultimately produced a rapid propagation in various infrastructural developments, government services and businesses that spread throughout the Chitwan valley. Consequently, those activities has dramatically altered and placed a high pressure on remnant forests of the district as well (Axinn & Axinn, 1983; Shivakoti et al., 1999; Axinn & Yabiku, 2001; Pokharel & Shivakoti, 1986 in Barber et al., 2003).

Although the forests of Chitwan district appear to be deteriorating, the Terai Shorea robusta forest area increased in some locations between 1989 and 2001(Table 4-3). This could be linked to the success of CF (Community Forestry) program in the district. CF in Nepal is a feasible strategy for reversing forest degradation and maintaining the biodiversity, which recognized as one of the highly successful participatory forestry program in the international community (Ojha et al., 2003).The government of Nepal handed over degraded patches of Terai Shorea robusta forest to the local communities in the past and local people have been conserving their own forest patch with active participation. Therefore, community-managed forest patches of secondary forests showed a positive change in the Terai Shorea robusta forest between the periods of 1989-2001. Nearly twenty four community forest with a total 9,29.92 ha of forest land has handed over to the 12,652 households in Chitwan district (DOF/CFUGs, 2006).

On the Other hand, patches of hill Shorea robusta forest still remain untouched (Personal observation.) (Figure 4-4). This could be attributed to accessibility of the terrain. Some mountains slopes in the northern part of the district are inaccessible (Personal observation). This could prevent legal or illegal logging over there. Nevertheless, during the 1989-2001, Hill Shorea robusta also remarkably decreased by nearly 13%. It shows the unavailability of forest resources nearby area and effect of conservation measures in the district as well.

In lowland areas, the course of most of the rivers has been changed rapidly due to topography of the country coupled with heavy deforestation, forest degradation and expansion of agricultural areas and infrastructure development. Expanded river banks potentially support riverine forest. This could account for the slight decrease in the area of riverine Acacia- Dalbergia forest. Moreover, most of the riverine forests in Chitwan district are dominated by species like Trewia nudiflora, which is far less valuable than Shorea robusta trees in Terai in terms of timber wood, fuel and fodder quality. Hence, this species could have remained untouched, thus resulting in a minimal decrease in forest area in particular places.

In this study, the forests outside the protected area appear to be in poor condition with almost low forest canopy density (Figure 4-4). This show the forests of Chitwan district outside the National Park are vulnerable and could further deteriorate if the government of Nepal will not execute proper forest management strategies and protection measures immediately.

Figure 4- 14 Hemispherical photograph of forest canopy density in Chitwan.

In some area forest canopy is frequently opened and forest is persistently degraded in Chitwan (Figure 4-14). As such, forest degradation is less straightforward to assess from satellite imagery and rates of forest degradation is difficult to obtain. However, remote sensing (satellite data) has been used to assess

forest canopy density as an indicator of forest degradation (Joshi et al., 2006). The intensity of canopy degradation affects the sensitivity of remote sensing measurement to the state of the underlying ground. Greater intensity results in an increased reflectance coefficient in areas where the forest canopy has been destroyed (Saich et al., 2001).Our main objective in this analysis is to assess the deforestation and forest degradation, while mapping forest canopy density from satellite data i.e. Landsat TM, ASTER and so on has been commonly practiced by various authors in assessing the forest condition and degradation status (Rikimaru, 1996; Rikimaru and Miyatake, 2002; Roy, 1999; Joshi et al., 2006; Panta and Kim, 2006). Hence, we also realize this approach is quite useful in our study as well. Thus, we map the forest canopy density from Landsat ETM+ 2001 using ANN classifier to assess and know the forest condition of Chitwan district for forest resource management purpose.

Although Nepal has made sustainable management of natural resources a priority since 1960, forest resources have been substantively depleted to date and forested lands have been converted to other land cover categories. This study revealed that the process of other land cover change increased between 1976 and 1989 and slightly decreased between 1989 and 2001 (Table 4-3). This could be related to the migration and development policy that emphasized the expanding the development of agricultural land, new townships and highways in Chitwan district. Until the early 1950s, Chitwan valley was covered by virgin forests and home to many flora and fauna, but at the mid-1950s, the government started to clear fell the forest and make agriculture farm obtainable to in-migrants (Barber et al., 2003). Looking back at the history of the Chitwan district, from the 1960s to the 1980s, historically the district was sparsely populated, because of hyperendemic malaria (Peters et al., 1955; Brydon, 1961; Darsi Jr and Pradhan, 1990). Malaria eradication was initiated from 1956 and a subsequent resettlement policy started in the 1960s drew settlers from the higher parts of Nepal (Kansakar, 1980; Ghimire, 1992; Isaacson et al., 2001). A rapid population increase resulted in conversion of much of the forest to cropland (Metz, 1991; Soussan et al., 1995) as well.

Continued degradation and deforestation reduces further the size of forest patches, increases the distance among remaining patches, hinders the migration of animals

between patches, and decreases the relative abundance, diversity of species and have long-term effects on forest composition (Rosenberg and Raphael, 1986; Matthiae and Stearns 1981, Galli et al., 1976; Whitney and Runkle, 1981).This emphasizes the importance of examining spatial and temporal landscape patterns.

We quantified and map the spatial and temporal degradation and deforestation of forest covers and five major forest types in the region. This could aid in the planning of future actions, particularly with respect to identifying areas and forest types under continual threat and forests that should be restored and managed. Further, maps presented in this study may support an understanding of where and how much land cover and land use patterns altered. It may be also used to prioritize limited human and financial resources for forest resource management and conservation of forest diversity. This provides resource managers with a basis for making practical landuse decisions. It is assumed that the processes of deforestation and forest degradation that have been monitored in Chitwan also could be similar over the whole of the Terai in nature though it may differ in magnitude. Hence, identifying the problem of degradation and deforestation at different spatial and temporal scales could provide useful information for planning and sustainable management of forests.

4.6.2 Livelihood and forest resource dependency

The interesting results were found that none of the respondent named a single strategy or occupation that can give sufficient income for their livelihood. Some of household members meet their cash demand by wage labour (33%), while other meet from petty shop (20%), public service (29%), foreign job (23%) and fire wood selling at the local market (20%) (Figure 4-9). However, crop and livestock farming which accounted 92% for rural livelihood is directly related with forest resources in terms of grazing animals and fodder collection (Figure 4-10). Some found that about 77% of households were raised livestock with feeding their animals in common grazing and/or forest land in Chitwan (Axinn & Axinn, 1983; Shivakoti et al., 1999 in Barber et al., 2003). But, Barber et al (2003) found only 22% of households they feed animal partly by grazing. Agriculture is also main source of livelihood, out of the total cropped area paddy shares highest in both total area (about 35%) and

production (about 56%), though the productivity of other crops were very low (Table 4-5). Nevertheless, 63% of the sample households responded that their production do not support their family (Table 4-6).

Our results reveals that almost 33% of the population was below the poverty thresholds (Nrs.14, 942/annually) with the poverty gap index at 0.0945 (about 10%) in the study area. Income distribution in the sample population is somehow more equal than the distribution of landholdings (Gini coefficient 0.25 and 0.37 respectively); this is possibly being the result of remittance because some of household's family member migrated temporarily for a job in foreign countries. However, this dream does not happen for all, only a very few personnel can get this opportunity because of the high cost. Having a very small size of land to grow crops and no job in the village or outside the village in the home country, they might push themselves towards the forest to harvest forest products in due course resulted heavily forest degradation in the district. We found that forest dependency is higher and the availability of forest products which can be extracted from the remaining forestlands is decreasing, whether from local processes or through population pressure.

It was observed that the availability of forest products, were perceived by respondents to have sharply declined over the past 20 years. The response ratio was declined slightly from 0.781 to 0.621 but it was sharply declined from 0.621 to 0.360 (Figure 4-12). Figure 4-13 also revealed that the sharp loss of timber wood availability as compared to firewood and fodder for 2007. Moreover, the household's respondents perception towards the forest resources availability during past 20 years has almost coinciding with the satellite images analysis for forest type's changes in Chitwan (Table 4-3). During the 1989-2001 periods, the forest area of all types has been reduced except Terai Shorea robusta. Interestingly, Chir Pine with Broad Leaved which used for both timber and firewood purpose in middle hills of Nepal and facing the resin and tapping problem has heavily degraded. Rural people frequently used Pine trees as commercial means with resin and tapping process and it is one of the serious issues of forest degradation in Pine forest of Nepal. Importantly, Hill Shorea robusta, however, has high value in firewood purpose due to its poor

quality in timber also sharply declined even in inaccessible terrain. While rural people have no access to enter into the National Park and community forest, they might be shifted to the other open access area such as hills to satisfying their needs. Generally, Shorea robusta forest more prone to over logged both legally and illegally process in Terai while mixed hard wood and Broad Leaved forest in hills of Nepal. But, oppositely increased of Terai Shorea robusta forest during 1989-2001 could be the effect of conservation measures such as protected area and community forestry in the district. Figure 4-15 confirmed this and timber wood found to be heavily logged during the field visit in the study area.

Figure 4- 15 Logged wood (left) and illegal wood inside the forest (right)

This supports the hypothesis that forest land has been excessively converted either to farm land or the forests resources were heavily used or forest resource extraction was high in the past, which could be the one reason of disproportionately reduced in forest area and forest types of Chitwan. 92% respondent's livelihood depends on livestock husbandry and 98% depends on agriculture occupation such as food crops (Figure 4-9). Most of the time animals do graze in the nearby forest. This shows a high forest dependency in the district.

The conversion of forest land or the resource extraction has had a dramatic and negative impact on forest resource availability. As United Nation (1995) reported that 84% of households' energy comes from firewood in Chitwan, we also found nearly similar result where 82% of households' responded they collect firewood from the forest. Similarly, about 81% of households collect fodder from the forest and about 42% households use forest or forest fringe for grazing their animals (Table 4-9).

Figure 4- 16 Collection of fire wood (left), fodder (middle) and grazing (right).

Figure 4-16 further confirm the spatial dependency of rural livelihood on the forest for satisfying their various basic needs in the study area. That indicates the high dependency on forest resources is still prevalent in the district. Moreover, we turn into econometric analyses of forest resources for some insightful information. The economic valuation of fuel wood, timber and fodder was found to be very high (Table 4-10). Similarly, uses and collection of firewood, timber and fodder from the forest was very high. Again it confirms their high dependency on the forest resources. Most of the respondents realized that firewood from their own land hardly contributes to their livelihood however; they only spend nominal income i.e. 0.33% of total income for fire wood purchasing (Table 4-8). That shows their high dependency on forest for firewood which eventually intensify to the forest degradation.

Forested area of the district had changed remarkably in 20 years. This could have a high impact on people's livelihood. The traditional dependency on forest products has been shifted towards small scale farming, business and service. Almost 34% of household income shares by agriculture (crop and livestock) and remittance (20%). This could due to shrinking forest resources in terms of availability which also confirms the forest of Chitwan was heavily degraded in the past and even in the present time hence the persistent forest degradation has also occurred in the district which has confirmed with our satellite image analysis. Spatial degradation of forest resources in Figure 4-17 also confirms this mechanism in the study area. Looking back at the consumption pattern of forest resources, out of 100 sampled household 82% of household, responded they were using firewood for cooking. Approximately similar result 92% of sample households were reported using wood for fuel (Barber

et. al., 2003) in same area. Various authors summarized the paper that offered the set of strategies to promote the forest conservation to favour the local livelihood in low income level countries.

Figure 4- 17 Degraded forest due to fires (left) & forest felling (right).

However, a very rare study had focused on formulation of those strategies which could realistically promote forest resource management as well as livelihood of the poor and marginalized at a local level in Nepal. Experienced has also frequently shown in the past in Nepal, not at all form forest conservation strategies that decision maker formulate has effectively corresponded the local needs. Though it looks quite sound on paper, however those strategies often stand either for abortive or for despair at the implementable level due to several constraints. Thereby conflicts in the concern of equitable benefit sharing and forest resource conservation has always been debated and is not solved yet at the local level which could be another reason perceived noticeable forest degradation in Chitwan district.

4.7 Summary

Firstly, this chapter showed the analyzed results on the forest degradation and deforestation trends in Chitwan district, Nepal which contains key habitat elements for wildlife in the region. Except riverine forest, forest area of all other forest types was reduced. Terai Shorea robusta forest which has high commercial value showed a loss of 23% between 1976 and 1989 and an overall forest covers loss of 15% between the year 1976 and 2001. Deforestation and forest degradation disproportionately reduced the sizes of the different forest types, a finding that has

important management implications. The maps presented in this study could be useful to prioritize limited resources for conservation.

Secondly, a households survey examined the rural livelihood sustainability with existing natural resources, forest resource availability, historical process of uses and management. The approach aims was to incorporate the rural people's knowledge and opinions in the planning and management of development projects and programs. Results showed that how people's livelihood strategy and their forest dependency is tied up with forest degradation process at local level. Livelihood strategy in the surrounding villages of forest corridor has a higher spatial dependence on the forest for their basic needs i.e. timber, fuelwood, fodder and grazing. Based on households' respondents, forest product availability was sharply decline over the past 20 years. However, other sectors do not fully support rural livelihood so without doubt the livelihood of rural poor has severely affected with limited resources and might be more relying on forest resources for their survival, which ultimately influence the forest destruction process.

Deforestation and forest degradation could be attributed by various socioeconomic factors. High population growth, migration tendency and poverty resulted land fragmentation, demand of agriculture land and high reliance on forest resources. Hence, all those activities could further stimulate low productivity, land scarcity and food security problems. Since remote sensing estimates do not integrate future trends in forest landscape change and human activities, we feel that the present analysis is not the final answer to spatial considerations in forest management. However, it does provide a good reference point for planning future forest management projects. So, we appreciate the series of socioeconomic factors and their present status need to be analyzed in subsequently to understand their influence in Terai deforestation and forest degradation in Nepal.

Moreover, there are likely to be more of these types of areas in the future as extreme population densities and severe poverty level in some areas force marginal people to migrate in other resourceful area. This will provide a cyclic impact on forest resources and forest dependency will constantly increase unless demand and supply of agricultural commodity and food security in installed. Hence it would be

interesting to further analyze the LULC change, food crop productivity and food security status in the region.

CHAPTER 5 SOCIOECONOMIC ASPECTS AT REGIONAL SCALE

5.1 Introduction

5.1.1 Population characteristics, poverty and forest degradation

In Nepal, the largest natural forests with commercially important species Shorea robusta and other mixed hardwood tree species are threatened and bearing heavy pressure due to various underlying factors such as agricultural expansion, infrastructure development and urbanization. Rapid population growth and migration from other parts of the country also play an undeniable role in this regard. Poverty, deforestation and forest degradation are mutually reinforcing, and unless proper understanding of these factors in an integrated manner, environmental protection and poverty reduction could impossible in any geography (ADB, 2003). Although a large number of programmes and projects have implemented to alleviate poverty in the past, poverty has not been reduced significantly yet and there is still widespread poverty in Nepal (NPC, 2004). We argued that the dynamics of rural land use system are very complex and deforestation is rarely the consequence of a single factor; rather it is the product of the interactions of multifaceted forces in particular. Therefore, spatial analysis of socioeconomic data could be valuable to identify and unravel various patterns and processes that may contribute to better understanding of current status and future planning process. One objective of this study is to analyze the spatio-temporal extent of the most apparent socioeconomic factors in terms of their proximity and dynamic impact in Terai forest degradation. The other, outputs presented in this analysis demonstrate how statistical and census data can be translated into readily understood spatial information that could contribute significantly to informed decision-making processes. Hence, data and techniques that mentioned in the methodology section 3.4.3 were used for analyzing and mapping the spatio-temporal extent of factors. ArcGIS 9.0, SPSS and some descriptive

statistics were used to take the whole procedure and come out in the results. Thus, in this Chapter we mainly demonstrate and link the results of spatio-temporal extent of various socioeconomic factors in regards with forest depletion process in Terai in subsequent sections.

5.1.2 LULC change, food production and food security in Terai

Agriculture is the foundation of livelihood (Regmi et al., 2002) since 80% of the population economy and 30% of the GDP has harmonized by agriculture sector in Nepal (DFID, 2008). The Nepalese economy is also dominated by an agrarian sector and largely depends on the natural resources. Agriculture census data can provide reliable information related to crop production, food access or deficit, population, and LULC systems information. It can provide a useful benchmark for improving the current crop status and other natural resource statistics. The integration of results and supplementation of food crop production data at the decision-making level could be greatly helpful in this regard.

However, regional level data are still inadequate in terms of providing plenty of spatially and temporally aggregated insights into the locations of crop production in Nepal. There is still not sufficient work related to the close monitoring of land use change, basic food crop production and food security, and without a proper understanding responses will be limited in scope and content. Though, an extensive study has carried out to identify the dynamics of population pressure and land degradation at a local level in order to attain a better understanding of mountain agricultural systems (ICIMOD, 1998). Such types of study however, have rarely been carried out for the Terai region of Nepal. Therefore, this study searches for the ways to obtain better food security statistics information in order to support committed decision-making platforms in Nepal to fight against food deprivation and poverty. It further explores and discusses how experiences and achievements can help to overcome the challenges of food security problem thereby reduce the pressure on the natural resources such as forest.

Based on the techniques derived on the methodology section 3.4.4.1 and 3.4.4.2 this chapter shows a results on comprehensive analysis by investigating land use

change, major food crops productivity trends and food security situation at a regional level in succeeding section.

5.2 Population factors & forest degradation analysis and results

5.2.1 Population size, distribution and density

The distribution of population and population density varies among the ecological zones. Data reveals that population size in Terai nearly doubled, from 6.56 million in 1981 to 12.44 million in 2005 (Figure 5-1). Similarly, the share of population increased by 11 percent in Terai whereas it decreased by 8 percent in the Hills and nearly 3 percent in mountain regions from 1971-2001 (Table 5-1). Figure 5-2 shows the concentration of population primarily in Terai districts, except Kathmandu valley (The capital) and its surrounding districts. Moreover, Eastern Terai has higher concentration of population than the Western Terai. Most of the Western Hills and Mountain districts have low population (i.e. less than 0.15 million).

