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An Assessment of Ecosystem Services of the Everest Region, Nepal

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A journey of a thousand miles begins with a few steps. It takes a lot of motivation and endurance to reach the end of the journey. Although many obstacles might be met on the way, we are encouraged by what we will achieve at the end of the journey. So has been the work towards my PhD dissertation. There have been tough times but I have sailed through it all and in this moment of conclusion, I want to express my heartfelt gratitude to all those who have helped me in various ways throughout this journey.

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List of Abbreviations

AMC	Acute Mountain Sickness
ETM	Enhanced Thematic Mapper
Ev-K2-CNR	Committee for High Altitude Scientific and Technology Research
GDP	Gross Domestic Product
GIS	Geographical Information System
GLOFs	Glaciers Lake Outburst Floods
GNP	Gross National Product
HRA	Himalayan Rescue Association
ICIMOD	International Centre for Integrated Mountain Development
IUCN	International Union for Conservation of Nature
MA	Millennium Assessment
PES	Payment for Ecosystem Services
RS	Remote Sensing
SAARC	South Asian Association for Regional Cooperation
SCEP	Study of Critical Environmental Problems
SNPBZ	Sagarmatha National Park and Buffer Zone
SPCC	Sagarmatha Pollution Control Committee
TEEB	The Economics of Ecosystems and Biodiversity
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organization
VDC	Village Development Committee
WISDOM	Woodfuels Integrated Supply/Demand Overview Mapping
WWF	World Wildlife Fund

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Abstract

Land use and land cover changes in the region were analyzed on the basis of information extracted from satellite image data. Based on this information, it is clearly noticed that the different land use classes have changed their forms and degrees in different time periods due to the driving forces such as national park activities, influx of Tibetan refugees, climate change and growth of tourism. Furthermore, the landscapes dynamics and their relation to the provisioning of ecosystem services were evaluated on the basis of the "mapping supply and demand of ecosystem services" instrument of ecosystem research. Based on the application of the GIS/RS tools, mapping has been carried out with the information extracted from literature reviews, focus group discussions, interviews and household questionnaire surveys. The relevant indicators of the ecosystem services were identified through focus group discussions. In addition, these indicators were also qualitatively assessed through experts' judgements and local people participations. The information obtained from mapping and expert assessment matrix indicated that the supply of multiple goods and services by nature on the one hand match the demands of society on the other hand, which proved that the system of the Everest is a self-sustaining system in most of the services cases. The land use changes, such as degradation of local forest condition mainly in the on-route trekking site villages from tourists related fuelwood demand and decreases of snow/glacier cover area from climate change phenomenon may put greater challenges in the provisioning of ecosystem services in near future. The challenges issues could be the availability of the fresh water, aesthetic value, soil erosion regulation and continuation of agro-pastoral farming. Despite some of the services deteriorate the environmental conditions, most of the services such as transportation, livestock products, carbon sequestration, crop productions, fuelwood supply etc. seem to develop towards better conditions. The flow of the tourists has had both positive and negative impacts in the region such as promotion of education, employment opportunities and in other hand, environmental degradation. Tourism has created additional demands on the Everest natural resources, some of them through the direct requirements of tourists and some of them through the indirect impacts of changing the Sherpa's traditional livelihood practices as a result of new patterns of lifestyle and tourism wealth. These additional demands have affected local resource and land-use practices. Consequently, this has resulted in a deficit area of

provisioning and regulating ecosystem services in the on-route trekking site villages even though the region is holding surplus quantities. Therefore, the Everest region includes both surplus and deficit areas in the local level for different kinds of services. Nevertheless, basing on the trade of ecosystem services, the deficit areas of the on-route trekking site villages are balanced by surplus areas of the off-route site villages. Furthermore, the promotion of religious values based on the tourism affluent has very much supported in the preservation of most of the ecosystem services through environment friendly religious beliefs and practices. Therefore, cultural services seem one of the main agents in promoting the condition of ecosystem services in the region. Due to the specific cultural values such as respecting natural landscapes as a god living place and worshipping natural landscapes, most of the services remain in a good conditions which makes a difference compared with other Himalayan regions in the ecosystem services context. Through discussing the findings in my analysis of the landscape dynamics I argue that the study region is experiencing influences from climate change. Thus an adaptive management approach is necessary to avoid the uncertainties and risks from ongoing change.

Keywords: ecosystem services, tourism, national park, climate change, mapping supply and demand, Himalayan region, Sherpa, land use and land cover

Zusammenfassung

In dieser Arbeit werden die Einflüsse des Klimawandels und des Tourismus auf die ökologische und sozio-ökonomische Entwicklung des Sagarmatha-Nationalparks in Nepal auf der Grundlage des Ecosystem-Service-Konzepts analysiert. Hierzu wurden Änderungen der Landnutzung und Landbedeckung auf der Grundlage von Satellitenbildern quantifiziert. Aus diesen Informationen kann abgeleitet werden, dass sich die Ausprägungen der verschiedenen Landnutzungsformen in den untersuchten Zeiträumen aufgrund verschiedener Triebkräfte (wie z.B. Nationalparkaktivitäten, Zustrom tibetanischer Flüchtlinge, Klimawandel und Wachstum des Tourismussektors) stark geändert haben. Die Landschaftsdynamiken wurden im Hinblick auf die Bereitstellung von Ökosystemdienstleistungen (Ecosystem Services) in Bezug auf eine Budgetierung von Service-Angebot und -Nachfrage bewertet. Basierend auf der Anwendung von GIS/RS-Werkzeugen wurden Regionalisierungen der gewählten Indikatorgrößen durchgeführt, deren Informationen aus geographischen Datenbasen, Literaturhinweisen, Gruppendiskussionen, Interviews und Haushaltsbefragungen stammen. Die Kartierungen und Budgetierungen zeigen, dass die Bereitstellungen der verschiedenen Ecosystem Services den Bedarf der regionalen Gesellschaft decken können. Hieraus wird gefolgert, dass das das Everest-System bezüglich der nutzbaren Ecosystem Services in den meisten Fällen grundsätzlich als ein autarkes und somit als ein nachhaltiges System eingestuft werden kann.

Landnutzungsänderungen wie die Degradierung des Zustandes der Wälder zur Deckung des Brennholz-Bedarfs in Dörfern, die an touristischen Trekking routen liegen, und die Abnahme der Schnee- und Eisbedeckung aufgrund des Klimawandels werden zukünftig aber wichtige Herausforderungen an die Bereitstellung von Ökosystemleistungen zur Folge haben. Die hiermit verbundenen Problemfelder werden vornehmlich auf der Verfügbarkeit von Süßwasser, auf der Erhaltung des ästhetischen Werts der Landschaft, der Regulierung der zunehmenden Bodenerosion und der langfristigen Fortführung der traditionellen agro-pastoralen Bewirtschaftung liegen. Obwohl einige der Ecosystem Services beeinträchtigt sind, scheinen sich die meisten Leistungen wie Transport, Produktion tierischer Erzeugnisse, Kohlenstoffbindung, Pflanzenbau, oder Brennholzversorgung nach der Installation des Nationalparks in einem besserem Zustand zu befinden.

Der Touristenstrom in die Umgebung des Mount Everest hat sowohl positive als auch negative Einflüsse auf die Region wie z. B. die Bildungsförderung und die Eröffnung von neuen Arbeitsmöglichkeiten, aber es bestehen auch die Risiken einer fortschreitenden Umweltzerstörung. Folglich hat der Tourismus zusätzliche Anforderungen an die natürlichen Ressourcen des Everests gestellt, einige davon aufgrund der direkten Ansprüche der Touristen und ihrer Träger und andere durch die indirekten Einflüsse der sich ändernden Unterhaltspraktiken der Sherpas, die als Folgen von

neuen Lebensweisen und zunehmendem Wohlstand zu betrachten sind. Hierdurch wurden lokale Ressourcen und Landnutzungspraktiken beeinflusst. Dies hat zu einem Defizitgebiet bezüglich der Bereitstellung und Regulierungen von Ecosystem Services in den von Trekking routen betroffenen Dörfern geführt, obwohl die Region insgesamt Service-Überschüsse bereithält. Daher sind in der Everest region Überschuss- und Defizitgebiete bezüglich verschiedener Arten von ökosystemaren Leistungen auf lokaler Ebene zu verzeichnen. Die Defizitgebiete der an den Trekking routen liegenden Dörfer werden aber durch die Überschussgebiete der außerhalb von Trekking routen befindlichen Dörfer ausbalanciert.

Darüber hinaus hat die auf den touristischen Einnahmen basierende Förderung religiöser Werte die Erhaltung der meisten Ecosystem Services durch umweltfreundliche religiöse Glaubensvorstellungen und Praktiken stark unterstützt. Somit kommt den kulturellen Services eine Hauptrolle bei der Überführung des Everests in ein nachhaltiges und anpassungsfähiges System zu. Die Diskussion der Ergebnisse der Analyse der Landschaftsdynamiken kommt u.a. zu dem Schluss, dass die Region zukünftig starken Einflüssen des Klimawandels unterworfen sein wird. Daher ist ein adaptiver Management-Ansatz erforderlich, um die Unsicherheiten und Risiken des zukünftigen Wandels zu minimieren.

1 Introduction

This study concerns an assessment of ecosystem services of the Everest region, Nepal. As a case study, the Everest (Sagarmatha) National Park and Buffer Zone, UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage site is ecological and culturally significant as one of the first national parks to permit human settlement within the park boundary (Stevens, 1997). Furthermore, the region has constantly been changing and evolving since its origin, basically due to tectonic uplift and recently due to global climate change (Byers, 2005) and extensive tourism development (Jefferies, 2004; Nepal, 2003). These circumstances; settlements of the local people, rapid growth of tourism and existing climate change have put challenges in the provisioning of ecosystem services (Spoon, 2008; Byers, 2007). Therefore, the objective of the research is to identify major land use changes and assess the trends of ecosystem services in relation to landscape dynamics. In assessing ecosystem services, the study adopts the MA (Millennium Assessment) topology of ecosystem services and focuses on mapping of ecosystem services in terms of supply and demand based on GIS technology. The method of collecting data was set within the context of broader field surveys. From a practical perspective, this subject is of great interest as a topic for academic research. Despite growing media attention detailing the negative and often alarming environmental and cultural impacts of tourism and existing climate changes to the Park and Buffer Zone, there has never been an assessment of ecosystem services of the region. Thus, while there have been a number of in-depth studies to profile the environmental and cultural impacts, this study is the first comprehensive attempt to assess the potential impacts of land use and land cover changes on the provisioning of ecosystem services.

1.1 Concept of ecosystem services

The modern **concept of ecosystem services** can be comprehended as a viewpoint stemming from the consciousness about the finite nature of natural resources which has been addressed in *Man and Nature* by Marsh (1864). An MIT Study of Critical Environmental Problems (SCEP, 1970), is the first study which had identified a set of environmental services that would decline if ecosystem structures and functions were

damaged. This list of "ecosystem services" was expanded by Holdren and Ehrlich in 1974. In 1977, the study of Westman (1977) termed these services as 'nature's services.' In subsequent publications, these services were referred to as "public services of the global ecosystem" and "nature s services", and were finally termed as "ecosystem services" by Ehrlich and Ehrlich in 1981.

The **evolution of the term** has been worked out by multiple disciplines with ecological and economic lines of reasoning to address several research questions. Such as, how to link ecosystem services and human well-being in complex human-environmental system (Müller et al., 2007; MA, 2005)**,** whether we are underestimating the value of public goods and services derived from ecosystems in decision making (Daily and Farley, 2004), whether the demands for ecosystem services are more than the provisioning capacity of ecosystem from rapid increase in human population (Bennett et al., 2005). These research questions and their results have made the ecosystem service concept not only popular within the scientific communities but also among policy makers and decision makers (Carpenter et al., 2009).

With the initiation of the **Millennium Ecosystem Assessment** (MA), many articles concerning the assessment of the condition of different ecosystems and their capabilities to provide ecosystem services have been came up with different results. MA (2005) documented a decline in over 60 percent of the world's ecosystem services. Based on these numbers, research initiatives on ecosystem services focusing on quantifications, modelling and mapping ecosystem services have been exponentially increasing (Fisher et al., 2009).

The concept of ecosystems services has become an important model for linking the functioning of ecosystems to human well-being in complex human-environmental system. To understand this link, there have been several efforts to come up with a common **classification system** for ecosystem services. However, a systematic typology and meaningful and consistent definition for ecosystem services remains elusive (Fisher et al., 2009; de Groot et al., 2002). Subsequently, a high diversity of ecosystem services definitions in the literature is appearing (de Groot et al., 2002; Kline, 2007; Costanza, 2008).

Three **definitions** commonly cited are:

• the conditions, and processes, and components of the natural environment that provide benefits for sustaining and fulfilling human life (Daily, 1997).

• the benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al., 1997).

• the benefits and values receive by people from the ecosystems (MA, 2005).

However, according to the Boyd and Banzhaf (2007) ecosystem services are not the benefits humans obtain from ecosystems, but rather, the **components** of nature directly enjoyed or consumed to yield human well-being. In their definition, the indirect processes and functions are not ecosystem services rather it is only the means for the production of final ecosystem services.

The broadest interpretations are often used to promote wider understanding and to educate the public about the services and **benefits** deriving from ecosystem to human societies (MA, 2005; Daily, 1997). Other, more specific and narrow definitions are intended not only to explain human environmental system but also to tackle the issue of public goods and services and specific accounting (Costanza et al., 1997; Boyd and Banzhaf, 2007). The importance of each definition varies on studying supply- and/or demand-side issues, recognition of market and non-market values, consideration of temporal and spatial scales. Therefore, the decision of how to define a given ecosystem service is always problem based and place depended. Nevertheless without a common and clear definition, challenges appear in the ecosystem services study to decide how, which, where and for whom they are evaluated, within a broad spectrum of interlinking multi-dynamic possibilities.

1.1.1 Ecosystem service classifications

Ecosystems provide several **services** that contribute to human survival. It is helpful to classify them, as done by e.g., de Groot et al. (2002) and MA (2005). This is because many services overlap. The number of papers addressing ecosystem services has been rising exponentially in the past few decades. However, there is a need of more efforts to bring a common typology for ecosystem services.

Most of the studies carried out on ecosystem services have evaluated some selected ecosystem services on selected scales (Goldman et al., 2007; Naidoo et al., 2008). The

lists of more than 15 important ecosystem services for human well-being have provided in different studies (Costanza et al., 1997; de Groot et al., 2002; de Groot, 2006). The MA has interlinked ecosystem services and human well-beings and offered a typology of ecosystem services by classifying them into four **functional groups** (see figure 1). These four functional groups are: provisioning services, regulating services, cultural services and supporting services.

Provisioning services are products obtained from ecosystems (e.g., food, fresh water); regulating services are **benefits** obtained from the regulation of ecosystem processes (e.g., climate regulation, disease regulation); cultural services are nonmaterial benefits obtained from ecosystem (e.g., aesthetic values, recreation) and supporting services are those that are essential for the production of all other ecosystem services (e.g., nutrient cycling, biomass production) (MA, 2003). Within these functional groups, the respective services are always place dependent. This means every place has its own kind of services that could be similar to other places. They could however be entirely different as well. Therefore, the different studies have provided different types of services with respect to the MA functional groups.

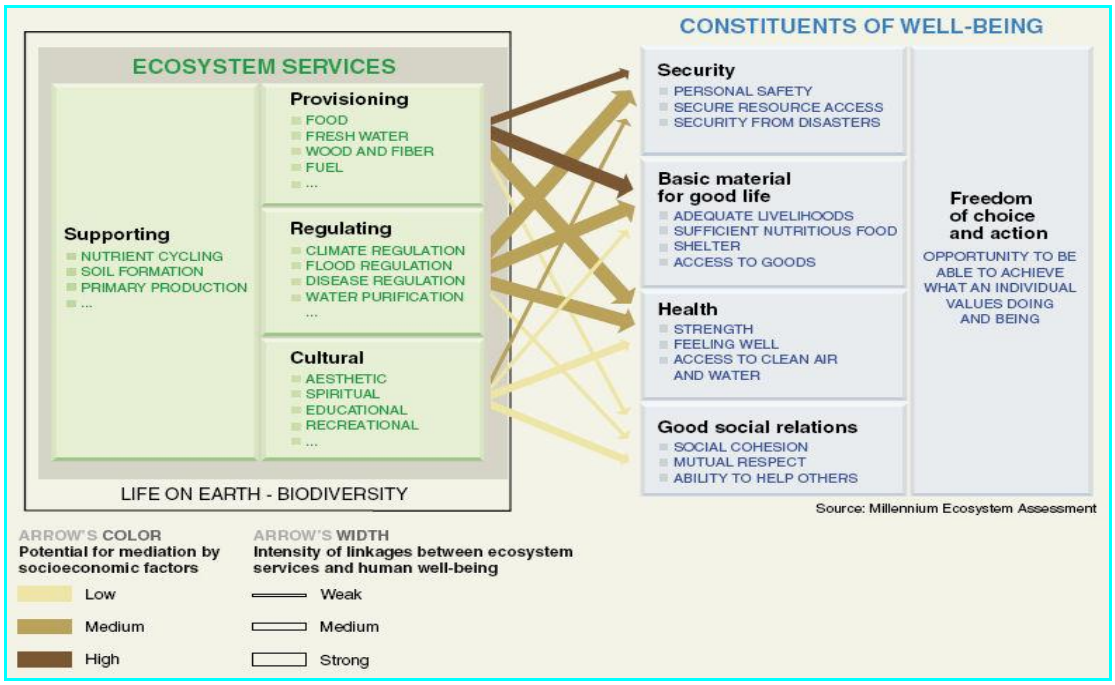

Figure 1: Cascade of ecosystem services (Source: Millennium Ecosystem Assessment).

The MA typology has been used for many studies concerning ecosystem services (TEEB, 2008; Burkhard et al., 2009). There are however, some suggestions to include and to connect ecosystem structure, functions and services (Turner and Daily, 2008; Müller and Burkhard, 2007; Wallace, 2007). Ecosystem structures were considered by Turner and Daily (2008) as ecosystem services to the extent it supports and provides benefits for human well-being. However, Wallace (2007) had proposed a similar classification of ecosystem services describing them in terms of the structure and composition of particular ecosystem elements. He emphasised these services to be based on the specific human values they support. Müller and Burkhard (2007) also proposed to take into account **ecosystem integrity** in place of supporting services based on the similarity in the definitions of ecosystem integrity and supporting services. Furthermore, Müller and Burkhard had put the concept of "ecological integrity as a prerequisite for providing ecosystem goods and services to humans". Similarly, a study of Burkhard et al. (2009) mentions the ecological ability for self-organisation of ecosystems which is mainly based on variables of energy and budgets and structural features of whole systems. These components are similar to those referred to as, supporting services in other ecosystem services studies.

Even though the MA has provided a framework for ecosystem services studies, there are difficulties in the evaluation of overall ecosystem services in a region. Some of these **challenges** can be listed as follows:

- double-counting among various ecosystem services;
- similar to double-counting, ecosystem services can be distinguished into the final products or the intermediate products within the ecosystem services flow chain;
- scales in relation to ecosystem services analysis;
- an aggregated Ecosystem Services Index for summing up of different units and values of ecosystem services in a single value ;
- proper evaluation and aggregation of multi-dynamic ecosystem services;
- interlinkages between the ecosystem services concept and human well-being, i.e. how to relate ecosystem dynamics to social dynamics and vice versa.

Various researchers have already worked on some other challenges. For example, in order to avoid double counting, the MA decided not to account for supporting services in

economic evaluation. Considering the intermediate and final services within the flow of ecosystem services, Boyd and Banzhaf, (2007) proposed only final services to be included in evaluations. It is attempted to capture the generation and consumption of ecosystem services based on spatial variation by introducing the concept of payment for ecosystem services (Engle, 2008; Wunder et al., 2008). In the economic evaluation of ecosystem services it was attempted to use a single monetary unit for the evaluation (Costanza et al., 1997). Till date, a lot of conceptual and theoretical work has been done to make ecosystem services **quantifiable** in a consistent manner. However, there is still enough room for improvement in this field.

1.1.2 Evaluation of ecosystem services

The valuation of ecosystem services depends on a good understanding of the relation between functions and services, but it is very difficult to predict it and to show how the provision of services will change due to human activities. This lack of information can be tackled through different instruments of ecosystem service valuation.

There are two approaches commonly used. The first deals with the economic evaluation of ecosystem services (Costanza et al., 1997; Fisher et al., 2008; de Groot, 2006; Farber, 2002; Daily et al., 2000) while the second focuses on a quantitative or qualitative physical evaluation of ecosystem services (MA, 2005; Burkhard et al., 2009; Müller and Burkhard, 2007; Boyd and Banzhaf, 2007; Egoh et al., 2007). Furthermore, with respect to the evaluation of ecosystem services there are two different conceptual foundations: the **ecological valuation** methods which neglect human needs and understand the perceived ecosystem goods and services as outputs produced by nature, independently of their relationship to humankind. On the other hand, the **economic valuation** methods emphasize consumer preferences but fail in capturing public goods values. Having such characteristics of the economic and ecological approaches the challenges remain, how to construct a valuation method that can be used to guide human behaviour towards a sustainable use of natural resources via a balanced approach (Winkler, 2006).

It has been convincingly notified that it is important to develop new methods and indicators for the assessment of ecosystem services. In order to improve the assessment outcomes, different studies related to **environmental accounting** focus on carbon

footprints, ecological footprints and green GDP (e.g., Wackernagel and Galli, 2007; Wiedmann, 2009). Nevertheless along good sides there are ranging concerns of difficulties in accounting all the services due to the absence of data in many regional and local cases. To overcome assessment problems, the mapping of ecosystem services based on land use and land cover information has been emerging (Troy and Wilson, 2006; Eigenbrod et al., 2010).

1.1.3 Mapping of ecosystem services

Most of the studies carried out on ecosystem services mapping have based on proxy-based maps (e.g. Costanza et al., 1997; Sutton and Costanza, 2002; Chan et al., 2006; Troy and Wilson, 2006). Furthermore, the **benefit transfer approach** is frequently adapted in the ecosystem service mapping approaches (Lautenbach, 2010). The value-transfer methodology needs both source and target area similar in the biophysical and socioeconomic contexts. Due to this features this approach is not applicable to all places (e.g. Hu et al., 2008; Kreuter et al., 2001; Li et al., 2007). Consequently, other techniques different from very simple benefit transfer approaches to map ecosystem services based on land use and land cover data have emerged, considering that the supply of the ecosystem services is based on their spatial context (Schröder and Seppelt, 2006) and also, demand of some of the services is based on spatial contexts (Lautenbach, 2010).

Pederson et al. (2006) and Lautenbach (2010) emphasize the consideration of both spatial configuration and spatial composition of land use for ecosystem service assessments. Similarly, Top et al. (2006) examined the relationship between **supply and demand** for fuelwood at three different spatial scales within Kampong Thom Province in Cambodia. The results revealed large differences in the estimation of fuelwood in terms of supply and demand from a spatial viewpoint. Similarly, Masera et al. (2003) developed the fuelwood integrated supply/demand overview mapping (WISDOM). WISDOM is a spatial-explicit planning tool for highlighting and determining fuelwood hot spots. Using the WISDOM approach, Ghilardi et al. (2007) studied fuelwood demand and supply patterns which are rather complex and very site-specific. In addition, his result reflects shortages that adversely affect fuelwood users and also impacts negatively on the environment. These impacts however, vary from one place to the other. He further

explained that regions with overall shortages may still have some areas with some surpluses. Similarly, areas with overall surplus may also have some areas with fuelwood scarcity. There are also several studies carried out on ecosystem services mapping based on combined spatial data sets to illustrate a range of obtained services by human society (e.g., Haines-Young et al., 2006; Gimona and Van der Horst, 2007; Egoh et al., 2008; Meyer and Grabaum, 2008).

It has been convincingly proved from different studies; ecosystem services are interlinked and interrelated with each other in different scales. Furthermore, the value of ecosystem services in terms of supply and demand differs among the spatially distributed stakeholders (Hein et al., 2006). Nevertheless **supply and demand** concepts of cultural ecosystem services were already highlighted in Saunders (1981). This study has raised concern regarding supply and demand issues of the recreational sites. But the concepts of supply and demand in the assessment of ecosystem services were not taken into account before. Whereas recently, mapping supply and demand of ecosystem services is taking place very intensively in order to snap the over-view if either the system is self-sustaining, having less demand than supply or if the system is experiencing ecological degradation, having higher demand than supplying capacities (Burkhard and Kroll, 2010).

A study of Burkhard and Kroll (2010) revealed that if the demand and supply is quantified for a specific region in biophysical units, they are directly comparable enabling the assessment of the region's sustainability. Therefore, mapping supply and demand is an appropriate instrument to illustrate spatial phenomena, distributions and their interrelations, supporting communications to the policy makers (Burkhard and Kroll 2010; de Groot et al., 2010).

Based on this approach of "mapping supply and demand", using quantitative and qualitative assessment data in combination with land cover and land use information originated from remote sensing and GIS data, the **quantification** of ecosystem services of the study site, "Everest region of Nepal" was carried out.

1.2 The Himalayas

Himalayan environments are highly fragile and inhabitants are prone to interlinked **environmental and non-environmental stressors** which can have adverse consequences

on their livelihoods (Sharma and Xu, 2007). These stressors include processes of socioeconomic development, globalization and rapid growing populations which impose pressures on available ecosystem services to fulfil the local needs. In addition, climate change acts as stressor which can even multiply existing effects on ecosystem services (Sharma and Xu, 2007). This may limit local people who have primarily relied on crop farming and other agricultural activities, such as horticulture and animal husbandry as well as tourism in their long term adaptation capacity.

Regarding these issues, there is currently a growing body of scientific literature addressing **environmental changes** in many places of the Himalayan region, caused by climate change and tourism impact (Harmon et al., 2004; Bajracharya et al., 2009; Nepal, 2003). However, these changes are not matched by a corresponding high level of applied research concerning land use and land cover change impacts on ecosystem services (Schnedier et al., 2007; Greenwood, 2008).

Land use and land cover change are important forms of environmental change taking place in the mountain regions (Körner et al., 2005). Recently, a study by Chaudhary et al. (2007) highlights the present landscape dynamics in the Himalayas. These ongoing transformations affect the provisioning of ecosystem services, which in turn, affects human well-being (Vejre et al., 2007). Among the services that could be highly affected are biodiversity, water provision, food production and carbon sequestration (Chan et al., 2006). Looking at the Himalayan region, so far only little information is available regarding the impacts of land use and land cover changes on the potential of ecosystem services.

Up to now, only few studies have been carried out based on the **ecosystem service approach** in the region such as the study of Sharma and Xu (2007) focusing on the ecosystem services generated from traditional agro-forestry. This study reveals the large cardamom based agroforestry system in the eastern Himalayan region accelerating nutrient cycling, increasing soil fertility and productivity, reducing soil erosion, conserving biodiversity as well as serving as carbon sinks. In clear language the results of the Sharma study have revealed that the agro-forestry system has enhanced the ecological integrity of the surroundings. A similar study by Chandra et al. (2010) reflects the replacement of traditional crops and multipurpose agro-forestry trees by cash crops (high

yields), showing a loss of soil fertility and soil degradation as well as directly influencing the forest ecosystem services and other resources in the central Himalayan villages in India. Similarly, Rasual (2009) found that the value of soil nutrient depletion is 27 times higher in annual cash crops farms than in horticulture in the hills of Tripura and Arakan Yoma villages, Bangladesh. Moreover, the study of Singh (2007) revealed that the forest carbon pool in Indian Himalaya is about 5.4 billion t (forest biomass + forest soil), which is about equal to the annual carbon emission from fossil fuels in Asia. In addition, Singh found 4.0-5.6 t C/ ha*yr and 2.52-3.53 t C/ ha*yr carbon sequestered in undisturbed and disturbed forests respectively in the Uttarakhand Himalayas. Furthermore, the study of Sharma and Xu (2007) reported from the Mountain Mainland of Asia that many ecosystem services, especially nutrient and soil erosion regulations are highly affected by the growing population converting subsistence farming into commercial agriculture.

Similarly, there are some other studies which are not totally based on the ecosystem service approach but also report **trends of ecosystem services** of the Himalayan region. For instance Sharma et al. (2002), Sharma (2003) has found out that climate change has triggered increased emissions of green house gases from many high wetlands that have impacts on the carbon sequestration potential. Similarly, Sharma et al. (2009) point out the importance of the Himalayas high wetlands as agents of nutrient cycling. In addition, the study of Smith et al. (1996) reported that grassland productivity is expected to decline by as much as 40 to 90 percent with an increase in temperature of 2 to 3 degree centigrade combined with reduced precipitation. Furthermore, Lal (2005) has shown that the net cereal production in the Himalayan region is projected to decline by at least 4 to 10 percent by the end of this century. Similarly, Alam and Tshering (2004) pointed out arising food insecurity in the Himalayan region of Bhutan.

There are also other studies which reflect various **environmental problems** in the Himalaya region. These problems include; the natural resource depletion (e.g., Palni et al., 1998; Tiwari, 1995; Toky, 1983; Rao, 1997), malnutrition (Kuniyal, 2003), fragmentation of agriculture land (e.g., Fürer-Haimendorf, 1984; Bjonness, 1983; Sherpa, 2007), a decline in crop yields (e.g., Bjonness, 1983; Fisher, 1990; Fürer-Haimendorf, 1984), fuelwood shortage and deforestation (e.g., Kumara and Sharma, 2009; Sherpa, 1979; Ives, 1989), soil erosion, trail erosion and flooding (e.g., Byers, 2005; Nepal, 2003;

Tiwari, 1997; Reiger, 1983), disruption of hydrological cycles of river basins (e.g., Singh, 1981; Valdiya, 1985), salinization, siltation of rivers and reservoirs (Shastri, 1999; Reiger, 1983), degradation of rangeland (Paudel and Andersen, 2010), climate change induced impacts: glaciers retreation, decreased snow cover area and glacier lake increase (e.g., Byers, 2007; World Wildlife Fund-Nepal, 2005, 2009; Philip and Shah, 2004; Bajaracharya and Shrestha, 2007; Yamada, 1992).

These problems reflect that there is a high **demand** of food, fuelwood, fodder and grazing land due to the rapid increase of the growing population accelerated by globalization processes during the recent years (Moseley, 2006; Xu et al., 2006). The resulting growing demand is placing more stress on the critical environmental components, like land, water and forests. Consequently, the Himalayan region is losing many types of ecosystem services (Shrestha et al., 1999; Liu and Chen, 2000; New et al., 2002; Sharma and Xu, 2007).

Along with these challenges, the **Himalayan ecosystems** are playing an important role not only for the people of this region, but also for a significant proportion of the global population. For example; supply of fresh water to the downstream people. This region's forests are playing a vital role in regulating river flow, carbon sequestration and reducing soil erosion loss. Similarly, the agro-ecosystems of this region have been providing food security to mankind. The Himalayan environment delivers not only services related to the production based on the land (e.g., food, livestock products and fuelwood) but also provides services such as aesthetic beauty, cultural heritage and tourism (Stevens, 1993; Beza, 2010), waste assimilation and preservation of biodiversity (Chan et al., 2006; Sharma and Xu, 2007 and Sharma et al., 2009).

Basing on the critical environmental situation described above, I have chosen to study one of the popular Himalayan site **"The Everest National Park and Buffer Zone"**. This region is experiencing both human and climate change induced impacts like other parts of the Himalayas (Byers, 2005, 2007; Stevens, 1993, 2003; Sherpa, 1979, 2009). This study broadly considers that there is a change in the trends of ecosystem services both in supply and demand context in different time periods. Therefore, it is crucial to have an assessment of the Everest landscape dynamics in relation to ecosystem services to get a clear picture which services are in danger of degradation, and which areas are having

deficit and surplus of specific services. The obtained results from the Everest region could be one good example for representing other parts of the Himalayan region.