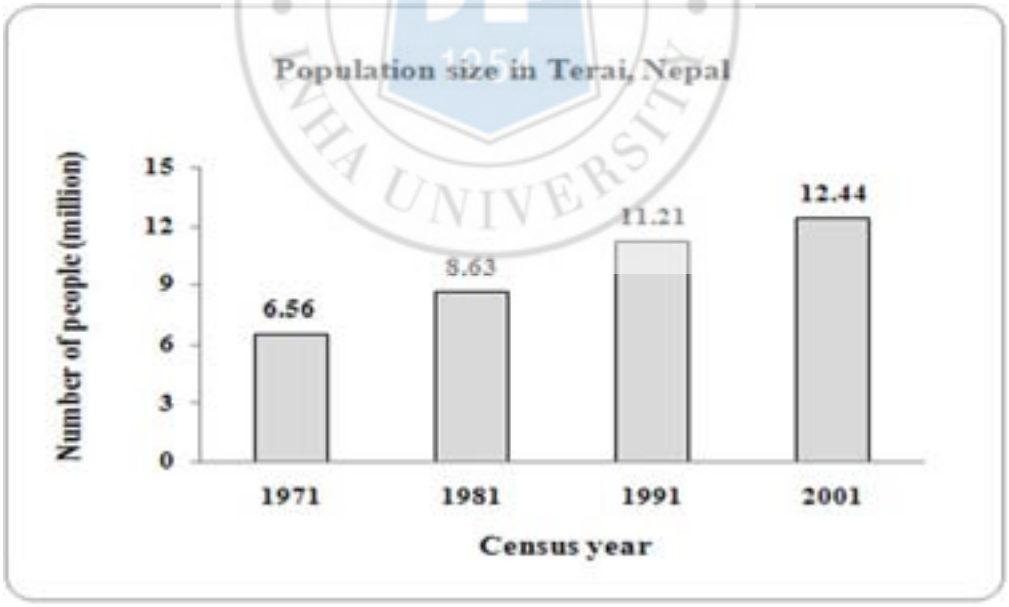

Figure 5- 1 Population Size of Terai in between 1971-2001.

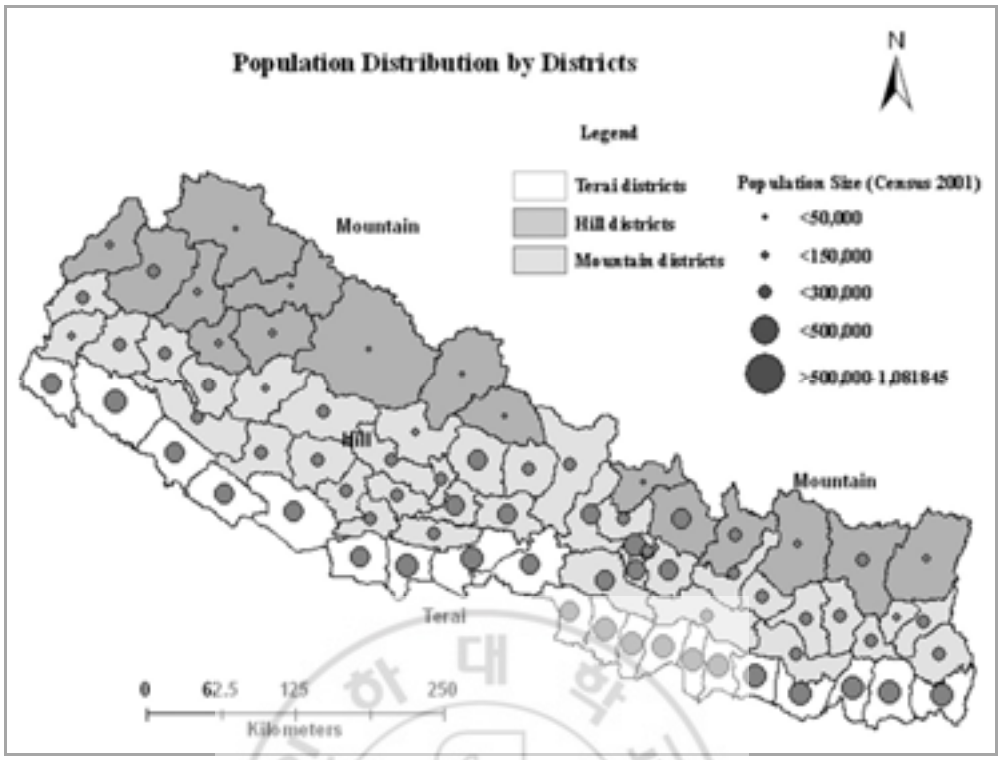

Figure 5- 2 Population distributions by districts in 2001.

Table 5- 1 Share of Population by Ecological Zones in Nepal

Ecological zones	1971	1981	1991	2001
Mountain	9.9	8.7	7.8	7.3
Hill	52.5	47.7	45.5	44.3
Terai	37.6	43.6	46.7	48.4
Total	100	100	100	100

Figure 5-3 also shows that population density in Terai has increased sharply, almost four-fold, reaching 330 person per square kilometre in 2001 from 85 person in 1952/54. Although population distribution trends in the Terai districts vary, the overall trend of population density is high in the Terai region.

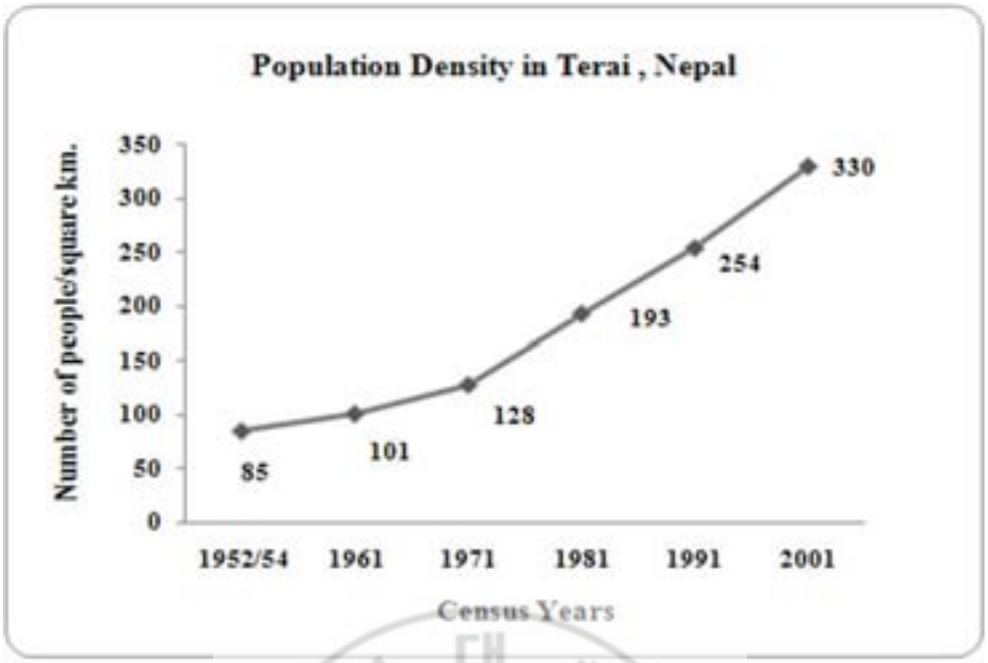

Figure 5- 3 Population density in Terai region from 1952/54 - 01.

5.2.2 Population growth and in-migration rate

Similarly, nearly half number of the districts out of 20 have high population growth rate, more than 2.75 percent per annum, considerably higher than the national average (2.25 percent per annum) during the period of 1991-2001. Jhapa has the lowest growth rate per annum and Kailali, Kanchanpur, Banke, Rupandehi, Bara and Sunsari have 3 or greater than 3 percent growth per annum (Figure 5-4).

It was estimated that a total of approximately 120,000 ha of forest land was lost during 1964- 1972 in Terai; of this 56,000 ha was due to spontaneous migration and illegal settlement (FAO, 1999). Similarly, our analysis also found that a high in-migration rate of more than 15 percent of district population in 10 districts. The highest in-migration rate was observed in Chitwan followed by Kanchanpur, Kailali, Rupandehi Jhapa, Sunsari and Morang with rates of 34, 33, 27, 27, 26, 26 and 22 percent respectively (Figure 5-5).

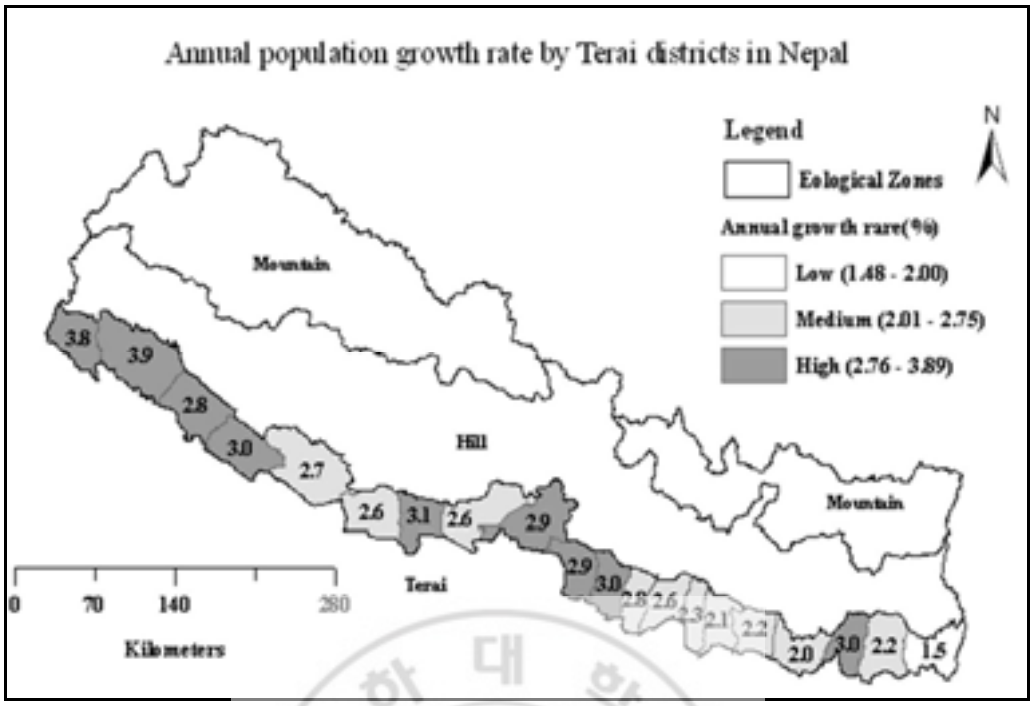

Figure 5- 4 Population growth rate by Terai districts in 2001.

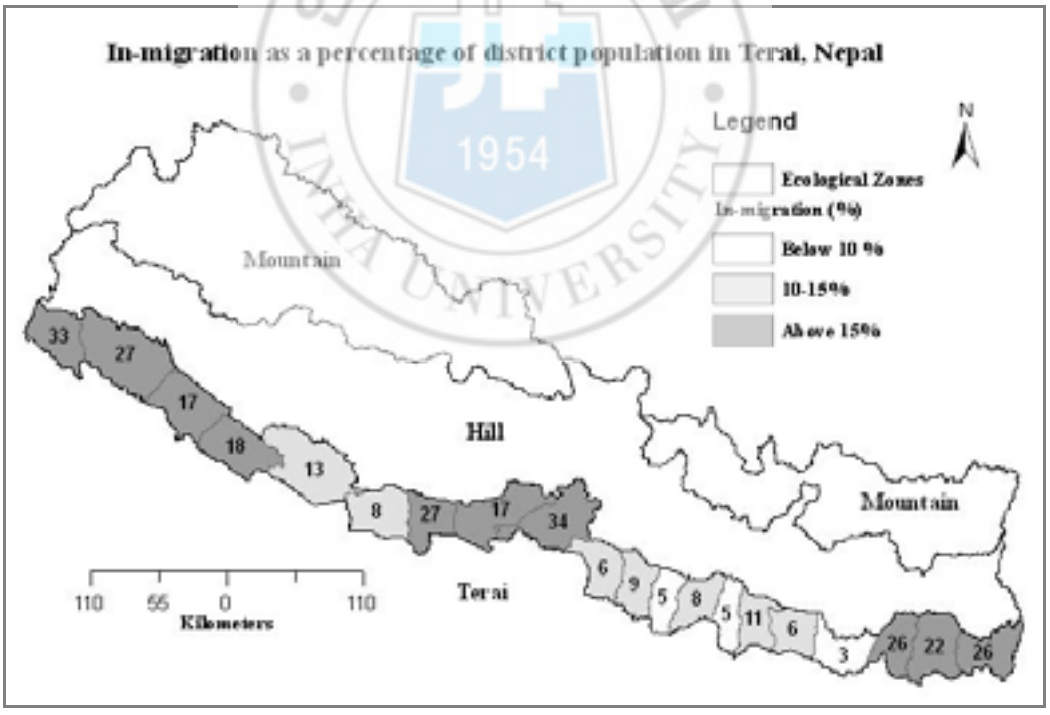

Figure 5- 5 In-migration percentage of district population in 2001.

5.2.3 Poverty status

Data revealed that poverty levels are relatively low in Terai compared to Hill and Mountain regions. However, the general poverty rate remains still almost 28 % of the population in Terai. Similarly, Figure 5-6 shows that rural poverty in Eastern Terai is significantly lower (by 13 %) than in Western Terai. Similarly, there was a reduction in head count poverty level, i.e., 12.7 %, in Terai from 1995/96 - 2003/04. However, the distribution of poor remains the same in Terai (Figure 5-7). Although a large number of programmes and projects have implemented to alleviate poverty in the past, poverty has not been reduced significantly and there is still widespread poverty in the country (NPC, 2004). But, policies include a broad range of social provisions and provide for an array of public work strategies to strengthen local livelihood can also help to counter poverty (RSS, 2006).

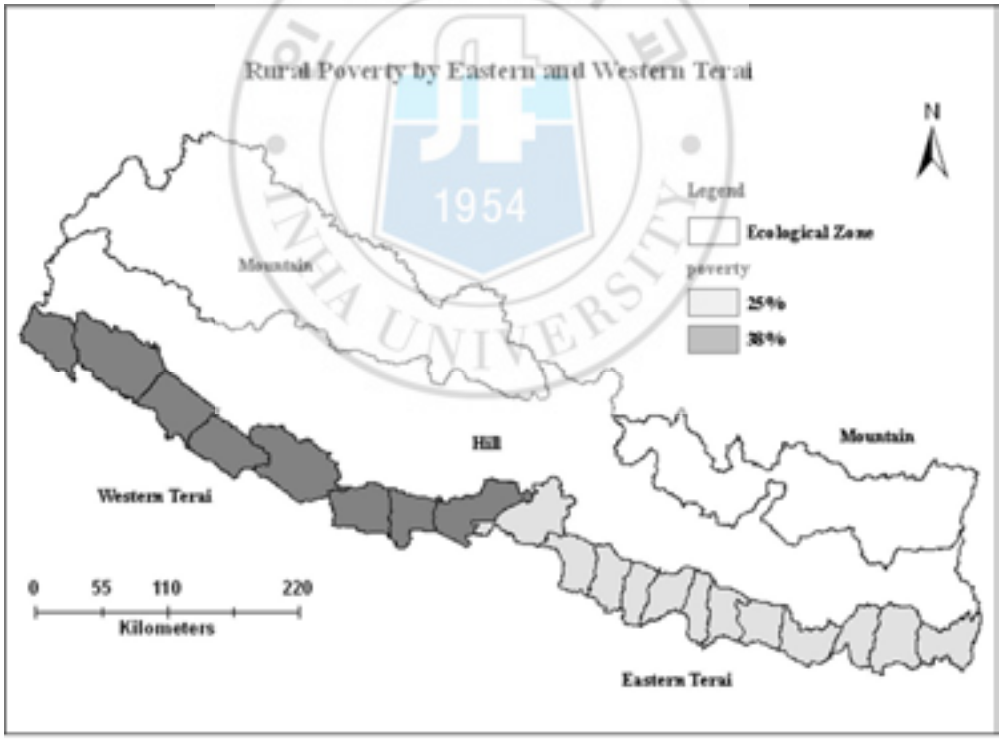

Figure 5- 6 Incidence of rural poverty by Eastern and Western Terai.

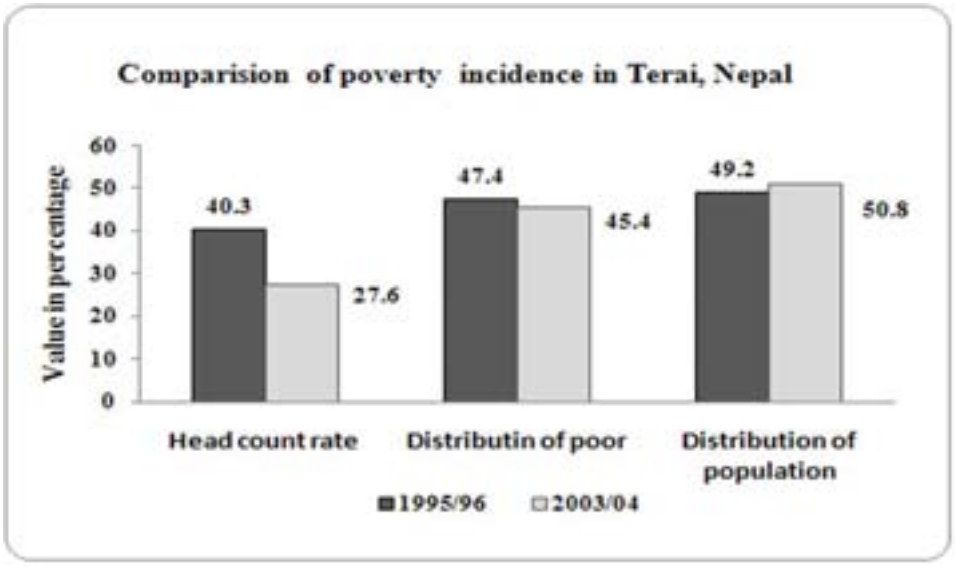

Figure 5-7 Incidence of poverty trends in Terai region.

5.2.4 Distribution of agricultural households by land holding size

Figures 5-8 and 5-9 illustrated that there is a similar pattern of agricultural land holdings size in Terai as well as at the national level. The figure 5-8 reveals that 42 percent of agricultural households have less than 0.5 hectare land holding whereas only 12 percent of households have more than 2 hectare land in Terai. This fact interestingly coincides with the national perspective, while 45 percent of agricultural households belong to less than 0.5 hectare landholding (Figure 5-9).

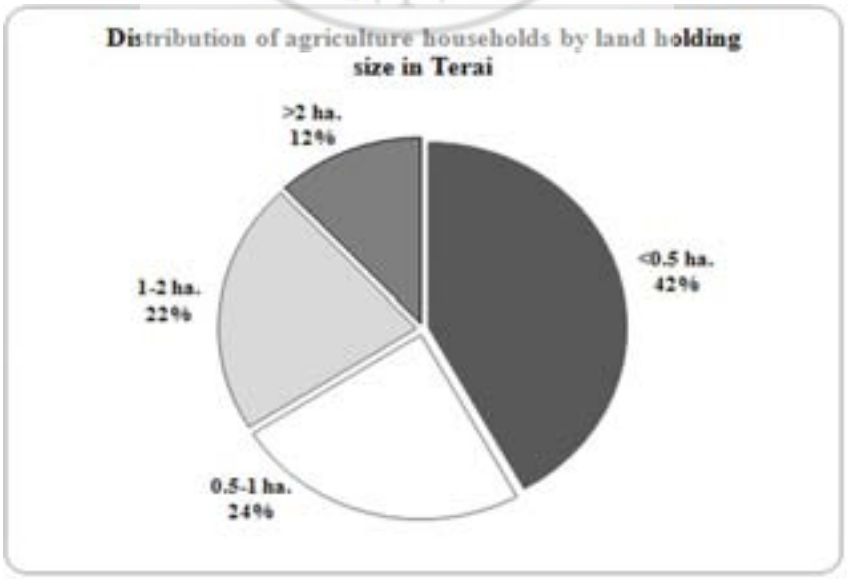

Figure 5- 8 Distribution of agricultural households by land holding size in Terai.

From the national perspective, the incidence of high head count poverty and the low availability of land are synchronized in Nepal. It is also found that poverty; the distribution of poor and the number of households is significantly high with low and marginal land holding size. Figure 5-10 clearly shows that the head count poverty and distribution of poor were very high with small landholding size such as less than 1 hectare. While head count poverty and distribution of poor is significantly reducing with increasing landholding size.

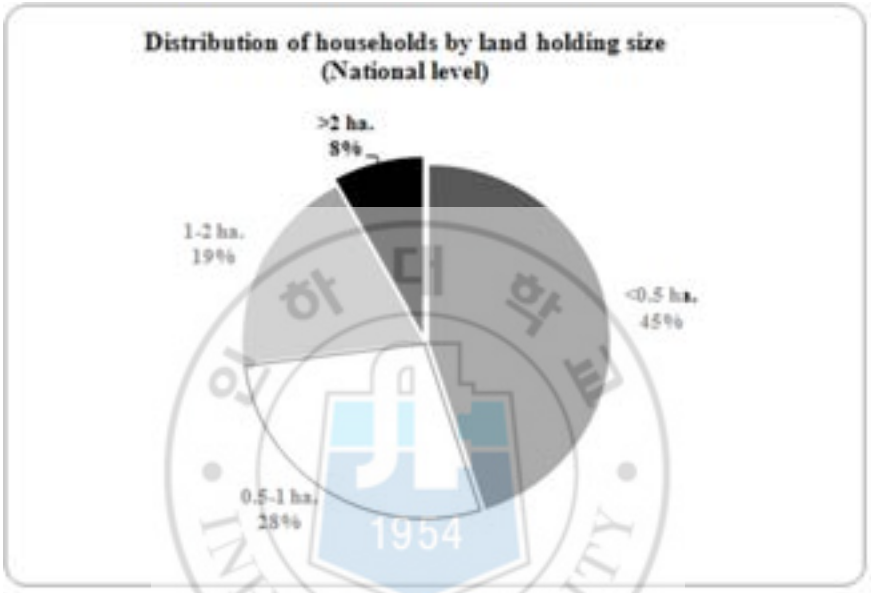

Figure 5-9 Distribution of agricultural households by land holding size in Nepal.

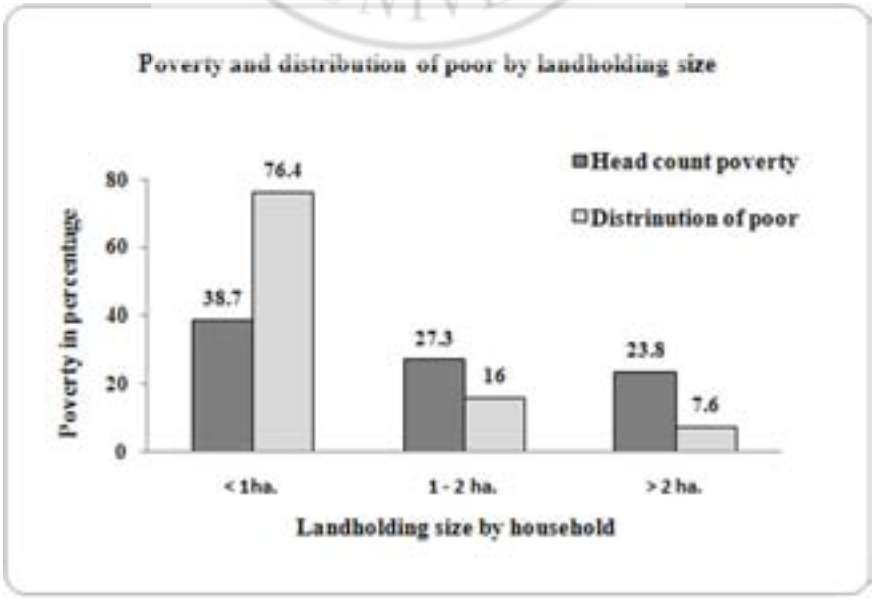

Figure 5- 10 Poverty and distribution of poor by landholding size.

5.2.5 Fuel energy types and collection source

The trend of using fire wood for cooking is increasing. In 1995/96, only 43% of the rural households used firewood for cooking but, it has increased to reach almost 62% of all households in rural Terai in 2003/04 and followed by Cow dung/straw/leaves at almost 32%. However, the share of Cow dung/straw/ leaves decreased significantly (>20%) in 2003/2004 as compared to Nepal Living Standard Survey (NLSS I) of 1995/96. There is nominal use of liquid propane gas (LP), kerosene and biogas for cooking (Figure 5-11).

This explores the fact that rural households in Terai are still widely dependent on forest for fuel wood collection. This might be due to the high poverty in rural Terai, which limits the use of other types of fuel (like LP gas, Kerosene and electricity) as well as high prices of other types of fuel category especially liquid propane (LP) gas.

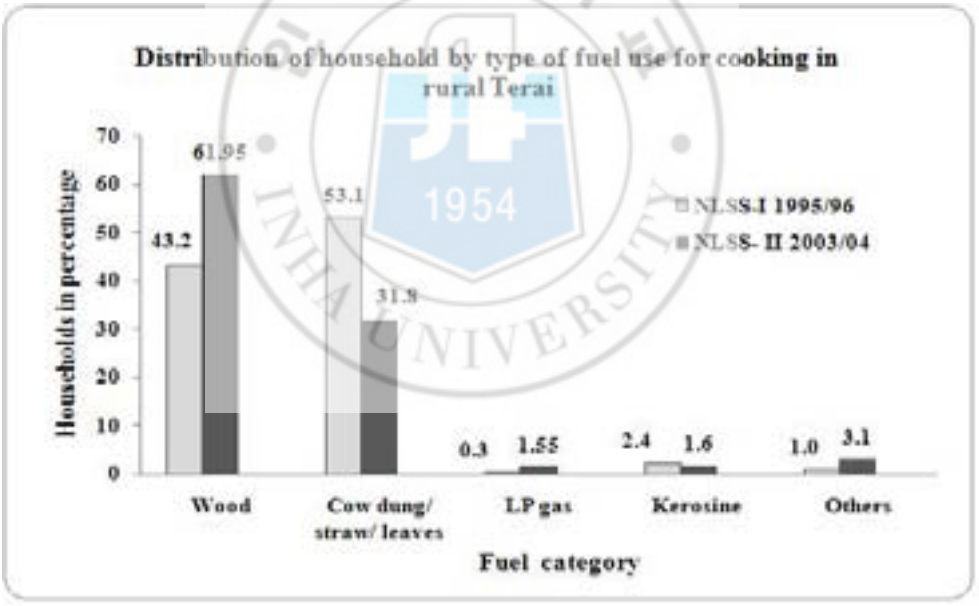

Figure 5- 11 Households using various types of fuel for cooking.

Forests and privately owned land are the main sources of firewood in Terai where 68% of fire wood collection source is forest-based, followed by 17 percent from private land and 10 percent purchased from markets. Only 5 percent of firewood is collected from other sources in 2003/04 (Figure 5-12).

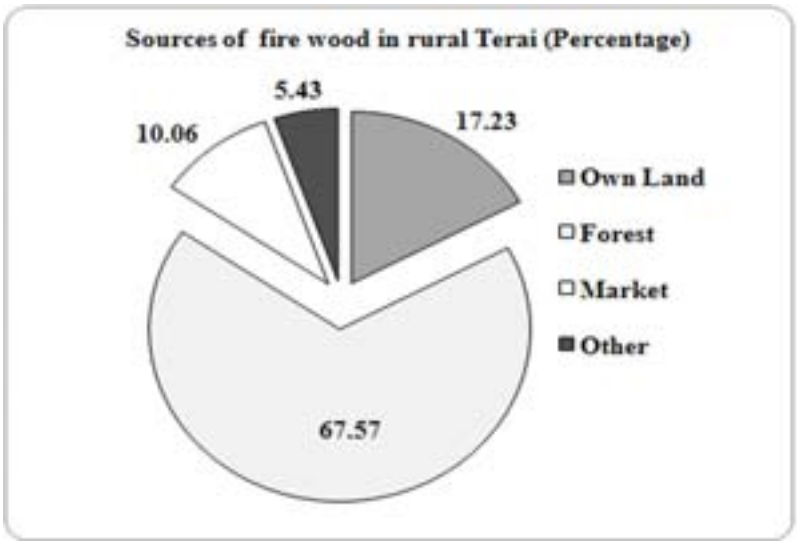

Figure 5- 12 Sources of firewood.

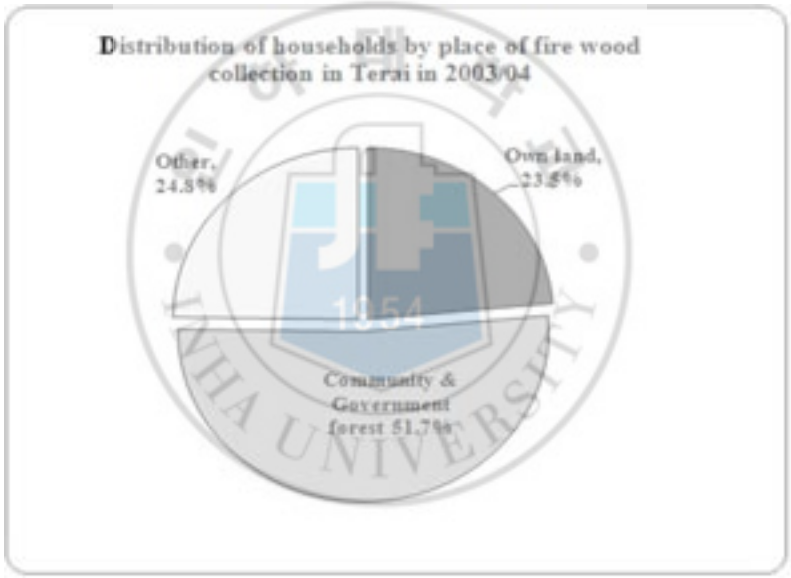

Figure 5- 13 Household distributions by place of firewood collection.

Almost 52% of households collect firewood from forest. This includes community and government forests. 25% of households collect from other sources while 23% collect from their own land (Figure 5-13).

5.2.6 Forest resource depletion trends

There were quite a lot of difficulties to get the time series data of forest cover and land use change at district level in Nepal because of low level of preference given to

the field surveys, complexities to gather and update the data and high cost for collection. However, some data are collected by various institutions for their own purposes that were made available in the present context in this research. Some of these data sources are CBS, MFSC, and other authorized institutions. Figure 5-14 states that in most of Terai districts, forest cover depleted noticeably during the period of 1958-1978 and depletion accounted for >15-30% in 6 districts, >30% in 8

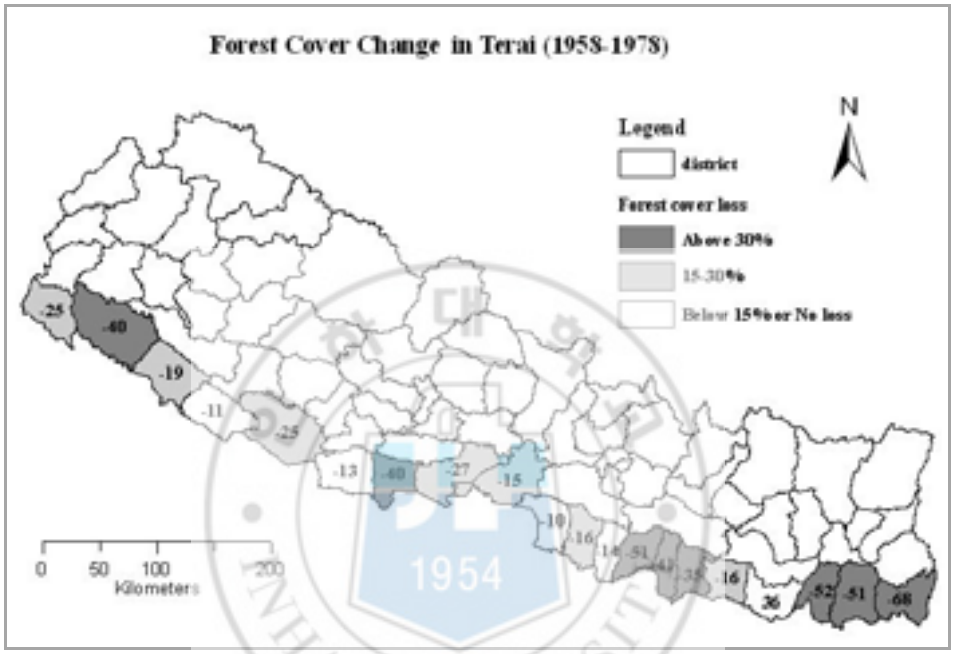

Figure 5- 14 Forest covers changes between 1958 and 1978.

districts out of 20 districts. Likewise, the situation of the forest cover change during 1958-2001 is presented in figure 5-15. Data revealed that there was >30% of forest cover depletion in between 1958-2001. Among them, Bardiya and Parsa accounted the largest forest cover loss by 80/80% and followed by Jhapa 79%, Sunsari 74%, Chitwan 67% and Kanchanpur 66%. In most of the districts forest cover was depleted by >40% of the total forest cover of the district. Besides this, from 1958 to 1978 almost 630,937 ha and in between 1978-2001 almost 448,429 ha which is a total of 1,079,366 ha of forest land is disappeared during the last 43 years.

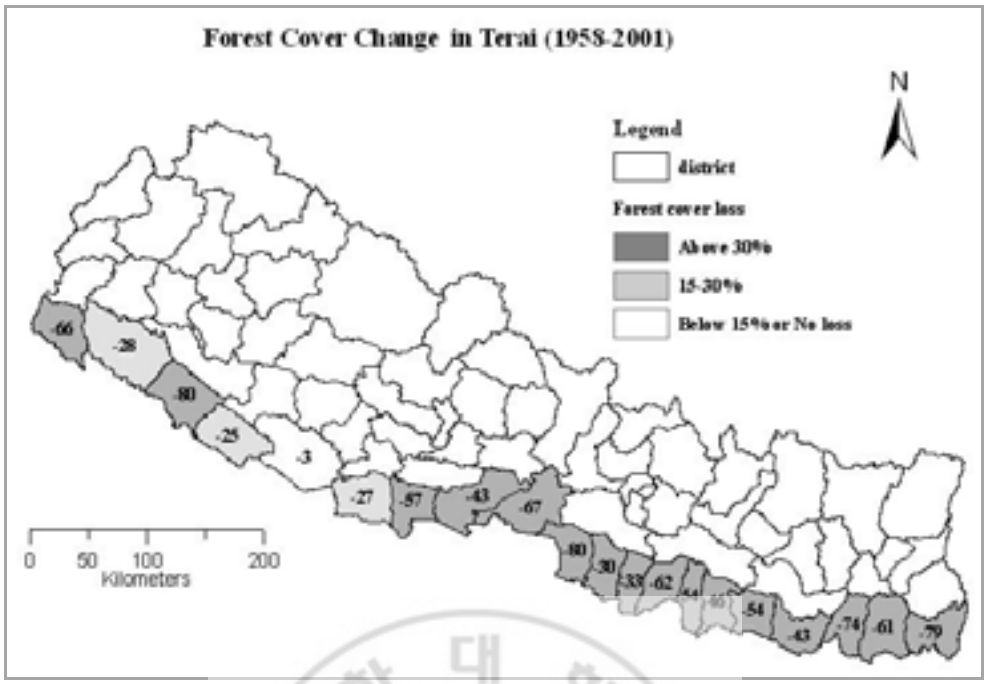

Figure 5- 15 Forest covers changes between 1958 and 2001/02.

Figure 5-16 reveals that there is considerable loss of forest resources during the period of 43 years. The loss of forest occurred in the whole Terai. In 1958 the total forest cover accounted for almost 2,299 thousand ha but the forest covers were reduced to 1,149 thousand ha in 2001. This could be due to human intervention in the Terai and it is probably accelerated by population growth, migration from mountain and hills to Terai, infrastructural development, resettlement program launched by the government and other human activities like grazing, illegal clearing and cutting trees to meet the basic need of poor. Terai region was sparsely populated before 1960 because it was infested with malaria (Darsi and Pradhan 1990). Migration started after malaria was eradicated in the early 1960s. The malaria infection rate in the Terai was reduced from almost 90% in the early 1950s to much lower levels in the 1970s (Joshi, 2006). Similarly, the infant mortality rate was reduced from 70% (1957) to zero in the early 1970s (Jung 2001, Guyatt and Snow 2004 in Joshi, 2006).

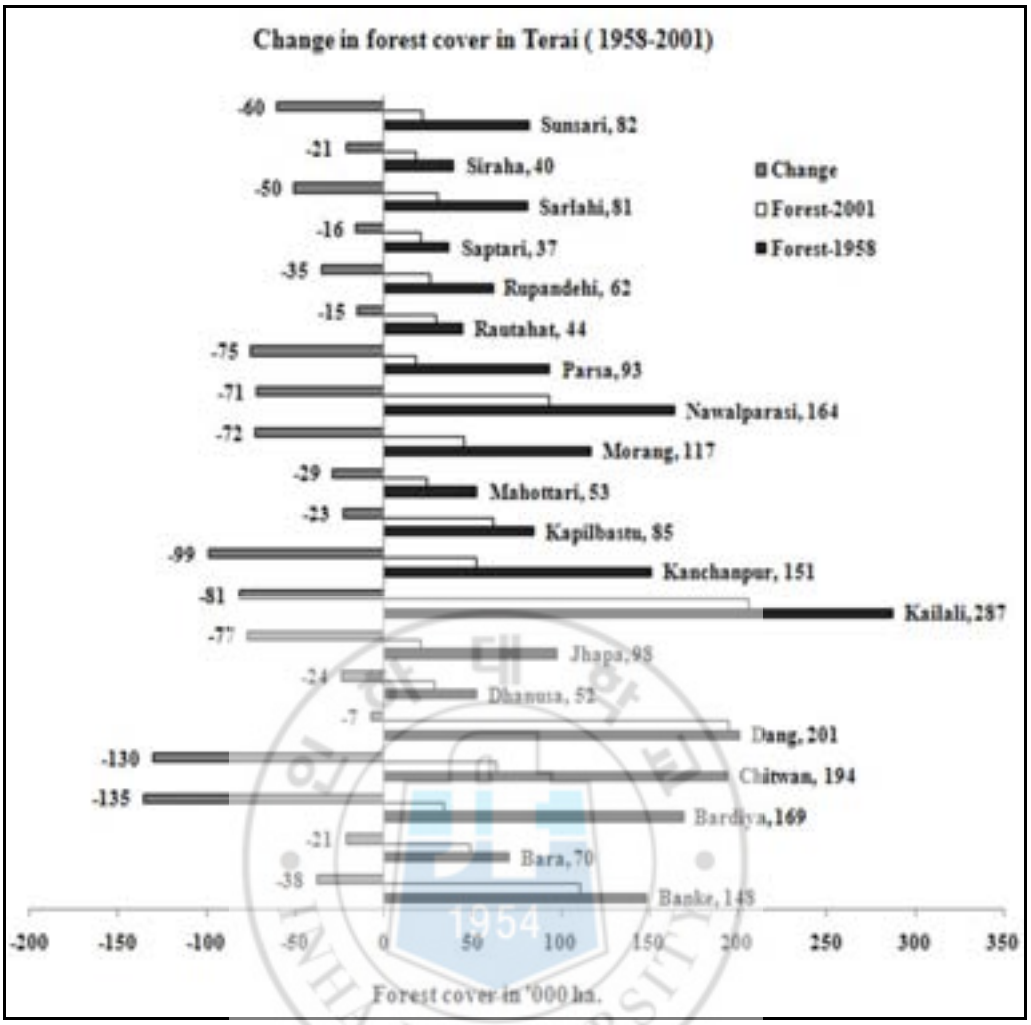

Figure 5- 16 Loss of forest covers by districts between 1958 and 2001.