Moreover, the following **research objectives** will be addressed from the assessment of the Everest ecosystem services:

- Identification of important land cover changes from human and climate change induced impacts;
- Quantification and evaluation of selected provisioning services;
- Quantification and evaluation of selected regulating services;
- Quantification and evaluation of selected cultural services;
- Provision of recommendations to foster regional sustainability.

1.3 Structure of the thesis

This thesis contains six chapters: Chapter 1, the introduction, provides an overview of the concept, definition and classification of ecosystem services. In addition, it gives an overview of assessment instruments for ecosystem services. Furthermore, an outlook of the major environmental problems of the Himalayan region and their impacts on ecosystem services is provided.

Chapter 2, the description of the study area, focuses on facts and figures of the study site. The biophysical, socio-economic and cultural aspects of the study site are incorporated in detail. In addition, the tourism development relations to livelihood strategies, religions and cultures are presented. Moreover, the local people's experiences and their perceptions regarding global warming are described. Furthermore, land use and land cover changes in relation to climate change induced impacts combined with an advent of tourism development are also discussed.

Chapter 3, the materials and methods, describes procedures of using satellite image data to detect the range of land use and land cover changes. Furthermore, it describes the use of mapping instruments to overview the trends of ecosystem services both on spatial and temporal scales. In addition, it describes procedures of finding relevant indicators of ecosystem services through focus group discussions. Moreover, it describes the

qualitative and quantitative data gathering techniques; interviews, household questionnaire surveys and experts surveys.

Chapter 4, the results, presents the change in land use and land cover. In addition, it presents the change of different aspects such as settlement patterns, local people income, religion and culture, and compositions of livestock. Furthermore, the observed trends of the supply and demand of ecosystem services in relation to landscapes dynamics are presented.

Chapter 5, the discussion, discusses the observed results. The land use and land cover changes and its drivers are discussed. Moreover, the roles of tourism in the provision of ecosystem services are discussed. In addition, it discusses the challenges and importance of land cover types in relation to the provision of ecosystem services of the study site.

The Chapter 6, the conclusion, summarizes the dynamics of landscapes in relation to ecosystem services. Furthermore, it discusses whether the system is self-sustaining or degrading. Moreover, it provides the list of degradations and enhancements of ecosystem services. In addition, it provides answers in what limit and extent ecosystem services have been changed from ongoing landscape changes based on the climate change induced impacts combined with an advent of tourism development. And finally, it provides recommendations for the sustainable development of the region.

2 Study region

This chapter gives an overview of the study site, the Everest (Sagarmatha) National Park and Buffer Zone. It also gives an outlook of the development of tourism in the study area and its impact. In addition, it provides an overview of main drivers of land use and land cover changes in the Sagarmatha National Park and Buffer Zone: National Park management, influx of Tibetan refugees and climate change.

2.1 Nepal

Nepal is an independent country. It is located between 26°22' and 30°27' north latitude and 80°4' and 80°12' east longitude. The total land area is 147181 square kilometres, and India lies in the west, south and east of its border and China to the north.

The high mountains and hills dominated the major part of the country. It accounts for about 83% of the total land while the remaining 17% area occupies by the Terai region. The altitude varies from 152 meters above sea level in the Terai region in the south to 8848 meters in the north Himalayas. This county comprises the **high Himalayas**, with altitudes above 3000m a.s.l., 27% of the territory with 5% of the area above 5000m. The general information about the Nepal is presented in table 1.

Table 1: General information about Nepal (Source: Central Bureau of Statistics-Nepal)

Population (2009)	GDP growth rate (2009/10)	Per capita GDP in US $ (2009/10)	Literacy rate (2001-02)	Average life expectancy (2006-07)	Human Development Index (2006-07)	Population density (2007)
29331000	3.53	562	54.1%	63.7 years	0.534	199.3/km^2

2.1.1 Himalayas of Nepal

The **Himalayas** which is the youngest and highest mountain system in the world, covers an area of 2400-kilometer. Nepal is its centre piece. Fully a third of 800 km^2 of its central section traverses Nepal and is known as the Nepal Himalayas. This part of the Himalaya consists of more than 250 peaks that exceed 6000m in height. Out of the fourteen world's highest mountains, eight are placed in the Nepal Himalayas.

2.1.2 People of Nepal

Nepal is country of mixed races**,** religions and languages. It has twenty-one ethnic groups with more than 90 different languages and dialects. The settlement provides various environmental conditions from very low nearly to the sea level up to 4800 meters of the Sagarmatha (Everest) National Park and Buffer Zone. The most known among the high mountain people are the **"Sherpa"**. They live in the high settlements of the Sagarmatha National Park and Buffer Zone. This national park was listed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a World Heritage Site in the year 1979 due to its outstanding aesthetic and scientific values (Sherpa, 2007).

2.1.3 Protected areas of Nepal

Nepal has been highly successful in establishing a network of protected areas as a means of protecting **biodiversity**. More than 18% of the country's surface area is under protected area authority. Although the country covers an area of just 147181 km², it nevertheless attributes over 2% of the world's flowering plants, about 8% of the world's bird species and over 4% of the world's mammal species. With such a huge globally significant species, Nepal is undoubtedly a biological and cultural hotspot that deserves special attention.

2.2 Everest (Sagarmatha) National Park and Buffer Zone

2.2.1 Physical aspects

Location

The Sagarmatha (Everest) National Park and Buffer Zone is located in northeast Nepal about 140 km east of Kathmandu at 27º45 -28º07 N and 86º28 -87º 07 E. Its borders are contiguous with the Makalu-Barun National Park in the east, the Rolwaling Valley of the Dolakha district in the west, and the Qomolangma Nature Reserve of China in the north. The Park is placed at the base of the world s highest peak- Sagarmatha/Mt. Everest. The Park and Buffer Zone includes three **Village Development Committee Areas**- Namche, Khumjung and Chaurikharka (see figure 2). The Nepal government designated the 1148

km² Khumbu area as a national park in 1976. Similarly, the 275 km² area of Chaurikharka VDC was added as a buffer zone in 2002.

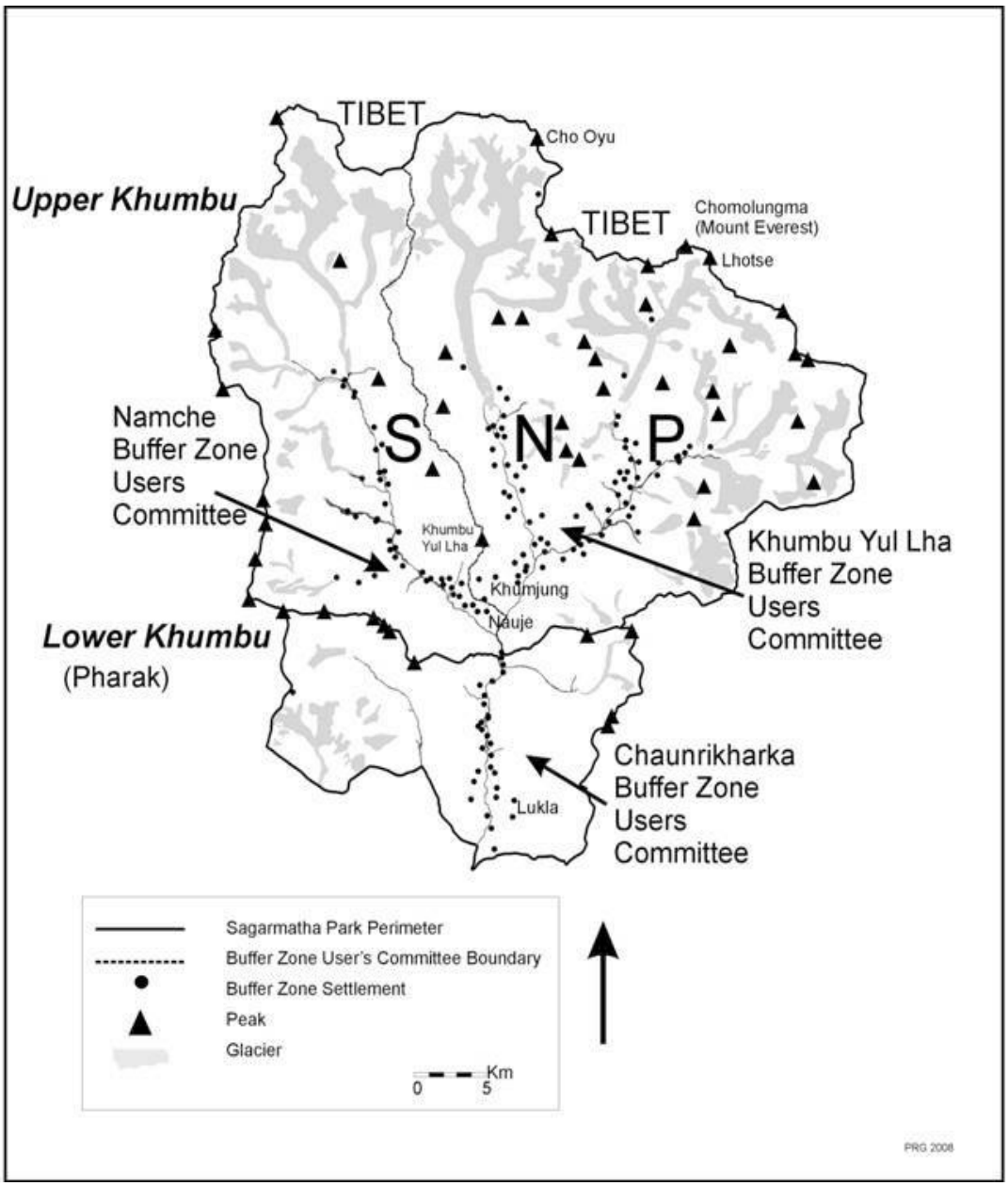

Figure 2: Everest (Sagarmatha) National Park and Buffer Zone (Source: Stevens, 2008).

The **Buffer Zone Users Committee** is formed among the local people living in the villages of the buffer zone to carry out local community development works and management of natural resources with the support of the national park.

Topography, slopes and drainage

The elevation of the Sagarmatha National Park and Buffer Zone ranges from 2300m at Surke to 8848m at the top of Everest within a distance of less than 50 km. There is no other place in the world where the altitude of the land increases so strongly (Sherpa and Bajracharya, 2009). The land in the park is mainly dominated by higher degrees of sloping areas. It accounts for about 23% of the **land slopes** (less than 15 degrees). These sloping areas at lower elevations (below 4000m), are mostly occupied by settlements and cultivated fields. Similarly, 38% of the area has slopes ranging from 16 to 35 degrees. These slopes offer best pastures for wildlife and domestic livestock. Another 38% of the Sagarmatha National Park and Buffer Zone possess slopes ranging from 36 to 60 degrees. These areas are not suitable for agriculture production. Limited grazing by yaks and naks could be seen. These areas however provide suitable habitats for wildlife because they are less disturbed by livestock and human interferences. Only about 2% of the land areas with slopes steeper than 60 degrees are placed in the park (Sherpa and Bajracharya, 2009).

The terrain is steep and uneven and broken by deep **river** canyons below and wide floored consisting large glaciers and glacier valleys at the upper reaches. Some of these valley glaciers are more than ten kilometres in length and nearly 32 kilometres long. The Ngozumpa Glacier, one of the longest in Nepal, is also placed in this research area (Stevens, 1993). From these high sources the rivers flow among herbaceous vegetation and shrub land and follows needle leaved, multilayer mixed and broad leaved forests of the region. The Park is drained north to south by Imja Khola and Nangpa Khola. The Khumbu, Ngozumpa, and Imja glaciers are the main sources of the Imja Khola. Similarly, the Nangpa and Chhule glaciers feed the Nangpa Khola (Sherpa, 2007). The glaciers, glacial lakes and river system of the Sagarmatha National Park and Buffer Zone are presented in figure 3.

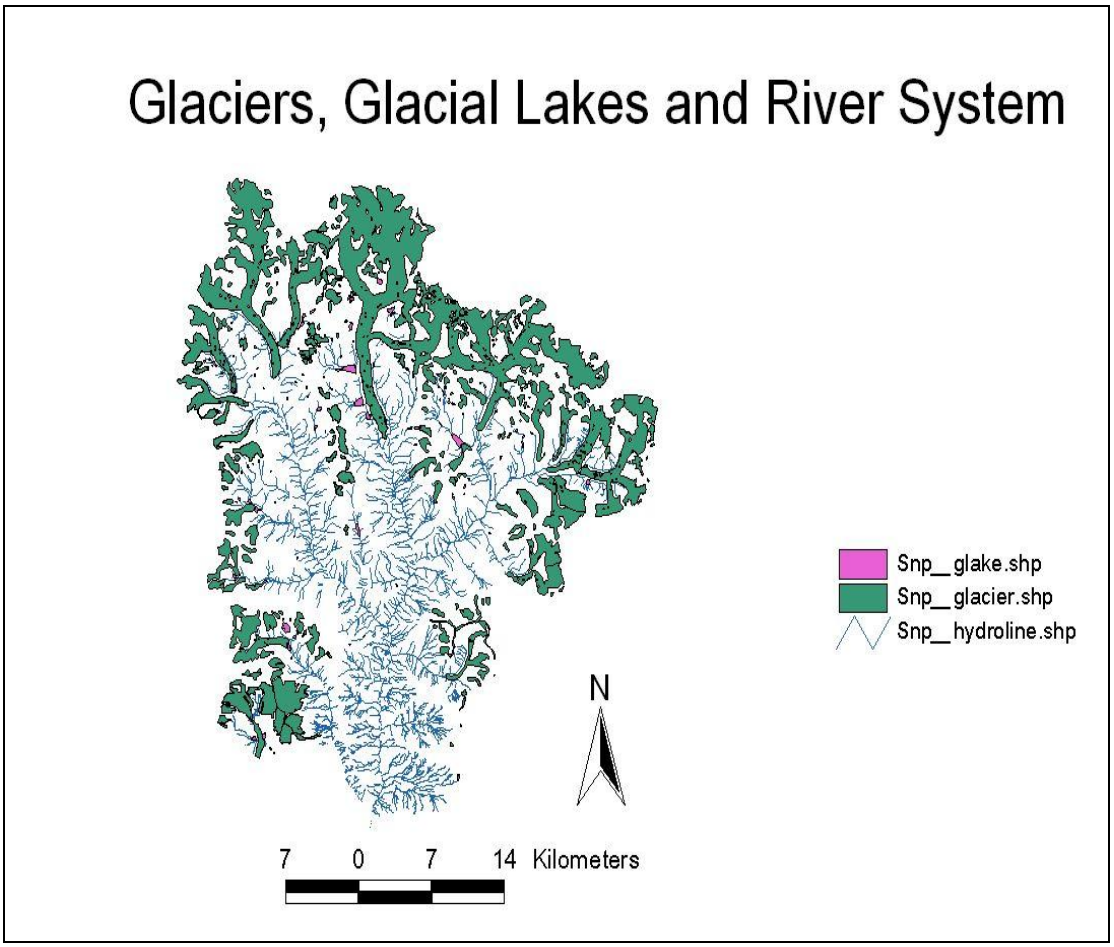

Figure 3: Glaciers, glacial lakes and river system in the Sagarmatha National Park (SNP) and Buffer Zone. Basemap adapted from International Centre for Integrated Mountain Development-Nepal, Sagarmatha National Park and Buffer Zone Land Cover Map. (shp: are the shape files of the land cover map).

Geology and soils

The Sagarmatha National Park and Buffer Zone is characterized by high, **geologically** young mountains and glaciers. It consists of outstanding features such as peaks higher than 8000m; Everest (8848m), Lhotse (8501m) and Cho Oyu (8188m). These mountain peaks have been uplifted as a result of the collision of the Eurasian and Indian continental plates about 120 million years ago. Research has shown that this uplift is still continuing but at a slower rate. Natural erosion processes are however counteracting this uplift to an unknown degree (Bajracharya et al., 2009).

Soils are mostly of glacial, fluvio-glacial and fluvial origin. Their development is highly dependent on climate and elevation factors. Between 2000m and 3000m, inceptisols are found. Similarly, spodosol found on coniferous and birch-rhododendron forests at around 3000m elevation. Likewise, entisols with limited profile development are common at above 4500m (Sherpa and Bajracharya, 2009).

Climate

The **climate** of this area can be described as generally moist and cool in summer while in winter it is cold and dry. The climate in the Park ranges from temperate to artic conditions (Brower, 1991). The mean daily temperature recorded in the Namche Bazzar is -4ºC in January and +12ºC in July. Precipitation is highly seasonal with higher intensities between June and September (see figure 4), and varies regionally depending on the local topographic conditions (Garatt, 1981). Precipitation generally decreases with elevation: 1076mm in Namche (3440m) and 518mm in Lhajung (4420m) (Nepal, 2003).

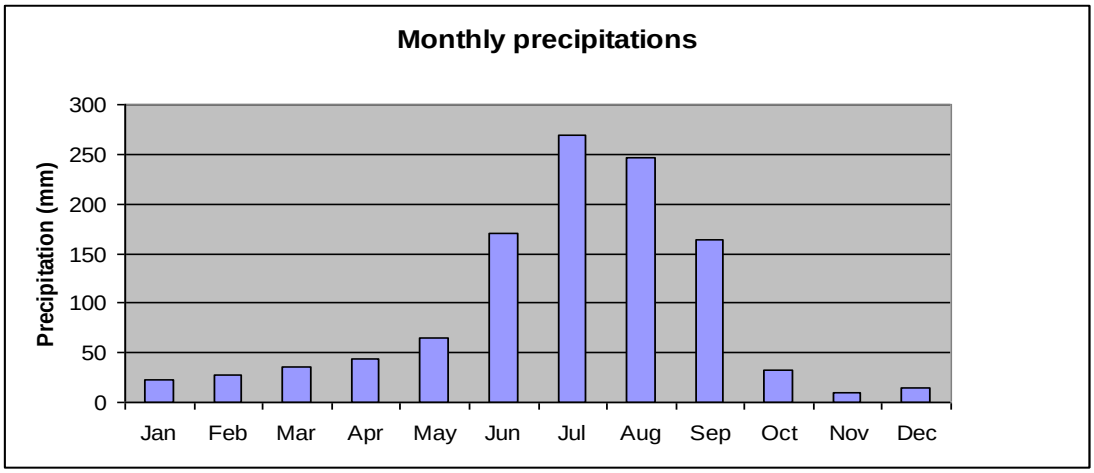

Figure 4: Monthly precipitations of the year 2009 in the Sagarmatha National Park and Buffer Zone (Data source: Department of Hydrology and Meteorology/Government of Nepal).

2.2.2 Ecological zones

The landscape roughly can be distinguished into five ecological zones based on **altitude**. These include Nival, Alpine, Sub-Alpine, Cool-Temperate and Warm-Temperate bioclimatic zones. The ecological map of the region is presented in figure 5.

Nival zone (≥ 5,000m)

Approximately, 58% of the total area lies within the Nival zone located above 5000m elevation. This area consists of bare soil, rocks, snow and ice and has very little **vegetation** cover. Plants such as *Rhododendron nivale, Androsace, Primula, Delphinium, Rodiola, Poa* and *Festucca* grasses could be found in this zone. Wildlife such as the Himalayan snow cock, snow partridge, snow leopard and gray wolf visit these areas seasonally.

Alpine zone (4000-5000m)

The Alpine zone is one of the harshest environments located between 4000 to 5000m. The **vegetation** such as *Rhodoendron anthopogon, Rhododendron setosum, Juniperus wallichiana, Salix calyculata* and *Cassiope fastigiata* are found in this zone. Tree growth is limited in this zone due to low temperatures and less precipitation. Xeric species such as *Cotoneaster, Juniperus, Poa, Festucca, Mayricaria, and Arenaria and Saussureas* are also available in this zone.

Sub-Alpine zone (3000-4000m)

The Sub-Alpine zone is located between 3000 to 4000m elevations. This zone covers an area of about 9% of the total area. This zone consists of **forests** of *Abies, Pinus, Juniperus, Betula, Rhododendron campanulatum*, and *Rhododendron campylocarpum*. It is one of the most disturbed landscapes due to grazing by livestock and the cultivation of crops such as potatoes and buckwheat (Sherpa and Bajracharya, 2009). Due to the conditions in this zone, **Wildlife** such as Himalayan tahr, musk deer, snow leopard, red fox, and yellow-throated marten visit these areas on a regular basis. Some bird species such as danphe, kaliz pheasant and blood pheasant are also found in this zone.

Cool-Temperate zone (2000-3000m)

The Cool-Temperate zone is very conducive for forest growth. This zone covers an area of about 3% of the total area. There is also a **high diversity** of flora and fauna due to the warm and moist climatic conditions. Tree species such as *Tsuga, Pinus, Quercus*, and *Rhododendron arborium* are found in this zone. Wildlife such as Himalayan black bear, red panda, barking deer, Himalayan palm civet, jackal, yellow-throated marten, squirrel and bat are commonly seen in this area.

Warm-Temperate zone (2000m)

The Warm-Temperate zone covers a small area near to the lower gorge of the Dudh Koshi below Chaurikharka. The **vegetation and wildlife** found in this area are similar to those of the Cool-Temperate zone. The most significant difference is that the zone rarely receives snow.

Flora and fauna diversity

The Sagarmatha National Park and its Buffer Zone have a high diversity of **flora and fauna.** Different plants and animal species are supported due to the diverse habitat conditions ranging from temperate to Nival zones. Out of 865 species of plants recorded, sixty-two species are globally significant and seventy-six of the total recorded plants species have economic value in terms of medicinal purposes (Sherpa, 2007).

The region consists of very low number of mammalian species due to the geologically young Himalayan areas and extreme climatic conditions. The main **mammals** of the park and buffer zone are *Hemitragus jemlahicus, Moschus chrysogaster, Selenarctos thibetanus, Ailurus fulgens, Uncia uncia* and *Canis lupus*. Many of these mammals are listed as endangered species (see table 2). In addition 8 species of reptiles, 7 species of amphibians and 30 species of butterflies are found in this area. 14 bird species of global significance find their habitat in this area (Basnet, 1993).

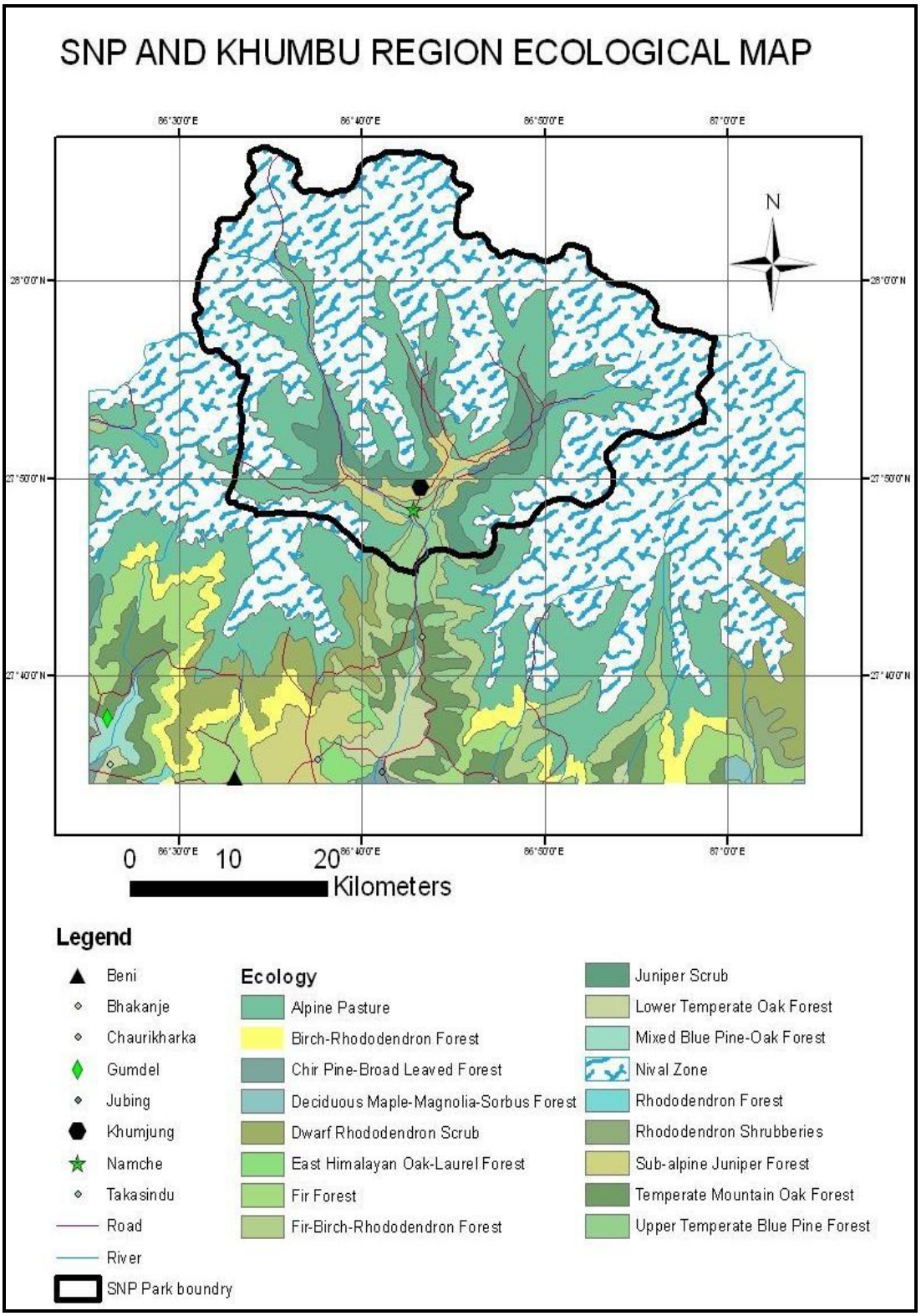

Figure 5: Ecological map of the Sagarmatha National Park (SNP) and the Khumbu region (Source: http://icimod.org).

Table 2: Some endangered, vulnerable and rare species of Sagarmatha National Park and Buffer Zone based on IUCN Code (Source: Sherpa, 2007)

Floral Species	**Status Code**
Picrorhiza scrphulariflora	Vulnerable
Nardostachys grandiflora	Vulnerable
Rauwolfia serpentine	Endangered
Aconitum hetrophyllum	Rare
Swertia chirayita	Vulnerable
Michelia spp.	Endangered
Fauna – Mammals	
Moschus chrysogaster	Endangered
Ailurus fulgens	Endangered
Uncia uncia	Endangered
Selenarctos thibetanus	Vulnerable
Bos grunniens	Vulnerable
Hemitragus jemlahicus	Vulnerable
Fauna – Bird	
Tragopan satyra	Endangered

2.2.3 Socio-cultural aspects

Ethnicity and demography

Due to the anthropogenic influences over centuries, the original landscape of the Sagarmatha National Park and Buffer Zone has been altered. A study by Byers (1987b) revealed that the area within the Park could have been inhabited by **Sherpas** as far as 1500 years ago based on the pollen analysis. There are however different opinions regarding the arrival of Sherpas in the area. A study of Sherpa (2001) reported the Sherpa people arrived in the late 1400s or early 1500s, from the eastern Tibetan province of Salmo Gang. Stevens (1993) also reported that they came some 1533 onward from Tibet. Furthermore, originally, Sherpas were nomads. They engaged in transhumance migration at that period. However, after the introduction of the potato in 1850 they began to settle

permanently around Thame Og, Thema Teng, and Yulajung villages (Hardie, 1974 cited in Nepal, 2003). They later on moved to other permanent sites at Pangboche, Phortse, Khumjung, Kunde, Namche Bazzar and Pharak areas (Rogers, 1997).

Sherpas are the main ethnic group and constitute 90% out of the total resident population. The remaining 10% are Tamang, Kami, Rai, Magar, Dami, Chhetri, Gurung and Newars ethnic groups. These groups recently migrated to the area to work in the tourism sector.

Populations and settlements

The total **population** of the Park in the year 1982 was reported to be 2524 (Pawson et al., 1984). The number has however increased to 2688 in 1991 and 3064 in 1997 (Government of Nepal, 1991, 1997). As off 2002 there were permanent residents of 5876 with an average household size of 4.3 persons (World Wildlife Fund-Nepal, 2003). There is a limited use of land for **settlements** within the Sagarmatha National Park and Buffer Zone. Settlements occupy less than 10% of the land of the total area (Sherpa, 2007). Most of the settlements are located below 4000m elevation on sloping areas which is less than 15 degrees. The main settlements are Namche Bazzar, Khumjung, Kunde, Phortse, Pangboche, Thamicho, Pheriche and Dingboche (see figure 6). Besides the main settlements there are also 60 other additional herding villages (Stevens, 1993). However, some of them have transformed to tourist villages.

Traditionally, the livestock herding were carried out during summer in the higher elevation summer **settlements** (Yarsa) and those located at lower elevations below 3700m were used as wintering settlements (Gunsa) for livestock herding in winter and agriculture in summer. However, after the introduction and rise of mountaineering and trekking tourism in the region numerous lodges and tea-shops have been set up along the trekking routes in many of the settlements (Stevens, 1993; Nepal, 2003; Rogers, 1997).

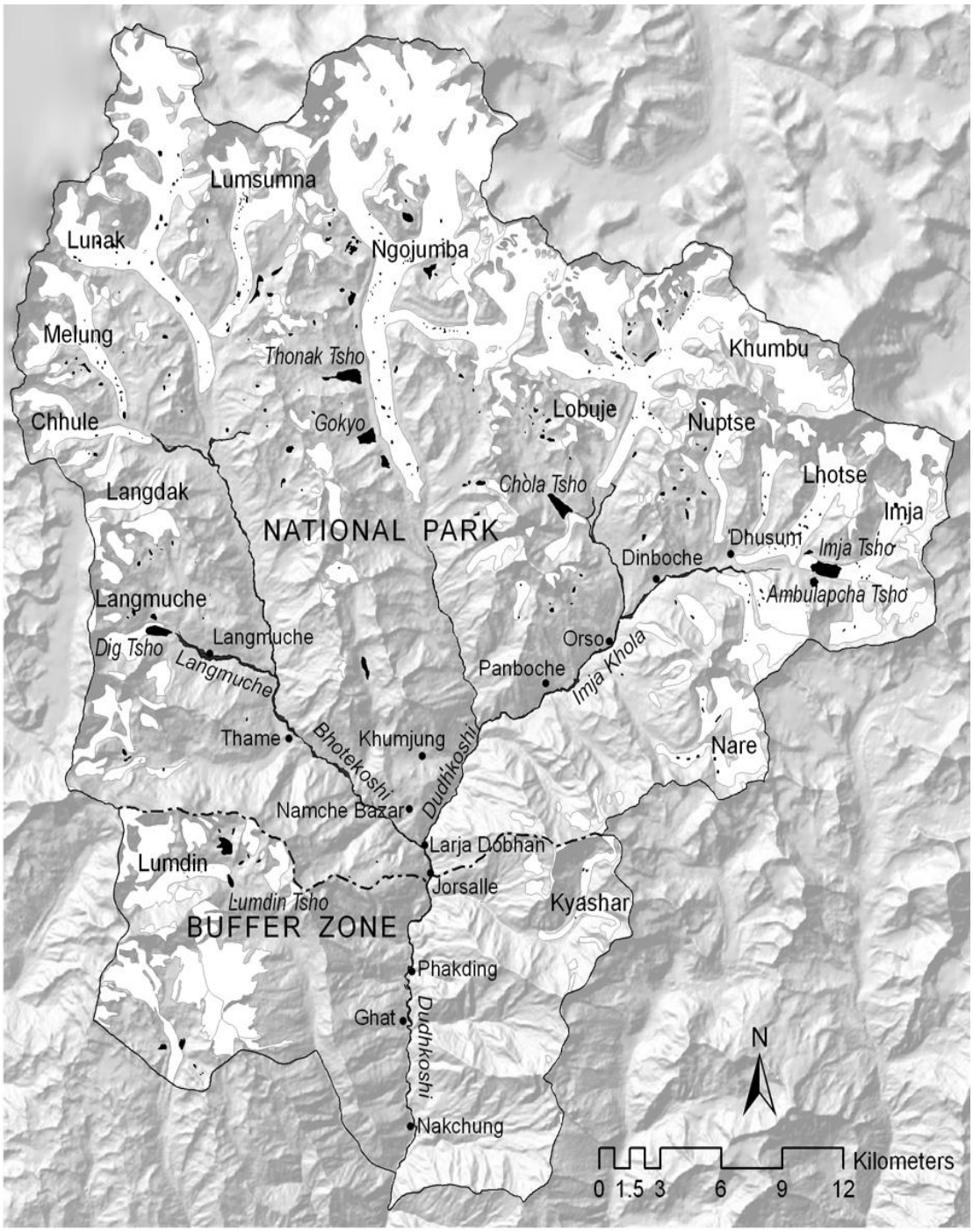

Figure 6: Major settlements of the Sagarmatha National Park and Buffer Zone (Source: Bajracharya and Shrestha, 2007).