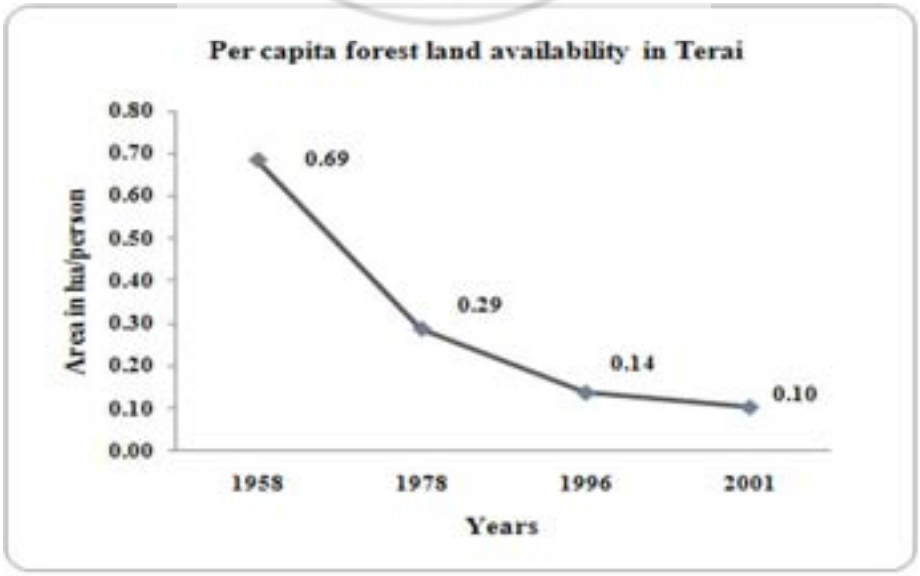

Figure 5- 17 Per capita forest land availability.

An area of 1,685 thousand ha of all agricultural holdings was reported in census 1961/62 but it has increased by 63.3% and reached at 2,654 thousand ha in 2001/02. Additionally the census 2001/02 also explores that about 1,626 thousand ha out of the total land belonged to the agricultural and operated by agricultural holding in 1961/62 however, this figure was increased by 53.6 percent and reached at 2,498 thousand ha in 2001/02. Similarly, there was a decrease in the area of non-agricultural land by 156.3 thousand ha in between 1991/92 to 2001/02. Probably the decreased area could be woodland and forest where the area abruptly decreased by 66% from 108.8 thousand ha in 1991/92 to 37.2 thousand ha in 2001/02. The reasonable explanation of this decreasing pattern is the shifting of the use of the land and some of the increase in the area of land under permanent crops may have also come from this land use category (CBS/Agriculture Monograph, 2006).

The per capita availability of forest land is also decreased considerably during the period between 1958-2001/02. It could be due to the pressure increased day by day on the forest land to meet the requirement of the agriculture land and other forest products to growing population in the Terai region of Nepal. Figure 5-17 revealed that there is considerable decrease in the per capita forest land during this period. It was 0.69 ha in 1958 and reduced at 0.10 ha per capita in the year 2001/02. This may be a caution for the policy maker in the context of sustainable forest management and biodiversity conservation.

5.2.7 Statistical analysis

5.2.7.1 Correlation analysis between total population and forest area

We performed the Pearson correlation analysis using total population and forest area of 1958, 1978, 1991 and 2001 in 20 Terai districts to see the relationship between forest area changes in respect to population increase. The correlation coefficient shows the significant ($r = -.750$ and $r = -.788$ at $p = 0.01$ level) for 1958 and 1978 years respectively (Table 5-2). Although a negative association has been shown for 1958 and 1978, however, a weak association showed between the forest area and population for 1991 and 2001. Similarly, the in-migration trend also

couldn't show the any significance relation with forest loss in Terai. The Pearson correlation coefficient of forest area and population is given below in Table 5-2.

Table 5- 2 Pearson's correlation coefficient test

	Forest Area 1958	Forest Area 1978	Forest Area 1991	Forest Area 2001
Population 1958	-.750(**)			
Population 1978		-.788(**)		
Population 1991			-.321	
Population 2001				-.227
In-migration 1991-2001				-.195

** refers P = 0.01 Level
* refers P = 0.05 Level

5.2.7.2 Descriptive statistics for population growth and forest area

Descriptive statistics shows that there was mean loss of forest area by 1.89% per year whereas mean population growth increased by 3.14% per year in Terai during the period 1958 - 2001 (Table 5-3). This shows the effect of population growth in forest loss (negative growth of forest) in Terai. Additionally, the pressure on forest land also increased significantly from about 2.4 people/ha in 1958 to 17 people/ ha in 2001. The details of the descriptive statistics of various parameters are presented in Table 5-3.

Table 5- 3 Descriptive statistics for various parameters.

Indicators	N	Minimum	Maximum	Mean	Std. Deviation
Forest growth	20	-3.77	-.08	-1.89	1.094
Population growth	20	1.92	4.90	3.14	0.841
Population forest ratio 1958 (No./ha)	20	.30	6.20	2.34	1.912
Population forest ratio 1978 (No./ha)	20	1.00	11.50	5.58	3.932
Population forest ratio 1991(No./ha)	20	1.90	27.90	13.05	8.287
Population forest ratio 2001(No./ha)	20	2.40	32.80	16.91	10.366
Immigration in Terai between1991-2001(%)	20	3.96	42.06	16.74	12.835

5.2.7.3 Regression analysis between population growth and forest area

To perceive the relationship between the growth of forest area and the population growth between 1958, 1978, 1991 and 2001, growth of both variables is calculated and plotted using curved estimate model (Figure 5-18, 5-19, and 5-20). We used following equation to calculate the forest and population growth of Terai.

$$G_{rate} = (FA/BA)^{(1/N)} - 1$$

Where,

BA = Base year forest area or population considered at 1958

FA = Final year forest area or population considered at 2001

N = Number of total year (42 year)

The regression coefficient of determination between dependent variable (forest growth) and independent variable (population growth) for 1958-1978 found to be low $R^2 = .182$. Similarly, regression coefficient of determination for the 1991-2001 showed comparatively lower than the previous years $R^2 = .138$. Moreover, it was noticeable observed a very low $R^2 = .016$ for the 1958-2001. Although, regression coefficient of determination could not give any reliable picture, however, the average negative trend somehow shows the relationship between forest area growth and population growth in Terai. Figures show that the forest area is decreased while population growth increased subsequently during the periods.

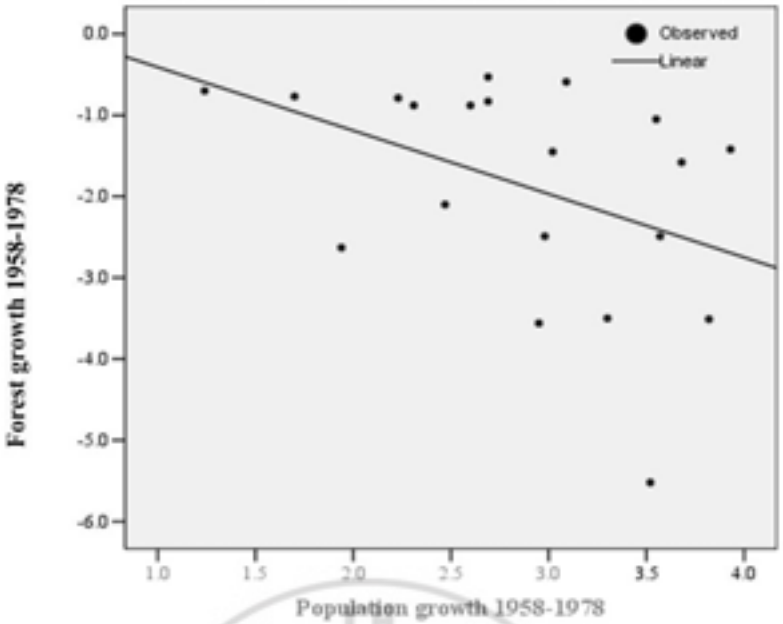

Figure 5- 18 Relation between forest area and population growth for 1958-78.

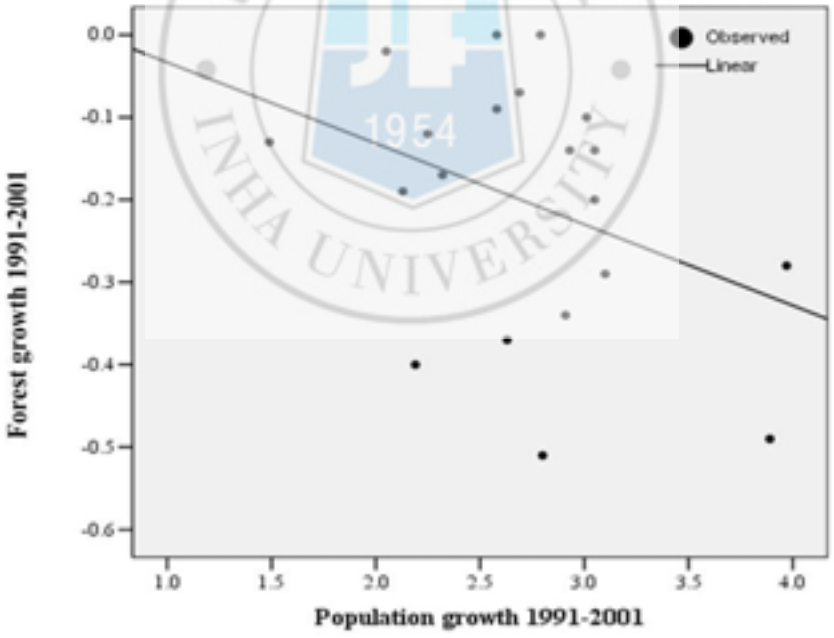

Figure 5- 19 Relation between forest loss and population growth for 1991-01.

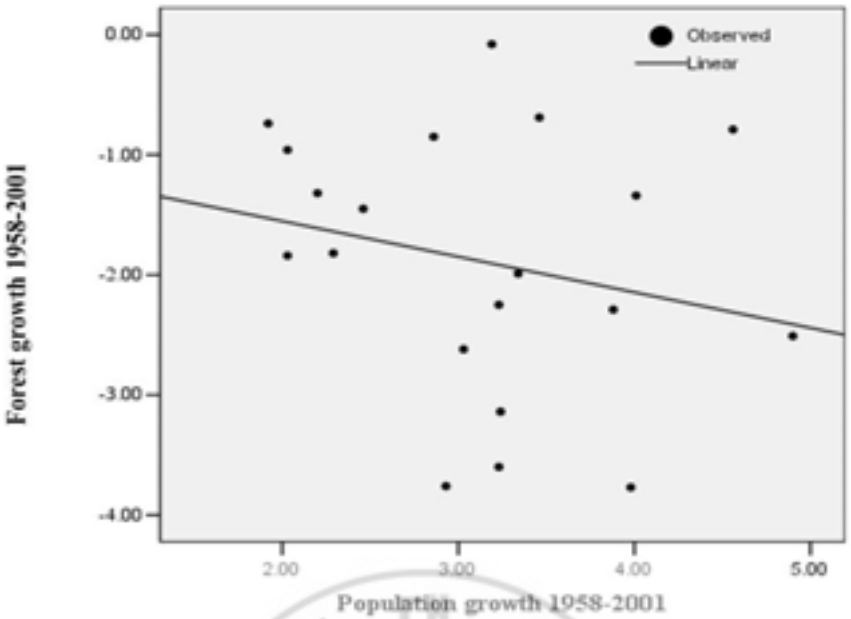

Figure 5- 20 Relation between forest loss and population growth for 1958-01.

5.2.7.4 Correlation analysis for forest loss and arable land expansion

We also perform the Pearson correlation analysis for forest area loss and rate of growth in arable land to observe whether Nepalese deforestation and forest degradation has any relation with agriculture expansion or not during the periods in Terai. Our analysis proved that forest cover lost significantly associated ($r = -.745$ at $p = 0.01$ level) and ($r = -.485$ at $p = 0.05$ level) with agriculture expansion during 1958-1996 and 1958-2001 respectively. There is a strong negative correlation between increase in the rate of growth in arable land and forest area loss over time (Table 5-4 and 5-5).

Table 5- 4 Correlation between forest cover change and arable land 1958-96.

		Forest cover change 1958-1996	Arable land change 1958-1996
Forest cover change 1958-96	Pearson Correlation	1	-.745(**)
	Sig. (2-tailed)	20	.000
	N		20
Change in arable land 1958-96	Pearson Correlation	-.745(**)	1
	Sig. (2-tailed)	.000	
	N	20	20

Table 5- 5 Correlation between forest cover change and arable land 1958-01.

Correlations		Forest cover loss 1958-2001	Arable land growth (%)
Forest cover loss 1958-2001	Pearson Correlation	1	-.485(*)
	Sig. (2-tailed)		.030
	N	20	20
ARgr5801	Pearson Correlation	-.485(*)	1
	Sig. (2-tailed)	.030	
	N	20	20

We further tried to apply curved estimate model (Figure 5- 21 & 5-22) and regression analysis to explain the forest cover loss with respect to the growth rate of arable land in Nepalese Terai. We found that regression coefficient of determination was comparatively higher R^2 = .565 between two variables for 1958-96 than other factors like population. Similarly, coefficient of determination found to be some how lower R^2 = .236 for the 1958-2001. However, it indicates the Nepalese Terai deforestation severely affected with the agriculture expansion in the past and even in the recent days.

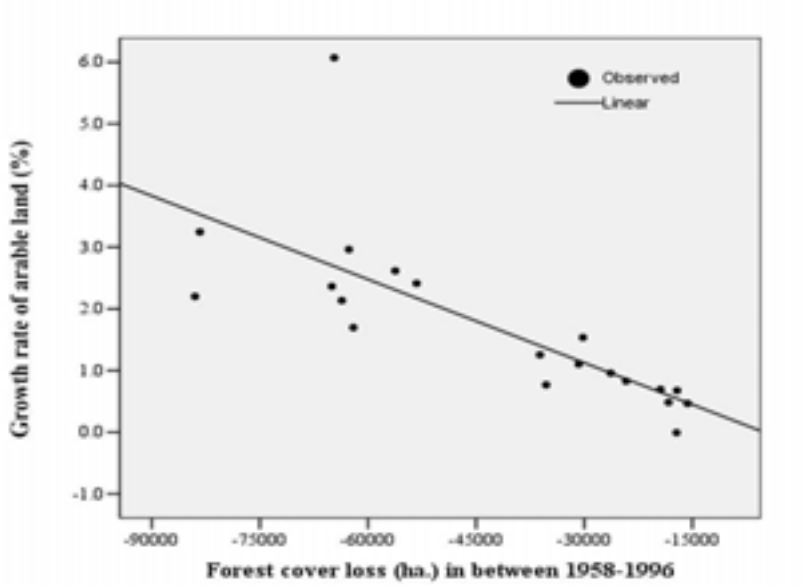

Figure 5- 21 Relation with forest loss and agriculture expansion for 1958-96.

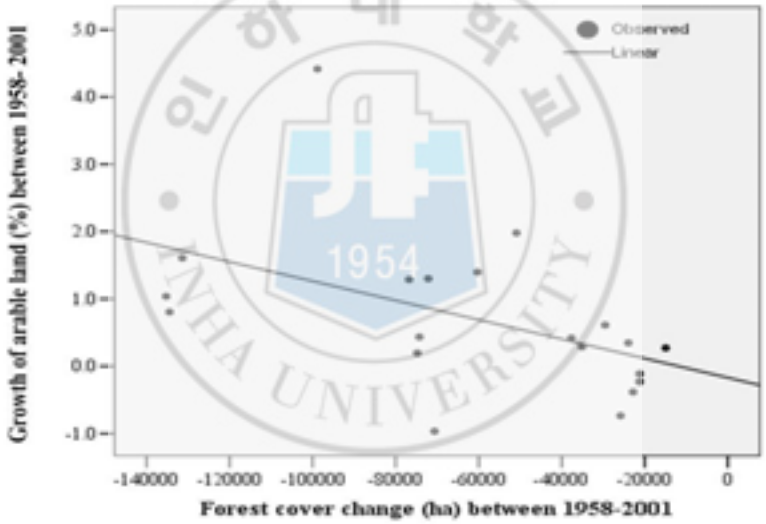

Figure 5- 22 Relation with forest loss and agriculture expansion for 1958-01.

5.2.7.5 Correlation analysis for forest area and food insufficiency

The correlation coefficient between the forest area and insufficiency of food production showed the negatively association with significance (r = - 0.492 at p = 0.05 level) (Table 5-6). This indicates that food sufficiency is positively associated with forest area. This is an interesting result, district with higher percentage of households reporting insufficient of agriculture production to feed their family is associated with low forest area in Terai.

Table 5- 6 Correlation between forest area and food insufficiency in 2001.

		Forest Area 2001	Percentage of household reporting insufficient to feed their family from their own food production
Forest Area 2001	Pearson Correlation	1	-.492(*)
	Sig. (2-tailed)		.028
	N	20	20
Percentage of household reporting insufficient to feed their family from their own food production	Pearson Correlation	-.492(*)	1
	Sig. (2-tailed)	.028	
	N	20	20

We further analyzed the regression and regression coefficient of determination showed R^2 = .242 between two variables for the year 2001 in Terai. The curved estimate model also showed the clear picture about the relationship with food insufficiency at rural households and the forest area, the trend of curve clearly follow the negative relationship between them in Terai (Figure 5-23).

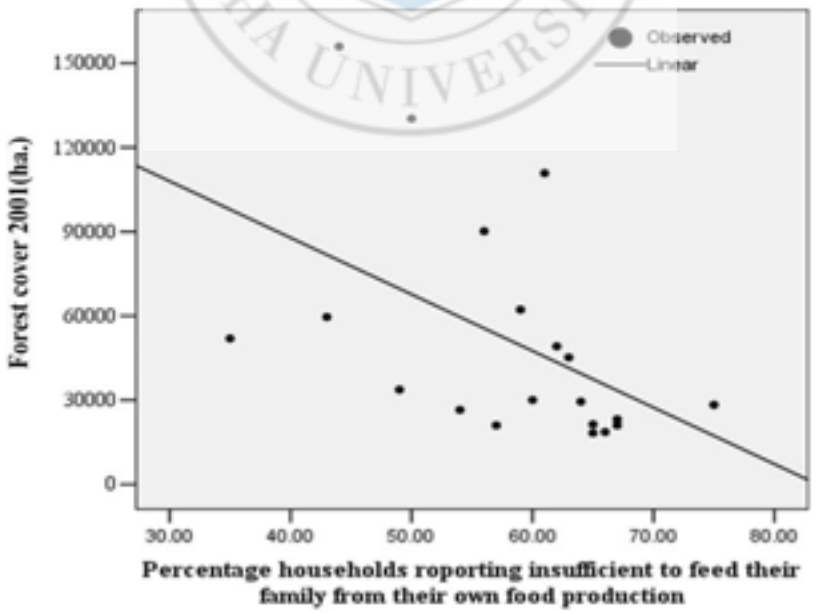

Figure 5- 23 Relation between forest area and food insufficiency for 2001.

5.3 Mapping LULC change, food production and food security status

5.3.1 LULC changes in Terai region

Table 5-7 reveals that the overall share of agricultural land and forest cover (including shrub) increased from 24 to 28% and 42 to 46% between 1986 and 2000, respectively. However, this may be the result of the use of different forest survey methods rather than reflection of a real change in 2000. Nevertheless, more land is being used for agriculture; the most fertile lands are being converted to non-agricultural uses, for urban expansion, settlement, and road construction. Large cities are encroaching upon prime agricultural land, especially in Kathamandu valley, and other Terai districts such as Chitwan, Rupandehi, Banke, Dang, Kailali, Kanchanpur, Moranang and Jhapa, as well as emerging urban areas nearby district city centers.

Table 5- 7 Distribution of land and land use by type

Land Use Category	1986		2000		Change 1986–2000	
	Area		Area		Area	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Agriculture	3,461,069	23.52	4,150,979	28.10	+689,910	+19.93
Forest (including shrub)	6,211,522	42.20	6,788,292	46.12	+576,770	+9.29
Other	5,045,509	34.28	3,778,829	25.67	-1,266,680	-25.11
Nepal 14,718,100		100	4,718,100	100		

Source: Environment Assessment of Nepal: Emerging Issues and Challenges, 2005

Similarly, the summary findings of Agriculture Census 2001/02 documented that "there was an increased of 4.4% of agricultural land and a decreased of 66% of the total wood and forested land between 1991/92 and 2001/02", i.e. an increase of 104.8 thousand ha of crop land and a decrease of 71.6 thousand ha of wood and forest land, respectively. Furthermore, there was a large increase in the area of land under permanent crops from 29.4 thousand ha in 1991/92 to 117.5 thousand ha in 2001/02, an increase of almost 300% in 10 years. The changing pattern of land use in agriculture may be indicative of the changing structure of land use in Nepal, from woodland and forest farming to permanent crop farming" (CBS, 2001/02).

Table 5-8 depicts that the overall per capita agricultural land declined slightly from 0.19 ha to 0.18 ha, but the main decline was in the Hill region. At the national

level, both forest and agricultural land resources have increased, possibly due to a decrease in the area devoted to other land uses. A distinct land use change was observed in Terai over time; Terai forest area declined from 50.4 to about 39% between 1986 and 2000. Similarly, Table 5- 9 shows that agricultural land with grass in Terai increased by 542,481 ha (47%) in 2001 from 1,150,196ha in 1963/64. Additionally, forest land (including shrubs) decreased by 487,364 ha (32%) within the same period.

Table 5- 8 Change in Agricultural and Forest Lands by Region.

Region	Agricultural Land (%)		Per Capita Agricultural Land (ha)		Forest Land (%)		Per Capita Forest Land	
	1986	2000	1986	2000	1986	2000	1986	2000
Mountain	5.33	10.02	0.19	0.31	27.50	31.03	0.99	0.95
Hill	33.37	28.06	0.24	0.17	50.06	62.89	0.36	0.38
Terai	41.57	56.17	0.16	0.17	50.43	38.88	0.20	0.12
Nepal	23.52	28.20	0.19	0.18	42.20	46.12	0.34	0.29

Source: Environment Assessment of Nepal: Emerging Issues and Challenges, 2005

Table 5- 9 Land Use Change in Terai, 1963/64 – 2000

Land use type	1963/64	2001	Change	
	Hectare	Hectare	Hectare	Percent
Agriculture land (with grass land)	1,150,196	1,692,677	542,481	+47.2
Forest land (including shrubs)	1,526,391	1,039,027	-487,364	-31.9

Source: Nepal Strategy for Development, ADB, 2005

5.3.2 Major food crops production

Food crops production depends on the availability of land, irrigation and other production inputs. Irrigation is a primary source for crop production and agricultural development in Nepal. Thus, there is variation in food crop production year by year due to a dependency on the uncertain monsoon, which in turn affects the local food supply. The Terai region is considered a food storage centre of the country, because of the plains area and developed irrigation infrastructure as compared to the Hills and Mountain regions, with high potentiality for food crops production. However, low productivity, large sections of inirrigated or partially irrigated crop land with a dry

winter, high population growth, and immigration from the hills and mountains pose major challenges to meeting requirements of food and resource management in Terai.

Table 5- 10 Changes in area covered by crops between 1986/87-2005/06

Crops	Area covered (ha) 1986/87	Area covered (ha) 2005/2006	Change 1986/87-2005/06		Percent change in total change	Percent share of total cropped area	
			(+/-) ha.	Percent		1986/87	2005/06*
Paddy	984,030	1,103,180	+11,9150	12	43.2	68.0	64.0
Wheat	292,760	3,82,154	+89,394	31	32.4	20.2	22.2
Maize	138,340	165,947	+27,607	20	10.0	9.6	9.6
Millet	11,180	11,585	+405	4	0.1	0.8	0.7
Barley	3,560	1,027	-2,533	-71	-0.9	0.2	0.1
Potato	17,770	59,364	+41,594	234	15.1	1.2	3.4
Total	1,447,640	1,723,257	275,617	19	100	100	100

Paddy is the dominant food crop grown in Terai, with other main food crops being wheat, maize, potato, millet, and barley. Table 5-10 reveals that paddy accounts for about 64% of the total agricultural crop area followed by wheat (22%), maize (about 10%), and potato (>3%); millet and barley constitute less than 1% of the total cropped area in 2005/06. There was a notable change in area covered by various food crops during the last 20 years (1986/87-2005/06) and the total cropped area of major food crops increased by 275,617 ha (19%). The incremental area by crop type is 119,150 ha (43%) for paddy, 89,394 ha (32%) for wheat, 41,594 (15%) for potato, and 27,607 ha (10%) for maize. In addition, the highest incremental change is observed in potato, from 17,770 ha to 59,364 ha, (234%), followed by wheat (31%), maize (20%), and paddy (12%) relative to the base year (1986/87) area for crop coverage in 2005/06. However, the share of cropped area of paddy among the total cropped area decreased by 4%. Similarly, the share of wheat and potato in the total cropped area increased by 2% over the last 20 years.

Primarily, the food requirement in Nepal depends on local food production and food supply systems. The import of food stuffs in the nation play an insignificant role in local (district level) food supply systems. Experience has shown that most of the Hill and Mountain districts face food deficits and food is supplied from the Terai. In 2005/06, paddy constituted the largest share of food production in Terai, i.e., 59% of the total food production, followed by wheat and potato (17%) and maize (7%).

Additionally, the incremental production of food crops was 2,700,528 metric ton in the last 20 years. The share of paddy decreased more than 10% and that of potato increased by about 13% during the study period. However, total food production shows more than doubled (Table 5- 11). This was due to an increase in area that is covered by food crops.

Table 5- 11 Production of food crops from 1986/87 to 2005/06

Crops	Production (Mt.)		Change 1986/87-2005/06		Percent share in total production		Average yield (Mt.) per ha.
	1986/87	2005/06*	Production(Mt)	Percent	1986/87	2005/06	
Paddy	1,731,080	3,069,375	1,338,295	77.3	69.9	59.3	2.489
Wheat	430,360	861,026	430,666	100.1	17.4	16.6	1.776
Millet	9,457	12,109	2,652	28.0	0.4	0.2	1.058
Barley	3,280	1,190	-2,090	-63.7	0.1	0	1.009
Maize	215,150	364,620	149,470	69.5	8.7	7	1.888
Potato	86,440	867,975	781,535	904.1	3.5	16.8	10.345
Total	2,475,767	5,176,295	2,700,528	109	100	100	3.094

Nepalese research found that the average yield potential of major crops is 5000 kg/ha for paddy, 6000kg/ha for maize, 4500-5000kg/ha for wheat, 2000-3000kg/ha for barley and millet and 36000-38000kg/ha for potato (MOAC, 2004/05). Based on the food crop production result during the study period, we concluded that the productivity of food crop is very low and is less than half of its potential, except for potato. The average yield of food crops per hectare per year during the last 20 years was only 3.094 mt. Similarly, the average yield of paddy was 2.489mt./ha, potato was 10.345mt./ha, and maize and wheat yielded less than 2mt./ha. Barley and millet yielded around 1mt./ha. The productivity trend of each crop by the Three Period Moving Averages is depicted in Figure 5-24 and 5-25. The results revealed that the productivity of barely and millet had stagnant over the last 20 year periods. The productivity of wheat and maize had steadily increased and the productivity of paddy fluctuated slightly and steadily increased whereas the productivity of potato also showed a fluctuating trend but increased after 1998/99 (Figure 5- 25) .

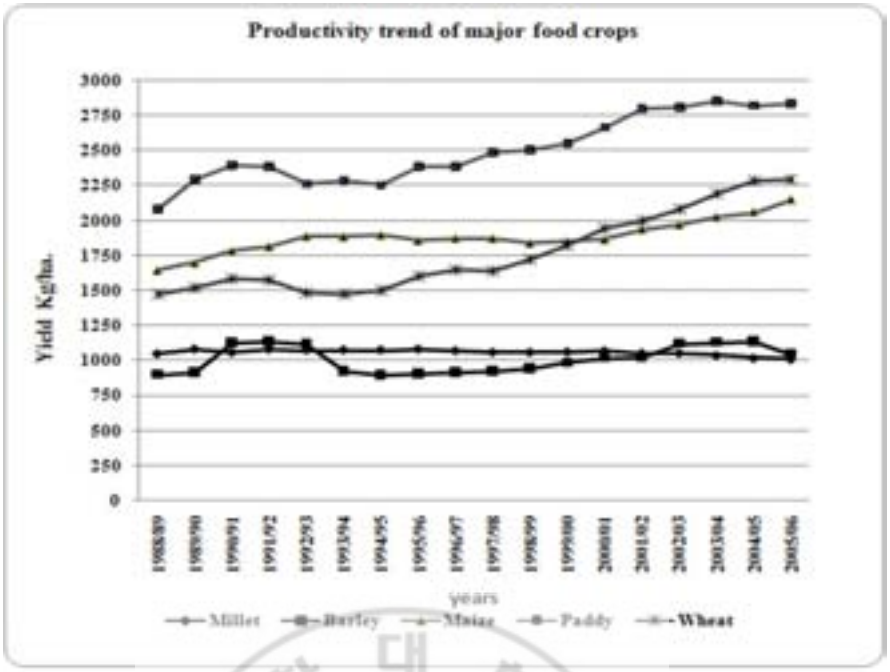

Figure 5- 24 Productivity trends of food crops (1986/87-2005/06).

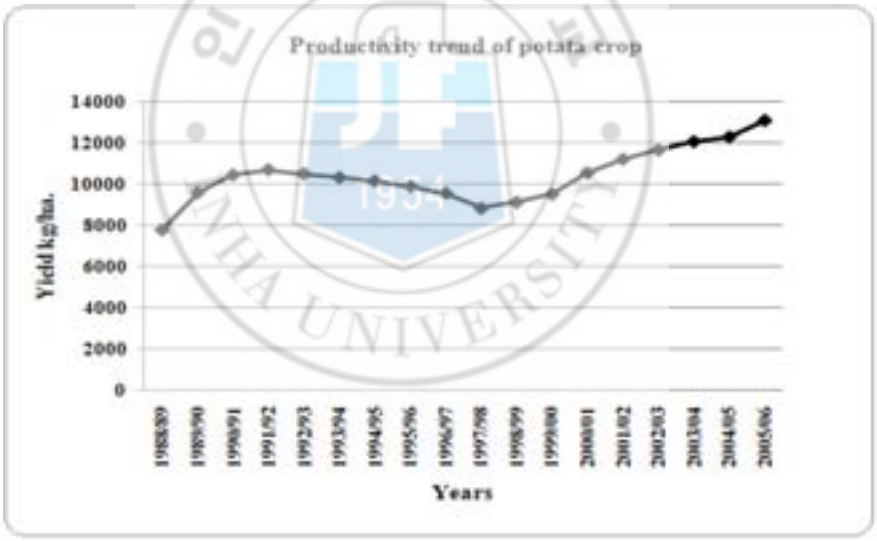

Figure 5- 25 Productivity trend of potato crop (1986/87- 2005/06).

5.3.3 Food production and food balance

Total supply of calories (food) in the spatial location is estimated after deduction of the parts of crops that are used for seed purpose, loss after harvest, and parts of the crop that are used for other purposes (see Table 3-3 and methodology). The parts of crop that are available for food purpose was transformed into calories produced from

each crop by using the standard conversion rate. The balance of food was determined by the Food Supply to Demand Ratio (FSDR).

To depict the temporal and spatial extent of the food supply, maps are prepared with the help of GIS software (Arc GIS 9.0) based on the 5 year average Food Supply to Demand Ratio.

(a) Food availability at districts

The status of food availability at the district level is depicted based on the FSD Ratio. Mathematically, ratio 1 is a balanced situation and ratios <1 and >1 reflect a situation of deficit and surplus of food production, respectively (Table 5-12). In reality, this relation may be considered somewhat arbitrary. Thus, we assume that at least a 20-25% surplus of food in any geographical boundary can overcome the unforeseen shock of food deficit. Hence, districts are classified according to following criteria.

Table 5- 12 Criteria for food surplus and deficit calculation

Average FSDR	Insecure	Potentially Insecure	Secure
<1	.....		
1-1.20		.....	
>1.2			.....

The temporal extent of the food availability in each district has produced a series of maps in each five year intervals. Similarly, the severity of food deficit is described by the number of periods (year) having lower food production than the food requirements for each district. Thus, we argue that the higher the period of food deficit, the deeper the risk of food security in any geographical boundary.

The Figures 5-26, 5-27, 5-28, and 5-29 show the food supply (production) status by district level based on the five year average FSDR indicator. Between 1986/87-1990/91, only the Nawalparasi had a food deficit and most of the Eastern Terai districts were potentially food secure (Figure 5-26). However, the food deficit trend increased in the subsequent five year period (1991/92-1995/96) and out of 20 districts, 11 districts fall in the food insecure category (Figure 5-27). The situation improved to some extent during the period 1996/97-2005/06. Most of the districts

fall in a potentially food secure category, i.e., FSDR <1.2, but 5 districts are in the (25%) food insecure category (Figures 5-28 and 5-29). However, overall, during this 10 year period, 8 districts (40%) fall in the food secure category, i.e., FSDR>1.2.

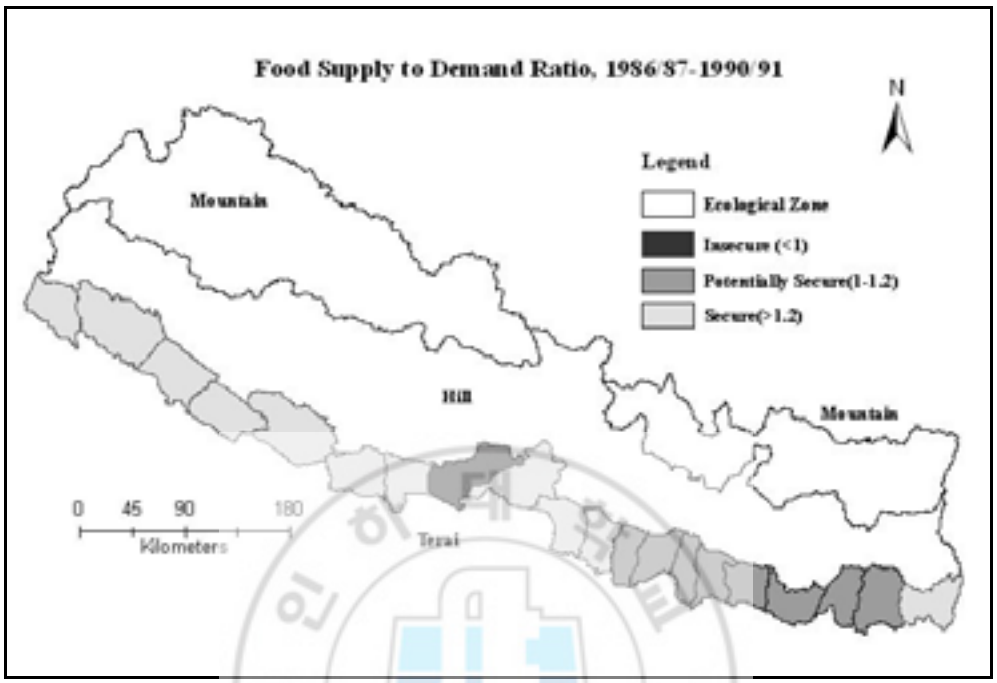

Figure 5- 26 Food Supply to Demand Ratio (1986/87-1990/91).