Local economy

Most Sherpas were quite poor in comparison to other regions, in pre-tourism period. Their major traditional **earning sources** were based on subsistence agriculture and transhumance herding (the migration of livestock up and down the slope in tune with the seasons). Since Everest began to attract tourist, activities such as climbing, pottering and guiding, and lodge management became common ways of generating income (Nepal, 2003). This new ways of income generation had a major impact on the viability of the farming and herding systems, resulting in labour shortages in the region. Nevertheless, animal husbandry and crop production still continue in the region (Brower, 1991). A study carried out by Bajracharya et al. (2009) reported that about 22% of the households in the region are depended entirely on agriculture and about 37% are partially involved. Furthermore, a survey of Mountain Spirit (2002) pointed out that 12% of the households fall under the rich category while 36% and 52% of the household fall under middle and poor categories respectively in the buffer zone. Furthermore, the Mountain Spirit study reported that 63% of the households lie in the on-trek route and 37% of the households lie in the off-trek route. The households which lie in the on-trek route depended mostly on tourism income whereas off-trek route households mainly relied on income from animal husbandry and agriculture.

Religion and culture

Sherpas are a **Buddhist** marginal group who speak a Tibetan dialect even though Nepali is the national language (Adams, 1992). A study of Ortner (1978) reported that the migration of the Sherpa ancestors from the Kham province of Tibet to Khumbu has taken place due to the politico-religious tension between the Kham people and their Mongol neighbours. There is also a guess that in the years 1531 to 1533 Mirza Muhammed Haider Duglat, the general of the Sultan Sa d Khan from Khashgar, Mongolia, invaded Tibet, which caused a lot of fear and disorder in the society. Consequently, the Sherpa escaped across the Himalaya into contemporary Nepal.

The Khumbu region was used for mediation retreats by Tibetan people before the Sherpa migrated here (Ortner, 1989). Further, some believe that the progenitor of Tibetan Buddhism **Guru Rimpoche** or Padam sambhava prophesized in the 8th century about Khumbu valley. He marked these areas for people as sacred hidden valleys that could be use in times of hardship.

The Sherpa "Tibetan Buddhists" follow the ancient Nyingmapa tradition. They assume the basic Buddhist principle of sin and merit is depending on the amounts of sin or merit mounted up in the course of a life time. The implementation of the Buddhism norms in the society lies in the hands of lamas, whom the Sherpa refer to as village priests (Ortner, 1978). The **Buddhist values** among the Sherpas promoted environment friendly activities (forest conservation, see figure 7), compassion, kindness, honesty, and the strength to survive in one of the world s highest ecosystem. For example, wildlife hunting and slaughtering livestock are still discouraged in the region because of religious beliefs attributed to Buddhism.

Figure 7: Forest around the Khumjung gompa (in Buddhist society monasteries are also called gompa).

The Sherpa people assumed Guru Rinpoche as **god** (see figure 8). According to the local people knowledge gods are protectors of the people. They believe protection from the

god is achieved through mediation and worshipping. Therefore, worship occurs both in the home and community temples, called gompa.

Figure 8: Guru Rinpoche who consecrated Khumbu (Everest) as a beyul, a sacred hidden Himalayan valley and Buddhist sanctuary (Source: Stevens, 2008).

Gompa are preferable because they provide calm environmental conditions to worship the gods. The first gompa in the region was built in Pangboche around 1667. The two other additional major gompa was built in Thame and Tengboche between 1667-77 and 1916 respectively. Similarly, smaller gompas were built in other villages: Kerok (1667-77), Khumjung (1831), Namche (1905), Devuche nunnery (1925), Thamo (1962), Khunde (1972), and Phortse (1997). Altogether there are 41 religious building sites with big and small Monasteries, Temples and Chortens. According to the Lama of Khumjung monastery the oral history of Juniper forest around the gompa were planted from the hair of lama. They have believed that anyone who will cut down these trees will be dying within one hour, but if the lama will offer bless the patience could stay alive.

Consequently, from such believe almost all gompa have forests around their surroundings. In addition, tourists (mountain climbers) visit gompas in order to receive blessing from lama in tremble of sickness.

The **oral history** which is written in the calendar of 2009 of the Everest, published from Namche-9, describes that long time ago the statue of Guru Rimpoche which was brought from Kham province of the Tibet escaped by flying during the burning of the gompa of Takpu place situated between Thamteng and Kerok to the centre of hill. After some days, one lady heard the bell sound from the centre of the hill and she saw the statue of the Guru Rimpoche at that place. The statue told her to build a gompa at that place. Then she conveyed that message to Rolwa dhoja. Consequently, Rolwa Dhoja built the gompa and the statue of Guru Rimpoche was kept. This Gompa named as Sdanka Choling.

The Sherpas are culturally rich; they celebrate different festivals and ceremonies such as Losar, Dhumji, Mani Rimdu and Nyingne. Sherpa people also maintain a tradition of respecting **natural landscapes** such as mountains, lakes, trees and rocks as abodes of spirits and deities. Moreover, the local people perform a tradition of worshiping forest around the Gumpa considering it as a female goddess (Spoon, 2008). Furthermore, the local people also worship mountains considering them as protector deities living places (Stevens, 2008). They believe that the region will not be protected from the events such as avalanches, landslides and glaciers lake outbursting by the protector deities if they are unsatisfied from the activities of the local people (Spoon, 2008). According to the local people, each deity has various livestock that help them to fulfil their tasks. Due to this believe as well as the viewpoint of Buddhism, it is forbidden to slaughter livestock in the whole area. Furthermore, the local people believe that the main protector deity is Khumbu Yul Lha (Khumbila) who lives in the mountain that is located directly above the Khunde and Khumjung settlements, presented in figure 9. Local tradition states that this mountain looks like the shape of the Khumbila's horse. From a special view, the corners of the mountain represent the deity riding on top with his weapons. The livestock of Khumbila are the yak, tahr, and sheep. Some people believe yeti is also one of the livestock of Khumbila. Local people celebrate Dumji festival once a year, where an entire

dance is performed to dedicate the deity. Furthermore, people put white flags over the house three times a year on specific days to please the Khumbila deity.

Figure 9: Behind me in the picture is the main protector deity living place "Khumbila Mountain".

Agriculture and animal husbandry

Subsistence agriculture, animal husbandry, and transhimalayan trade are the **traditional occupations** of the local people (Stevens, 1993; Rogers, 1997). These activities are however complicated mainly by the promotion of tourism in the region (Mountain Spirit, 2002). Almost every household of the VDC (Village Development Committee) is either directly or indirectly influenced by tourism economy. Even though more people are involved in the tourism industry, there are still villages like Thame in the park area and various villages in the buffer zone where people are still operating animal husbandry and cultivation practices.

Among the three Village Development Committees within the national park and buffer zone, the highest agriculture land lies in Chaurikharka VDC (39%), whereas Khumjung and Namche consist of 34% and 27% respectively (Sherpa, 2007). The distribution of land size is heterogeneous. The land holding size varies from 0.01ha to 0.05 ha whereas 33% of the households are completely landless (Sherpa, 2007).

The dominant foods of the region were buckwheat, barley, Tibetan varieties of Turnip and radish during the eighteenth century. Subsistence agricultural practices and the local diet were significantly changed around 1850 due to the introduction of **potato** in the region (Stevens, 1993). Between seventy five percent (Stevens, 1993) and ninety percent (Fisher, 1990) of the agricultural land was planted with potatoes in the early 1990s. In the past, potatoes were also traded to Tibet while in recent times Sherpas traded to the lowland communities (Spoon, 2008).

Livestock farming is still common in off-site trekking site villages. This farming strategy is strongly linked to the agriculture system. One of the commonly cited reasons for keeping livestock is to provide manure for agriculture. In this area several species of livestock are kept for providing milk, butter, manure, meat, hair and for transport purposes. The main species include yak and naks, cows and bulls, yak-cattle crossbreeds (zopkio/zhum), sheep and goats, and horses. Recent research indicates that the number of livestock is generally on the decline with yak/nak disappearing faster than the others. The crossbreeds are more stable and increasing under certain circumstances because of the demand for pack animals to move tourist luggage (Sherpa, 2007; Spoon, 2008). Cross breeds can graze over a larger range of elevation than the yak, which do not go below 3000 meters (Stevens, 1993). Furthermore, the local people reported that a number of naks and yaks are taken to Tibet for agricultural purposes and meat production. According to an estimate, there were about 4675 heads of livestock in Sagarmatha National Park and Buffer Zone in 2003 (Sherpa, 2007). Similarly, a study carried out by Sherpa and Bajracharya (2009) reported that there were about 5000 large livestock of which 50% were yaks and naks in the year 2008. The other 50% were yak-cow cross breeds, horses and mules.

Education

Prior to the establishment of the Himalayan Trust schools, **monasteries** were the only educational institutions in the region. Only students destined to become monks joined the monasteries, others were left without any formal education. However, the only form of education in the monasteries was based on Buddhist doctrines. The first initiative to teach local people Nepali language and Devanagari script in the region began in 1960 with lack of proper facilities (Sherpa and Bajracharya, 2009). The first school with proper facilities was established in 1961 by Sir Edmund Hillary. There were no local people literate in Nepali or English at the time. At present, there are 11 primary and 2 secondary schools. The current literacy rate of this area is estimated at 60% which is even higher than the national average of 53% (Sherpa, 2007; Sherpa and Bajracharya, 2009). There are limited numbers of local people with college and university degrees. Less than 7% out of the 3534 literate population of this area have obtained higher education beyond School Leaving Certificate.

An awareness of local people towards **education** is gradually increasing, indicated by an increased number of people involvement in conservation activities. However, there is the need for further establishment of institutions for the promotion of environmental education and sustainable resource management including the provision of technology (Mountain Spirit, 2002). There is only one curriculum in the formal education systems related to conservation and environment. Since 1997, eco-clubs have been established in schools through which different activities like plantation, awareness of conservation (see figure 10), and cleaning programs are carried out in the region. In recent times there have been eco student networks, comprising about 8 schools. This network also implements different conservation and environment activities in the region.

Figure 10: Khumjung School biodiversity conservation notice urging the protection of both musk deer and snow leopard (Source: Stevens, 2008).

Health

Prior to the advent of tourism in the Sagarmatha National Park and Buffer Zone, local religious leaders and Shaman were primarily responsible for influencing attitudes towards health problems (Rogers, 1997). More recently, health posts and hospitals have been established in the region. It was however noted that the local people still relied on **traditional** herbal medicine of Amchis, spirit mediums and religious practitioners for cure. According to the Doctor of the Khunde hospital, around 20 % of people are still dependent on traditional knowledge. Nowadays modern treatment facilities complement and improve the local health situation very much. According to the Khunde hospital sources, the infant mortality rate in 2009 was 0 %. Furthermore, the number of patience in the Khunde hospital recorded in the year 1966, 1995 and 2009 were 5, 25 and 36 respectively. Most of them were related to the following problems: high altitude sickness, respiratory, snow and waterborne diseases. In the last 15 years, there has been a decrease in the number of patients with problems related to waterborne diseases such as diarrhoea. This is due to good drinking water facilities and improvement of hygiene in the region. Consequently, life expectancy of the Khumbu people is 75 whereas the average life expectancy in Nepal is only 62 years.

The Khunde **hospital** was established in 1966 by Sir Edmund Hillary. It was run for many years by volunteer doctors from New Zealand and Canada but is now staffed by local doctors and nurses. There are also small clinics located at Thame, Phortse, Monjo and Debuche villages. These clinics are run by locally trained health workers. The Himalayan Trust and the Sir Edmund Hillary Foundation of Canada provides financial help to the Khunde hospital. Similarly, the American Himalayan Foundation and Everest Marathon organizers support the Namche Dental clinic. Recently, in order to help porters suffering from high altitude sickness a clinic was also established at Machermo village in the Gokyo valley. According to the Khunde hospital sources, over the last 25 years 200 people have died in the Khumbu from high-altitude sickness.

There is also another big hospital in Lukla which was built in 2005. According to the **Lukla hospital** sources, this hospital is financially supported by a private donor- Nicole Niquille and the Pasang Lhamu Foundation. This hospital provides services totally free of cost for the patience's. I also benefited from this facility during my field visit suffering from high altitude sickness.

2.3 History of Everest (Sagarmatha) National Park and Buffer Zone

More than half a century since the first ascent of Mt. Everest in 1953, **tourism** has brought major changes in the region, fostering prosperity for many Sherpas but also altering traditional subsistence practices and accelerating pressures on high altitude land use (Stevens, 1993, 2003; Byers, 1987 b, 1987c; Sherpa, 1979, 2009; Rogers, 1997; Garrat, 1981; Furer-Haimendorf, 1975, 1984; Bjonness, 1980a, 1980 b; Nepal, 2003).

These altering factors in relation to land use changes are the reasons that forced the declaration of the Khumbu (Everest) area as a **National Park**. For example; firstly, Edmund Hillary forwarded the issues concerning tourism impact on Khumbu environment to the international level. According to Rowell (1980), Sir Edmund Hillary found the Juniper virtually wiped out in the upper area of the Khumbu in the year 1976, when the region was visited on the basis of 5000 tourists per year. Some other observers reported that the rapid development of tourism in the late 1960s and early 1970s had increased the use of fuelwood. In addition, they reported firewood selling was becoming

a popular way to make money in the Khumbu. Secondly, with the passage of the Forest Nationalization Act of 1957, any local rights to forest management were denied, which effectively undermined local management regulations and institutions. This accelerated the forest destructions in the region (Nepal, 2003). Thirdly, the indigenous forest and wildlife protection systems of the local people were being weakened as external influences grew stronger (Sherpa, 2007). Wildlife hunting began to increase. Thus, the national and international communities concerned about the future of tourism, culture and biodiversity in relation to the above ongoing problems has forced to create the Khumbu (Everest) area a "Sagarmatha National Park" in the year 1976. Moreover, it is sure that the natural features of the region, particularly the magnificence of Sagarmatha (Mount Everest), make the area an obvious choice for the National Park status. In addition, the remaining villages of the Chaurikharka Village Development Committee were set up as a Buffer Zone in the year 2002 to foster conservation and development.

2.3.1 Major role of Sagarmatha National Park and Buffer Zone

After the establishment of the National Park and Buffer Zone there have been important **achievements** in wildlife conservation, promotion of alternative energy sources and preservation of forests in the local vicinity (Nepal, 2003). The prohibition of timber and fuelwood cutting within the boundary of the park resulted in a forest cover enhancement to some extent as well as preservation from further degradation, for example in the areas between Phunki Tenga and Tengboche, Jorsale and Namche, and Namche and Phurte (Sherpa, 2007; Nepal, 2003). This is one of the major success stories of the National Park (see figure 11). However before the setting up of the Buffer Zone in the Pharak area, in 2002, there was a prohibition of timber and fuelwood cutting only in the park areas. Consequently, the Pharak area receives more pressures to meet the growing demands of fuelwood and timber of local villages as well as park households. As a result, the additional demand of fuelwood and timber from park households caused some of the high Pharak forest degradation (Rogers, 1997).

Figure 11: Forest, around the headquarters of the Sagarmatha National Park (left in 1985) and (right in 1995) (Source: Photographs by A. Byers).

The Park's highest priority is **forestation**. Nurseries were established to supply seedlings for planting in several "demonstration" plantations sites in the villages of Namche, Khumjung, and Khunde. However, up to the year 1992, a recovery of grasses and herbaceous vegetation was only visible (Messerschmidt and Navin, 1992). In recent times however, planted trees in these sites have also shown proper growth, which is another success story of the National Park in the region. In addition, the Park has bought all goats from the local people in 1980s in order to get rid of goats from the region. Consequently, the trampling and seedling impacts in some extent have been decreased. Moreover, a recent study (Ale and Lovari, 2005) revealed that after almost three decades of National Park effective protection measures such as virtual cessation of hunting and the recovery of the endangered Himalayan tahr *(Hemitragus jemlahicus)* and musk deer *(Moschus chrysogaster)* resulted in a return of **snow leopards** back to the world s highest national park. This great effort of the National Park has made all nature lovers proud.

At present, the **Buffer Zone** system is still in the early stages of implementation. It is sure that after the Pharak area was set up as a Buffer Zone area in the year 2002, the local

forest has been preserved from further degradation (Sherpa, 2007). Moreover, the Buffer Zone organizations in the region are oriented towards spending the 50% of park revenue in the local community development.

In addition to the good sides of the national park and buffer zone also some **negative impacts** in the region have been reported during the household's interviews. The problem of potato crop damage by Himalayan tahr and depredation of local livestock by snow leopard, wolf, and other carnivorous are main negative impacts.

Moreover, there are 9 houses of Bishwokarma families in the Namche village and two houses in the Khumjung village and others in Thamo and Gumela. Their **traditional livelihood** was based on preparing kitchen vessels for local markets whereas nowadays their traditional work has been more or less completely displaced. According to Namche and Khumjung families, since the establishment of the National Park more than 75% of their traditional work has been stopped due to the shortages of coals due to the prohibition of timber and fuelwood cutting in the region. Nowadays, these families are working in the supply of stone for houses and lodge buildings.

In addition, the Namche weekly market business persons who are selling **bamboos** derived products such as locally named doko, dalo etc. reported that more than 60% of the malingo bamboos have disappeared in the lower elevation areas since 2000. The reason for this decrease is due to the ban on bamboo cutting by the National Park authority. This is because this species needs to be cut from time to time for its proper growth and spreading. Moreover, some of the local people of Khumjung village reported that with the establishment of the National Park, there has been a destruction of **prey-predator** relationship. For instance due to the ban on goats rearing in the village by the National Park, the vultures and eagles no longer appear in the local vicinity. Before the banning of goats, snow leopards and common leopards used to attack the baby goats so that the eagle and vultures got their food from the dead bodies of baby goats in the village arena. But nowadays no more dead bodies of goats are available, thus the eagles and vultures stray from the local vicinity.

To sum up, there are both positive and negative impacts from the National Park activities. The activities of the National Park have definitely resulted in the changes of provisioning of **ecosystem services**. For example, the increase of forest covers may have enhanced soil

erosion regulation, increase of biodiversity and increase of aesthetic beauty of the region. From which, the tourist numbers could be enhanced due to the promotion of aesthetic value. Similarly, the increase in area of forest cover attributed to the National Park activities could play a major role to meet the growing demand of fuelwood and timber.

2.4 Tourism

Mountain tourism in Nepal

As in many countries, tourism has grown to become one of the biggest industries in Nepal over the last three decades. It has generated much revenue for development activities in the country. The Nepal Government has started mountain tourism primarily based on **protected areas** since the 1950s. There are five national parks and three conservation areas covering almost 18,000 km² playing an important role in attracting international mountaineers and trekkers. The country earned 0.6 million and 4.3 million Nepali rupees from mountaineering expeditions respectively in the years 1979 and 1987 (Nepal, 2003). The government further set up new destinations to attract more trekkers. Consequently, 22 percent (107960) of all visitors were trekkers and mountaineers in the year 1999 (Government of Nepal, 2000). The majority of trekkers came from the United States, United Kingdom, Germany, Japan and France.

The **Everest**, the Annapurna and the Langtang regions are the main destinations for mountaineers and trekkers. Out of these three destinations; 24 % of mountaineers and trekkers visited the Everest region in the year 1999 (Nepal, 2003).

Tourism development and its trend in the Everest region

Although mountaineering in the Everest region began in the early 1950s, only few numbers of tourists visited Khumbu until the late 1960s. Beyond specific expeditions, intended at summiting Everest, the region received only twenty foreign **visitors** in the year 1964 (Sherpa and Bajracharya, 2009). The first expedition to Everest was a U.S. British exploratory party led by Charles Housten and William Tilman. Although there was the first attempt from the Tibet side by a 1921 expedition, the first expedition from the Nepal side took place in 1952 by a Swiss team (Stevens, 1993).

The establishment of the **Lukla airport** in 1964 has played a vital role in the development of the tourism industry. This has significantly reduced the spending time of the visitors to reach the destination and climb the mountains, from around a ten-day work from Jiri (where the road ends) to a few days from Lukla to Namche Bazzar (Stevens, 1993). Consequently, Khumbu tourism has steadily increased since the 1970s (see figure 12).

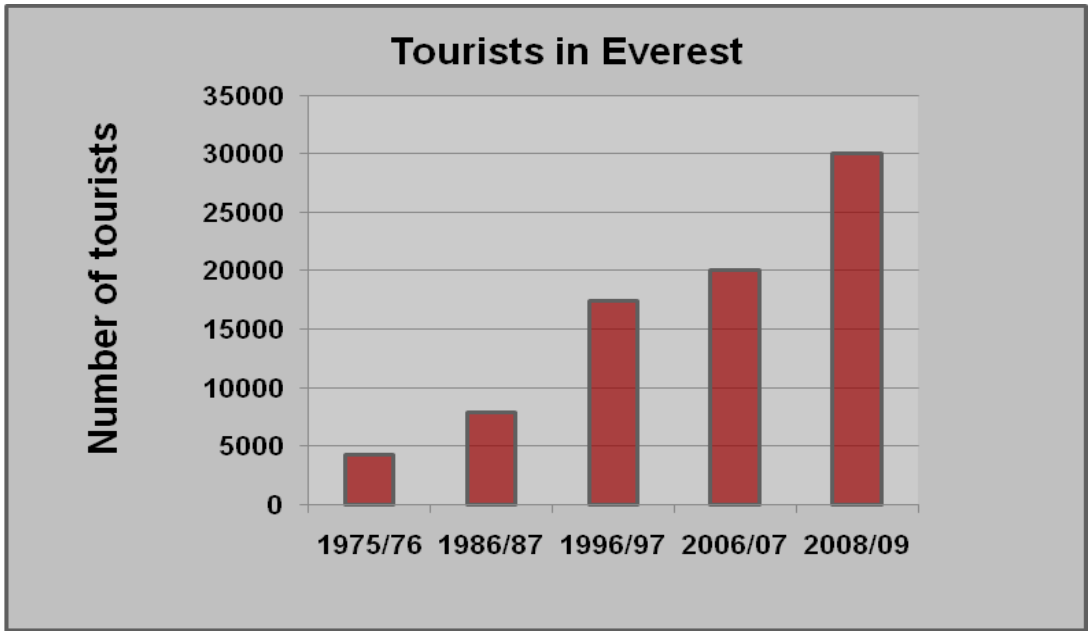

Figure 12: Number of tourists in Everest (Source: Nepal Tourism Board).

The increases in the number of Everest tourists afforded the Sherpa interests in establishing tourism business. With the escalating number of tourists, an influential development has taken place in the region. The number of **lodges** increased from 1 small inn in 1971 (Stevens, 1993) to 7 in 1973, 17 in 1980 and 74 in 1990, 225 in 1997 (Mattle, 1999 cited in Nepal, 2003) and nearly 500 lodges in 2009 (Sherpa and Bajracharya, 2009). The increasing number of lodges since 1980s also changed the structure of tourism from tent to lodge accommodations. Consequently, the number of potters that are needed to transport tents and food has been reduced. Bjonness (1980b) reported that until 1978, 70 % of the trekkers to the Everest region stayed in tents. Similarly, Spoon (2008) revealed 80.5 % of the visitors slept in local lodges, 10.4% were camping, and 9.1% doing a combination of both.

Furthermore, the rapid increases in the number of tourists also reflects that there could be high **consequences** in the provisioning of ecosystem services by increasing the demand of fuelwood, timber attributed to new lodges, food and livestock products. Therefore, the patterns of supply and demand of ecosystem services could be guided by the number of tourists in different years.

2.5 Tourism and socio-cultural change in the Everest region

Sherpas are so knotted with mountain tourism work today that their name, **Sherpa**, has come to symbolise the heroic for mountain climbing. Sherpa people are internationally celebrative due to their honest and hard working nature. According to the local people (Sherpas), they were named locally as Bhotas in pre tourism period in the region. The involvement in tourism however, changed them from Bhotas to Sherpas. Along this change, they are also having other visible modifications in their lifestyles (Brower, 1987; Fisher, 1986; Furer-Haimendorf, 1984; Bjonness, 1983; Pawson, 1984; Sacherer, 1977; Rogers, 1997 and Spoon, 2008). However, these changes have both positive and negative relationships with indigenous cultures and religious practices which are elaborated in detail below.

2.5.1 Culture and religion

The impact of **tourism** on the Everest region has been wide and diversified. The fostering economic prosperity based on the tourism industry in the region directly helped the Sherpas to upgrade their living-standards, their general health conditions and their schooling as well as meeting their nutritional needs. These are the positive sides of tourism. There are also negative aspects which raise a lot of concern. Some of these are loss of cultural values and local identity as well as local languages (Sherpa, 2009; Haimendorf, 1984 and Fisher, 1990).

A study of Haimendorf (1984) reported that many undesirable transformations have developed in the **Sherpa culture**, leading e.g. to shortages of lamas in some monasteries. Furthermore, Haimendorf reported that only few families seem eager to send young Sherpas for lamaistic studies. In spite of the negative impacts, there are also positive parts

of tourism in the Sherpa culture and religion. A good part of their new wealth based on tourism is spent in the cause of their religion, which is the Nying-ma-pa sect of Tibetan Buddhism. Fisher (1990) reported that during the annual Dumji festival, rich families who depend on tourism income are always willing to sponsor the activities of this festival.

Most families use excess crops and livestock products to pay for other services. Families that consumed all of their household productions earned extra income from alternative works such as wage labour as domestics, farm hands, or craftsmen. This extra money was used to purchase **religious services** and to sponsor secular ceremonies in the pre-tourism period (Adams, 1992). But nowadays most of them are dependent on the tourism income to purchase the religious services and the expenditure for these religious activities has increased.

It is a fact that the expenditure for hosting **religious events** are steeply increasing from tourism associated incomes. The average expenditure per household for religious services per year in 2009 in Namche and Khumjung VDCs were Nepali Rupees 110000 and 68480 respectively (Field Visit, 2010). Furthermore, the average expenditure per household for buying worshipping materials in Khumjung VDC per month was NRs 520 in the year 2009 (Field Visit, 2010). In comparison to the pre-tourism period, most of the festival events are more interesting and systematic in the present days due to the affluence of the tourism income (Rogers, 1997). According to the local people the fourteen day rotation "Lhosar" traditional festival has been wiped out since 1995 in order to make more time for professional trekking. In this festival the people who were living far from Khumbu came to their houses in order to celebrate with their neighbours and relatives.

Gompas (monasteries) are a vital component of the Sagarmatha National Park and Buffer Zone cultural heritage and are important cultural destinations. Information gathered from the local people, lamas and tourist indicate that tourism has had positive impacts on the cultural aspects such as the restoration and building of new gompas. The Tengboche monastery receives more tourists than any other gompa. There were only three tourist lodges at Tengboche in the year 1987 (Martin, 1987 cited in Nepal, 2003). This monastery was destroyed by fire in the year 1989. But it was rebuilt from tourist

donations. A total of 8 lodges can now be found at the site. The standard of living of the people has improved with increasing number of lodges as a result of high rents paid by the tourists in the region. Moreover, a British individual raised funds and organised tours to build a completely new gompa in Phortse village in the year 1995 and 1996. The construction of a small gompa above Choblung was also successful due to the contribution from French tourists. During the field visit programme several other examples of tourist's contributions to build and maintain gompas were seen.

Besides this good side of tourism there are also some **negative impacts**. For example; the Rinpoche (reincarnate abbot) of the Thame monastery has opened a lodge himself and allows his monks to take leave for two months to work in the tourism industry (Nepal, 2003) which has sometimes especially in the peak season resulted in shortages of lamas in the villages.

To sum up, tourism has led to both positive and negative impacts on the local cultures and religions. It is not surprising that the impacts on local cultures and religions have changed the provisioning of **ecosystem services**. This is because the local people's daily life activities are highly guided by cultural values.

2.5.2 Local income structure

Tourism is the strongest driver of the **socio-economic** change in Khumbu (Everest). Operating inns and working in the tourism industry as guides or porters are the main earning sources for the local people. Adapting these sorts of income generating activities has resulted in better living standards (Stevens, 1993; Sherpa, 2007). Similarly, it has promoted education, health conditions and religious functions in the region (Rogers, 1997). However, the traditional economic activities such as agriculture, animal husbandry and trading are being replaced by these alternative economic opportunities (Sherpa and Bajracharya, 2009; Nepal, 2003 and Rogers, 1997).

Most of the Khumbu households **earn** some money directly or indirectly from tourism. 80% of the household's incomes are attributed to tourism based income (Adams, 1992).

In addition, tourism income has shared greater percentage in rich and middle families of household's income which has been observed through questionnaire surveys among 160 local people's households of the Namche village development committee (see table 3). The occupation involvement of households is also presented in table 4.

Table 3: Share of Namche Village Development Committee household income in percentage made through different sectors in the year 2009 (Source: Field visit, 2010)

Level of Family	Number of households	Average household monthly income (NRs)	Average household income percentage from different sectors					
			Agro-pastoral	Trekking	Hotel and lodges	Business	Government services	Others
Rich	27	40000	7	8	83	2	0	0
Middle	69	15000	28	23	34	5	3	7
Poor	45	6000	21	21	11	8	0	22
Very Poor	19	3500	30	30	0	0	0	15

Table 4: Occupation involvement of households in the year 2005 by Village Development Committee in percentage (Source: Sherpa, 2007)

Occupation	Village Development Committee			Total
	Namche	***Khumjung***	***Chaurikharka***	
Agriculture Only	11.8	28.3	22.3	21.8
Agriculture and Hotel	1.7	9.8	6.0	6.2
Agriculture and Trekking	19.1	27.0	27.0	25.2
Agricultural, Hotel, and Trekking	0	3.3	7.0	4.3
Hotel Only	13.9	6.1	7.3	8.4
Hotel and Trekking	9.0	3.0	3.1	4.4
Trekking	21.5	12.9	6.5	1.8
Jobs/Service	5.9	4.0	8.1	6.4
Others	17.0	5.6	12.7	1.5
Total	100.0	100.0	100.0	100.0

Furthermore, Spoon (2008) revealed that the economic transactions in the years 2006-07 were in total US dollar $ 1369826.37, out of which the tourism services provided (64.1

%), lodges (24.1%), tea shops (5.5%), Tibetan vending (4%) and shops (1.9%). Additionally (with the least being) the weekly market in Namche was involved. Thus it seems that the Khumbu Sherpa have a high economic benefit from tourism, from which they can afford a higher standard of living even though the prices for goods and services are also increasing. But the question still remains whether the increasing **demand** of fuelwood and other food items could be met by local production or not. Furthermore, the increasing demand may have introduced some changes in land cover types such as forest degradation from fuelwood demand. Therefore, the development of tourism has affected changes in the trends of the provisioning of ecosystem services.

Moreover, there could be major economic adjustment problems in case of a sudden collapse in the tourism industry. For instance it would be difficult to return to traditional livelihood practices (Sherpa and Bajracharya, 2009). Some s**ocio-cultural** problems have also emerged from the tourism industry. Some of which, are the widening of the gap between the rich and the poor people and strained relations between Sherpas and non-Sherpas. In addition, during the household interviews some of them reported that tourism is a "parasite business" because it destroys the life of wife`s and daughters (but they did not indicate how it destroys their life). With these examples, there might be in future some rising social problems between the rich and poor classes as well as problems within the family member relationships.

2.5.3 Education

According to the teachers of the region over the past 20 years the numbers of students have increased because the parents have learned the value of education. Another motive is to get a better English education so that they can become more suitable to work in the **tourism industry**. A study of Fisher (1990) reported that there was a sharp increase in schooling from the 1970s to 1980s, with a tapering off in the mid-80s. Similarly, Spoon (2008) revealed that the total number of students increased from 599 in 1995-96 to 626 in 2006-07.

Furthermore, teachers of the region reported that **students** often learn more English participating in trekking and mountaineering services than at school. Parents can afford to send their children to boarding schools as result of support from foreign donors and the

affluence of tourism. In addition, they added that the biggest challenge is that people are being influenced by tourism based wealth, which causes the students to feel that receiving a higher degree will not get them a high paid job. Consequently, only limited numbers of students possess higher degrees. Moreover, teachers remarked that "most of the students only want to work in the tourism industry and to go abroad for work".

The number of **students** since 30 years in one of the big schools in the region, the "Khumjung School", is more or less constant (300-350), out of which around 250 are local students. Most of them belong to poor families. The rich families who are earning more money from tourism are sending their kids to Kathmandu for study (e.g. in the Khumjung village 8-10 students per year go to Kathmandu). According to the headmaster of Khumjung School, this new trend is coming up with new problems such as a loss of traditional language and culture.

Educational infrastructures

Educational development has received a lot of support from **tourist's funds** in the region. For example, the Sir Edmund Hillary s Himalayan Trust established the Khumjung School in the year 1961. A Swiss organization, donated one modern substantial wooden building to the Khumjung School in the year 1995. The upper secondary school at Chaurikharak was established by private donors who visited the area as tourists. Other infrastructure developments in the field of education have resulted from the work of philanthropic tourists. The above activities demonstrate that tourism has highly contributed in the promotion of Khumbu education.

To sum up, one can say that firstly, tourist's funds have contributed towards **educational infrastructure.** Secondly, children from rich families typically have greater educational opportunities and attain higher educational standards in the major cities of Nepal. Thirdly, the students who are rear outside Khumbu have been encountering the loss of their traditional language and cultures. Similarly, the increasing number of schooling along tourism development reflects promotion of **conservational activities** in the region through eco-clubs in each school. Consequently, these activities could effect an

enhancement of the provisioning of ecosystem services. For example, afforestation could provoke a promotion of soil erosion regulation and increase of biodiversity.

2.5.4 Food and clothes

Most of the local people relied on their traditional **food** of potato items till 1990. Whereas nowadays people are mostly dependent on imported foods such as rice, nodules etc. Similarly, imported beer and whiskey are more popular in the region instead of locally made millet/rice wine. In addition, before the 1970s, people were used to drink bloods of yak and nak through pipe. This practice has however stopped due to the escalating tourism the small number of yaks and naks available in the vicinity. The changes in the demands in relation with diet may have reduced the demand for potatoes on the other hand; the demand could have remained high because of the growing number of tourists. Therefore, the increase in demand for potatoes due to increasing numbers of tourists and the decrease due to the introduction of other food items may alter the trends in the demand and supply of potatoes.

Up to around 1995, the local people used to mend **clothes** and spin wool to prepare their necessary clothes (Adam, 1992), but nowadays they rely on ready made clothes which mainly come from Kathmandu or Tibet. Before 1995, Sherpa traders even sold Khumbu made clothes to Tibet. The reasons noted by the local people behind the displacement of their traditional clothes are due to the shortage of raw materials (livestock derived wools), manpower and the influence from western tourists' dress patterns. They also indicated that Tibetan clothes are more cheap and comfortable than the traditional ones. The Tibetan vendors at present supply locally and regionally made food and beverages from their home town and higher priced clothing and jewellery, which had an annual profit of US dollar $185904.47 in the year 2006-07 (Spoon, 2008). Nowadays, traditional dresses are worn especially by men when they attend important functions. More so, during the field visit traditional dresses were hardly seen on the young generation (see figure 13).

Figure 13: Local people in Namche Bazzar on western dress patterns, 2010.

2.5.5 Tourism and settlement characteristics

There are over one hundred **settlements** including large and small scattered ones at different elevations and slopes in the study site. These settlements range from small yak herding camps to large commercial tourist centres. Pre-tourism times found the settlements being used in different seasons for cultivating crops and keeping livestock. These settlements were usually around altitudes of 3500-4000m (Sherpa, 2009; Stevens, 1993). The settlements have gradually changed due to tourism development (Rogers, 1997). Early houses were simple ground-floor huts, a single-room, and built of locally available rock, timber and mud. Those houses have been changed due to the expansion of the tourism industry. Consequently, multi-storey houses and lodges, wood panelling, cement rather than mud-wash to finish external walls, extensive use of glass, and corrugated iron roofing features have been promoted in the villages (Stevens, 1993; Rogers, 1997). For example, these changes are reflected in the houses of Namche village (see figure 14). In the previous years before 1965, all the houses were roofed with a

combination of local materials like rock slates and bamboo mats. About 25% of the houses however changed to aluminium roofing by 1975 and this increased to about 50% by 1985. Most of the households have been converted to aluminium by 1995 (Sherpa, 2009). Therefore, the promotion of new house structures due to tourism development has caused changes in the demand of timber. Consequently, there have been changes in the conditions of local forests and their ecosystem services.

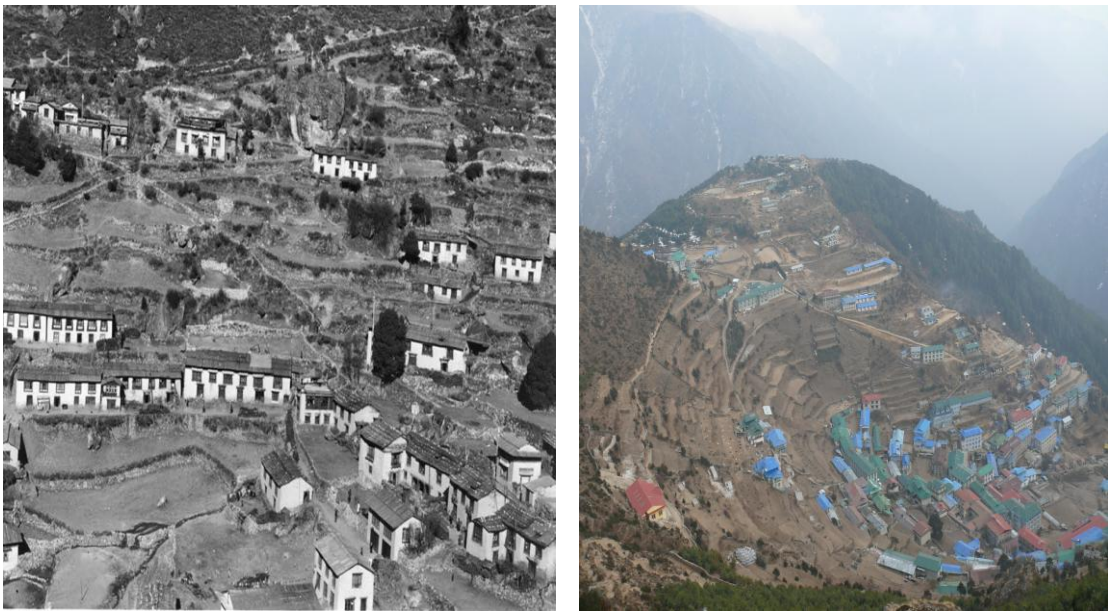

Figure 14: Namche Bazzar in the year 1973 (left, photograph by Alton Byers) and 2010 (right, field visit, 2010).

Another most striking change in village appearance from the affluence of tourism is attributed to the growth of houses and lodges in different settlements. The number of increased **houses and lodges** has been reported by different studies such as Nepal (2003). He reported that the number of houses and lodges were doubled in the built up area (Namche) between the year 1955 and 1997. In addition, Nepal showed that the number of lodges increased in Namche from four lodges in 1980 to 33 lodges in the year 1999.

Similarly, a study by Mattle (1997) cited in Nepal (2003) reported an incredible 13-fold increase in 17 years from 17 lodges until 1980 to 225 lodges by the end of 1997 (see table 5).

Table 5: Growth of lodges in different years in the Park (Source: Mattle, 1999 cited in Nepal, 2003)

Settlements	**Until 1989/90**	**Until 1993/94**	**After 1995**
Lukla	12	19	23
Phakding	6	9	13
Monjo/Jorsale	5	7	8
Namche	16	26	32
Thame	3	5	9
Phortse	2	3	5
Gokyo	1	5	8
Pangboche	3	8	10
Dingboche	4	9	10
Pheriche	3	5	10

Similarly, the increased number of households within the park settlements can be examined between the estimation by Fürer-Haimendorf (1964) and Stevens (1993) (see table 6).

Table 6: Household numbers in the years 1957 and 1991 (Source: Fürer-Haimendorf, 1964 and Stevens, 1993)

Village	***1957***	***1991***
Nauje	73	123
Khumjung	93	135
Khunde	45	50
Pangboche	58	83
Phurtse	63	62
Thamicho	192	

In addition, a study by Rogers (1997) reported an increased number of lodges and households within different settlements of the park and buffer zone areas (see table 7).

Table 7: Number of households and lodges in different settlements in the years 1993 and 1996 (Source: Rogers, 1997)

Villages	**1993**		**1996**	
	Households	**Lodges**	**Households**	**Lodges**
Lukla	130	25	130	28
Chaurikharka	200	4	200	4
Choblung	20	6	20	6
Phakding	50	14	50	21
Gomilla	30	0	30	0
Benekar	20	1	21	4
Monjo/Jorsale	30	9	30	11
Namche	130	25	130	28
Khumjung	180	3	180	6
Khunde	70	1	70	5
Thami/Thame Teng	75	2	75	6
Thamo/Phurte	80	2	80	2
Yulajung	15	0	15	0
Phortse	63	2	63	3
Luza/Machermo	24	5	24	7
Gokyo	13	4	13	6
Tengboche	15	3	15	5
Debuche	25	2	25	3
Pangboche	60	7	60	11
Pheriche	4	5	5	9
Dingboche	50	8	50	13
Chukhung	10	3	10	6
Lobuche	0	4	0	4

A recent study by the Sherpa (2007) reported that the total household number in the Park (Khumjung and Namche Village Development Committees) and Buffer Zone (Chaurikharka Village Development Committee) has reached 865 and 490 respectively.

To sum up, there has been a significant expansion of lodges and households in different settlements after the tourism has started. This increase reflects that there is a high **demand** of timber and fuelwood. Therefore, the question arises whether the local forest can meet the demand on a sustainable basis or not. The demand of timber and fuelwood has modified the forest conditions and the provisioning of ecosystem services.

2.5.6 Tourism and animal husbandry

Tourism has also become one of the main driving factors affecting the **livestock** number and composition in the Khumbu (Everest) region. There are different studies related to the number and composition of the Khumbu livestock for different years. Almost all studies have pointed out the changes due to the new employment opportunities from the tourism industry (e.g., Mountain Spirit, 2002; Stevens, 1993; Brower, 1987 and Sherpa and Bajracharya, 2009).

In the past, people kept more female animals for breeding, milking and for wool production. Nowadays, the trend has shifted to more male animals (zopkios and yaks) for transporting tourist loads as well as local goods (see figure 15). For example the male animals' urang and dimzo **zopkio**: in Nauje, Khumjung, Kunde, and Thamicho have become increasingly important since 1975. By 1978 the total number of adult zopkio (urang and dimzo) had reached 80 (Bjonness, 1980a). During the next few years this number has increased to 482 in 1984 (Brower, 1987). Similarly, across Khumbu this number has reached 580 in 1991 (Stevens, 1993). This new trend of rearing high numbers of zopkios has definitely increased the supply of provisioning services in terms of income from transportation purposes.

Furthermore, the demand of **male animals** for transporting tourist goods encouraged the introduction of non-traditional animals such as mules and donkeys in the region, but so far it is a small number only (Sherpa and Bajracharya, 2009). The proportional increase

of male animals is mostly focused on-trek route villages, whereas villages with a less tourism dominant economy are still common in livestock herding without much change in the composition of genders (Sherpa and Bajracharya, 2009; Sherpa, 2009).

Figure 15: Zopkios carrying household as well as tourist loads near Lukla, 2010.

A study of Sherpa and Bajracharya (2009) reported changes in **livestock number** in different settlements such as Thamichok village where the total number of yak has doubled between the years 1984 and 2009 whereas the zopkio number has increased from 170 to 220. The numbers of naks have slightly decreased from 520 to 480 within 24 years. Sherpa also reported that livestock of all kinds has decreased in the Namche village. There has been a decrease of 60 % in the zopkio numbers, and only one dzum is left from 25, while the nak number has become null, starting from 75 animals within 24 years. In addition, Sherpa mentioned a sharp decline in the abundance of dzum at least by 80 % since 1984 in the Khunde village.

There are different studies which have estimated the average **livestock** heads per household and the total number of livestock in each village development committee. A

recent study by Mountain Spirit (2002) indicated that the average livestock holding in Chaurikharka, Namche and Khumjung VDCs (Village Development Committee) are 3.2, 5.4 and 3.27 heads per households respectively. Chaurikharka consists of an average number of 1.85 heads of yak/zopkio per household, 1.53 cows and 0.6 horses. Similarly, Namche provides 4.55 heads of yak/zopkio, 0.54 heads of cow and in Khumjung there are 2.62 heads of yak/zopkio, 0.51 cows and 0.04 horses per household. Similarly, a study by Sagarmatha National Park and Buffer Zone (2003) cited in Sherpa (2007) reported an overall number of 4675 heads of livestock in the park and buffer zone area in the year 2003 (see table 8).

Table 8: Livestock population of three Village Development Committees (Source: Sagarmatha National Park and Buffer Zone, 2003 cited in Sherpa, 2007)

Village Development Committee	**Number of livestock**					**Total**
	Yaks	***Goats***	***Cows***	***Zopkios***	***Horses***	
Namche	597	43	522	4	21	1187
Khumjung	849	0	1105	10	18	1982
Chaurikharka	358	100	852	157	78	1506

Summarizing there are significant changes in the number and composition of **livestock** in tourist on-trek route villages because people prefer tourism-related activities rather than animal husbandry whereas off-trek route villages do not show drastic changes in the composition of livestock as they still rely on traditional husbandry practices. According to the local people, the significant changes and decreased numbers of livestock in the tourist on-trek route are due to the shortage of manpower for herding. For example, associated with tourism, parents send their children to school instead of sending them to tend the animals grazing. Furthermore, they reported that the younger generation does not have much interest in animal husbandry because the yields are lower than the tourism returns.

Moreover, the supply quantities of the **livestock products** (milk and butter) have decreased due to the small number of female animals. Therefore it is necessary to quantify the amount of livestock products in terms of supply and demand and to

investigate whether the changes in the composition of livestock could have introduced deficit areas of milk and butter in the region.

2.5.7 Tourism and agriculture

Different researchers have pointed out a number of **adverse tourism impacts** on the traditional subsistence agriculture. Among the impacts are the increase in generational gap in farming (Bjonness, 1983; Fisher, 1990), fragmentation of croplands (Fürer-Haimendorf, 1984; Bjonness, 1983; Sherpa, 2007; Mountain Spirit, 2002), decrease in the crop productivity (Bjonness, 1983; Fisher, 1990; Fürer-Haimendorf, 1984), shortages of agricultural workers (Fürer-Haimendorf, 1984; Mountain Spirit, 2002), and increased use of labour from other regions (Fisher, 1990). Stevens (1993) reported that some of these impacts did really appear but others are just exaggerations. According to him, there is a flow of non-Khumbu agricultural workers, but other reported issues are not reflected in the region.

The recent studies such as those of the Sherpa (2007), Mountain Sprit (2002), Rogers (1997) and Spoon (2008), revealed that **agricultural land** sizes are fragmented more than before**.** The study of the Mountain Spirit (2002) reports an average landholding size in Namche, Chaurikharkha, and Khumjung of 0.42, 0.47 and 0.47 hectare respectively. In addition, the Mountain Spirit study reports that the average landholding size is directly proportional to the economic level with higher areas of rich households (1.08 ha) associated with tourism income, than the estate size of the poorest (0.32ha) households isolated from tourism in Namche.

However, there is a controversy on whether tourism has actually replaced other traditional occupations or not. Mountain Sprit (2002) reports that agriculture is still the main earning sources of the Buffer Zone inhabitants, 41% of the households entirely depend on agriculture for livelihood with potential involvements in tourism activities. In addition, the villagers are totally dependent on the single crop of **potato** with very rare cultivation of barley, wheat, maize and buck wheat in the lower elevation zones. Furthermore, Mountain Spirit revealed an average household potato production of 1.55 MT, 2.64 MT and 2.88 MT annually respectively in Chaurikharka, Namche and

Khumjung village development committees. The average household productions of potato are higher in off-trek route than on-trek route villages (Spoon, 2008).

There is an increasing trend of **vegetable** fields in the region due to increasing tourist numbers in recent years. Some vegetables being grown are; Cabbage, cauliflower, carrot, and spinach. It is estimated that an average of 0.28 MT, 0.09 MT and 0.16 MT vegetable produced per household annually can be found in Chaurikharka, Namche and Khumjung Village Development Committees respectively (Mountain Spirit, 2002).

Hence, the major differences between the pre-tourism and the recent period are as follows: off-trek villagers still maintain **agriculture** as their main occupation whilst the on-trek route villagers are into hotel and lodge business. The agricultural area is characterized by an overwhelming dominance of small size land holdings. The greater size of landholding is directly proportional to the family income associated with tourism. Villagers are inclining towards vegetable cultivation to fulfil the growing demands of the tourists.

The replacement of traditional occupations in the on-trek route villages could impact the production amount of the main crop, potato. Similarly, it is sure that the demand for **potatoes** could have increased from a growing number of tourists in the on-trek villages. Therefore, there are trade of potatoes between the on-trek and off-trek route villages. Furthermore, there might be potato deficit areas due to the alternative occupations adapted in the on-trek route villages.

2.6 Tourism and forestry

The first environmental issues in the Sagarmatha National Park and Buffer Zone concerned the forest change and the alpine degradation. There is controversy as to whether the flow of **tourism** into the region has degraded the forest or not. Earlier studies suggested that after the 1950s, much of the forest, particularly within the Park boundary, has been depleted (Fürer Haimendorf, 1975; Sherpa, 1979). Furthermore, Haimendorf (1975) reported that the forests in the vicinity of villages within the park, particularly near Namche, have been seriously depleted from the growing demand of fuelwood from

tourism. Bjonness (1983) and Fisher (1990) revealed that the villagers sold large volumes of firewood to tourist groups and ignored local conservation traditions. This led to the breakdown of Sherpa community forest management, and consequently, the forest has been degraded. Similarly, a study by Stevens (2003) also confirmed this. He reported that the pressure on the forest was intensified by tourist related activities in the 1980s. The Sherpas built inns and expanded their houses to provide facilities for tourists. This also put the forest under pressure. Overgrazing also contributed to the degradation when the use of yak-cattle for transport became very lucrative (Sherpa, 1979; Bjonness, 1980a; Garratt, 1981; Byers, 1987b).

On the other hand, there are also some studies which state that not only tourism is an agent of forest degradation. Jefferies (1982) and Coburn (1984) argue that the influx of **Tibetan refugees** into the region combined with growing tourism were the main causes of forest degradation. This view has been supported by the local people during the interviews. They reported that the influx of Tibetan refugees is responsible for the degradation of the forest around the Tengboche and Thame village.

Byers (1987b) promotes another opinion: basing on the comparison of historical and present-day **photographs** of the forest covers of the Imja Khola-Namche-Everest, Khumjung-Phortse-Phunki Tenga and Phorste-Tengboche, he states that the forests conditions represents similar conditions to the past. Similarly, aerial photographs of the Everest region taken in 1979 and 1992 show a definite improvement in the vegetation cover in many areas, including the forest slopes around Tengboche**.** Furthermore**,** Stevens (1993) reported that the forests around the main villages were cleared more than three generations ago. In addition, Stevens reported that there has been a recent (between 1930 and 1965) localised clearing near Pangboche, Milingo, Phortse, Kyangjuma, Syangboche, Thamo and other small villages.

To sum up, tourism-related firewood and timber use have magnified the local Sherpas' **demand**. This has intensified the use of certain areas of forests and alpine junipers, but not the whole forest areas of the region. There has also been an enhancement of the forest cover which could be related with the active role of the National Park, with measures such as plantation, prohibition of fuelwood and timber cutting in the region. This trend of

local increase and decrease of the forest cover has definitely provoked changes in the provision of ecosystem services. Therefore, it is necessary to snap the overview of the provision of forest ecosystem services in relation to the demand from the local people, influx of Tibetan refugees and tourists.

2.6.1 Tourism and fuelwood

The impact of tourism on local **fuelwood** consumption was not very significant until the early 1970s, but the region has experienced more pressures from the growing number of tourists since that time (Sherpa, 1979; Nepal, 1997, 2003; Stevens, 1993, 2003). These increased pressures are reflected in many studies on the estimation of fuelwood consumption by tourism attributed lodges and households in different years. A study of Sherpa (1979) reported that the average household burns half a basket (1 basket = 27 kg) of fuelwood load per day which means that the total annual consumption of firewood sums up to 116435 basket loads from 638 households in the park (see table 9). For the conversion unit from basket to kg, there is no fix standard; some of the researchers consider 1 basket equivalent to 27 kg and some others 25 kg.

Similarly, a study of Rogers (1997) estimates between five and fifteen loads of fuelwood (one load=25 kg) and between three and five loads consumed per week by **lodges** and houses respectively during the year 1993. The study of Nepal (1997) describes that during the peak tourist seasons, more than 9 metric tones of fuelwood are consumed daily by 225 lodges located in and above Lukla with an average of 43 kg (1.5 loads) per lodge. Furthermore, Nepal estimated a total annual fuelwood consumption of 4014 tonnes within the national park boundary, out of which 21 percent is consumed by the 155 lodges in the park (see table 10). Taking into account, the comparison of the estimation of 2781 tonnes in 1982 (Pawson et al., 1984) and 4014 tonnes in 1997, an increase of 44 percent over 15 years can be indicated. Furthermore, Stevens (2003) reported that a relatively large, busy inn requires more than 600 loads (16 tonnes) of firewood annually, and that the total firewood use by Khumbu inns is about 2000t per year. Khumbu firewood constituted only about 10% of tourism related firewood used in the mid 1970s and increased to about 21 % in 1986 (Pawson et al., 1984; Hardie et al., 1987), and 40% in 2000 (Stevens, 2003). The firewood collection in the households is shown in figure 16.

Table 9: Loads of fuelwood burnt each day in each village (Source: Sherpa, 1979)

Villages	**Number of loads burnt each day: 27 kg per load**					**Total households**
	1/2	1	2	3	4	
Jorsalle	1	3	3	1	-	8
Namche Bazar	15	55	29	3	2	104
Khumjung	35	74	16	-	-	125
Khunde	16	25	10	2	3	56
Phortse	19	26	9	-	-	54
Pangboche	16	36	4	-	-	56
Dingboche	1	5	-	-	-	6
Thame Valley	37	59	58	4	1	159
Thyangboche	14	4	2	-	-	20
Debuche	15	1	-	-	-	16
Milingo	12	3	-	-	-	15
Pheriche	3	1	-	-	-	4
Zarok	1	2	2	-	-	5
Lobuje	2	-	-	-	-	2
Total	189 29.7%	297 46.7%	136 21.2%	10 1.5%	6 0.9%	638 100%

Table 10: Consumption amount of fuelwood per day by lodges located at various settlements (Source: Nepal, 1999)

Villages	***Number of lodges***	***Firewood (kg/day)***
Ghat	6	300
Phakding	13	780
Cheplung	5	250
Zhampute	2	180
Toc Toc	1	150
Benkar	5	200
Chumoa	4	240
Jorsalle	3	180
Monjo	5	320
Lukla	23	1125
Namche	32	1865
Khumjung/debuche	7	214
Milingo	4	230
Phortse	6	200
Thame	9	67
Khunde	2	30
Tengboche	5	60
Syanboche	4	110
L. pangboche	5	270
Upper Pangboche	5	170
Shomare	5	180
Dole	3	240
Lapharma	1	30
Pheriche	10	475
Dingboche	10	405
Luja	3	98
Machermo	5	135
Phanga	1	60

Tuglha	3	60
Dragnag	2	60
Chhukung	4	165
Gokyo	8	183
Djongla	2	30
Lobuche	5	30
Goraksheep	3	0

Figure 16: Fuelwood collection in the household of Khunde village, 2010.

Regarding the average **household** fuelwood demand, SPCC (Sagarmatha Pollution Control Committee) (1997) recorded a consumption of 8460 loads per month, averaging 13 loads per month per household in the Park area. Furthermore, SPCC reports 10.3 and 13 kg of fuelwood consumption per day in the Namche and Khumjung households respectively which are not engaged in tourism, whereas 19.2 and 19.4 kg of fuelwood per day are consumed in the households engaged in tourism of Namche and Khumjung

respectively. Stevens (2003) reported an average of household consumption of fuelwood of 13.5 kg per household per day in the park area.

Along with the estimation data of fuelwood consumption, different studies also examined whether the Sagarmatha National Park and Buffer Zone forests could fulfil the **demand** of local fuelwood on a sustainable basis or not. A study of Bauer and Poudel (1995) reported that the Buffer Zone inhabitant's daily demand cannot be met on a sustainable basis. Bauer revealed that the annual demand of fuelwood in the Buffer Zone reached 5946 cubic meters whereas this forest zone supplies only 4823 cubic meters fuelwood annually. On the other side, Ledgard (2002a) reported that the Sagarmatha National Park and Buffer Zone forests could fulfil the demand of fuelwood on a sustainable basis, to cater for up to 20000 visitors a year. Ledgard estimated that the park area's forests could sustainably provide around half of the regional needs and that the remaining demand can be fulfilled by the buffer zone's (Pharak) forests. In addition, Ledgard reported that the region s potential annual supply is five times more than the current total demand of the region. He further explained that the region s annual demand of fuelwood has now reached 3000 cubic meters whereas the study of Sherpa (2007) estimated the total potential supply of fuelwood per year of 15000 cubic meters.

To sum up, there is no doubt that the tourist related fuelwood consumption has been highly increased. The amount varies among the lodges. The high consumption is attributed to frequently visited tourist site lodges. Therefore, it seems that the pattern of fuelwood **demand** varies spatially. The high demand of fuelwood in the lodges of on-trek villages could have impacts on the provision of ecosystem services. Nevertheless, the total demand of the region could be fulfilled by Sagarmatha National Park and Buffer Zone forests on a sustainable basis. But it is necessary to track the supply and demand ratio of fuelwood of each land cover type around the inhabited settlements, in order to insight whether the land cover types are fulfilling their demands on a sustainable basis or not.

2.7 Soil erosion, landslide and trail degradation

There are different studies which have highlighted different causes of soil erosion and trail degradation in the region. Nevertheless most of the studies have emphasized on the combination of natural and human induced factors. Nepal (1997, 2003) pointed out that natural factors may play an important role in determining the amount and type of impacts whereas human use had triggered the processes of **trail erosion** in the region. Furthermore, Nepal stated that highly degraded trails are placed along the more popular tourist trails: the Kala Patthar route which exhibits 35 "hot spots", the Namche and the Gokyo route. He concluded that visitor density, vegetation conditions, topographic conditions, human settlements and environmental factors such as climate and geology influence the severity of trail impacts. These results are also comparable to the study of Marion (1994).

Similarly, based on the results from five separate research expeditions conducted between 1984 and 2004, Byers (2005) has found that during the past twenty to thirty years, the higher **alpine** ecosystems of the region have been highly disturbed due to poor management of tourism. He estimated the soil erosion in the year 1984: 0-1/ha*season for the moist sub-alpine, 0-2 t/ha*season for the dry sub-alpine forest, 0 -2t/ha*season for the sub-alpine shrub grassland, and unexpectedly high 20-40 t/ha*season for the disturbed alpine slopes.

There are other studies which have identified other **causes** besides tourism. A study of the World Wildlife Fund-Nepal (2009) reveals that due to the steep slopes, fragile geology, active tectonics and climate change, soil erosion has been triggered in the region. Furthermore, Bjonness (1980a) and Brower (1987) reveal that new regional livestock practises, especially the emerging of Zopkios, are important agents of soil erosion in the region.

Due to the extreme relief and younger geology with high seismic activities **natural hazards** such as: landslides, earthquakes, avalanches, rock falls, and floods are common in the Everest region (Ives, 2004). Bajracharya et al. (2009) also reported that rainfall intensities, land use practices and land cover also influence these landslides. They reported that out of the total landslide area, rock fall constituted about 28 % and 72% of the area is covered by rock and debris slides (see figure 18). The higher region is prone to

gully erosion due to the high velocity of runoff water and glacier erosion. The maximum area of the gully erosion is 585130 m² and the minimum area is 3589 m² (Bajracharya et al., 2009). During my interviews local people reported that wind is also an important agent of **soil erosion**. They also report that forest degradation has accelerated soil erosion in the region. Based on the views of the local people and the field observations, the high rates of soil erosion are located in the high alpine areas (see figure 17). This is mostly due to the harvest of juniper shrubs in massive amounts to fulfil the growing demand of tourists (Rogers, 1997).

Figure 17: Landslide in the upper Thame, 2010.

Summarizing, there is **evidence** of tourism caused accelerations of soil erosion, especially in the alpine areas. Highly visitor flow trail areas are impacted with especially high extent. The combined effects of human induced and natural impact has triggered soil erosion in the region. Therefore, these impacts cause changes in the provisioning of ecosystem services. For example, the cultural services in terms of aesthetic beauty, inspiration, recreation and tourism can be impacted from ongoing soil erosion in the tourist destination sites. Furthermore, impacts on other services such as the provisioning services in terms of food, herbs production etc. can be suspected.

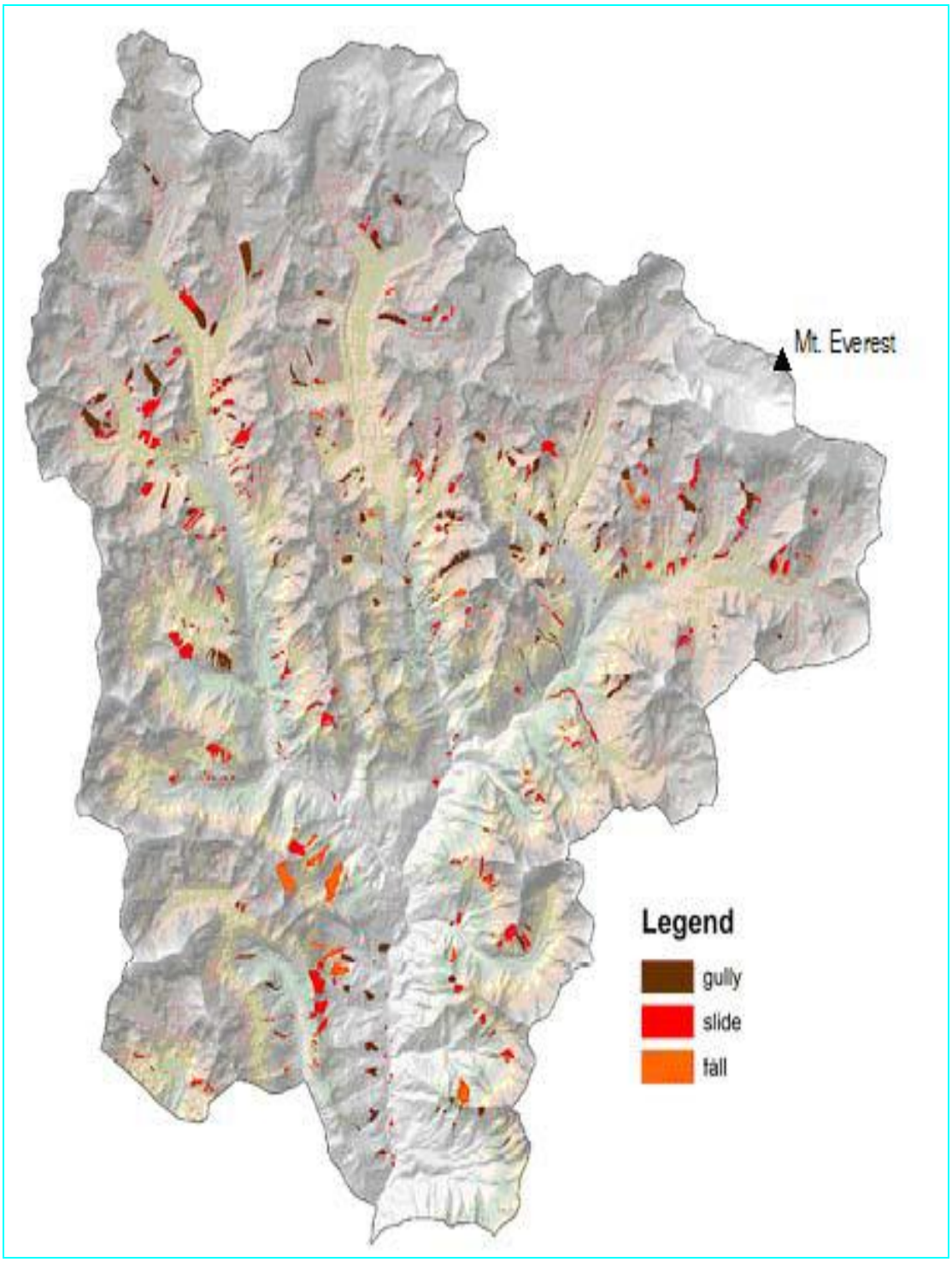

Figure 18: Distribution of landslides in Sagarmatha National Park and Buffer Zone (Source: Bajracharya and Shrestha, 2007).