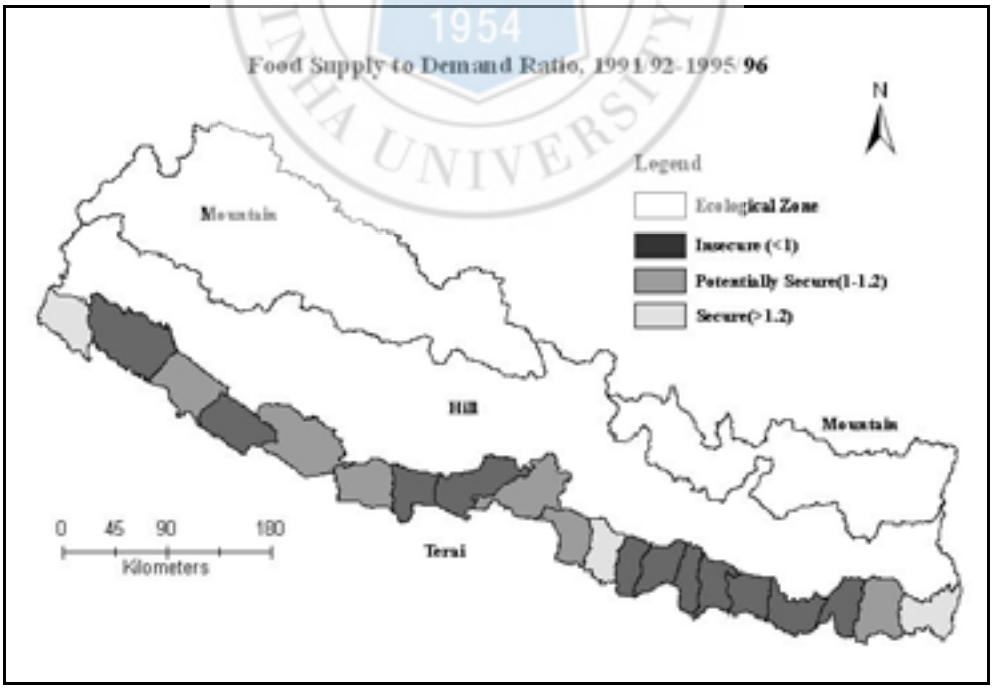

Figure 5- 27 Food Supply to Demand Ratio (1991/92-1995/96).

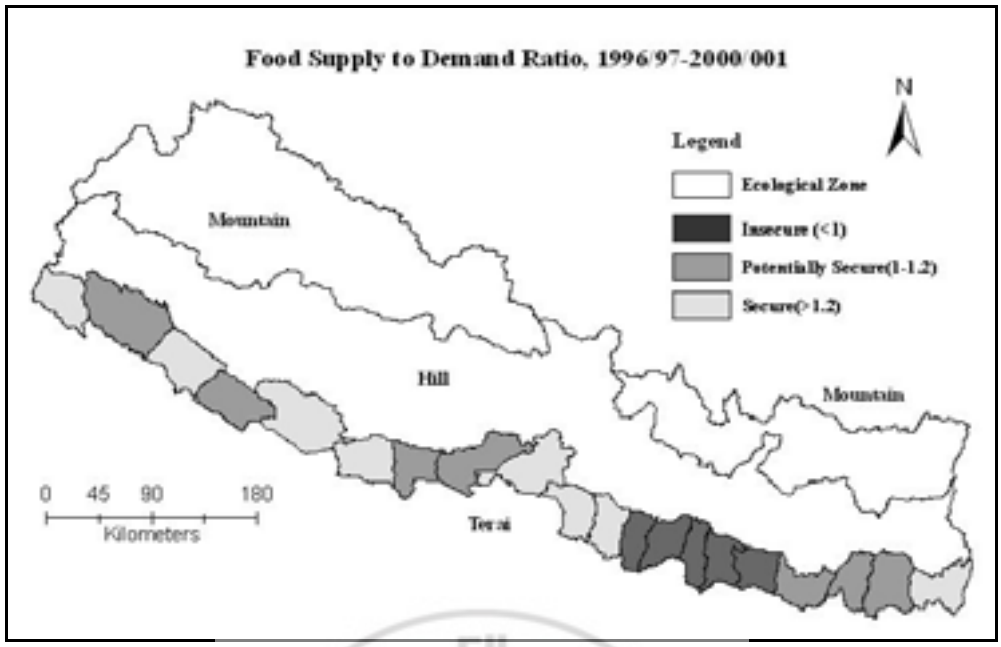

Figure 5- 28 Food Supply to Demand Ratio (1996/97-2000/01).

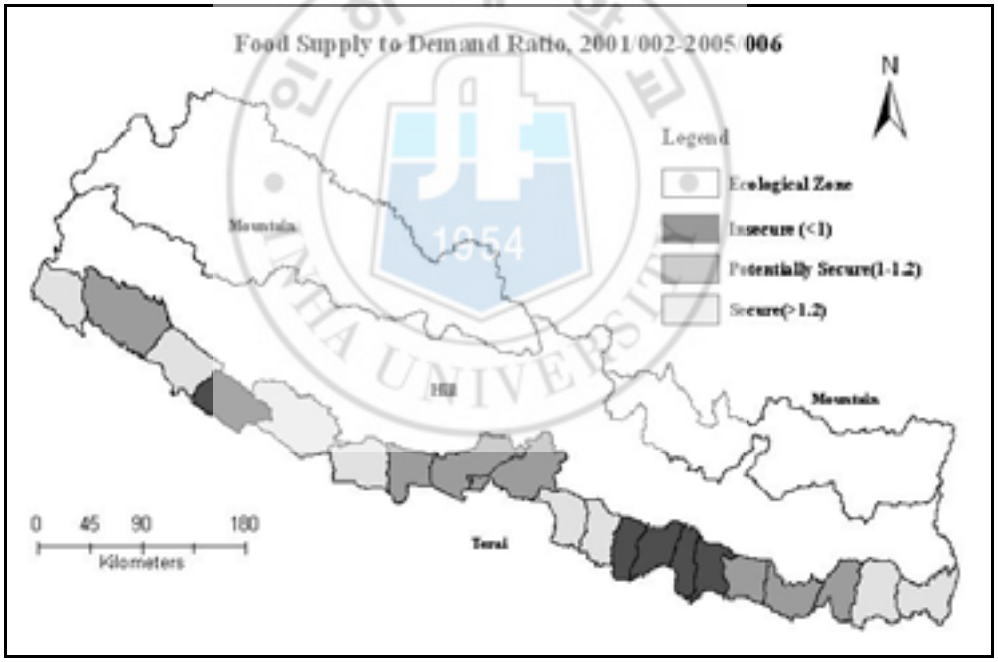

Figure 5- 29 Food Supply to Demand Ratio (2001/02-2005/06).

(b) Frequency of food deficiency

Stability of local food production in any spatial location can be described on the basis of the number of years where there was a food deficit based on the production system. We argue that the higher the period of low food supply, the higher will be the risk of food insecurity.

Figure 5-30 shows that Dhanusha, Mahottari, Sarlahi, and Rautahat districts have 16/16 and 14 periods of food deficit, followed by Nawalparasi, Saptari, and Banke districts, which have 8-10 periods of food deficit out of the 20 study periods. Thus, these districts are more insecure with respect to food security.

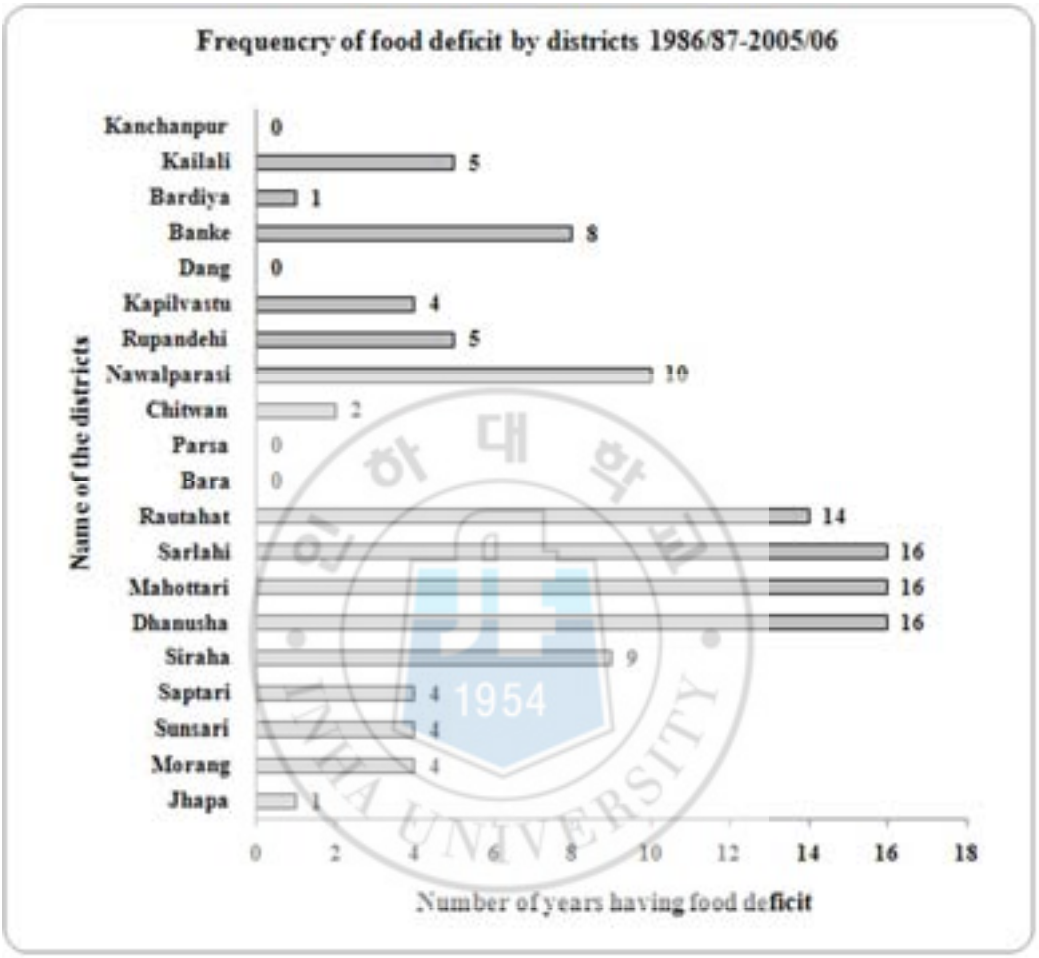

Figure 5- 30 Frequency of food deficit between 1986/87 and 2005/06.

(c) Food production and demand

The trend of calorie production in the Terai region is not hopeful considering the present trends of population growth and food crops productivity. However, during the study period of 1986/87-2005/06, the produced calories is a slight surplus over the requirements and the food supply situation fell below the requirement from 1991/92-1995/96 (Figure 5-31).

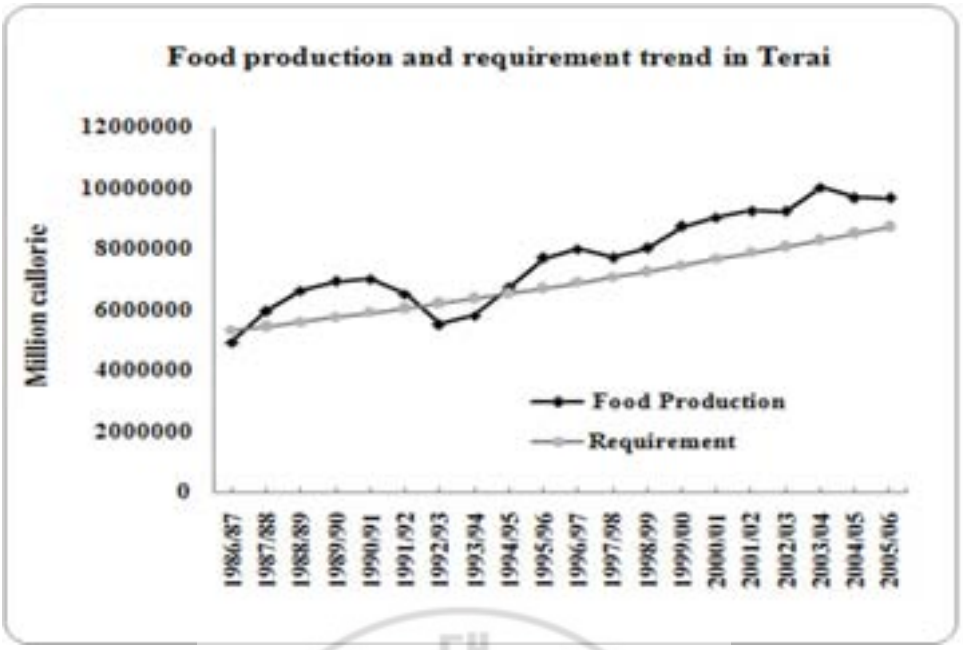

Figure 5- 31 Trends of food production and requirement.

Moreover, Figure 5-32 shows the status of Food Supply to Demand Ratio (FSDR), which indicates that, the average FSDR is less than 20% of surplus during the study period, and after 1995 the FSD is somehow stagnant. This indicates that Terai is not a potentially food secure region based on the local production of calories. Additionally, a significant proportion of households report an inability to meet the food demands of their family from their own agricultural production.

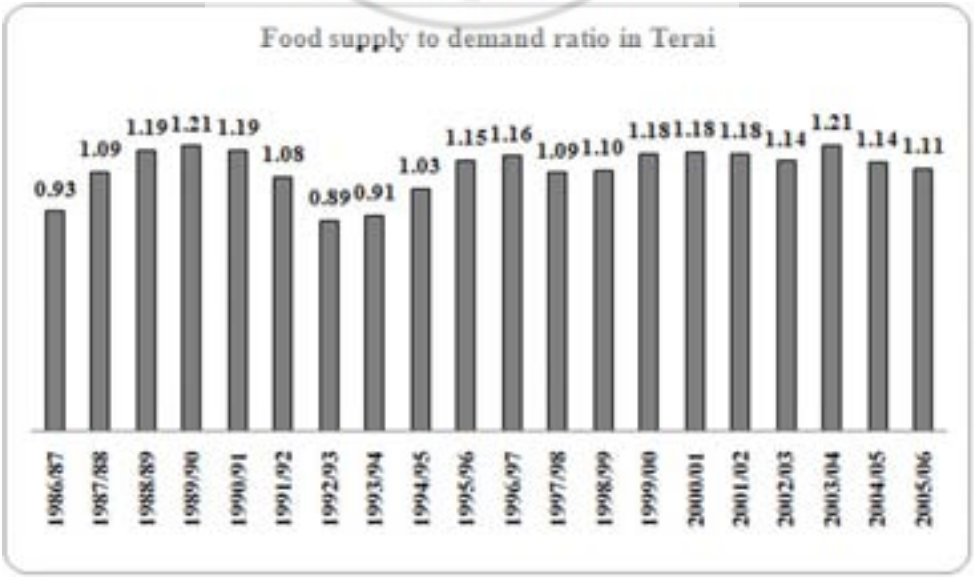

Figure 5- 32 Average food supply to demand ratio during last 20 years.

5.3.4 Future food production and supply

The future food production in the whole region is predicted by the ordinary least square method, and the predicted population is acquired from the Central Bureau of Statistics (www.cbs.gov.np). Based on this prediction, we concluded that the food supply situation in the Terai will remain almost at the same level as that of today, only a 16-17% (Table 5-13) surplus until 2021. Terai is also potentially not secure with respect to food supply, even though the region is considered a storage house of food.

Table 5- 13 Prediction of Food demand and supply

Items	2011	2016	2021
Estimated Population	14,048,710	15,454,964	16,894,748
Food Requirement (Million Cal.)	9,599,203	10,560,068	11,543,844
Estimated Calorie Production (Million Cal)	11,119,832	12,315,735	13,511,639
Balance (+ or -)	+1,520,630	+1,755,668	+1,967,795
Food excess (Percent)	16	17	17

5.3.5 Food access

Food access refers to the ability to obtain appropriate and nutritious food in the case of a particular household or individual. Several studies have underlined the finding that sufficient overall production is a minimum condition for food security; however it is not a sufficient condition on its own. Access to food depends on levels of poverty, purchasing power of households, the existence of transport and market infrastructure, and the effectiveness of food distribution systems in particular geographical locations.

(a) Adequacy of food at a household level

Based on the Agriculture Census 2001, food supply and food availability at a household level did not meet the food demand of most households in Terai districts. Generally, the landless are poor in Terai as well as in other parts of the country. This analysis also found that in the Terai region most agricultural households (about 41.2 % of total households) have small land holding size of less than 0.5 hectare.

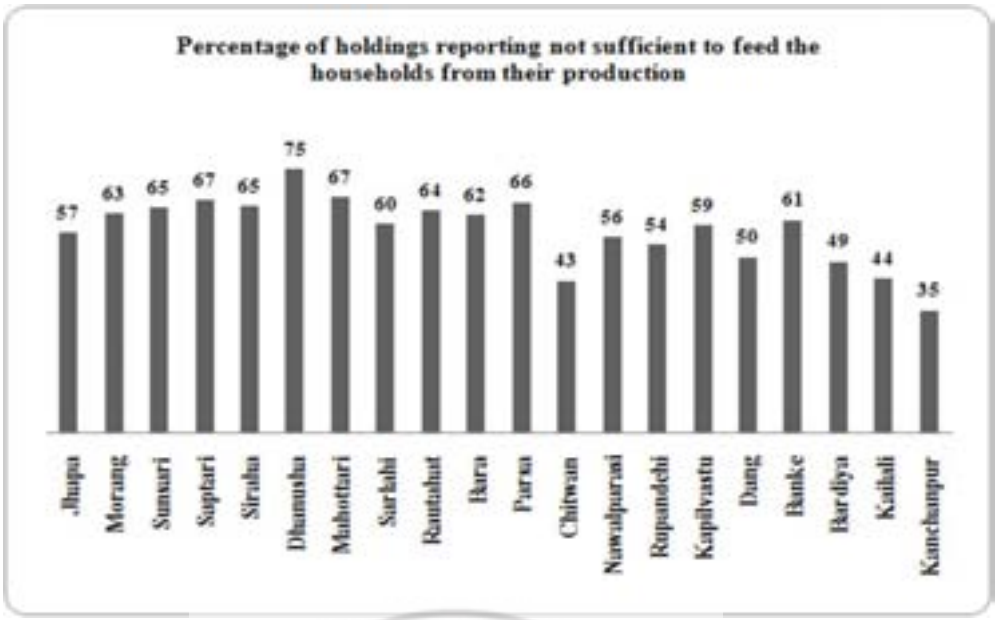

Figure 5- 33 Percentage of holdings reporting not sufficient to feed households.

Figure 5-33 reveals that 35% in Kanchanpur, the lowest level, and 75% of holdings in Dhanusha, the highest level, report inability to feed their households from their own agriculture production. Similarly, in most of the districts, more than 60% of the holdings out of the total holdings report inability to feed their households from their own agriculture production. "Food surplus group is defined as those who have enough production to support their families for the entire year and have even surplus foodstuff for selling. Food sufficient farmers are defined as those, who have sufficient food production available for at least 6-12 months per year. Food deficit farmers are those, who have limited access to food for less than 6 months a year from their own production" (Regmi et al., 2002). Figure 5-34 shows that about 59% of total holdings report having insufficient food stores to feed households in the Terai. Moreover, out of the total number of the holdings reporting insufficient food stores to feed their households, 17%, 29%, 17%, and 27% holdings report insufficient food stores for 1-3, 4-6, 7-9, and 10-12 months, respectively (Figure 5-35). This presents a clear picture of food insecurity in rural Terai and large sections of holdings were under food deprivation, even though the region produced at least the required level of calories.