2.8 Climate change

There are now many compelling evidences in the Sagarmatha National Park and Buffer Zone that global climate change is causing a rapid melting of glaciers in recent years and this will probably worsen in the future (Bajracharya and Shrestha, 2007; Byers, 2007; Salerno et al., 2008). Out of several evidences of the **melting glaciers**, the Khumbu glacier in 1995 was lowered by about 10 m compared with the year 1978 (Kadota et al., 1997). Similarly, the majority of glaciers were retreated in the range of 30 to 60 m during the 1970s to 1989 time period (Yamada, 1992). This retreating rate has increased to 74 m per year between 2001 and 2006 (Sherpa and Bajracharya, 2009).

Based on comparing **satellite imageries** of the years 1975, 1992 and 2000 the World Wildlife Fund-Nepal (2009) estimated that there has been a decrease of nearly 40% (290208.3 ha) of snow and ice cover areas between 1975 and 2000. More so, the World Wildlife Fund-Nepal found the rapid growth of Imja Lake by 0.23 kilometres between the years 1991 and 2001. The changes in the size of the Imja lake and glacier retreats can be seen in figures 19 and 20. Similarly, based on temporal series of satellite images from 1962 to 2006, a study of Bajracharya and Shrestha (2007) revealed that the lake increased in area from 0.82 kilometres to 0.94 kilometres in 2006. Their study describe that during the past six years, 34 major lakes appear to be growing in the Khumbu region. Similarly, Byers (2007) supports and complements those findings of Bajaracharya basing upon the loss of certain small (less than 0.5 km²), clean glaciers between approximately 5400-5500 altitude, the retreat of larger (greater than 0.5 kilometres) clean glaciers by as much as 50 percent of the 1955 volumes at elevations ranging from approximately 5500-5600, the formation of new and potentially dangerous glacial lakes that had been debris covered glaciers in the 1950s. Similarly, a study of the International Centre for Integrated Mountain Development (2007) cited in Central Department of Hydrology and Meterology Tribhuvan University (2007) found between 1960 and 2000 that the number of moraine dammed lakes increased from 33 to 89 in the region. Furthermore, the International Centre for Integrated Mountain Development study indicated that the area of total moraine dammed lakes reached 7.254 km² from 2.291 km² between the years 1960 to 2000.

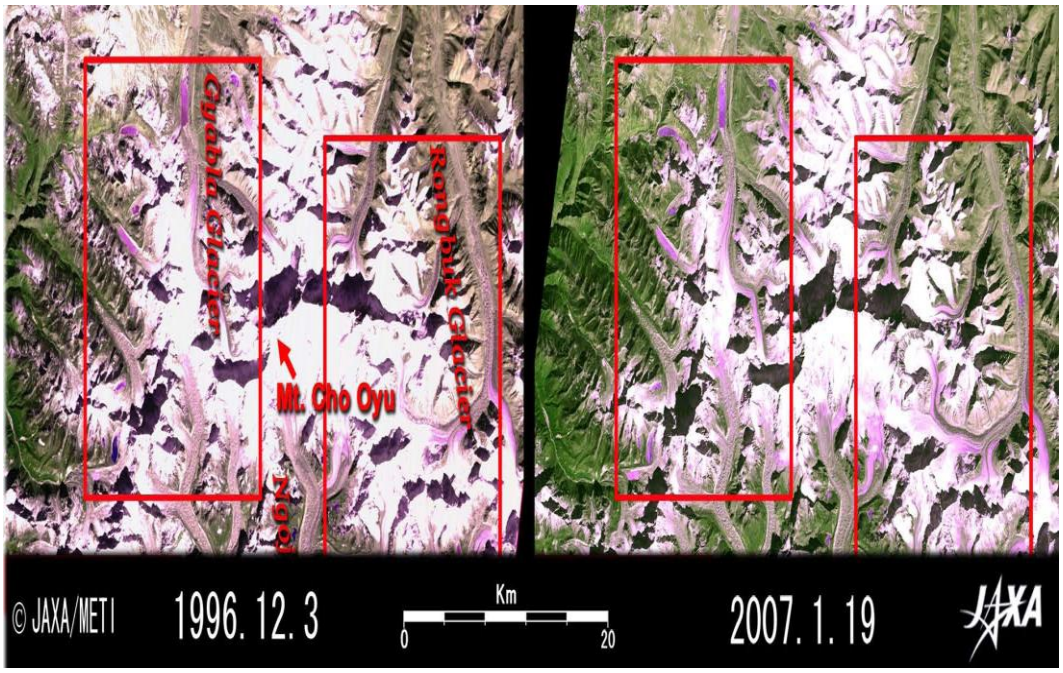

Figure 19: Glacier retreat, Imja Lake (Source: University of Maryland).

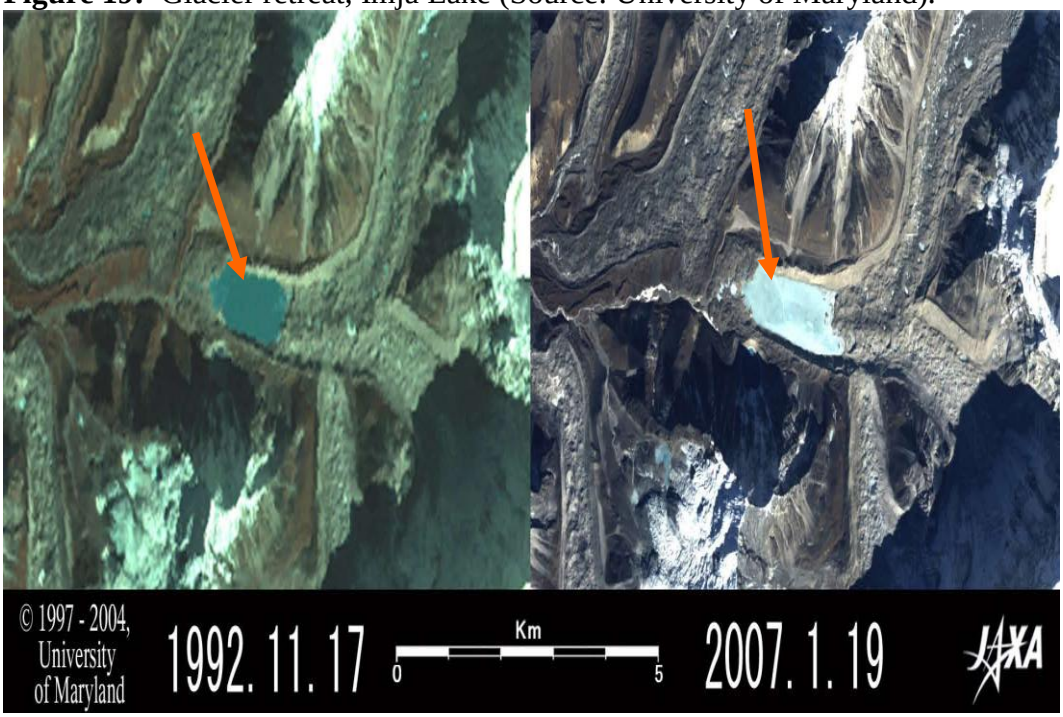

Figure 20: Imja Lake (Source: University of Maryland).

Summarizing, the **impact** of global warming is extremely evident in the national park and buffer zone area. It is true that climate change is one of the most urgent contemporary research topics in the region. Furthermore, global warming is an emerging environmental

concern because almost 60% of the Park's land falls under the extremely high-elevation zone (Sherpa and Bajracharya, 2009) where a mixture of snow, ice, water and bare rock covers the landscape. The accelerating melting of glaciers and snow on mountain tops is likely to affect the water availability, biological diversity and aesthetic quality of the Park. The mountain trekkers are inspired by these mountain ranges because of their beauty and tranquillity whereas the ongoing climate change impacts will affect these features consequently climate change could impact the whole tourism based economy of the region. Therefore, the impact of global warming in relation to the provision of ecosystem services should be assessed urgently.

Climate change and the perceptions and experiences of the local people

Even though many studies have traced out climate change evidences and described their potential impacts in the whole Himalayan region, there is an **absence** of studies covering local people's experience and perceptions related to climate change induced impacts on their livelihoods. This thesis has tried to cover the local people's views through household interviews and questionnaire surveys.

According to the **local people and mountaineers**, nowadays they observe that snow is melting along the trekking routes while bare rocks remain. They have also observed that the distance to the base camp from the village has increased by more than two hours due to glacier shifts. In addition, the Everest summiteer (owner of Khumbu village lodge of Khunde), Dhan Bir Lama (staff of Sagarmatha Pollution Control Committee) and Dawa Tshring Sherpa of Khumjung (mountaineering guide) reported that climbing Mt. Everest is becoming easier and takes a shorter duration than before**.** Furthermore, the study of the World Wildlife Fund-Nepal (2009) reported that the past events of climate change induced disasters in the Khumbu region which are: Nare and Cholatse GLOFs (Glaciers Lake Out Burst Floods) in 1977, avalanches in Phortse and Thanga village in 1988, GLOF Naktok in 2001, Digtscho flood in Pangboche in 1985, landslides in Machherma in 2000, avalanches in Phangka village in 1996, Tawoche GLOF in 1995, and the GLOF in base of Kang Tenga in 2006. Glaciers Lake outburst floods are the disastrous results from the glaciers retreat.

The villagers explain their **experience** on damages of their property and infrastructure from the above disasters. Furthermore due to warmer winters and less snowfall, the local people reported that the housing patterns in the Khumbu region have been changing. The thicknesses of walls have been reduced from 20cm to 8cm. In addition, the business persons, who are selling the products of bamboos (see figure 21) on the weekly market of Namche, mentioned that the local floral species "malingo bamboo", which is found in lower elevation, nowadays is decreasing due to the improper snowfall and lack of rainfall. Consequently, due to the lack of bamboos (good fodder of naks), the number of naks is also decreasing in the villages.

Bhim Sherpa, staff of EvK2CNR (Pyramid International Laboratory/Observatory in the Park), mentioned that around 20 to 30 % of **mushrooms** has been decreased around the laboratory vicinity since 2006 due to the poor rainfall. Similarly, local people around the Tsengboche village reported that there can be found a more proper growth of **junipers** than before due to the warmer climate.

Besides the above experiences, snow amount has reduced in the winter, there is increased incidence of spring snow fall, recession of snow line and increasing trend of glacier retreat. The local people think of this as **indicators** of climate change.

A survey conducted among the local people regarding ongoing climate change, showed that out of 160 households only 13.5 % are aware of the **adaptation measures** of the climate change. 45 % of households have participated in climate change related seminars and trainings. In addition, providing the options in order to choose adaptation measures in the face of climate change illustrated the following figures (see table 11):

Table 11: Number of household preferring adaptive measures in the face of climate change (Source: field visit, 2010)

	Options of adaptive measures							
	Increase of agricultural productivity	Cultivation of more agricultural species	Migration to the safe places	Promotion of income generating activities	Changes in the cultivation timetable	Forestation	Mitigation of disasters	Pre-information flow
N	0	0	11	0	19	55	45	30

N: Number of households

Figure 21: Malingo bamboo product "Doko" in the weekly market Namche, 2010.

2.9 Land cover of Sagarmatha National Park and Buffer Zone

Land use and land cover changes of Sagarmatha National Park and Buffer Zone are very dynamic (Bajaracharya et al., 2009; Sherpa and Bajracharya, 2009; Byers, 2005). The land use and land cover dynamics of the region are mainly attributed to two kinds of **drivers**; internal and external. The tourism and the activities of the National Park are internal drivers whereas the influx of Tibetan refugees and climate change are seen as external drivers (Sherpa, 2009; Rogers, 1997; Sherpa, 2007; Nepal, 1997 and Byers, 2007). Based on these two kinds of drivers the most striking change has been the increase/decrease of different land cover types in the region which is presented in table 12. According to the studies of Sherpa and Bajracharya (2009) and Bajracharya et al. (2009), between 1992 and 2005, the forest area has decreased while the shrub area has increased. Grass cover and bare areas have increased minimally at all elevations. But shrub cover decreased in the higher alpine regions. Furthermore, the authors reported that there is a small increase in built up areas and consequently, a decrease in cultivated areas. Similarly, the glacial lake area has increased while glaciers have decreased in area. The maximum changes in snow cover which has decreased by 11344 hectare over the 14-year period which has been investigated by them. The changes occurring in the different land cover types reflect that there could be many consequences for the provision of ecosystem

services. In addition, the changes in the area of land cover types may have impact on many aspects of the socio-cultural and bio-physical environments of the region because land cover is a fundamental variable that impacts and links all aspects of the environment. For example, the decrease in area of snow cover in the mountain tops will affect the availability of fresh water, biological diversity, and the aesthetic values of the region. With respect to land cover changes there could be changes in landscape capacities to provide ecosystem services. Therefore, based on the land cover information, it is necessary to assess landscape dynamics in relation to provision of ecosystem services to have an overview of which services are in the place of degradation or enhancement in the particular land cover type and which land cover type is more important for the local peoples' livelihoods. The **mapping** of ecosystem services was carried out in this study to identify the trends of ecosystem services in relation to the landscape dynamics of the Khumbu. In doing so, the relevant indicators of ecosystem services were selected based on the focus group discussions. In addition, the required data for mapping was obtained through household and tourist surveys, literature reviews and interviews.

Table 12: Areas of land cover types of Sagarmatha National Park and Buffer Zone in 1992 and 2005 (Source: Bajracharya et al., 2009)

Land cover Types	1992 (ha)	2005 (ha)	Changes (ha)
Bare rock	21882	31677	+9795
Bare soil	26706	27499	+793
Broad leaved forest	1952	2688	+736
Needle leaved forest	3150	3437	+287
Mixed multilayer forest	5084	3674	-1410
Cultivated	924	895	-29
Built up area	37	47	+10
Glacier	21719	21710	-9
Snow	32423	21075	-11348
Shrub land	16469	16689	+220
Open herbaceous vegetation	6342	8216	+1874
Glacier lake	586	822	+236
Gravel, stones and boulders	3581	2312	-1269

3 Materials and methods

This chapter describes procedures of using satellite image data to detect the range of land use and land cover changes. Furthermore, it describes the use of mapping instruments to overview the trends of ecosystem services both on spatial and temporal scales. In addition, it describes the utilized procedures of finding relevant indicators of ecosystem services through focus group discussions. Finally chapter 3 describes the qualitative and quantitative data gathering techniques: interviews, household questionnaire surveys and expert surveys.

3.1 Method of analyzing land use change

There are various methods that can be used in the collection, analysis and presentation of resource data but the use of remote sensing and geographic information system (RS/GIS) technologies can greatly facilitate the process. Repeated **satellite images** are useful for both visual assessment of natural resources dynamics occurring at a particular time and space as well as quantitative evaluation of land use and land cover changes over time (Gautam et al., 2003). This technique has been applied to detect changes in major land use types between the years 1975, 1992 and 2000 of the Sagarmatha (Everest) National Park.

The data used in the research included a Landsat Multi Spectral Scanner (MSS) satellite image from 1975, a Landsat Thematic Mapper TM satellite image from 1992 and Enhanced Thematic Mapper (ETM+) from 2000. A brief description of the satellite images used is given in Table 13.

Table 13: Satellite images used in land use classification

Satellite type	Sensor	Number of bands	Pixel Res (m)	Observation date
Landsat 2	MSS	4	60	1975-10-15
Landsat 5	TM10	7	120	1992-11-17
Landsat 7	ETM+	9	30	2000-10-30

The satellite images from the years 1975, 1992 and 2000 consist of 4, 7, and 9 bands respectively. **Band** is a range of wavelengths of electromagnetic radiation. These images

consist of 60 m, 120 m and 30 m pixel resolution respectively. Pixel denotes the number of consisting data.

The study area boundary of Sagarmatha National Park was defined basing on the map produced by the Survey department of Nepal. Remote sensing data was taken from the http:/glcfapp.umiacs.umd.edu:8080/esdi/index.jsp website. These data were converted to a map with the software ArcGIS (ESRI). Furthermore combination of maps was done on the basis of these bands. This study considered red, green and blue colour to interpret the map. On the basis of these colours, the five different **land use classes**; vegetation, glacier, glacier retreat, lake and barren cover were identified. Manual digitizing was carried out by producing polygon and shape files for each land use class. Finally, the land use maps were produced and the areas of the different land covers were calculated using ArcGIS functions.

3.2 Identification of indicators

The variable spatial nature of service generations and service flows has made mapping tools an important instrument for the quantification of ecosystem services (Naidoo et al., 2008; Egoh et al., 2008). In order to quantify these service generations through **mapping**, appropriate indicators are needed (Burkhard and Kroll, 2010). Within this broad framework, this study has carried out focus group discussions and intensive literature reviews to identify relevant indicators of ecosystem services.

The **focus group discussion** is a qualitative way of obtaining information. This is usually done by bringing about six to ten people together to discuss a topic. It is an established technique designed to bring the best ideas on the topic of discussion avoiding any cultural and social issues among the participants (Corbetta, 2003). In addition, the participants of each focus group session possess similar characteristics (Krueger and Casey, 2000). In order to find relevant participants for each focus group session, the study has considered local people's sources of income. Through literature reviews and consultations with the staff members of Sagarmatha Pollution Control Committee-Namche, and Sagarmatha National Park and Buffer Zone headquarters-Namche, and the village development committees, the following focus groups were considered: Herders; farmers; hotel and

lodge owners; teachers and students; visitors, porters and tourist guides; lamas and monks; government and non government organizations.

The study has considered **focus group locations** based on the land cover map of the study site developed by the study of Bajracharya et al. (2009). This land cover map has originated in remote sensing data (satellite image of the year 2005), thus the land cover units provide a logical combination of land cover and land use – as it can be reflected in the real landscapes. With the help of the ArcView software, this study has identified a number of settlements in the particular land cover classes through the following steps: Firstly, land cover class was added. Secondly, the unique value and class-names were selected in the legend editor icon after adding the settlement layer. After selecting the class-name in the value field, the table provided a number of settlements situated in different land cover classes. Then, the shape icon in the attribute table of the land cover class and the point icon in the attribute table of the settlement layer were selected respectively. Finally, with the help of the "join" option, the settlement layer and the land cover classes were linked. After joining the layers (settlement and land cover class), 49 permanent settlements were noted with the help of the "identify key" option (see table 14).

Table 14: Number of permanent settlements of the different land cover types

Land cover types	No. of settlements
Bare rocks	0
Bare soils	1
Broad leaved forest	2
Needle leaved forest	4
Multilayer mixed forest	5
Cultivated area	25
Built up area	1
Glacier	0
Snow	0
Shrub land	6
Closed to open herbaceous vegetation	1
Glacier lake	0
Gravel, stones and boulders	4

In order to conduct focus group discussions, the **settlements** of a particular land cover type were selected based on reported issues in the literature and consultations with the

staff of Sagarmatha Pollution Control Committee and National Park. The settlements were also selected according to the availability of the local people. Because of the tourist season (September to March), most of the local people along the on-route trekking site settlements remained busy with operating hotels and lodges.

This study has taken 6-12 people in each **focus group session** like other studies (e.g., Morgan, 1997; Krueger, 1994). The focus group discussions were placed in 10 settlements of the cultivated area, 4 settlements of the shrub land, 1 settlement each of the bare soil, built up and the closed to open herbaceous vegetation, 3 settlements each of the gravel, stone and boulders, needle leaved and the multilayer mixed forest, and 2 settlements of the broad leaved forest land cover type. The two sessions for herder and farmer groups and one discussion session were carried out for hotel and lodge focus group in each settlement of all land cover types. Similarly, the teacher and student, and the lama and monk focus groups were carried out in only one discussion session in the Khumjung and the Thame village of the cultivated land cover type and the Tengboche village of the shrub land area. Likewise, only one session each was carried out in the Namche, Goraksheep, and Lukla villages for the visitor, porter and tourist guide focus group. Only one discussion session each in the Namche, Khumjung and Lukla villages was carried out in the case of the government and non-government organization focus group. All of the focus groups discussions were held between January 2010 and 25th March, 2010.

The discussions were **moderated** by two staff members, Bhattari and Tamang of the Sagarmatha Pollution Control Committee. Being locals, they had a very good background of the regional conditions. They also had experience of being moderators, comprising the qualities mentioned in the study of Krueger (1994) and Morgan (1997). The discussions were structured to move from general to specific topics. At the beginning of each session of all groups, the moderator briefly described the purpose of the study and opened up with warm up questions and introductions. He then moved toward more specific questions. Each group meeting lasted between one to two hours. The moderator provided guidance and alternatives from time to time. The questions were open-ended, neutrally presented, conversational, clear and concise, like in a similar study by Krueger and Casey (2000). The questions were related to strengths and problems of the region, livelihood

strategies, tourism and climate change impacts, local people's daily needs and their supply, cultural practices, environmental conditions, and the role of organizations. For each type of focus group, there were five questions. The questions were developed through intensive literature reviews and brainstorming sessions with the staff of the Sagarmatha Pollution Control Committee, local school teachers and members of the Village Development Committee. Finally, the following **indicators** of ecosystem services were identified through focus groups discussions, which are presented in table 15. However, there were also some other indicators reported during discussion sessions. The excluded indicators were less important. These indicators were distributed based on the MA (2003) presented typology of ecosystem services like done in other studies (e.g., TEEB, 2008; Burkhard et al., 2009).

Table 15: Indicators of ecosystem services

Provisioning services	**Regulating services**	**Cultural services**	**Integrity/supporting services**
Fuelwood	Local and global climate regulation	Tourism	Abiotic heterogeneity
Timber	Water runoff regulation	Scientific research	Reduction of nutrient loss
Crops	Carbon sequestration	Religious value	Biodiversity
Herbs	Nutrient regulation	Sense of place	Storage capacity
Water	Erosion control	Natural and cultural heritage	Biotic water flows
Transportation via livestock			
Fodder			
Livestock products (butter and milk)			

3.3 Assessment matrix: land cover vs. ecosystem services

Two kinds of assessment matrices (supply and demand) were prepared to assess the land cover types' potentials of providing ecosystem services, and the demand for ecosystem services in a spatial manner. The supply assessment matrix was made based on the judgement values of local people and experts. The **demand assessment matrix** was made based on the total size of population inhabiting the particular land cover types in relation to the demand for the particular ecosystem service. The total number of households and hotels/lodges of the different land cover types and the average number of the household family members were obtained through the questionnaires surveys. The number of households per hectare per land cover type was determined based on the reported area of the different land cover types in the study of Bajracharya et al. (2009).

The **supply assessment matrix** was qualitatively assessed through expert judgements, similar to the study of Burkhard et al. (2009). Each expert was requested to assess the potential of land cover types in relation to the ecosystem services listed in the assessment matrix. The assessment matrix was made by linking 23 ecosystem services (on the x-axis) which was derived through the focus group discussions, to 13 land cover types (on the y-axis) which were distinguished according to the study of Bajracharya et al. (2009). This matrix was mailed to 20 national and international experts. Those experts were chosen based on their research activities in the Sagarmatha National Park and Buffer Zone (SNPBZ). It was noted in the email to put value at the interactions of 13 land cover types and 23 ecosystem services based on; 0= no relevant capacity, 1= low relevant capacity, 2= relevant capacity, 3= medium relevant capacity, 4= high relevant capacity and 5= very high relevant capacity of the particular land cover type to provide the particular service. 12 experts have responded. Furthermore, the assessment matrix was assessed by 8 staff members of different local organizations and 20 local people representing all of the considered focus groups. The survey was carried out during the field visit and the participants were selected based on non-random sampling. Finally, the supply assessment matrix was produced based on the average value of the total respondents (experts and local people).

3.4 Quantification of ecosystem services

A review of ecosystem services assessments reflected that mostly the quantification of ecosystem services is carried out in monetary terms. Although standard approaches to quantify ecosystem services are required, there are very few studies which adapt non-economic measures (Vandewalle et al., 2009). Among the non-economic measures, **mapping** of ecosystem services has been listed as one of the standardised approach to quantify ecosystem services (Burkhard and Kroll, 2010). In recent years, different scientists have developed many new mapping approaches of ecosystem services (e.g., Tallis & Polasky, 2009; Nelson et al., 2009; Egoh et al., 2008 and Naidoo et al., 2008). These studies adapt non monetary valuation on the quantification of different number of ecosystem services without considering the biophysical variations of landscapes (Willemen et al., 2008). The Willeman's study revealed that field visits and literature reviews are necessary to capture these variations. Similarly, the other studies (e.g., Burkhard and Kroll, 2010; Gee and Burkhard, 2010) apply questionnaires surveys, field observations and literature reviews. Likewise, this study is also designed within that framework based on literature reviews, interviews and questionnaires surveys to quantify selected services. The study follows the methodology of evaluating the potential of land cover types to provide selected services either economically or ecologically. In addition, this study considers ecological integrity in place of supporting services as ecological integrity is a prerequisite for providing ecosystem goods and services to humans (Müller et al., 2007). Therefore, based on the **MA recommendations** not to account for supporting services in quantifications to overcome double counting issues, this study excluded integrity from the service quantifications.

3.4.1 Questionnaire survey

A **questionnaire survey** is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents. In this study different questionnaires targeted to different groups have been carried out.

Households and hotels/lodges questionnaires survey

This survey was made only with local households and lodges that have been settled before the year 2006. 50 percent of the sample **households and hotels/lodges** have been settled before the year 1992. The sample numbers of the households and lodges in the different settlements are presented in table 16. This survey consisted of both random and non-random sampling but most of the households and lodges attributed to random sampling. Non random sampling procedures were considered mostly in the on-route trekking settlements because the local people remained busy with operating hotels and lodges. The survey was conducted between January, 2010 to May, 2010.

Table 16: Sample numbers of the households and lodges in the different settlements

Shrub land			**Needle leaved forest**		
Villages	*Households*	*Lodges*	*Villages*	*Households*	*Lodges*
Lobuche	2	2	Tok Tok	2	2
Chuklung	2	2	Ringdingma	2	
Pangboche	5	3	Pharonythokpa	2	
Tengboche	3	3	Monjo	3	2
Bengkar	3	3			
Thame Gumba	2				
Multilayer mixed forest			**Gravel, stones and boulders**		
Villages	*Households*	*Lodges*	*Villages*	*Households*	*Lodges*
Bakong Dinma	2		Jorsalle	3	2
Gumlha	3	0	Rokumba	2	
Kusum Tsanga	2		Chhuthawa	2	
Pakhepani	2		Thak Chokpo	2	
Surke	2	2			
Broad leaved forest			**Bare soil**		
Villages	*Households*	*Lodges*	*Villages*	*Households*	*Lodges*
Chumoa	2	2	Goraksheep	2	2

Teka	2				
Built up			**Closed to open herbaceous vegetation**		
Villages	*Households*	*Lodges*	*Villages*	*Households*	*Lodges*
Namche	6	10	Dejen	2	2
Cultivated area					
Villages	*Households*	*Lodges*			
Dingboche	3	2			
Pheriche	3	2			
Milingo	2	2			
Debuche	4	2			
Phortse	4	2			
Dole	3	2			
Luja	3	2			
Machherma	3	2			
Gokyo	2	2			
Marlung	3	2			
Yilajung	3	2			
Thame	4	3			
Thamteng	3	3			
Thamo	4	3			
Khunde	6	3			
Khumjung	10	4			
Phurte	4	2			
Thulo Gumelo	4	2			
Phakding	3	3			
Sano Gumela	3	2			
Ghat	3	3			
Chheplung	4	2			
Chaurikharka	6	3			
Lukla	10	6			
Nakchung	3	2			

The numbers of households and hotels/lodges of the different settlements included in the survey were based on the **size of the settlements**. In the settlements which possess a limited number of households and lodges at least two houses and hotels/lodges each per settlement were selected. The survey questions covered a three years (1992, 2005 and 2009) time period. The years 1992 and 2005 were taken according to the study objectives, whereas, the year 2009 was taken as a reference year to control the respondent data of the years 1992 and 2005. The questions that were included in the survey were as follows:

1) How much monthly income did you have in the years 1992, 2005 and 2009?
2) How many family members did you have in the years 1992, 2005 and 2009?
3) How many houses and lodges were located in your village in the years 1992, 2005 and 2009?
4) How many potatoes fields did you have in the years 1992, 2005 and 2009? Please specify the total amount of potato production during those years.
5) What quantity of potatoes was consumed by your household in the years 1992, 2005 and 2009 respectively?
6) How much fuel wood was consumed in your household work in the years 1992, 2005 and 2009?
7) How much livestock did you have in the years 1992, 2005 and 2009? Please specify types of livestock and the numbers of animals.
8) Could you trace out the total number of livestock belonging to your whole village in the years 1992, 2005 and 2009? If yes, please specify the types and numbers of livestock.
9) How much milk and butter did you produce in your household in the years 1992, 2005 and 2009?
10) How much milk and butter do you collect per cow and nak?
11) How much milk and butter was consumed in your household in the years 1992, 2005 and 2009?
12) Did you use zopkios for transportation purposes in the years 1992, 2005 and 2009? If yes, how much money did you earn each year?

13) Could you trace out the total number of zopkios of your whole village that were used for transportation purposes in the years 1992, 2005 and 2009?
14) How much money did you spend for celebrated religious functions in the year 2009?
15) How much money did you spend for worshipping materials in the year 2009?
16) How much time did you spend to visiting the gompa every day in the years 1992, 2005 and 2009?

In addition, the surveys focused on the **household income** shared by the different sectors, and the social level of the family (rich, middle, poor and very poor). The **climate change** related surveys were carried out in the Namche Village Development Committee among 160 households. Those households were selected randomly. The questions in the survey were as follows:

1) Can you trace out the sources of your household monthly income in percentage and how high is your monthly average income? (Agro-pastoral, trekking, hotels and lodges, business, government office and others).
2) In which status would you like to place your household? Please tick out (rich, middle, poor and very poor).
3) Are you aware of the adaptation measures of climate change? If yes, which measures are you willing to choose?

   a) Increase of agricultural productivity b) Cultivation of more agricultural species

   c) Migration to the safe places d) Promotion of income generating activities

   e) Changes in the cultivation timetable f) Forestation g) Mitigation of disasters

   h) Pre-information flow.

4) Have you already been involved in the climate change seminar/training?

Tourist questionnaire survey

Tourists are attracted to the high mountain landscapes to experience the natural qualitities such as topography, scenic beauty and forests (Munic, 1997; Price et al., 1999). Within this broad view, 100 tourists were included in the survey to obtain the **aesthetic value** of the study site. Most of the tourists were encountered in the lodges of the Namche, Khumjung, Tengboche, Lukla and Goraksheep villages, whereas, some of them were captured along the tourist trails of the different settlements.

In order to sample the number of tourists and the distribution of the total numbers of tourists of the years 1992 and 2005, this study has considered **tourist origins** (country) and their percentage out of the total number of tourists from the years 1996 and 2006. The average percentage was taken from both years of each country. Based on this average percentage the total number of sample tourists was distributed (see table 17). Similarly, the total number of tourists that visited Sagarmatha National Park and Buffer Zone in the years 1992 and 2005 was also distributed based on this average percentage to the respective countries. Whereas, in the case of other European and Asian countries, this study considered sample numbers consulted with the tourist guides who have been working in this region for a long time (see table 18). In addition, the total number of tourist data from the years 1992, 1996, 2005 and 2006 were obtained from the Sagarmatha National Park entry check post at Jorsalle.

Table 17: Sample number of tourists included in the survey from the different countries

Country	Sample number
UK	11
Japan	11
Germany	11
USA	12
France	8
Australia	8
Netherland	1
Switzerland	2
Canada	4
Austria	2
Italy	3
Denmark	1
Spain	2
Russia	1
Other Europe	8
Asia	17

Table 18: Sample number of tourists included in the survey from the Asia and other European countries

Country	Sample number
Belgium	4
Norway	2
Portugal	1
Poland	1
Korea	4
India	3
Thailand	2
China	4
Singapore	2
Indonesia	1
Malaysia	1

The survey was carried out by providing **photographs** of all land cover types to each tourist. They were asked to rank their satisfaction level derived from the particular land

cover type out of their total expenditure. Similarly, a study of the Beza (2010) used photographs to assess the aesthetic value of the region. The photographs which were used in the survey were taken from the study of Bajracharya et al. (2009). They took these photographs during field verification in developing land use and land cover maps of the region. Those pictures were scanned and printed in good quality on A4 sized sheets. The tourists also had the option for evaluation on a scale consisting of; 0= no relevant capacity, 5= low relevant capacity, 10= relevant capacity, 15= medium relevant capacity, 20= high relevant capacity and 25= very high relevant capacity of a particular land cover type (i.e. the relevant capacity of a particular land cover type is based on tourist satisfaction level about the particular land cover type out of his/her total expenditure). Each tourist was asked to assign values up to 100.

3.4.2 Personal interviews

Interviews were targeted to **different groups** such as lamas and monks, local people, teachers, tourist guides and porters, trekking agencies, weekly Namche market business people, and government and non government organizations. The participants were selected non-randomly. The interviews were unstructured and each personal interview was lasted between 15 and 60 minutes.

Monastery lama and monk

Interviews with lamas and monks took place in forty-one **religious** sites (gompa, charten and temples). Each lama and monk was asked regarding the history of the religious sites and their roles in the vicinity. In addition, the amount of donation collection per religious site per year and the number of tourists and local people visiting the religious sites per day were asked in each interview.

Namche weekly market business people

Four participants were interviewed. Two participants attributed to **livestock** products business were asked regarding the tourism role in livestock compositions and numbers. The other two participants were asked about the sources of bamboo and its conditions.

Teachers

These group interviews were placed in the Khumjung, Thame, Chaurikharka and Lukla schools. Each interview included questions regarding the trends of the number of **students** and status of the education in the region. Also the impacts of tourism and climate change in the region were objectives of the interviews.

Tourist guides and porters

Fourteen participants were interviewed on this group. Nine tourist guides were asked for the number of important **tourist sites** and the tourist's opinions about them, the average number of zopkios used for transportation, the average total expenditure of money per trip per tourist according to their nationality, and the average money donated per tourist per religious site. Five porters were asked about their problems and their salaries per trip.

Trekking agencies

These group interviews were carried out with twenty **trekking agencies** of Kathmandu city. 7 trekking agencies have been established before the year 1991 and the rest before 2004. This study covered only trekking agencies that have been established before the year 2004.

Each trekking agency was asked about the **total cost** (including two-way tickets) per trip per tourist that was charged to visit Sagarmatha National Park and Buffer Zone in the years 1992 and 2005. In addition, it was asked which countries are the origins of most of the **Everest trip customers**.

Local people

Thirty local people were interviewed in different settlements. They were asked about their **perceptions and experience** regarding tourism development and climate change in the region. Furthermore, Sherpa history, local cultural practices, and the role of the national park were items of these surveys.

Government and non-government organizations

Nine organizational staff members were interviewed. They were asked about their **organization's role** in the region. Also, the attitudes of local people and their expectations regarding the respective organization were asked. In addition, experience regarding climate change and tourism induced impacts in the region were asked for them.

3.5 Provisioning services

3.5.1 Fuelwood

The potential **supply of fuelwood** from shrub land and forest (needle leaved, broad leaved and multilayer mixed forest) data were based on the literature review; mainly referring to the studies of Ledgard (2002a, 2002b), Stevens (2003), Sherpa (2007), Sherpa (1979) and World Wildlife Fund-Nepal (2003). I have considered 2500 tons of fuelwood as annual requirement of the park people based on the reported value of Stevens (2003). That value is similar to the findings of Sherpa (1979). I have also considered that half of the annual requirements of fuelwood were supplied from the park forests and the shrub land based on Ledgard (2002a, 2002b). The study of World Wildlife Fund-Nepal (2003) reported an area of shrub land which is five times higher than the forest land in the Park. Based on the above reported values, this study has assumed that 70 percent of the used fuelwood was supplied by shrub land out of 1250 tons of annual requirement. Then the supply of fuelwood per hectare of shrub land was evaluated. The total annual supply of fuelwood of the whole region reported in the study of Sherpa (2007) was deducted from the shrub land's potential. The derived value was distributed to the potential of the broad leaved, needle leaved and the multilayer mixed forest, based on the field visit observations concerning the respective forest conditions.

The **demand for fuelwood** was obtained through the questionnaire surveys. The average value of household fuelwood consumption was evaluated considering all land cover types because the fuelwood consumption patterns were similar in the households of all land cover types. On the other hand, the consumption patterns are different with respect to the hotels/lodges. Therefore, the average value of the hotel/lodge fuelwood consumption was evaluated according to the particular land cover type.

3.5.2 Potatoes

In the Khumbu region 90 percent of agricultural land belong to potato farming fields (Fisher, 1990). Therefore, this study has considered only **potatoes** in the case of crops. The supply and demand data of potatoes were obtained through household and hotel/lodge questionnaires. In addition, both average production and demand of potatoes per hectare was determined based on the average value of the total respondents belonging to the particular land cover type.

3.5.3 Livestock products (butter and milk)

The production and consumption data of the livestock products (butter and milk) were obtained through the household surveys. This study has considered milk production only from **cows** and butter production from **naks**. Even though, some of the families made butter from cow's milk, but that is a very small percentage.

3.5.4 Transportation via livestock

Transportation based on livestock in the region is one of the key **earning sources** of the local people. This income source is widely popular because of a lack of other means in transporting tourist loads. So far, this service has not been included as ecosystem services in any other study but it has to be accounted here due to the special conditions of the study site.

This study has considered only the zopkios as a **packstock** for transportation even though some of the yaks and horses are used but only in a very small number. It has been assumed that the total numbers of zopkios available in the settlements are used only three months per year on a daily basis. Furthermore, the income of Nepali Rs 180 per zopkio per day and Rs (760/zopkio*day) of the years 1992 and 2005 was based on the value reported in the studies of Stevens (1993) and Chettri (2005). It has been considered that 1 US $ = 37 NRs, and 1 US $ = 70.65 NRs respectively for the years 1992 and 2005.

3.6 Regulating services

3.6.1 Soil erosion

The data of soil erosion are based on a literature review including (Byers) 1987, Watanable (1994), Schaffner (1987) and Ries (1993). Besides the study of the Byers

(1987), also findings from other **high mountain** parts of Nepal such as Langtang, Bamti-Bhandara, Dandapakhar and Bonch have been taken into account. The altitude thus varies between 1700 m and 4900 m.

Forest soil erosion data are based mainly on the study of Byers (1987). Byers reported soil erosion values between 0-1 t/ha*season for the moist subalpine forest. The average value of this figure was considered for broad leaved soil erosion data. On the other hand, this value was also estimated based on the study of Chalise (1997). He noted that the average value for forests is 0.6 t/ha*year while Ries (1993) found 1.4 t/ha*year. I have considered the average value from these figures for broad leaved forest. This value was also considered while estimating the data for other forest types.

Byers reported a **soil erosion** value between 0-2 t/ha*season for dry subalpine forests. The average value of these numbers was considered for soil erosion of needle leaved forest in this study. The soil erosion value for multilayer mixed forest was assumed from the average value between broad leaved and needle leaved forests. Byers estimated soil erosion data for the subalpine shrubland/grassland between 0-2 t/ha*season. This maximum value was assumed for the shrub land soil erosion data. In the Byers study, forest values were not specified according to the types of forest. Therefore, based on the field observations of current forest conditions this value was roughly distributed to the soil erosion potentials of broad leaved, needle leaved, multilayer mixed forest and shrub land types. The close to open herbaceous vegetation soil erosion data are based on the findings of Byers (1987) and Watanable (1994). Byers has reported soil erosion in the pasture land between 2.22 and 16.93 t/ha*year. Similarly, Watanable has evaluated soil erosion in the pasture land between 0.43 and 2.95 t/ha*year. This study has taken average value between the maximum value of Byers and the minimum value of Watanable. The bare soil data are based on the findings of Byers (1987) and Shaffner (1987). Their estimated values range between 16.9 - 66.6 t/ha*year. Based on the field observations of this land cover type, I have roughly assumed 41 t/ha*year for bare soil. The soil erosion data of the cultivated area were based on the study of Ries (1995). He has reported about a soil erosion in potato cultivations of 13 t/ha*year. The reference data do not totally match each specific land use type of the Khumbu. Therefore, the soil erosion amounts of each land use type were estimated on the base of field observations (exposures of tree

roots and depth –loss of the A and B horizons of the soil profile), interpolating between the reference types.

3.6.2 Carbon production

This item was assessed on the amount of fuelwood consumption in the households and hotels/lodges. It has been considered that carbon production is related only to **cooking sources** because the supply of carbon in the region, besides fuelwood, is very small. The estimated amount of carbon emission per kg of fuelwood was based on the values from the study of Pradhan et al. (2009). They reported that one kg of fuelwood consumption produces 3.48 gram of carbon monoxide. Due to the limitation of the data concerning carbon dioxide production from the burning fuelwood source, Pradhan reported figures have been assumed as carbon dioxide production values.

The data of the carbon sink potential of different land cover types were based on a literature review (Baskota et al., 2007; Water and Energy Commission Secretariat-Nepal, 2001 and HMG/ADB/FINIDA, 1998**).** Due to the limitation of the carbon sink data for the direct study site, this study here also considered findings of other parts of Nepal. It is true there is a lack of high level **scientific research** concerning this topic in Nepal. Some studies however presented rough estimations. These data are not specified according to the types of forest covers. Thus, based on the field observations rating the reported values are distributed to represent data of different forest covers. HMG/ADB/FINIDA reported a value of 1.78 t/ha*year which has been considered for broad leaved forest. Similarly, Baskota et al. (2007) reported values of 1.41 t/ha* and 1.13 t/ha*yr for multilayer mixed and needle leaved forests, respectively. The Water and Energy Commission Secretariat-Nepal reported values of 0.294 t/ha*year and 0.042 t/ha*year for shrub land and closed to open herbaceous vegetation, respectively.

3.7 Cultural services

3.7.1 Religious value

The investigations of Huntington (1993, 1996a,b, 1997), Inglehart (1995, 1997), Inglehart and Baker (2000), Inglehart and Flanagan (1987) and Norris and Inglehart (2003) reveal interesting **relationships** between religious sites and the economic development of the regional society.

The number of **religious sites** in a particular land cover type was determined through field observations. Furthermore, the number of religious sites per hectare in a particular land cover type was estimated based on the reported area of land cover types in Pradhan-HKKH partnership project/ICIMIOD-Nepal (2009). Based on the local peoples' views and the oral histories of the **gumpas** (see also chapter two) this study has assumed that every religious site has a place based meaning. On behalf of this meaning, it has been considered that the amount of donation received by the religious sites per year in the particular land cover types represents the supply of religious value of that land cover type.

The demand data of the religious value were estimated based on the household time spent on visiting the **gumpas** per year. This spending time was calculated in terms of money on the basis of the households' yearly income. The demand for religious values of the land cover type was derived based on the average time spent and the average income of households belonging to the particular land cover type.

3.7.2 Aesthetic value

The supply aesthetic values was quantified through the following steps: firstly, the average assigned value attributed to the particular land cover type was determined among the **tourists** from the same country and secondly, this value was multiplied with the number of tourists from that particular country out of the total numbers of tourists in the respective year. Thirdly, this figure was multiplied with the total costs per trip per tourist, which were found in interviews with trekking agencies. The expenditure of travelling costs money per trip was classified based on the continents which the tourists come from. For example, all the countries of Europe besides United Kingdom were assigned to the

same costs, similarly, Asia and SAARC (South Asian Association for Regional Cooperation) countries.

3.8 Supply, demand and balance map of ecosystem services

The supply and demand data of the selected services were transferred into scale based values ranging from 0 to 5 in the assessment matrix. After transferring both data on a similar scale, these assessment matrices were saved in dbf file and related to the respective land cover types in the **Arc View software**. Each service supply and demand map was produced through the following steps: Firstly, *class-name* in the attribute table of land cover class and secondly, *land cover types* of the assessment matrix were selected respectively for each service. Each assessment matrix was joined with the respective land cover by using the "Join" key option. The unique value was selected in the legend type. Similarly, the particular ecosystem service was selected in the value field of the legend editor of the land cover shape file to produce a map. The information in the maps of supply and demand was merged to analyse source and sink dynamics of selected services in terms of balance maps.

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4 Results

This chapter presents results concerning the major changes in the land use form of the Sagarmatha National Park and Buffer Zone. The changes in the different land cover types will be presented based on the different drivers. In addition, the trends in supply and demand of ecosystem services in relation to landscapes dynamics will be presented.

4.1 Changes in land use

The land use maps of the years 1975, 1992 and 2000 are presented in figures 23, 24 and 25. The areas of the five **land use classes** (vegetation cover, lake, glacier cover, glacier retreat cover and bare rock cover) during the three periods are shown in figure 22. In 1975, the land use form of Sagarmatha National Park comprises 38.69% of vegetation cover, 0.88% of lake, 39.88% of glaciers/snow, 4.6% of glacier retreat and 15.91% of bare rock. In 1992 the distribution is: vegetation covers 38.39%, lakes 0.27%, glacier/snows 32.98%, glacier retreats 10.83% and bare rocks 17.51%, and in 2000 I find vegetation covers 38.57%, lakes 0.33%, glacier/snows 23.79%, glacier retreats 14.45% and bare rocks 22.84% respectively.

Among these five land use classes, **vegetation cover** remained unchanged from 1975 until 2000. In 2000, glacier/snow melted and lakes shrunk approximately by 59% and 37% of the area from 1975. Glacier retreats and bare rocks increased around two and a half times between 1975 and 2000 respectively. In addition, vegetation cover decreased slightly during the first (1975-1992) period but increased during the second (1992-2000) period with low percentage. Comparing the forest area within the vegetation cover between 1992 and 2000, the forest area decreased slightly in 2000 which is shown in table 19.

Table 19: Areas in km² of the forest land use during 1992 & 2000 time period in the Sagarmatha National Park

Year	**Forest area (km²)**
1992	27.51
2000	26.37

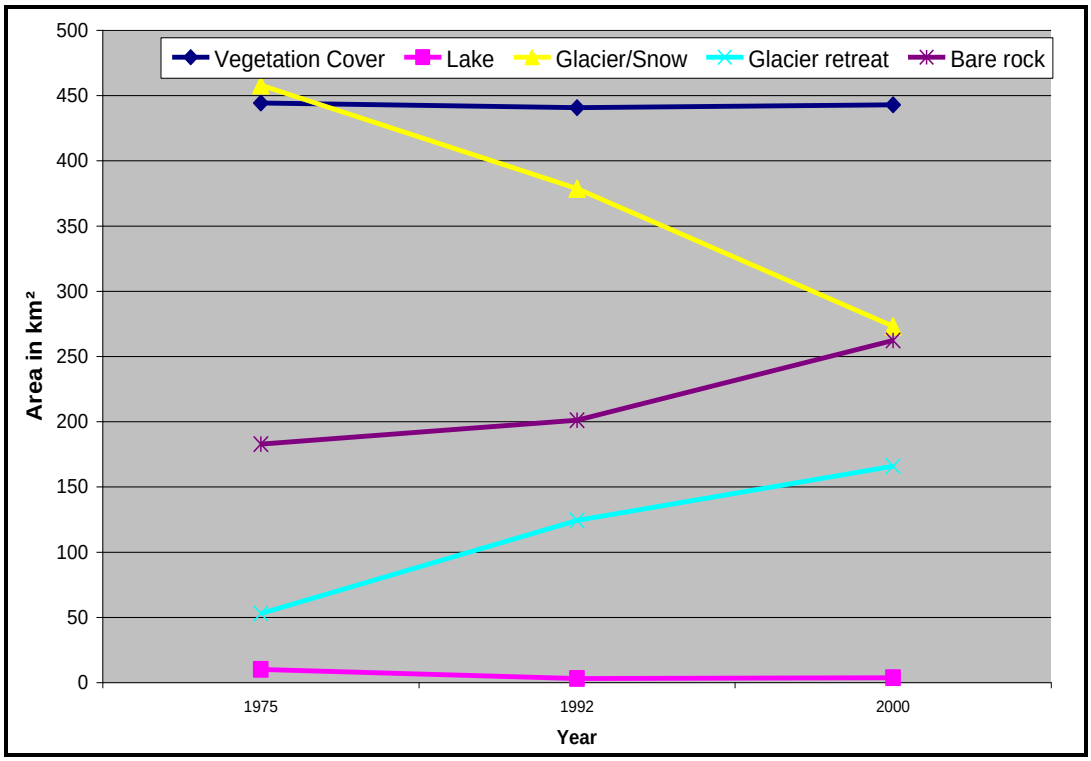


Figure 22: Changes of the land covers in the three observed period (1975, 1992 and 2000) based on the analysis of satellite images.

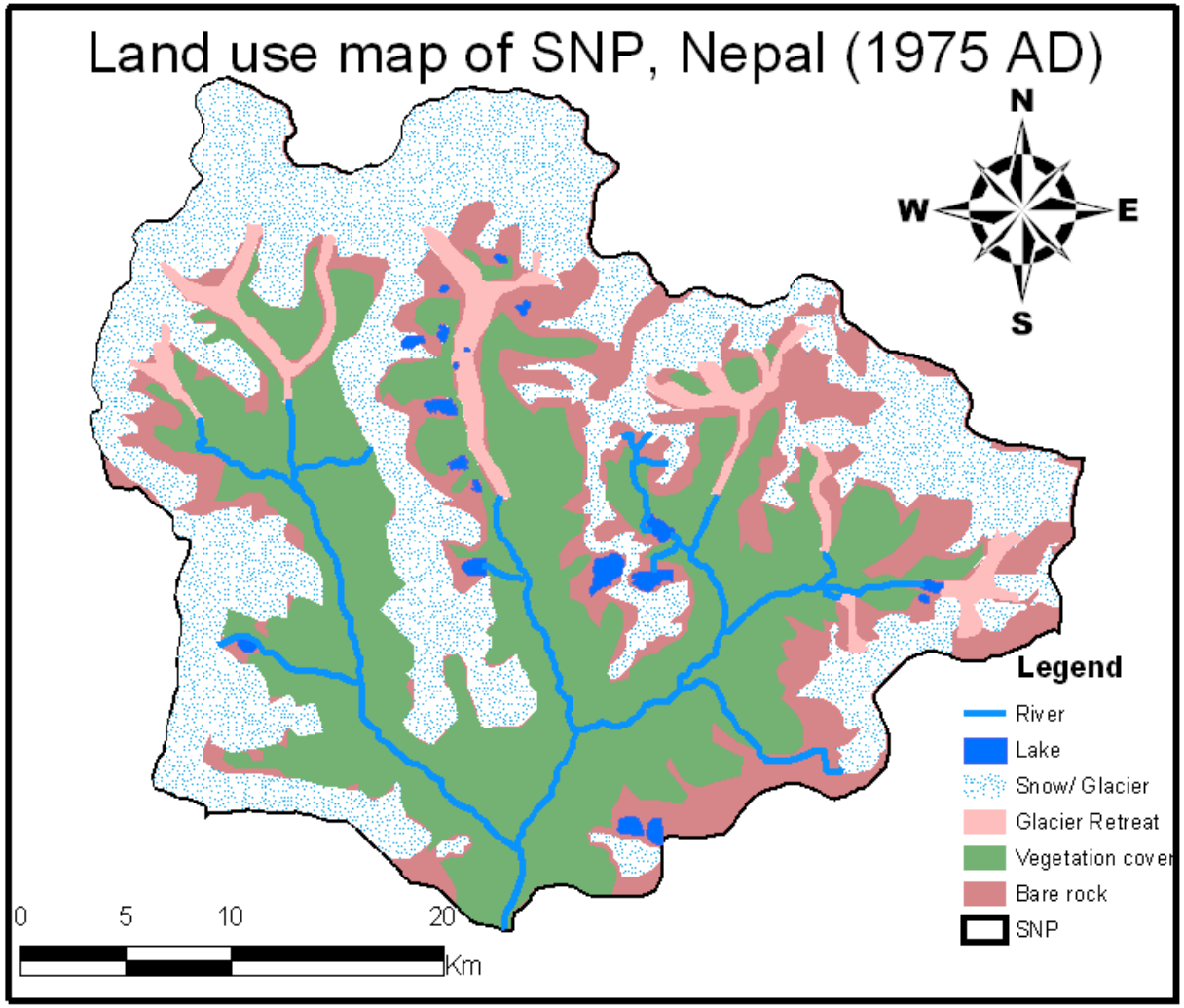


Figure 23: Land use map of SNP (Sagarmatha National Park), Nepal 1975.

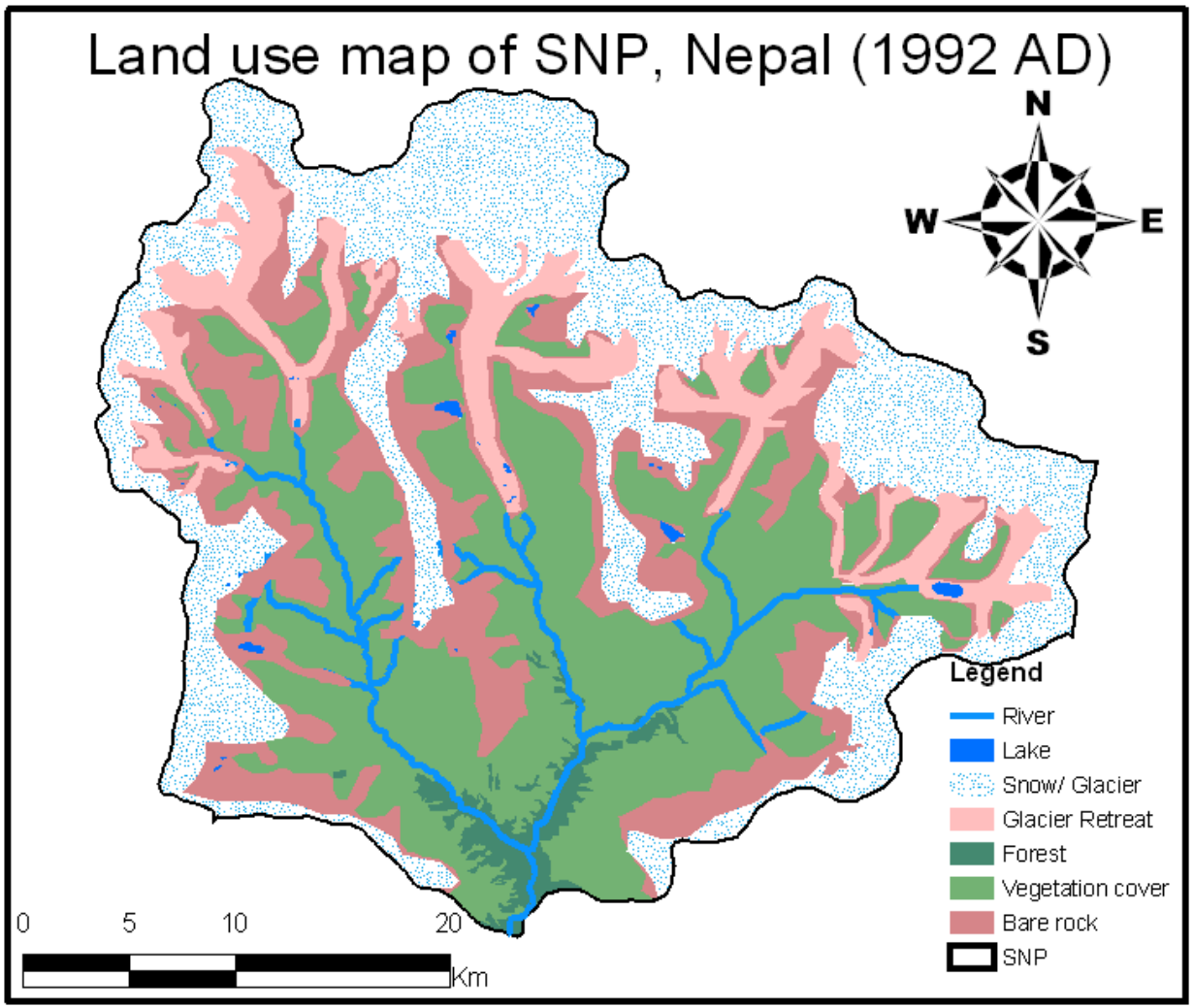


Figure 24: Land use map of SNP (Sagarmatha National Park), Nepal 1992.

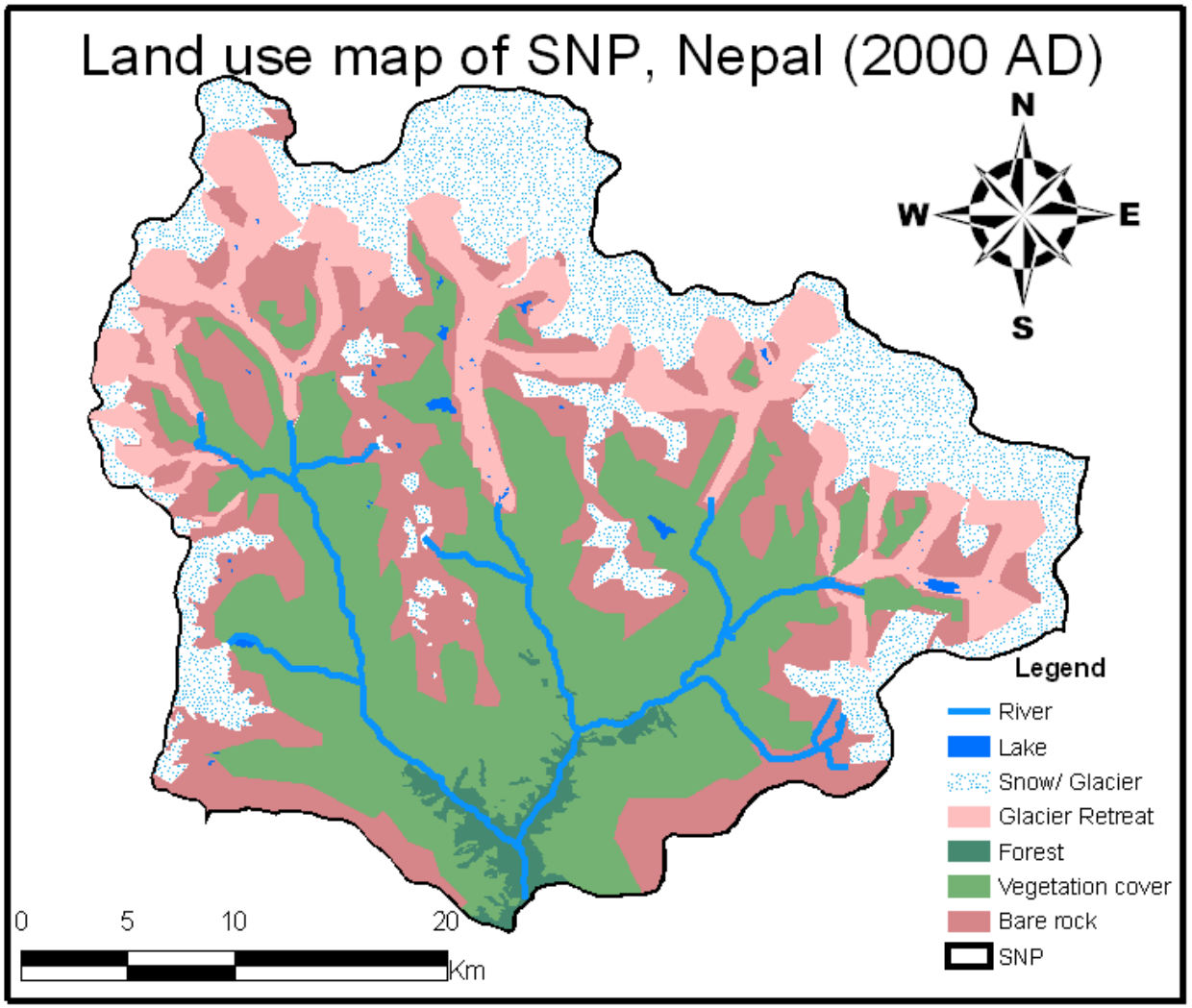


Figure 25: Land use map of SNP (Sagarmatha National Park), Nepal 2000.

4.2 Changes in the inhabited settlements of the different land cover types

4.2.1 Growth of number of households and lodges

The total number of **households** and lodges in the whole region of the years 1992 and 2005 are presented in figure 26. The total numbers of households and lodges were estimated through questionnaire surveys. The total number of the households has reached 1058 and 1137 respectively during 1992 and 2005, in which the total number of the households has increased by 7% between 1992 and 2005. In 1992, the land cover types cultivated area, shrub land, bare soil, needle leaved forest, broad leaved forest, multilayer mixed forest, built up area, closed to open herbaceous vegetation, and the gravel stone and boulders constituted 66.26%, 10.89%, 0.17%, 3.3%, 2.46%, 5%, 9.65%, 0.27% and 2% households out of the total number of households. Whereas, during the year 2005, these land cover types constituted 66.5%, 11.53%, 0.17%, 3.51%, 2.55%, 5.01%, 8.18%, 0.27% and 2.28% households respectively out of the total number of households. Between 1992 and 2005, the total number of households remained the same in the bare soil and closed to open herbaceous vegetation land cover types. Similarly, the total number of households decreased in the built up area between 1992 and 2005 because traditional households were transformed into inns. The total number of households has increased in the cultivated area, shrub land, needle leave forest, broad leaved forest, multilayer mixed forest, and the gravel stone and boulders land cover types. Among these six land cover types, the cultivated area has a higher number of households and the broad leaved forest has a smaller number of households.

The total number of **lodges** reached 158 and 307 respectively in the years 1992 and 2005. Along with the development of tourism, the number of lodges has rapidly increased, which can be observed in figure 26. Most of those lodges are situated on the trekking route site villages. During the year 1992, the land cover classes; cultivated area, shrub land, bare soil, needle leaved forest, broad leaved forest, multilayer mixed forest, built up area, and gravel stone and boulders land cover types constituted 60.76%, 11.39%, 1.26%, 3.8%, 1.9%, 1.9%, 16.45% and 2.53% lodges out of the total number of lodges. Whereas, in 2005, these land cover types constituted 64.17%, 11.73%, 1.3%, 2.93%, 1.3%, 1.3%, 15.63% and 1.63% lodges out of the total number. The total number of lodges increased in all the land cover types between 1992 and 2005.