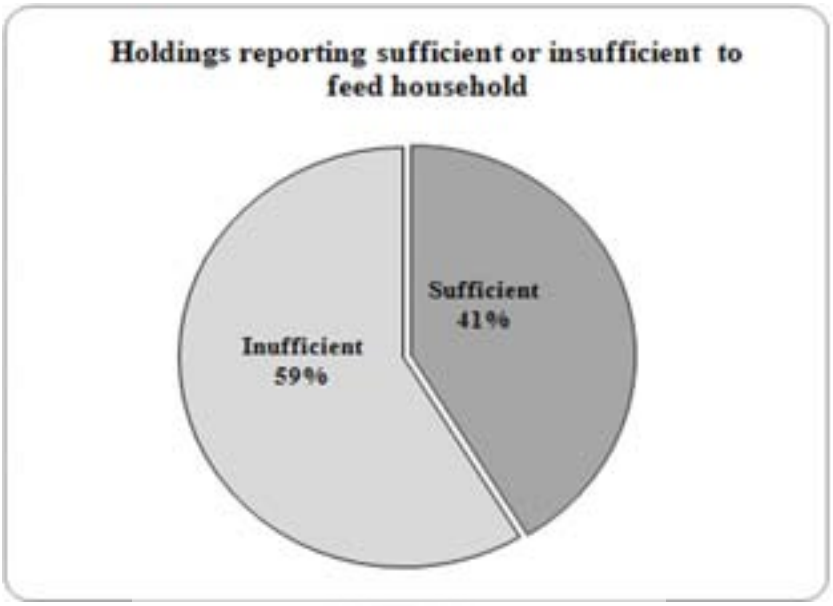

Figure 5- 34 Holdings reporting sufficient or insufficient to feed households.

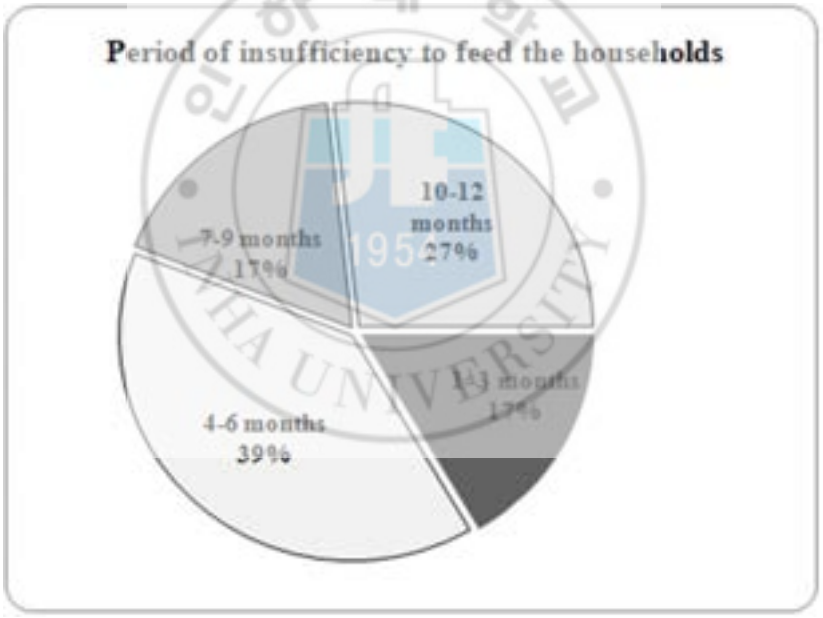

Figure 5- 35 Periods of insufficiency to feed the households.

(b) Poverty

Poverty is a complex occurrence. Hunger and poverty are closely related. Obviously, a lack of sufficient food production at the household level and insufficient income to buy food are the root causes for household food insecurity, and a low intake of nutritious food is directly related to labour productivity and

linked with poverty as well. “Hunger perpetuates poverty by reducing productivity and poverty prevents people from producing or acquiring the food they need” (FAO, 2005).

The incidence of poverty in Nepal is widespread; 31 % of the population lives under the national poverty line (A to Z Nepal, 2007). Since most of the marginalized poor live in rural areas, they have less access to education and are trapped in a vicious circle of poverty (ADB, 2005). Poverty incidence varies across ecological zones. Poverty status in Terai is comparatively lower than in the Mountain and Hills but is still about 28%. However, distribution of poor in Terai is about 45%, and it spreads among 51% of the population. In addition, based on head count rate, there is still 38% poverty in western Terai (Table 5-14).

Table 5- 14 Poverty status by Ecological Zones.

Ecological zone	Head count rate	Distribution of poor	Distribution of population
Mountain	32.6	7.5	7.1
Hill	34.5	47.1	42.1
Terai	27.6	45.4	50.8
Western Rural Terai	38.1	18.9	15.3
Eastern Rural Terai	24.9	23.5	29.1

Source: CBS /NLSS II, 2005.

(c) Resource access

Agricultural land is the prime source of household level food production and agriculture is the major economic sector, although agricultural land accounts for less than one-fifth of the total land area of the country. Out of the total households in the country, 78 % are agricultural households with land and about two percent are agricultural households without land. Terai is home to about 44% of the households out of the total agricultural households of the country.

The average size of land holding has also decreased (CBS, 2003/04). The percentage of holdings operating <0.5 hectare of land (small farmers) in Terai is about 42% and the proportion of households’ decreases considerably as the size of the land holding increases (see for details Figure 5-8). Figure 5-10 further revealed that the distribution of poor decreases significantly with an increase in land holding

size in 2003/04 in Nepal. Out of the total poor, about 76% of poor fall in the category of having under < 1 ha land.

(d) Other indicators

Some other parameters that are generally considered to affect the status of food security are outlined in Table 5-15. The table shows that the health situation of children is inferior and chronic malnutrition among children below 5 years of age and the infant mortality rate are about 47% and 60% in Terai, respectively. Similarly, the life expectancy is 63 years including about 16% of population with life expectancy rate less than 40%. This indicates that a large proportion of children and adults do not obtain sufficient nutritious food in Terai.

Table 5- 15 Some important social indicators of Terai in 2001

S.N.	Indicator	Percentage
1	Chronic malnutrition among the children (under 5 years of old)	47.1
2	Infant Mortality	59.76
3	Proportion of population with life expectancy less than 40 years	15.51
4	Life expectancy	
	Male	62.6
	Female	63.6
4	Population without accesses to safe water	12.10
5	Adult literacy (15 +)	52.9

Source: Human Development Report-Nepal, 2004

5.4 Discussion

5.4.1 Population and forest resource degradation

Our findings showed that population distribution is markedly higher in Terai compared to other regions of Nepal (Figure 5-2). Population density accelerated since 1961 and increased more than four-fold within forty-seven years from 1952/54 (Figure 5-3). A rapid population growth in Terai not only exerts pressure on the natural resources but also has had negative impact on deforestation and forest degradation process (FAO, 1997).

This confirms with the correlation analysis of 1958, 1978, 1991 and 2001 data on population and forest area losses in Terai. Our analysis found a strong negative

correlation association and significant (r = -.750 and r = -.788 at p = 0.01 level) for the year 1958 and 1978 (Table 5-2). A heavy human pressure on forest with 17 people/ha in 2001 from 2.4 people/ha in 1958 clearly shows the high impact in forest loss. A high rate of annual growth of population by 3.14% with annual forest loss by 1.89% also shows the population effects in forest area loss in Terai (Table 5-3) but low regression coefficient of determination between growth rate of population and forest with R^2 = .182 and R^2 = .138 during 1958-1978 and 1991-2001 showed less effect of growth rate of population in forest depletion process (Figure 5-18 and 5-19). Correspondingly, correlation association could not show any significance between these variables for 1991 and 2001 (Table 5-2). It shows that population factors affected deforestation and forest degradation significantly in the past but the effects have been decreased by other socioeconomic factors such as forest policies, conservation and management strategy. For instance, conservation measures like protected area, community and leasehold forestry programs could have also positive role in the management of Terai forest. Moreover, there could be other socioeconomic factors that could play an important role in forest degradation and deforestation process rather than population effect.

The highest in-migration rate noted in Chitwan (Figure 5-5) could be attributed to malaria control and the Rapti Valley Development Project, where 7,759 ha of forest land were distributed to 5,233 families (Guneratne, 1994 in Joshi, 2006). The control of malaria in the Terai was followed by rapid in-migration from the higher parts of Nepal (Ghimire, 1992). Generally, people migrate to search the livelihood sources for a better life, except in the case of conflict scenarios. In some cases, people migrate from overpopulated, depressed regions to forest frontiers in search of a more prosperous and secure life. These circumstances could be the one reason leading the high population growth and poverty incidence in Terai. However, a deep understanding of the effect of migration on poverty and forest degradation process requires to examine for the characteristics of migrants (NPC, 2005).

About 31% of population still live below the poverty line in Nepal (IFAD, 2007; CBS, 2001/02). But, a nearly 28 % poverty rate exists in Terai and there are significant differences in poverty between Terai (28%), Hills (35%) and Mountains

(33%). There is no significant difference between the distribution of poor and poor population from 1996-2004 (Figure 5-7). In Terai, many people are landless, while others who possess their own land have only small holdings. Confirming with this, almost 40% of head count poverty and nearly 76% of poor population distribution having a <1 ha landholding size in Terai (Figure 5-10). CIFOR (2000) also found an inverse correlation between land tenure security and deforestation while poverty matched consistently higher with small land holders (MDG, 2004). Faced with such extreme poverty, many people in Terai turn into the forest frontiers to seek livelihood and satisfying their basic needs while agriculture and forestry are the major sources of livelihood in rural Nepal. Hence, Terai forests have faced serious problem of deforestation and forest degradation in the recent decades (MPFS, 1988).

Our analysis showed that the per capita availability of forest land decreased considerably from 0.69 to 0.10 ha during 1958-2001/02 (Figure 5-17). Interestingly, Bardiya and Chitwan district has lost the largest area of forest land by 135,000 and 130,000 ha respectively during 43 yrs periods (Figure 5-16). Forest degradation and deforestation accounted more or less similar process in whole Terai region. However, specific characteristics in some district that allowed government and non-government authorities to launch various developmental programs which exacerbated the heavy forest destruction in the territory. Ideally, possible reasons behind the largest forest area lost from Chitwan district has already explained in the Chapter 4 section 4.6.1. However, a huge difference of forest lost with remote sensing output and historical data set is quite mentionable. Almost 52% more forest lost showed by historical forest statistics during the same periods of remote sensing data analysis for forest cover change in Chitwan. Apparently, the use of secondary data in country like Nepal where frequent use of remote sensing image may not be possible, could play an important role in forest resource management. However, the compile data from different forest inventory source including season, method, technology, number of involved expertise, hence there might be inconsistency in data collection and the level of error can be varied. In this regards, remote sensing data which has been used for a long time to monitor deforestation and recently attention has been shifted in

forest degradation could more accurate and constant than the other conventional methods to map and monitor the forest status in any geographical unit.

Similarly, in these districts government has launched resettlement program by clearing the large part of their forested land obtainable to the migrated people in the past. Forest of these districts was converted into the other land mainly for agriculture expansion and infrastructural development purpose. These districts are accessible for migrants who wander from the other parts of the country and have comparatively more productive land for agriculture commodities (Rautiainen, 1999; Achard et al., 2002; Conway et al., 2000; MPFS, 1988; DFRS, 1999; FAO, 1999; Sinha, 2003; Brown, 2003; Barber et al., 2003; Hobly, 1996; Joshi, 2006; Timilsina et al., 2007).

Moreover, these districts were rather virgin and comprised with a good shape of commercially valuable forest species such as Shorea robusta and others species (Hobly, 1996; Webb and Sah, 2003; Siwakoti, 2006) which has subject to frequently over logged and clear felled with both legally or illegally processes in the past. These all sequences could be privileged behind largely misplaced the forested land area. Data further revealed that almost 62% of households still use firewood for cooking, followed by 32% using cow dung and straw or leaves (Figure 5-11). About 68% of firewood source is forest based and 52% of households collect firewood from the forest, including both government and community forests (Figure 5-12 and 5-13). These statistics supports that a high degree of dependency on forest resources for fuel materials in Terai. Interestingly, all fuel types used in households are either directly related with forest or their products. A higher rate of forest loss in Bardiya and Chitwan might be due to the greater forest dependency as well.

Nepal's Terai has long been recognized as commercially important from a number of aspects, since most of the potential resources such as agricultural and forested land lie in this region (Sinha, 2003; Bampton et al., 2004). Besides, in most of the big cities, the main source of timber wood is Terai forest because of valuable and high quality hardwood. It was also reported that a large amount of exploitation also took place when the Indian railroad was built and the Terai forest provided all the sleepers. A total of 182,770 ha were cleared from 1956 to 1985, primarily for food production too (FRA, 2000).

5.4.2 LULC change, food security and forest degradation

Our analysis revealed that the total cropped area of major food crops has increased by 275,617 ha (19%) during the last 20 years (Table 5-7) while the average yields of food crops/ha/year was only 3.094mt (Table 5-11). However, about 59% of holdings out of the total households reported that they do not have sufficient food (Figure 5-34). In 11 districts out of 20, about 60%, or >60% of holdings, reported having not sufficient food from their own agriculture production (Figure 5-33).That situation could force them shift their livelihood in forest dependent services for survival which can also accounted for the deforestation and forest degradation process in Terai. The predicted future situation of food production and supply in Terai revealed that Terai is potentially not safe region for food supply. The food supply situation is expected to remain at almost the same level as today, with only a 16-17% surplus till 2021 (Table 5-13).

The increasing demand for food, poverty and relative scarcity of land has forced expansion of cultivation in steep slope and forest frontiers nearby settlements which directly encourage the deforestation process. Our study also depicted that about 42% of households among total households had holdings of <0.5 ha in Terai while nearly same result has in National level by 45% (Figure 5-8 and 5-9). Those people could not survive with their existence resources; hence undoubtedly inspire to get forest services which can directly provide means for satisfying their daily needs. Similarly, steep slopes and hilly areas do not support food production adequately due to the unsuitable landscape and other biophysical constraints. Consequently, every year, a huge amount of food must be supplied to the hill and mountain regions. Experience has shown that food supply is always more limited than demand. It could be reason of internal migration from the hill and mountain regions to Terai, resulting again high pressure on the forest and other resources in Terai. According to Bhandari (2006), negligible use of modern inputs is one of the major reasons for low and stagnant agricultural productivity in Nepal. Increased productivity in farm land, farmers would cultivate less land to perform their subsistence needs which ultimately leads to reduced pressure on the forest (Maertens et al., 2006).

A rapidly growing population by 2.25% per annum obviously increases the demand for food, but the low productivity of agriculture in rural areas, cannot cope with demand. Still around 50% of total district is recording a food grain deficit (NPC/HMGN, 2003) in Nepal. This analysis also found that food accessibility in the Terai districts is still insecure, although some districts have potentially secure conditions (Figure 5-27, 5-28 and 5-29). Thus, this could be the cause of food insecurity and poverty in Nepal. Poverty status is comparatively lower in the Terai than the mountain and hills regions, but distribution of poor by head count (45%) and poor population (51%) is relatively higher in the Terai (Table 5-14) than the other two regions. While rural livelihoods fail to endure their life with existing environment, then they start to search the easiest options which can fulfil their requirement. In this case, forest could be the most possible way of their survival due to often open access on it, therefore, forest and forest frontier nearer from the villages and rural town more susceptible with the deforestation for agriculture expansion through forest encroachment process. Now this situation has noticeably observed in many district of Terai such as Bardiya, Kailali, Kanchanpur, Rupandehi, Chitwan and so on (COMFORTC, 2006).

The correlation analysis also confirmed that the relationship between forest cover losses and agriculture expansion (arable land growth rate) has strongly correlated and highly significance with ($r = -.745$ at $p = 0.01$ level) and ($r = -.485$ at $p = 0.05$ level) during 1958 -1996 and 1958 - 2001 periods respectively in Terai (Table 5-4 and 5-5). Similarly, regression coefficient of determination also observed with $R^2 = .565$ and $R^2 = .236$ during same periods correspondingly (Figure 5-21 and 5-22).That indicates the deforestation process via forest clearing or forest encroachment was continuously accelerated in the past and is still prevalent in Nepal. Therefore, agriculture expansion could be one of the proximate factors behind the forest depleting process of Nepalese Terai. Similarly, insufficient food production at households' level significantly affected ($r = -.492$ at $p = 0.05$) in the forest area lost (Table 5-6 and Figure 5-23). Interestingly, the district reporting higher percentage of insufficient food production had coinciding with district with low forest area in Terai in 2001. Population density could have its anticipated effect on the conversion of forest land

into agriculture. However, interestingly, neither population density nor growth necessarily led to decreased yields. This is encouraging and suggests that to some extent, there are some induced responses occurring within communities. Poverty and other socioeconomic factors could also play an equal role in the forest destruction process.

Shortage of land is often one of the main causes of poverty; while it is more likely to be a problem in rural area, resulting an exacerbated food security problem. In many situations, it is frequently observed that most poor farmers do not have access to sufficient land for crop production. However, Gurung (1989) explained that the proportion of cropland in the Terai increased from 38.5% to 49.8% from 1963-1979. In this analysis, it was observed that crop area has exceedingly expanded in Terai during the last 20 years (Table 5-7). Nevertheless, food productivity and food demand to supply ratios do not meet the requirements in the region. Consequently, five Terai districts, Rautahat, Sarlahi, Mahottari, Dhanusa, and Siraha, were under food deficit conditions from 1991/92-2005/06 (Figure 5-27, 5-28 and 5-29). And these districts has also lost their forest land area by >40% of the total forest area of the district during the 1958 – 2001 period (Figure 4-15), perhaps limited access of agriculture land and poverty in Terai and food security problem in those districts could force to high forest dependency.

However, the first challenge is to develop the capability to understand the ongoing changes in food productivity and food deficit, and then to be able to alter activities as needed both at local and regional scales. Hence, mapping crop productivity and food deficit area facilitates improvement of the targeting of aid measures. If the status of basic food crop production can be quantified earlier in certain areas, there could be considerable benefits in planning strategy and the logistics of supply when needed (Sannier et al., 1998). Joma (2007) also realized the importance of sharing food security information to improve the coordination between the actors working in the food security sector. Once rural people have sufficient food access at households' level, the intensity of poverty and hunger could be somehow reduced, hence pressure on the forest could also decline compare with high poverty and without any options for livelihood.

5.5 Summary

Human dimensions such as demography, poverty, agricultural expansion and infrastructure development are some of the factors underlying deforestation and forest degradation. The interrelated association of population growth, poverty and forest dependency could have a great influence on deforestation and forest degradation. Firstly, this chapter illustrates the results on population factors, poverty and forest resource status in the tropical region of Nepal. This study demonstrated that how forest resources degradation and socioeconomic conditions are interacting with each other in the Nepalese Terai. Rapidly increased population growth; poverty, in-migration, and forest resource dependency are highly interactive with each other which substantively influences the deforestation and forest degradation process in Terai. Results showed that a total of 1,079,366 ha of forest land were disappeared in between 1958-2001 in Terai. Forest covers were depleted by >40% of the total forest cover of the districts. Moreover, Bardiya and Chitwan district has lost the largest area of forest land by 135,000 and 130,000 ha respectively between 1958 and 2001. This information could be helpful to government and policymakers to analyze and evaluate the extent of problems, search for alternatives and decide on a course of action. Additionally, continued increasing population, in-migration and poverty incidence with a low level of livelihood has brought a high dependency on natural forests in including forest.