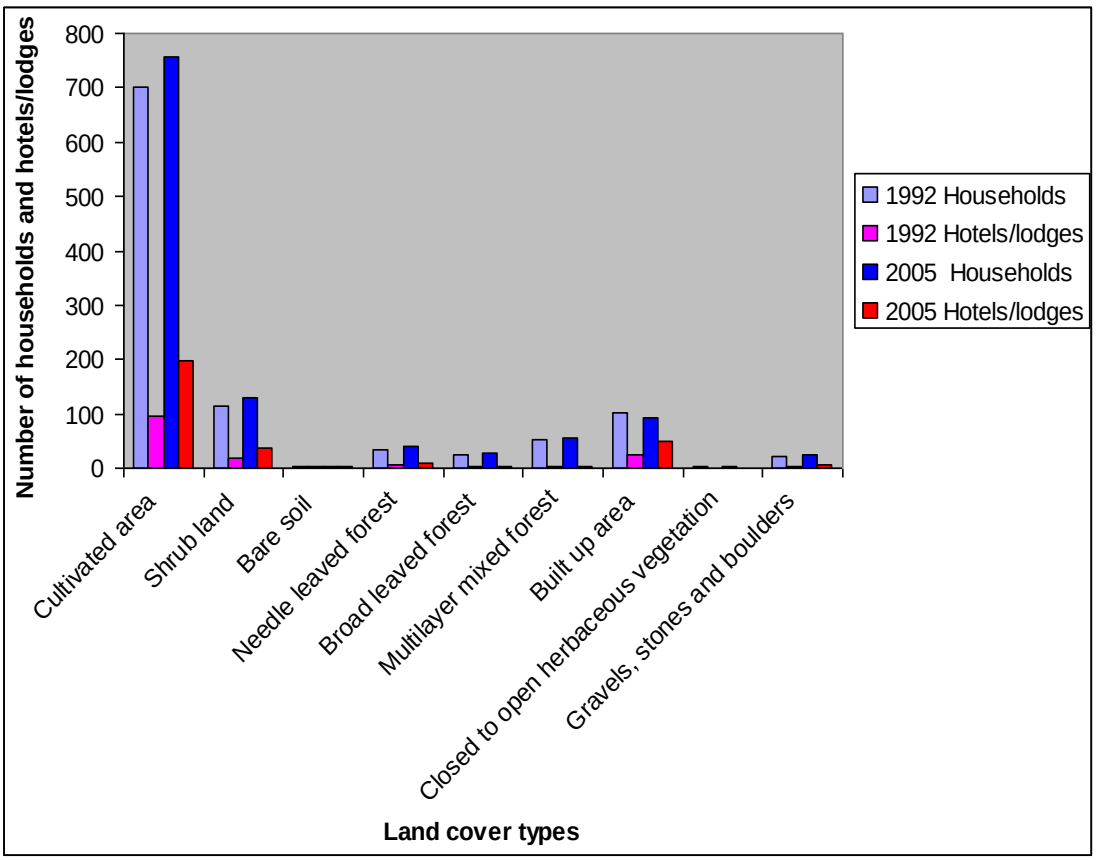


Figure 26: Total number of households and lodges in different land cover type's settlements.

The number of households including lodges per hectare in each land cover type of the years 1992 and 2005 are presented in table 20. The built up areas and the cultivated areas had higher number of households, whereas, the bare soil and the closed to open herbaceous vegetation had a few number of households in years, 1992 and 2005.

Table 20: Number of households including lodges per hectare of each land cover type in the years 1992 and 2005

Land cover Types	Number of household per hectare (1992)	Number of household per hectare (2005)
Bare soil	0.0001	0.0002
Broad leaved forest	0.014	0.012
Needle leaved forest	0.013	0.014
Multilayer mixed forest	0.011	0.016
Cultivated area	0.86	1.06
Built up area	3.45	3
Shrub land	0.008	0.01
Closed to open herbaceous vegetation	0.0004	0.0003
Gravels, stones and boulders	0.0058	0.011

The total number of **religious sites** (monasteries, temples and chartens) in the whole region totalled 41 sites in the years 1992 as well as 2005. Out of this number, 27 sites are located in the shrub land. Similarly, the cultivated area, multilayer mixed forest, built up area, needle leaved forest and the broad leaved forest possess 2, 2, 1, 8 and 1 sites respectively in both years. The built up area, multilayer mixed forest, cultivated area, needle leaved forest, broad leaved forest and the shrub land constituted 0.027, 0.0004, 0.002, 0.0047, 0.005 and 0.0016 religious sites per hectare respectively.

4.2.2 Increases of the household members

The average number of **household members** of 1992 and 2005 are presented in figure 27. Among all the land cover types, the shrub land constituted a higher average number of household members in 1992, similarly, during 2005, the broad leaved forest and the shrub land constituted a higher average number of household members. Whereas, the built up area, bare soil and the closed to open herbaceous vegetation constituted of few household members in 1992 and 2005. The average number of household members increased in all the land cover types between 1992 and 2005. The average number of household members of the whole region was of 4.82 and 5.15 persons per household respectively in 1992 and 2005.

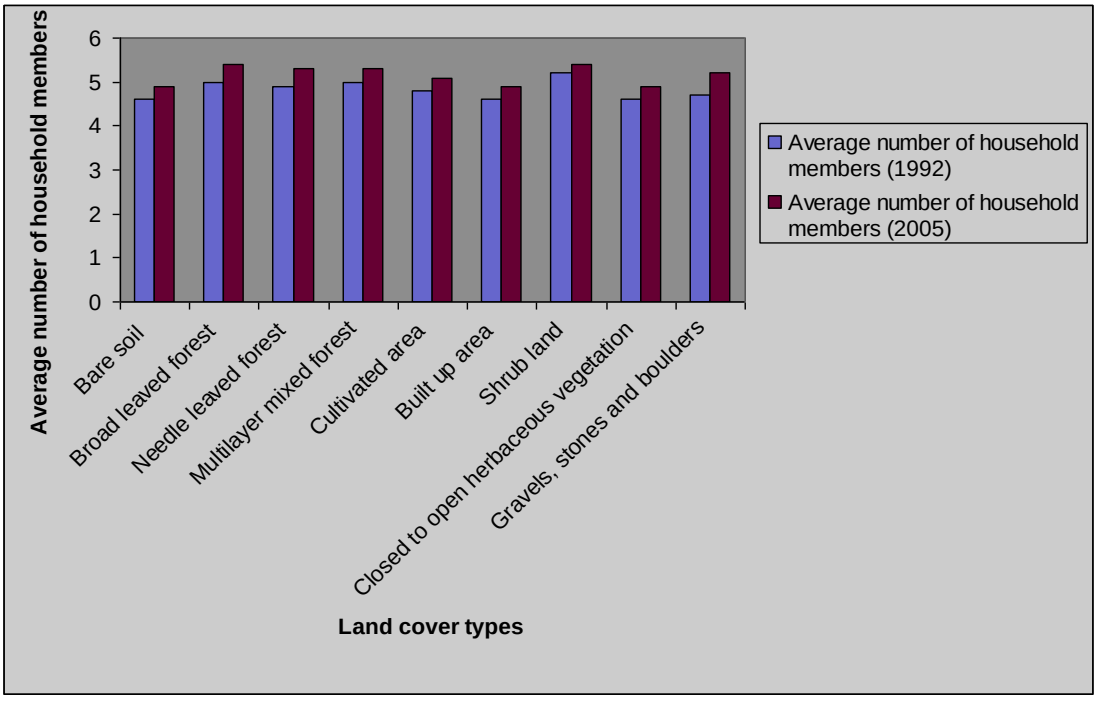


Figure 27: Average number of household members in 1992 and 2005.

4.2.3 Increases of the household yearly income

The average **household annual incomes** of 1992 and 2005 are presented in figure 28. During 1992, the average household yearly income ranged between US $ 1070 to 4183, whereas, during 2005, the average household yearly income ranged between US $ 1358 to 4959. Furthermore, among all the land cover types, the built up area households constituted higher average household yearly income both in the years 1992 and 2005, whereas, the low average household yearly income was attributed to the closed to open herbaceous vegetation. The average household income increased in the cultivated area, shrub land, bare soil, needle leaved forest, broad leaved forest, multilayer mixed forest, built up area, closed to open herbaceous vegetation and the gravels, stones and boulders land cover types by 27.12%, 54.94%, 19.03%, 35.40%, 34%, 61.15%, 18.55%, 26.91% and 73.81% respectively between 1992 and 2005.

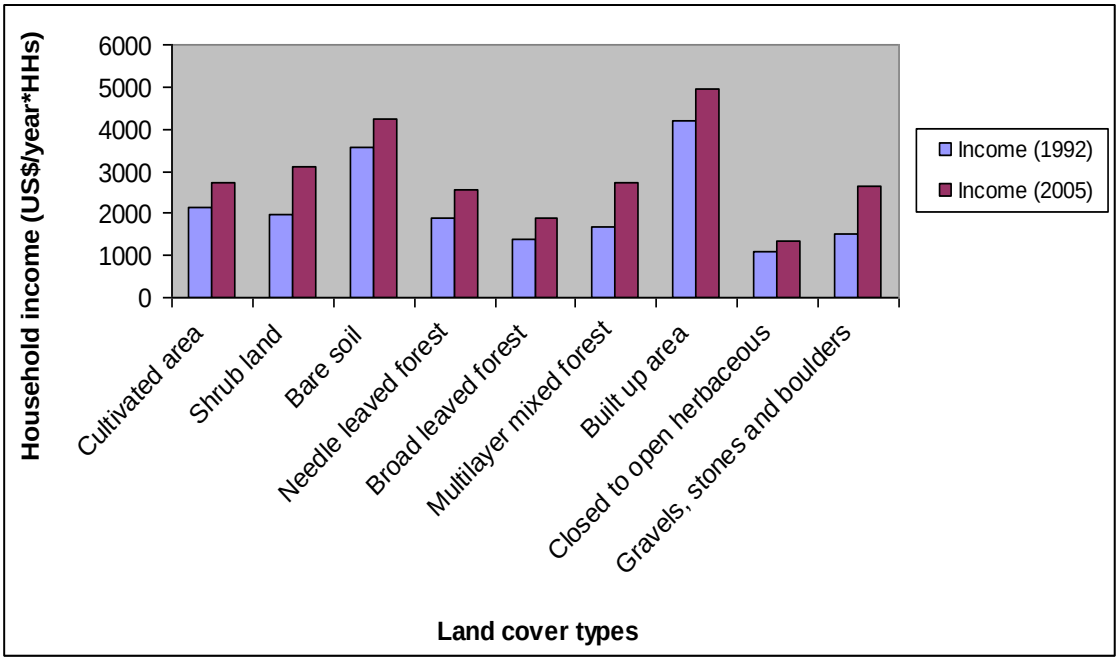


Figure 28: Average household incomes in 1992 and 2005.

4.2.4 Changes in the household's time spent on religious purposes

The average household times spent in **visiting religious sites** (monasteries, temples and chartons) in 1992 and 2005 are presented in figure 29. Based on the household questionnaire, times spent in religious sites have been estimated. Among all the land covers, the built up area households spent an average time of 121 hours/year*household in the year 1992, similarly, the cultivated area households also recorded a high average time in visiting religious sites; 122 hours/year*household during 2005. The closed to open herbaceous households spent a

smaller average time of 55 hours/year*household in 1992. Similarly, the bare soil and the closed to open herbaceous households spent a time of only 49 hours/household*year each in 2005. Those households in the other land cover types; shrub land, needle leaved forest, broad leaved forest, multilayer mixed forest and the gravels, stones and boulders spent an average time between 61 to 109 and 61 to 103 hours/household*year respectively in 1992 and 2005. Between 1992 and 2005, the average household time spent in visiting religious sites increased in the cultivated area, shrub land and the broad leaved forest by 34.06%, 30.37% and 19.67% respectively. But the households in the other land cover types the bare soil, needle leaved forest, multilayer mixed forest, built up area, closed to open herbaceous vegetation and the gravels, stones and boulders recorded a decreased time spent by 32.87%, 27.52%, 11%, 29.75%, 10.90% and 22.78% respectively over the 14-year period. Beside the built up area households, most of the people from other settlements involve in the tourism works such as trekking guides, porters, supply of foods and livestock products to the lodges, than before. The households of built up area settlements "Namche" remains most of the time busy, because this place is the main tourist hub centre. Therefore, the households of this land cover possess decreased time spent in visiting religious sites. Whereas the households of cultivated area, shrub land and broad leaved possesses increased time spents because most of the households operated hotels and lodges. The visiting numbers of tourists are not high like Namche but also they receive good money. From these incomes they hired employee to do their mundane activities, which led more spare time from them. Due to the Buddhism motivations and lack of alternative recreation facilities such as parks, theatre and cinema hall, mostly they used spare time in religious purposes.

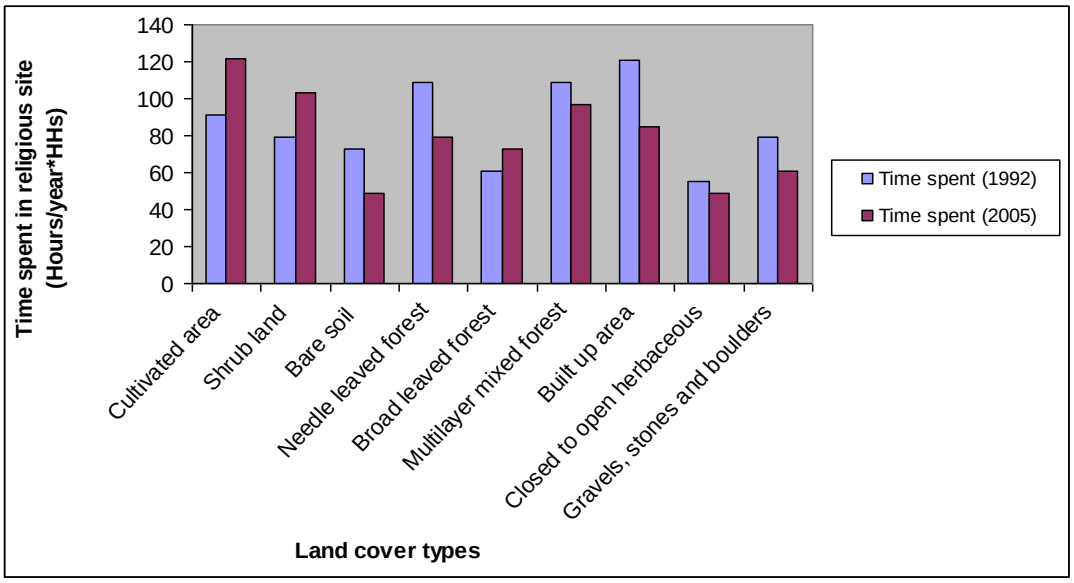


Figure 29: Average household's time spent in visiting religious sites of different land cover types in 1992 and 2005.

The average **household money spent** on religious purposes in terms of time given for visiting religious sites in relation with their monthly income of 1992 and 2005 are presented in figure 30. The higher average household money spent on religious purposes was attributed to the built up area in both years 1992 and 2005; 58.56 and 48.78 US $/year*household respectively, whereas, the low average household money spent on religious purpose was attributed to the closed to open herbaceous vegetation in both years; US $ 6.81 and 7.7 per year per household respectively. Between 1992 and 2005, the average household money spent on religious purposes increased in the cultivated area, shrub land, broad leaved forest, multilayer mixed forest, closed to open herbaceous vegetation and the gravels, stones and boulders land cover types by 77.40%, 102.25%, 60.52%, 43.39%, 13.06% and 34.43% respectively. Whereas, the average household money spent on religious purposes decreased in the bare soil, needle leaved forest and the built up area by 19.81%, 1.85% and 16.70% respectively over the 14-year period.

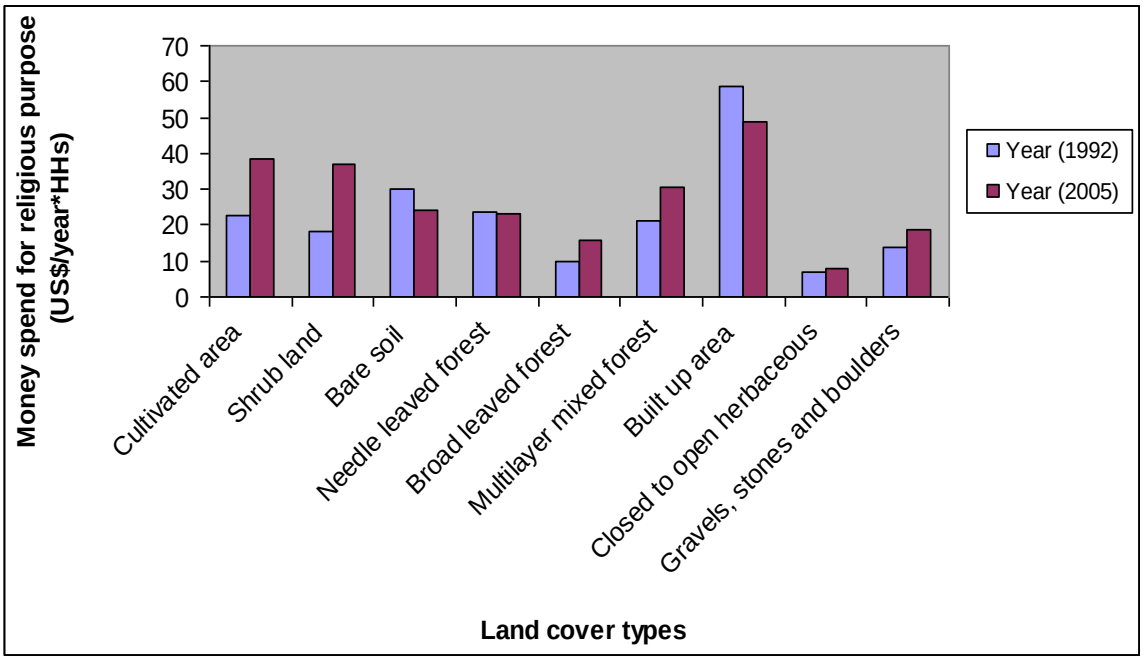


Figure 30: Average household money spent on religious purposes in different land cover types in 1992 and 2005**.**

4.2.5 Changes in fuelwood consumption patterns

The average quantity of the household **fuelwood consumption** of 1992 and 2005 in each land cover type settlement is presented in figure 31. The demand of fuelwood in the different settlements was estimated based on the questionnaire surveys. The average quantity of the household fuelwood consumption had almost similar patterns in all the land cover types. Furthermore, between 1992 and 2005, it decreased by 1.75 kg per household in all land cover types. Due to the promotion of alternative sources for cooking such as kerosene, solar panels and electricity a decrease in the fuelwood consumption has resulted. On the behalf of lodges, the average quantity of the fuelwood consumption also decreased by more than 19% in all the land covers types over the 14-year period. Among them, the built up area recorded a higher decrease of 36% between 1992 and 2005, because of the installation of solar panels for cooking purposes in most of the households. Similarly, the needle leaved and the multilayer mixed forest recorded a higher average quantity of the lodge fuelwood consumption, whereas, the shrub land recorded a small quantity of fuelwood consumption in both years 1992 and 2005.

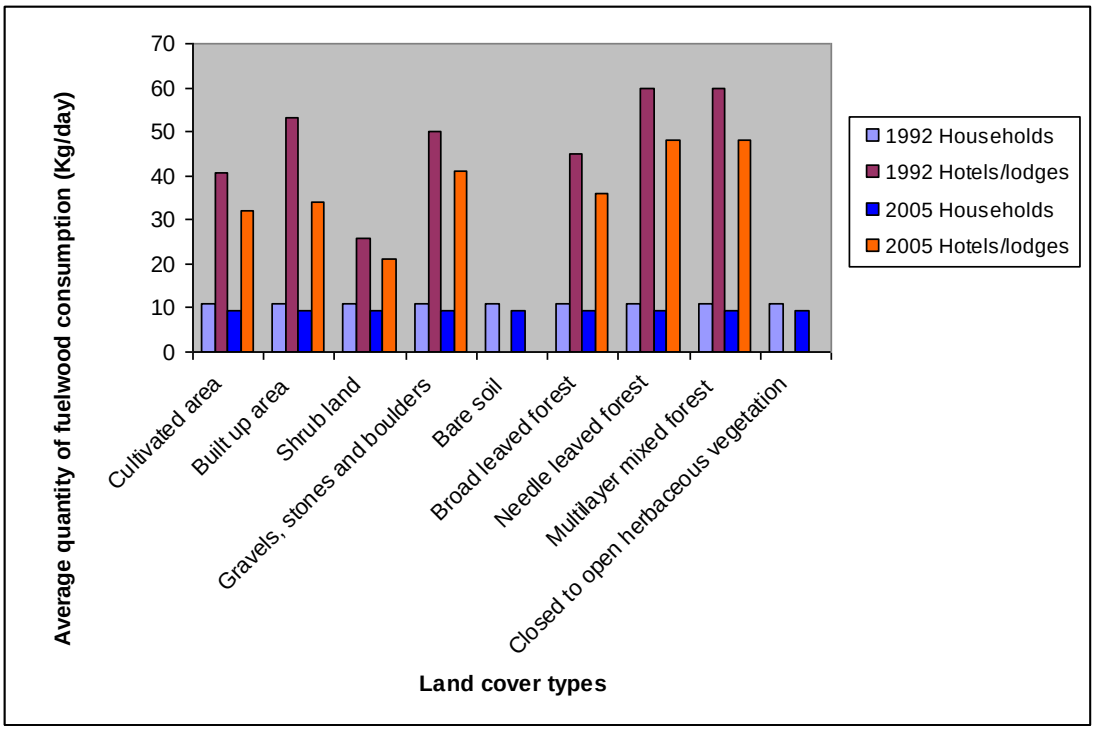


Figure 31: Average quantity of household and hotel/lodge fuelwood consumption.

4.2.6 Changes in the livestock numbers and compositions

The numbers of **livestock** and its compositions of 1992 and 2005 in each land cover type are presented in figure 32. The total numbers of livestock was estimated based upon questionnaire surveys. The total number of livestock reached 5819 and 6035 respectively in 1992 and 2005. This shows that the numbers have increased by 3.5% between 1992 and 2005. During 1992, the livestock such as cows, horses, yaks, naks and zopkios constituted 34.94%, 1.37%, 16.17%, 24.8% and 22.72% respectively out of the total number of the livestock, whereas, during the year 2005, they constituted 40.35%, 2.14%, 14.2%, 21.67% and 21.64% respectively out of the total number of livestock. Among them, between 1992 and 2005, the total number of yaks and naks decreased by 1.97% and 3.13% respectively, and cows and horses increased by 5.41% and 0.77% respectively. The numbers of yaks and naks have slightly decreased due to the meager returns, whereas cows and horses have been increased due to the tourism based affluence. The total number of zopkios has also slightly decreased by 1.08% over the 14-year period because the people are motivated in rearing horses mainly in the trekking route site villages. Out of the nine land cover types, the cultivated area constituted of higher numbers of all kinds of livestock and bare soil constituted of few numbers of livestock in both years 1992 and 2005.

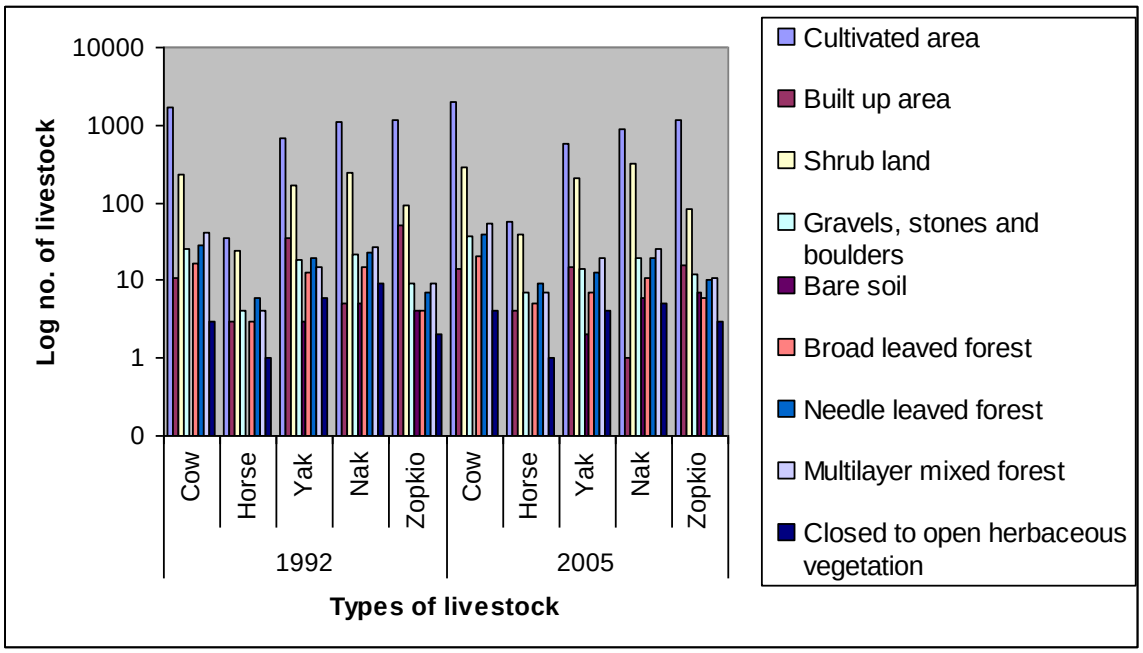


Figure 32: Total number of livestock attributed to the different land covers types of 1992 and 2005.

The total numbers of **cows** in each land cover type of 1992 and 2005 are presented in figure 33. Among all the land cover types, the cultivated area constituted a higher total number of cows; 1673 and 1984 cows respectively in 1992 and 2005. Similarly, the shrub land also

constituted higher total numbers of cows; 232 and 283 cows respectively in 1992 and 2005, whereas, the bare soil constituted null, and the closed to open herbaceous vegetation constituted only 3 and 4 cows in 1992 and 2005. Similarly, the other land cover types built up area, gravels, stones and boulders, broad leaved forest, needle leaved and multilayer mixed forest constituted between 11 to 42 and 14 to 53 cows in 1992 and 2005. Furthermore, the total number of cows increased in the cultivated area, built up area, shrub land, gravels, stones and boulders, broad leaved forest, needle leaved forest, multilayer mixed forest and the closed to open herbaceous vegetation land cover types by 18.58%, 27.27%, 21.98%, 42.3%, 23.52%, 34.48%, 26.19% and 33.33% respectively over the 14-year period mainly due to the tourism affluence as well as to represent the wealth of the families in the society.

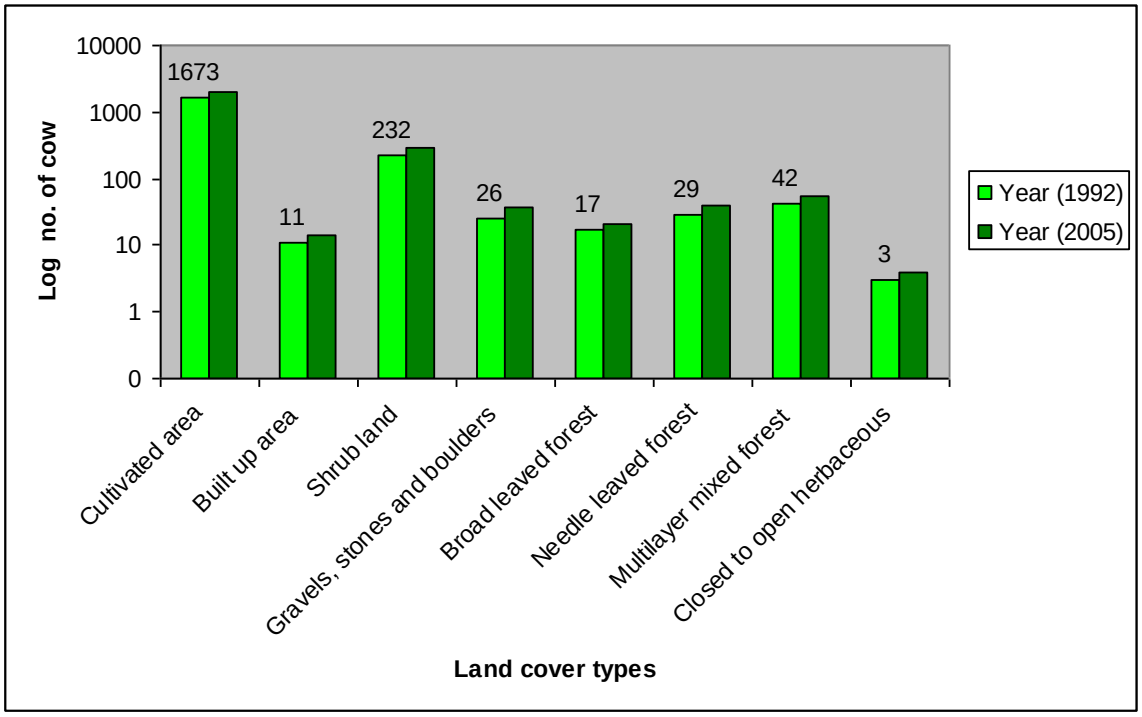


Figure 33: Total number of cows attributed to the different land covers types of 1992 and 2005.

The total numbers of **naks** attributed to the different land cover types of 1992 and 2005 are presented in figure 34. Among all the land cover types, the cultivated area constituted a higher total number of naks; 1094 and 901 naks respectively in 1992 and 2005. Similarly, the shrub land also constituted a higher total number of naks; 243 and 322 naks in 1992 and 2005, whereas the built up area and bare soil constituted less than 7 naks in both years 1992 and 2005, and even in the year 2005, nak remained absent in the built up area. The households of the Namche settlements (built up area) remain totally busy on operating lodges. Therefore, due to the shortages of manpower to tend the livestock, naks are not found in this area. The other land cover types provide the following numbers: open to closed herbaceous vegetation,

broad leaved forest, gravels, stones and boulders, needle leaved and multilayer mixed forest constituted total numbers of naks between 9 and 22, and 5 and 25 respectively in 1992 and 2005. Between 1992 and 2005, the total number of naks increased in the shrub land and the bare soil by 32.51% and 20% respectively. Whereas, the total number of naks decreased in the cultivated area, built up area, gravels, stones and boulders, broad leaved forest, needle leaved forest, multilayer mixed forest and the open to closed herbaceous vegetation by 17.64%, 100%, 13.63%, 26.66%, 17.39%, 7.40% and 44.44% respectively over the 14-year period.

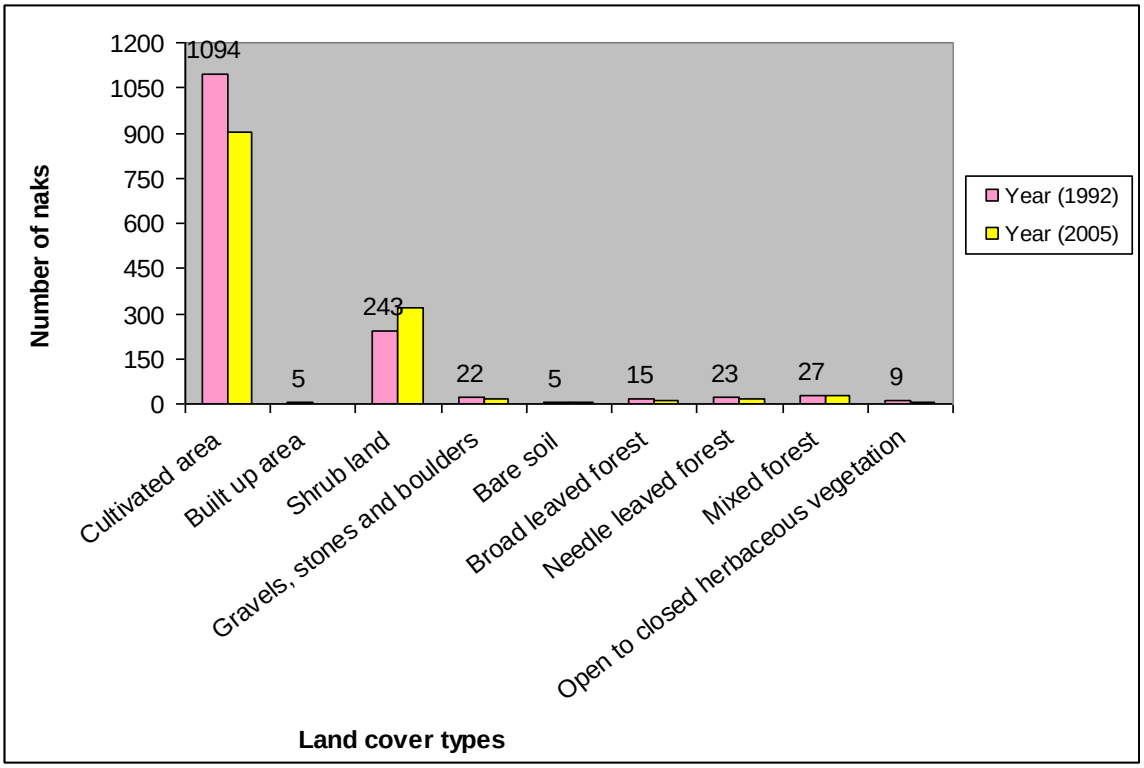


Figure 34: Total numbers of naks attributed to the different land cover types of 1992 and 2005.