Secondly, this chapter shows the consequence on LULC change, major food crops production and food security status of Nepalese Terai. Results showed that the total area of major food crops has increased by 275,617 ha (19%) during the last 20 years and the highest incremental change was observed in potato at 593,64 ha (234%). However, the average yield of food crops per hectare per year was only 3.094mt except potato while others crops yielded low. Similarly, the productivity of crops was very low at less than half of their respective potential yields, with the exception of potato. Three period moving averages indicated that the productivity trends of barley and millet were stagnant while the other crops showed slightly fluctuating or steadily increasing.

Furthermore, the status of food availability maps showed that 8 out of 20 districts have food secure whereas 5 districts are still under food insecure condition. The analysis further revealed that 7 districts had a food deficit, from 8-16 times during the study period. There was a food supply surplus relative to the requirements dictated by Food Supply to Demand Ratio. However, the average FSDR was less than 20% of the surplus and after 1995, it was relatively stagnant. Least square method predicted that the future food supply in Terai would remain at almost the same level as now, and there would only be a 16-17% surplus until 2021.

CHAPTER 6 CONCLUSION

6.1 Research contents

In this research we tried to understand the socioeconomic consequences in deforestation and forest degradation in Nepal, mainly from four perspectives. Therefore, in Chapter 3 we take in account detail procedure and methodology for data analysis regarding with research objective. Thus, at local scale we assessed the deforestation and forest degradation processes, people's livelihood and their dependency on forest in Chitwan district in Chapter 4. Firstly, we quantified and mapped the spatio-temporal degradation and deforestation of the major forest types and forest cover changes using remote sensing and GIS technology based on methodology explain in Chapter 3. We used aerial photographs of 1976 and 1989 to classify MSS and TM images of 1976 and 1989 to generate training samples. Forest cover maps for 2001 were generated from an ETM+ image of 2001 using field observation data from 2002 and 2004. Satellite images were classified by a supervised classification technique using a MLC classifier. Potential forest type maps of 1976 (Dobremez, 1976) were cross-referenced with forest maps of 1976, 1989 and 2001 and the area of forested land and forest types of for each year was calculated. An artificial neural network was used to predict forest canopy density in five classes using Landsat images of the year 2001.

Secondly, we used primary data from 100 sample households' survey. For the data analysis, we used mainly descriptive analysis. Similarly, Head Count Poverty Index and Poverty Gap Index were used to calculate the poverty. Lorenz Curve and Gini-coefficient were used to assess the inequality of income and land distribution among the sample households. Forest Product Availability Index was constructed based on the households' response to measure the forest service and forest products availability over time. For the analysis of other socioeconomic characteristics of households and the information on forest resources in the study area, descriptive statistics were also used.

Thirdly, we analyzed spatio-temporal extent of foremost socioeconomic factors and forest resources degradation process at regional scale in Chapter 5. For this, we first try to explore and visualize the spatial and temporal extent of population factors, poverty incidence and forest resource degradation process in Terai. Socioeconomic data on population factors (size, density and growth), migration, poverty, land tenure and pattern of forest products uses were optimally integrated and analyzed with GIS and simple descriptive statistics. Moreover, forest covers of the Terai region were analyzed and quantify using various forest statistics. ArcGIS 9.0 was used to map and visualized the spatio-temporal extent of those casual factors, underlying forces and forest resource status as well. Similarly, we applied Pearson's correlation and regression analysis to find out whether statistically population and other socioeconomic factors affect in forest degradation and deforestation process or not in Terai.

Then, we analyzed the major food crops production and food security status using agricensus data from 1986/87-2005/06. The aggregate data was used to depict the regional level trends of food production and food supply. We developed a simple logical equation to calculate the food production and food requirement. Ordinary least square analysis and 3 periods moving average was used to depict the production and productivity trends of the major food crops in Terai. Finally, the modeling and mapping of food security and stability (frequency of food deficit over time) has accomplished by adopting the food availability approach (Food Supply to Food Demand Ratio). Descriptive statistics were also used for this analysis.

6.2 Results

The results of mapping deforestation and forest degradation, livelihood strategy and forest dependency in Chitwan (Local scale), analysis of socioeconomic factors, major food crops production and food security status at Terai (Regional scale) are presented in Chapters 4 and 5 respectively.

According to these results, Chapter 4 explored about the deforestation and forest degradation pattern, livelihood sources and their dependency on forest in Chiwan

district at local level. Results showed that forested area was reduced by 15 % between the year 1976 and 2001 with an annual rate of decline of about 0.6% (Table 4-1). Forest canopy map (Figure 4-4) revealed that dense forest of over 60% canopy density has remained only within the confines of the National Park boundary and some high mountains in the northern part of the district. But, forest canopy density in all other areas in the district remained below 40%. Except riverine forest, forest area of all other forest types was reduced in Chitwan. Terai Shorea robusta forest which has high commercial value showed a loss of 23% between 1976 and 1989.

The livelihood strategy and forest dependency at local level observed that although agriculture is the dominant occupation with multiple livelihood strategies in the study area however none of a single occupation is sufficient to meet their basic requirements. Result showed that 63% of households responded their production did not support to survive for their family (Table 4-6). About 34% of annual household income was shared by agriculture and forest followed by remittance 20% (Table 4-7). The largest share of income from agriculture and forest explores the fact of dependency on agriculture and forest resources in the study area.

The distribution pattern of income and land holdings revealed that both income and landholding distribution were relatively unequal with low Gini coefficient 0.25 and 0.37 respectively in the sample population (Figures 4-11). There is >33% of population below the poverty thresholds (Nrs 14,942) with poverty gap index 0.0945 which is considerably higher than NLSS II, 2003/204 (27.6%) in Terai. Results further showed that 82% of households admitted to firewood and 81% for fodder collection from the forest where 42% households were use forest or forest fringe for grazing animals (Table 4-9). The value of the forest products were estimated about NRs 10,223.28 per annum. On an average about 104 kg of fire wood and 66 kg/week of fodder were extracted by single household (Table 4-9). About 1.21 hr/day was spent for animal grazing in the forest or forest fringe. Based on the villagers responses, the availability of forest products and services decreased significantly from 0.781 to 0.308 (Figure 4-12) between 20 year before and current year (2007).

Similarly, the results presented on Chapter 5 at regional scale revealed that population factors: population size increased by double to 12.44 million in 2001 from

6.56 million in 1971 (Figure 5-1) and density increased almost 4 fold from 85/person/km to 330/person/km between 1952-2001 in Terai (Figure 5-3). Population growth rate was considerably higher by >2.75% per annum, which is higher than the national average (2.25%) during the 1999-2001 (Figure 5-4). Moreover, a high in-migration rate of >15% of district population has found in 10 districts. Interestingly, a highest in-migration rate was observed in Chitwan with 34% followed by Kanchanpur 33%, Kailali 27%, and Rupandehi 27% (Figure 5-5).

The general poverty rate still remains almost 28% of the total population in Terai. Interestingly, rural poverty in Eastern Terai is significantly lower (by 13%) than in Western Terai (Figure 5-6). It shows that rural poverty is still more severe in Western Terai of Nepal. Similarly, the head count poverty rate decreased by 12.7%, however the distribution of poor (almost 45%) was remained the same in Terai between 1995/96 - 2003/04 (Figure 5-7). Further, 42% of agriculture households holding a <0.5 ha land in Terai whereas almost similar figure were found in National level with 45% agrihouseholds having a <0.5 ha land (Figure 5-8 & 5-9).76% of poor households also having a<1ha landholding size (Figure 5-10).

Looking back at the forest depletion pattern in Terai, a total of 1,079,366 ha of forest land disappeared between 1958 and 2001 in Terai. Forest covers were depleted by >40% of the total forest cover of the districts (Figure 5-15). Moreover, Bardiya and Chitwan district were lost the largest area of forest land by 135,000 and 130,000 ha respectively in between 1958-2001 (Figure 5-16). Similarly, per capita availability of forest land was also decreased considerably from 0.69 to 0.10 ha during the same periods (Figure 5-17). The trend of firewood using for cooking was also increased from 43% to 62% between 1995/96-2003/04 and 68% firewood collection source is apparently forest in Terai (Figure 5-11 and 5-12). Further, Pearson's correlation and regression analysis proved that the significant effects of total population, growth of arable land and food insufficiency in forest area lost in Terai (Table 5-2, 5-4, 5-5 and 5-6 and Figure 5-21, 5-22 and 5-23).

Similarly, the share of forest land in Terai was decreased by about 12% from 1986 to 2000 (Table 5-8) with a considerable decrease in per capita forest availability from 0.20 ha (1986) to 0.12ha (2000). Agricultural land with grass land increased by

almost 47% whereas forest land decreased by 32% in between 1963-2001 (Table 5-9). There was a notable change in the area covered by various food crops during 1986/87-2005/06 and the total cropped area of major food crops increased by 275,617 ha by 19 % (Table 5-10). However, the productivity of food crops showed very low less than half of its potential, except for potato. FSDR indicated that, the average FSDR is less than 20% of surplus during the study period, and after 1995 the FSD is somehow stagnant. This indicates that Terai is not a potentially food secure region based on the local production.

Dhanusha, Mahottari, Sarlahi, and Rautahat districts are considered as risky districts in terms of food security; these districts were faced 16/16 and 14 periods of food deficit, followed by Nawalparasi, Saptari, and Banke districts, which faced 8-10 periods (Figure 5-30) with low average FSDR. Moreover, about 42% of agriculture household have <0.5 ha of land holding (Figure 5-8), 25% and 38% of the poor are in Eastern and Western Terai respectively (Figure 5-6) and 59% of household reporting their production did not support them to feed their family (Figure 5-34). It also explored the problem of food access including 47% chronic malnutrition (children under 5) and 60 infant mortality rates (Table 5-15).

6.3 Conclusion

We used a wide range of socioeconomic, spatial and temporal data to explore the forest changes and socioeconomic factors which could be the potential driving forces that initiate deforestation. In this work we were able to isolate degraded and deforested areas in time and space and to represent them cartographically, allowing us to point to multifaceted interaction of drivers behind such degradation and deforestation. This was shown to be equally true for local and regional scale.

6.3.1. Deforestation, forest degradation and forest reliance at local scale

At local scale deforestation and forest degradation disproportionately reduces the sizes of the different forest types, a finding that has important forest management implications. Forest species which has high commercial value were found to be more

prone to deforestation and degradation than that of less valuable species. The canopy status of different forest type could act as an indicator of forest degradation.

Deforestation in Chitwan district was most intensive in the 1970s when malaria disease was eradicated, large numbers of migrants settled there and agricultural activities were expanded. By early 1990s with introduction of conservation areas and community forestry programs in Nepal, reforestation process started. Such deforestation and reforestation pattern can be analyzed by using temporal remote sensing satellite data. The techniques, maps and information presented in this thesis could be useful to policy makers and resource planner in prioritizing limited resources for forest conservation in Nepal.

Majority of the households largely depends on agriculture and livestock husbandry while animal raising was either through stall feeding or grazing into the forests. Fodder is the main source for stall feeding and collects from nearby forests which have a direct effect on the forest. At household level, high consumption and extraction of forest products found to be an indispensable means of survival, leading to forest degradation and deforestation. At local scale we observed a constant depletion of area of forest types having commercially high value tree species and decreasing trend of forest products availability index. This could be crucial and supplementary information for planners in planning or providing alternative livelihoods strategy especially for rural and poor households who are near by forest frontiers. Once they have alternative ways of living, their dependency on forest resources would be gradually reduced.

6.3.2. Socioeconomic consequences, forest degradation at regional scale

At regional scale diverse anthropogenic explanations for deforestation and forest degradation were observed, namely: population factors, poverty, forest dependency (timber, fuel, fodder and grazing), LULC change (intensive agriculture), food production and food security status. Spatially and temporally population in Terai region expanded rapidly. Unexpectedly, population growth, in-migration and rate of forest area lost found to be dissimilar in Terai districts. Maps and results presented here could be practical reference in assessing the potential situation of those areas

subject to vulnerable in future. Similarly, a large number of inhabitants still depend on wood or firewood and nominally use of other means of fuel for cooking showed an indication of heavy dependency on forests which ultimately accounted for the forest degradation as well.

Moreover, Pearson correlation association between population and forest area lost showed significant for 1958 and 1978, but association couldn't show any significance for 1991 and 2001. Therefore, we could conclude that population factors affected deforestation and forest degradation greatly in the past but the effects could be decreased gradually with other socioeconomic intervention. Introduction of various conservation measures i.e. protected areas, community and leasehold forestry programs and effectiveness of forest policies in the recent decades could play a positive role in forest management process in the region. Interestingly, regression coefficient of determination between growth rate of population and forest area lost (negative growth) during the same periods couldn't show strong relation. With this indication, it is difficult to summarize whether the growth rate of population acted as casual factor behind the lost of forest coverage in Terai or not.

At the same time, agriculture expansion brutally encourages the deforestation. Our statistical analysis proved that growth in arable land significantly affected in the forest area lost in Terai during the last 43 periods. Regression coefficient of determination between those variable further confirm this. That indicates the deforestation process via forest clearing or forest encroachment was continuously accelerated in the past and is still prevalent in Nepal. Therefore, agriculture expansion could be one of the proximate factors behind the forest depleting process of Nepalese Terai, Similarly, food insufficient at household also significantly correlated with the forest lost in 2001. Districts which have reported higher percentage of food insufficiency, having lower forest area in Terai in 2001. Yet, the productivity of major food crop is not promising and below the production potential. Out of 20 districts, seven had food deficit of 8-16 times during the past 20 yrs periods. Therefore, we could conclude that Terai is also not a food secure region in Nepal. These situations could further warranted to the worsening of deforestation and forest degradation process in the region. Previously deforestation and forest

degradation could be explained by a few major factors such as population density, growth, but recently we must include many socioeconomic factors such as agriculture expansion, food security, poverty level etc and analysis of those factors at smaller scale such as national scale – regional scale – local scale is vital.

This thesis introduces the state of forests in Nepal, the role of socioeconomic data in forest degradation and deforestation and describes the applications of remote sensing and GIS in forestry research. Remote sensing is the most cost effective tools to analyze and quantify the deforestation and forest degradation issues. Although, satellite remote sensing data is increasing available, spatial detection of deforestation and forest degradation for biological conservation is not widespread in tropical regions. While some analyses and initiatives have been carried out to some extent, hard data and updated information are still insufficient. Understanding of canopy structure, vegetation and spatial and temporal extent of different forests is vital for researchers, managers and policy makers for updating existing forest maps, detecting forest changes and planning forest resource and biodiversity management. That's why remote sensing data which can generate and quantify the deforestation and forest degradation status is so important for this kind of analysis. Monitoring of forest landscape spatial structures has been recommended to detect degenerative trends in forest conditions. GIS and remote sensing play an important role in the generation of such data to identify degraded and deforested areas as well as potential areas for conservation.

6.4 Limitations and future direction

This research tried to uncover intuitive information in the context of socioeconomic perspectives of deforestation and forest degradation in Nepal. It attempts to use the GIS and RS approach at local and regional as well as temporal scale to focus on the interaction between the deforestation and the needs of subsistence of local people, namely the food production, in the Terai district of Nepal. However, it has some limitations.

6.4.1. Limitations

We mapped and quantify the major forest types and forest cover changes at local scale in Chitwan. We used spatial and temporal data from variety of sources, including historical maps, sensors, resolutions, and image acquisition time and classification techniques. Hence there is possibility of inconsistency in image classification. At finer scale the number of forest types, composition, canopy classes an cover can differ. Furthermore, persistent rates of deforestation and forest degradation were perceived in whole Terai region, we however, unable to get satellite imagery of same season for the whole region.

Data on demography, ethnicity, agricultural land and forest cover/area/ have been analyzed on the basis of administrative boundary of each district in order to find out the relations between these phenomena. However, some of the forest patch can be utilized by the neighbouring people and even from neighbouring country. Hence spatial sharing of a forest patch by the unnoticed people cannot be included in socioeconomic analysis.

To understand the socioeconomic consequences in forest resource degradation at regional scale, we considered scattered secondary data from various sources. It further limits the sequential flow of analysis and employment of any hypothesis or statistical test. Similarly, data may sometimes contradictory between sources, because of many institution involved in data collection for their own purposes. Moreover, time series data on forest statistics (area or biomass) could not available for district level as other socioeconomic data somehow available such as population and crop production. Therefore, we couldn't well establish the statistical relation between these factors and forest resource depletion process in Terai region. Since the temporal data on poverty level measurement for each district have not yet collected in Nepal, poverty measurement on regional and national basis was consider for this analysis. Further, the extent of temporal food crops production and food security mapping at regional scale analysis has based on the calorie supply from only cereals and tubers. Due to unavailability of districts wide data on food export and import for the whole study period; we were unable to incorporate the effect of export and

import of food stuff. Although the age groups and gender could have an effect on calories consumption, however, we only considered average threshold calorie value for calculating the calorie requirements in this analysis. There are still few more research potential endeavours for future work that could not uncover in this analysis due to various reasons and limitations that we mentioned previously.

6.4.2. Future direction

Mapping and quantifying remotely sensed deforestation and forest degradation could be more prolific if analysis mutually performed with the consideration of biophysical parameter (forest, biomass, stem density, species richness and annual growth of forest). The effect of local livelihoods and forest dependency in deforestation and forest degradation analysis can better accomplish with: categorization of local livelihood and their reliant on forest based on livelihood indicators, spatial dependency (considering distance factor), and forest resource consumption by different stakeholders other than local households, and annual production and extraction of forest resources (carrying capacity) of the forest.

Detail understanding of socioeconomic consequences in deforestation process is essential in Nepalese Terai, where administrative units lost their forest area rigorously. Further analysis could be interesting if impact of environmental (biophysical and climatic, farm management and technological input) factors on major food production considered in Terai. There are significant differences in socioeconomic structures, forest resources, historical processes in the use and management of forests between Terai districts and within districts as well. Therefore, further studies on systematic forest resource monitoring integrated with better understanding of socioeconomic consequences, considering location specific problem could be more prolific to sustain the tropical forest resources in Nepal.

Analyzing complex socioeconomic interrelations of deforestation and forest degradation processes, our emphasis includes both existing source information and spatially derived information. At present forest information in Nepal is scattered and analysis of driving forces behind deforestation and forest degradation is contradictory. Much interest has recently been attached to changes in forest area. The

reported forest condition depends highly on the national policy context. In this context also it is necessary to strengthen capacity at the national level. Similarly, forest information provided by local institutions needs to be classified and scrutinized carefully by analyzing vital factors responsible for a particular area.

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