The total numbers of **zopkios** attributed to the different land cover types of 1992 and 2005 are presented in figure 35. The cultivated area constituted a higher total number of zopkios in both years; 342 and 464 zopkios respectively, whereas, the open to closed herbaceous vegetation, bare soil and the broad leaved forest constituted less than 5 zopkios each in both years 1992 and 2005. Similarly, the other land cover types, gravels, stones and boulders, needle leaved and the multilayer mixed forest constituted 5-10 zopkios in both years. The shrub land and the built up area constituted of 30-42 and 11-52 zopkios respectively in 1992 and 2005. However, between 1992 and 2005, the total number of zopkios decreased in the built up area by 63.33%, whereas, the total number of zopkios increased in the cultivated area,

shrub land, bare soil, needle leaved forest, multilayer mixed forest and the closed to open herbaceous vegetation by 35.67%, 23.80%, 100%, 33.33%, 12.5% and 100% respectively over the 14-year period. Furthermore, between 1992 and 2005, the total number of zopkios remained unchanged in the gravels, stones and boulders, and the broad leaved forest land cover types.

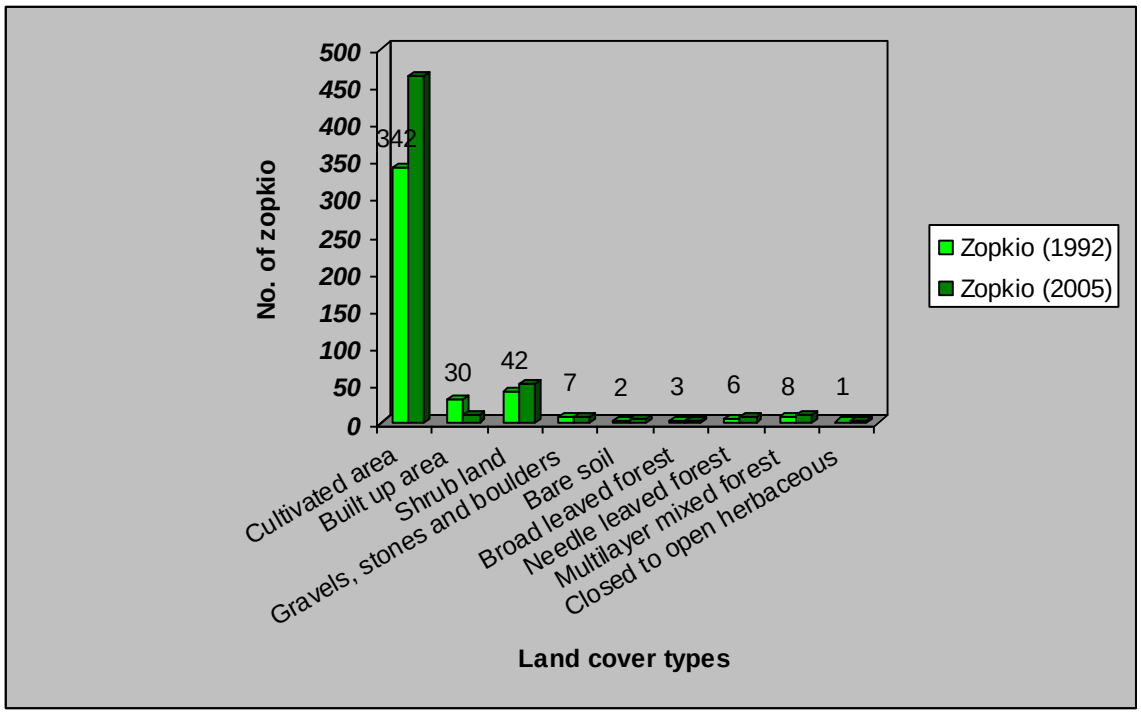


Figure 35: Total numbers of zopkios attributed to the different land cover types of 1992 and 2005.

4.3 Changes in tourism

4.3.1 Increases in the costs of Everest trips

The average costs per **Everest trip** per tourist based on the national origin of the tourists in 1992 and 2005 are presented in figure 36. The expenditure of travelling costs per tourist per Everest trip was obtained from the interviews with trekking agencies. The higher average cost per trip was attributed to the USA/Canadian tourists with US $ 1700 and 2600 per trip respectively in 1992 and 2005. Similarly, European tourists also had to spend high average cost: US $ 1400 and 2300 per trip respectively in 1992 and 2005, whereas, the SAARC (South Asian Association for Regional Cooperation) countries' tourists averaged between only US $ 650 and 1100 per trip respectively in 1992 and 2005. Similarly, the tourists from other Asian countries incurred an average cost of US $ 900 and 1400 per trip in 1992 and

2005. The Russian tourists spent an average of US $ 1100 and 1800 per trip and the Australian tourists spent between US $ 1300 and 2100 per trip in 1992 and 2005.

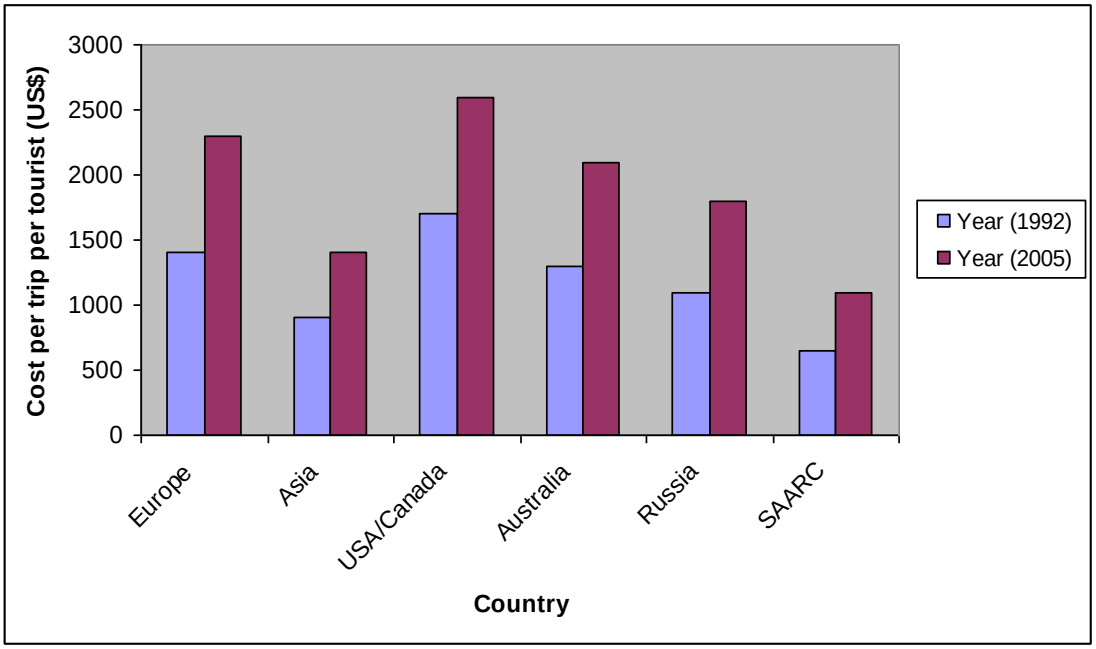


Figure 36: Average costs per trip per tourist based on origin (country) of 1992 and 2005.

4.3.2 Changes in the tourist expenditure

The average **money expenditures** per tourist attributed to the different land cover types based on the origin of the tourist for 1992 and 2005 are presented in figures 37 and 38**.** These values were determined through tourist surveys by providing photographs of land cover types to rank their satisfaction level derived from the particular land cover type out of their total expenditure. Based on this result, I have included only a few countries' results in this chapter, the other countries' list are provided in the Annex. Among all the land cover types, snow and glaciers provided a high satisfaction to all tourists from different origins i.e. these land cover types recorded higher average expenditures in both years 1992 and 2005. The amount ranged from US $ 110 to 380 to 170 to 510 per tourist respectively in 1992 and 2005 for all tourists from different origins. The built up area, shrub land, broad leaved forest and glacial lakes also recorded higher average expenditures between US $ 70 to 270 and 100 to 350 per tourist respectively in 1992 and 2005. The bare soils, bare rocks, closed to open herbaceous vegetation and the gravels, stones and boulders land cover types constituted a low average expenditure; almost less than 5% out of the total expenditure per tourist in most of the tourists cases are spent here. The needle leaved and multilayer mixed forest constituted an average expenditure of 10 to 15% out of the total expenditure per tourist. This is a sum between US $ 50 to 140 and 70 to 200 per tourist in 1992 and 2005. The snow land cover type constituted

almost 25% out of the total expenditure in all tourists' origin. However, besides visitors from Russia, the cultivated area constituted an average expenditure of less than 100 US $ in both years for all tourist's origins. The value remained zero for cultivated area in the case of UK. Similarly, the bare rocks and the bare soils constituted nil in most of the tourist's origins such as Japan, Russia, SAARC countries, UK and Germany.

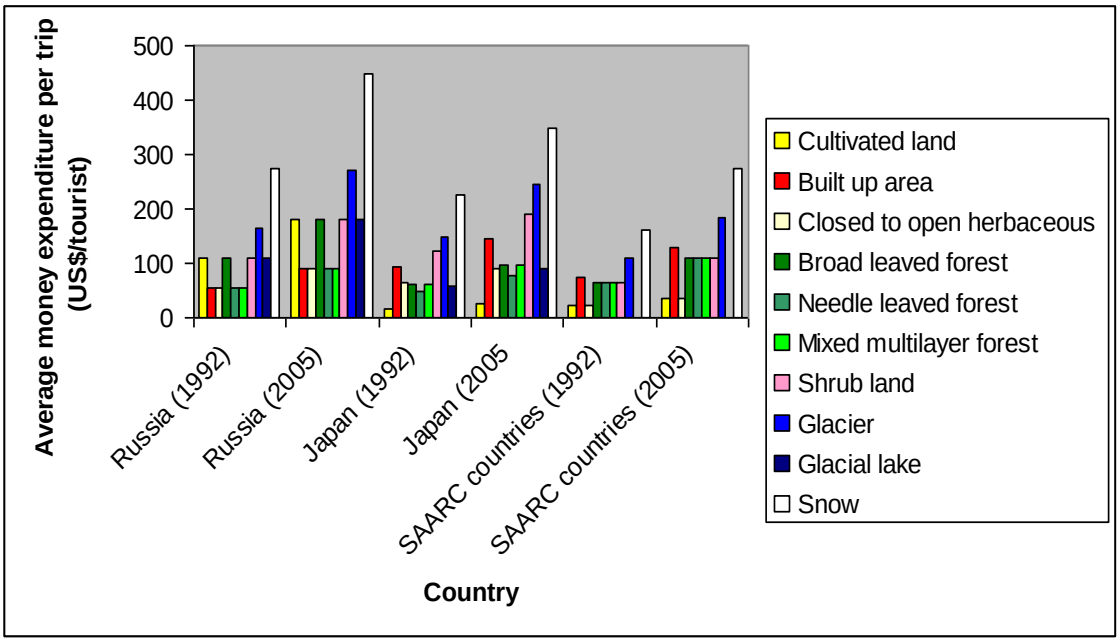


Figure 37: Average money expenditure per tourist attributed to the different land cover types of 1992 and 2005.

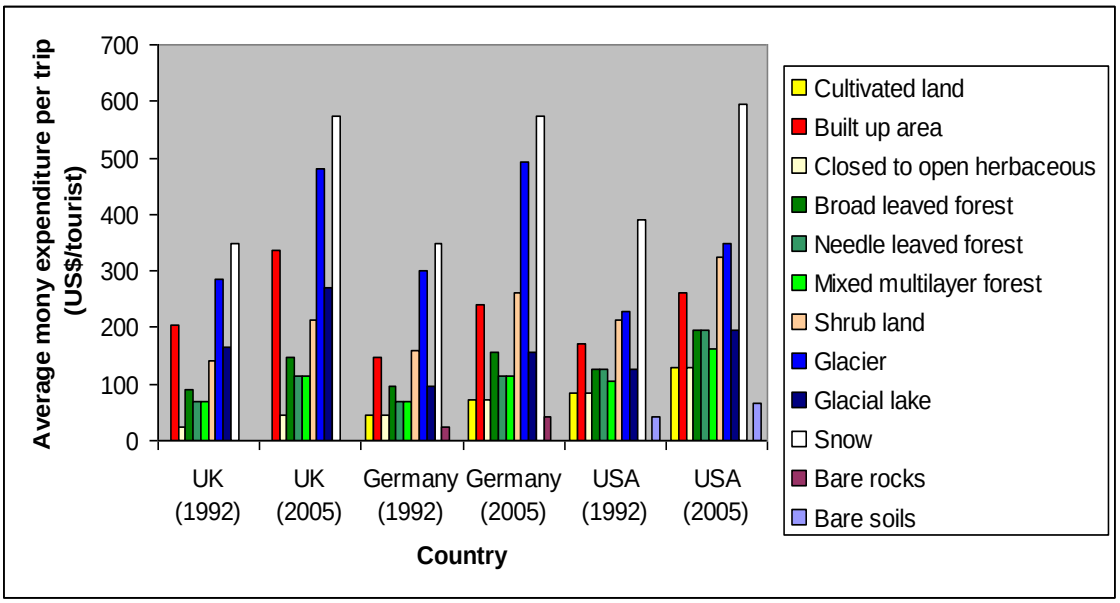


Figure 38: Average money expenditure per tourist attributed to the different land cover types of 1992 and 2005.

4.4 Ecosystem service supply and demand matrices

4.4.1 Landscape capacities providing ecosystem services

The supply values of the integrity, provisioning, regulating and cultural services are presented in figure 39. These values are based on the judgement values of local people and experts**.** The aggregate values of integrity, provisioning, regulating and cultural services constitute 145, 115, 131 and 164 respectively. Out of a maximum value of 25 that could be assigned to each land cover type for the supply of **integrity**, the highest value was attributed to the broad leaved forest, whose value was 23. The multilayer mixed forest, needle leaved forest and the shrub land constituted values of 22, 20 and 17 respectively, whereas the built up area constituted null, similarly, the bare rock, glaciers, snow, bare soil and the gravels, stones and boulders comprised values of less than 6. In addition, the other land cover types closed to open herbaceous vegetation, cultivated area, glacial lake and river constituted values between 7 and 16.

Out of 35 maximum values that could be assigned to each land cover type for the supply of the **provisioning services**, the highest value was attributed to the multilayer mixed forest and the cultivated area, which was equal to 17 out of 35. The broad leaved forest, shrub land and the needle leaved forest show values between 15 and 16, whereas, the built up area and the bare rock constituted null and the river, bare soil, glacial lake, glaciers and the gravels, stones and boulders constituted values between 7 and 10.

As done in earlier paragraphs, a maximum value of 25 could be assigned to each land cover type for the supply of the **regulating services**. The highest value was attributed to the broad leaved forest, which was equal to 25 out of 25. Similarly, the needle leaved forest, multilayer mixed forest and the shrub land comprised values between 18 and 24. The bare soil and the built up area constituted null. The cultivated area and the closed to open herbaceous vegetation constituted values of 12 and 13 respectively.

A maximum value of 30 could be assigned to each land cover type for the supply of the **cultural services**, the highest value was attributed to the snow which was 25 out of 25. Similarly, the built up area, glacial lake and the glacier land cover type constituted values between 22 and 23. Furthermore, the closed to open herbaceous vegetation, cultivated area and the gravels, stones and boulders constituted values of less than 6, whereas, the bare rock and the bare soil constituted null. The other land cover types river, shrub land, needle leaved forest, multilayer mixed and the broad leaved forest constitutes values between 9 and 16.

Land Cover Types	**Ecological integrity Σ**	Abiotic heterogeneity	Biodiversity	Reduction of nutrient loss	Storage capacity	Biotic waterflows	**Provisioning services Σ**	Timber	Fuelwood	Crops	Fodder	Livestock products	Herbs	Fresh Water	**Regulating services Σ**	Local and global climate regulation	Water runoff regulation	Air quality regulation	Nutrient regulation	Erosion control	**Cultural services Σ**	Tourism	Scientific research and education	Aesthetic beauty	Religious value	Sense of place	Natural and cultural heritage
BR	**4**	3	1	0	0	0	**0**	0	0	0	0	0	0	0	**1**	0	0	0	0	1	**0**	0	0	0	0	0	0
BS	**5**	4	1	0	0	0	**2**	0	0	0	0	0	0	2	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0
BL	**23**	3	5	5	5	5	**16**	5	4	0	2	2	3	0	**25**	5	5	5	5	5	**16**	3	2	3	3	2	3
BU	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	0	**0**	0	0	0	0	0	**23**	4	3	3	5	4	4
CO	**16**	3	3	4	3	3	**10**	0		0	3	3	4	0	**13**	2	3	2	3	3	**6**	1	1	2	0	2	0
CA	**14**	3	2	3	3	3	**17**	0	0	5	5	5	2	0	**12**	2	4	1	3	2	**5**	2	1	1	0	1	0
GL	**7**	3	2	2	0	0	**5**	0	0	0	0	0	0	5	**5**	1	3	0	1	0	**22**	4	5	3	4	3	3
G	**1**	1	0	0	0	0	**5**	0	0	0	0	0	0	5	**2**	2	0	0	0	0	**22**	5	5	4	0	3	5
GS	**4**	3	1	0	0	0	**1**	0	0	0	0	0	0	1	**1**	0	0	0	0	1	**1**	0	0	0	1	0	0
MM	**22**	3	5	4	5	5	**17**	5	5	0	2	2	3	0	**24**	5	4	5	5	5	**13**	2	2	2	3	2	2
NL	**20**	3	5	4	4	4	**15**	5	4	0	2	2	2	0	**24**	5	4	5	5	5	**13**	2	2	2	3	2	2
SL	**17**	3	4	4	3	3	**16**	0	5	0	3	3	5	0	**18**	4	4	3	3	4	**9**	2	2	2	1	1	1
R	**9**	5	4	0	0	0	**4**	0	0	0	0	0	0	4	**4**	1	2	0	1	0	**9**	2	2	2	0	1	2
S	**3**	1	2	0	0	0	**7**	0	0	0	0	0	2	5	**2**	2	0	0	0	0	**25**	5	5	5	0	5	5

Figure 39: Supply assessment matrix based on the local people' and expert's values.

BR: Bare rocks, BS: Bare soils, BL: Broad leaved forest, BU: Built up area, CO: Closed to open herbaceous vegetation, CA: Cultivated area, GL: Glacier lakes, G: Glaciers, GS: Gravels, stones and boulders, MM: Multilayer mixed forest, NL: Needle leaved forest, SL: Shrub land, R: River, S: Snow

4.4.2 Ecosystem service demand assessment

The demand values of ecological integrity, provisioning and regulating services are presented in figure 40. These values are based on the total size of the population inhabiting the particular land cover types in relation to the demand for the particular ecosystem services**.** The aggregated demand values of integrity, provisioning and regulating services constituted 100, 156 and 109 respectively. Furthermore, out of a maximum value of 25 that could be assigned to each land cover type for the demand of the **ecological integrity** the highest value was attributed to the cultivated area, with a value of 25 out of 25. The shrub land, bare soil, broad leaved forest, gravels, stones and boulders, multilayer mixed and the needle leaved forest comprise values between 8 and 14. The glacial lake, glacier, bare rock, river and the snow constituted null, and the built up area constituted a value of 2.

Out of 35 maximum points that could be assigned to each land cover type for the demand of the **provisioning services** the highest value was attributed to the cultivated area which is equal to 34 out of 35. The built up area and the shrub land comprises values of 24 and 22 respectively, whereas, the bare rock, glacial lake, glacier, river and the snow constitute values of null. The bare soil and the closed to open herbaceous vegetation comprise values of 7 each. In addition, the other land cover types broad leaved forest, gravels, stones and boulders, multilayer mixed and the needle leaved forest constitute values between 15 and 16.

Furthermore, out of 25 maximum points that could be assigned to each land cover type for the demand of the **regulating services**; the cultivated area was given the highest value with 21 out of 25 points. The shrub land, bare soil and the gravels, stones and boulders constituted values of 17, 14 and 13 respectively, whereas, the bare rock, glacial lake, glacier, river and the snow comprised null. The other land cover types broad leaved forest, built up area, closed to open herbaceous vegetation, multilayer mixed and the needle leaved forest land cover types constitute values between 8 and 10.

To sum up, the results of the **supply and demand matrix** reflect that the supply of the cultural services is higher than the other services, whereas, the demand of the provisioning services is higher than the other. The cultivated area constitutes a higher demand of all kinds of services, whereas, the bare soil and the closed to open herbaceous vegetation land cover types constitute small demands. In addition, besides the cultural services, the multilayer forest, broad leaved and needle leaved forest possessed a higher supply of all kinds of services, and the snow and built up area types constitute a higher supply of cultural services than the other land cover types.

Land Cover Types	Ecological integrity ∑	Abiotic heterogeneity	Biodiversity	Reduction of nutrient loss	Storage capacity	Biotic waterflows	Provisioning services ∑	Timber	Fuelwood	Crops	Fodder	Livestock products	Herbs	Fresh Water	Regulating services ∑	Local and global climate regulation	Water runoff regulation	Air quality regulation	Nutrient regulation	Erosion control
Bare Rock	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	0	**0**	0	0	0	0	0
Bare Soil	**9**	1	1	3	2	2	**7**	1	1	1	1	1	1	1	**14**	1	5	1	2	5
Broad leaved Forest	**8**	2	2	2	1	1	**15**	2	2	2	2	2	3	2	**8**	2	1	2	2	1
Built up Area	**2**	1	1	0	0	0	**24**	4	4	4	1	5	2	4	**10**	4	1	4	0	1
Closed to Open Herbaceous Vegetation	**9**	1	1	3	2	2	**7**	1	1	1	1	1	1	1	**10**	1	3	1	1	4
Cultivated Area	**25**	5	5	5	5	5	**34**	5	5	5	5	4	5	5	**21**	5	3	5	5	3
Glacial Lake	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	0	**0**	0	0	0	0	0
Glacier	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	0	**0**	0	0	0	0	0
Gravels, Stones and Boulders	**13**	2	2	3	3	3	**15**	2	2	1	3	2	3	2	**13**	2	3	2	3	3
Multilayer Mixed Forest	**10**	2	2	2	2	2	**16**	2	2	2	3	2	3	2	**8**	2	1	2	2	1
Needle leaved Forest	**10**	2	2	2	2	2	**16**	2	2	2	3	2	3	2	**8**	2	1	2	2	1
Shrub land	**14**	3	3	3	3	2	**22**	3	3	3	4	2	4	3	**17**	4	2	4	4	3
River	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	0	**0**	0	0	0	0	0
Snow	**0**	0	0	0	0	0	**0**	0	0	0	0	0	0	0	**0**	0	0	0	0	0

Figure 40: Demand assessment matrix based on direct human demands for ecosystem services.

4.5 Spatial and temporal changes in provisioning services

4.5.1 Changes in the quantities of fuelwood demand and supply

The fuelwood demand maps of the years 1992 and 2005 are presented in figure 42. And the fuelwood supplies and demands per hectare of the years 1992 and 2005 are shown in figure 41. The fuelwood demand value is based on the household survey data collection which was added by literature reviews for the supply data. Among all the land cover types, the built up

area has higher quantities of **fuelwood demand** in both years 1992 and 2005; 21282 and 16142 kg/ha respectively because this village has the highest number of hotels and lodges in the Khumbu. The cultivated area also constitutes high quantities of fuelwood demand; 4192 and 4111 kg/ha respectively in 1992 and 2005, whereas, the bare soil and the closed to open herbaceous vegetation constitute fuelwood demand quantities of less than 2 kg/ha in both years. The other land cover types shrub land, gravels, stones and boulders, multilayer mixed forest, broad leaved and the needle leaved forest constitute fuelwood demand quantities between 35.77 to 75.75 and 38.84 to 73.54 kg/ha in 1992 and 2005. Between 1992 and 2005, the quantities of fuelwood demand per hectare increased in the shrub land, gravel, stones and boulders, and the multilayer mixed forest by 8.58%, 60.26% and 32.68% respectively, while, the quantities of fuelwood demand per hectare decreased in the cultivated area, built up area, broad leaved, needle leaved forest, closed to open herbaceous vegetation and the bare soil by 1.93%, 24.15%, 29.45%, 2.91%, 29.10% and 20% respectively over the 14-year period.

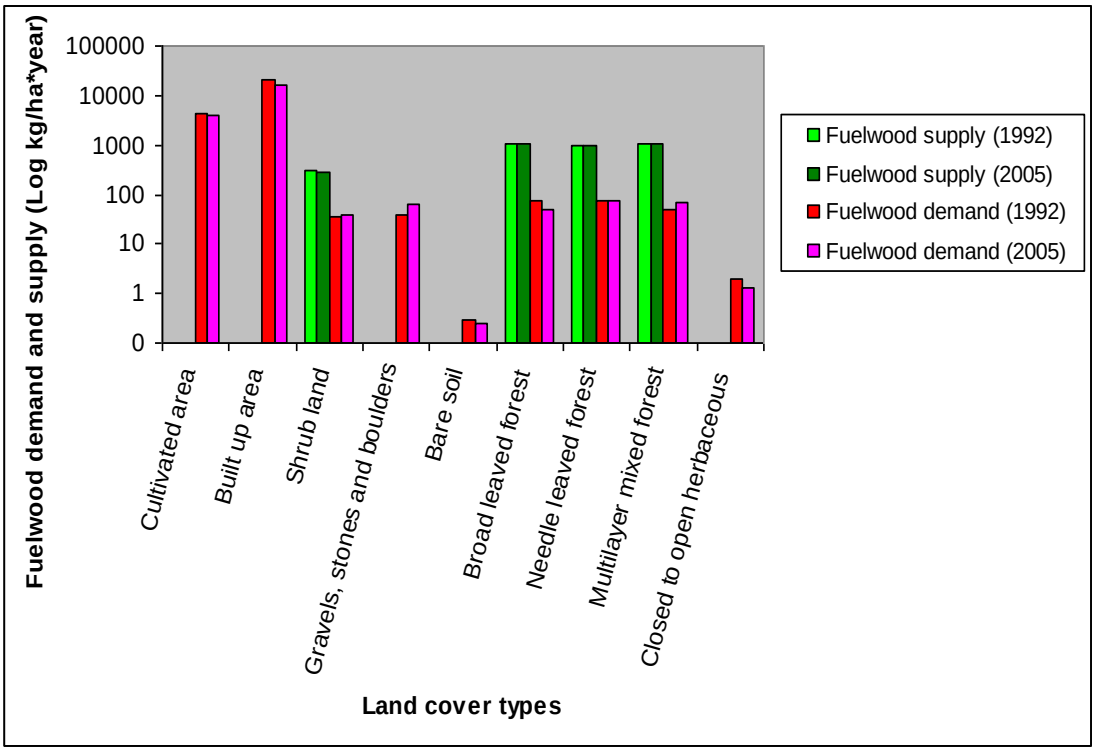


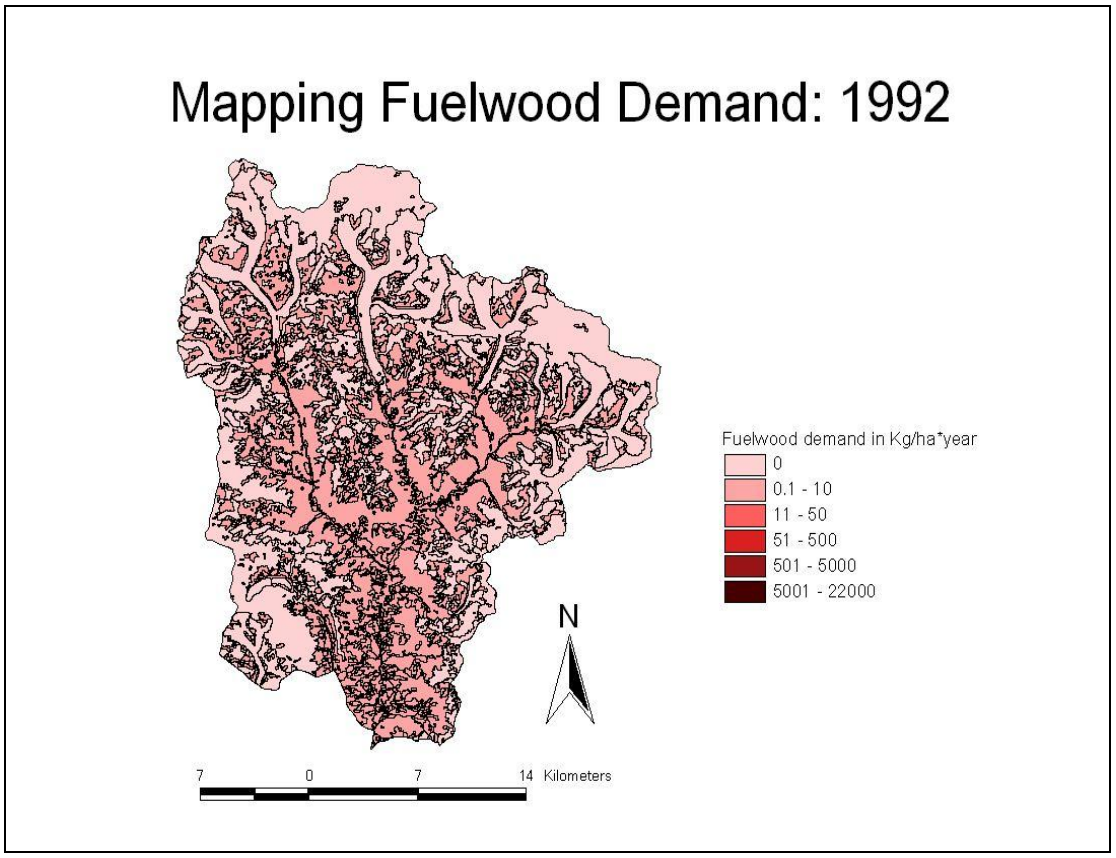
Figure 41: Demand and supply of fuelwood per hectare attributed to the different land cover types in 1992 and 2005.

The broad leaved forest provided higher quantities of **fuelwood supply** in both years 1992 and 2005; 1078 and 1087 kg per hectare respectively, whereas, the shrub land's fuelwood supply shows values of only 306 and 286 kg per hectare in 1992 and 2005. It was observed that between 1992 and 2005, the supply quantities of fuelwood per hectare decreased in the

shrub land, needle leaved and the multilayer mixed forest by 6.53%, 1.87% and 1.23% respectively, while the quantities of fuelwood supply per hectare increased in the broad leaved forest by 0.83% over the 14-year period.

The supply and demand quantities of **fuelwood per hectare** represent that among all the land cover types, the built up area constituted of higher fuelwood deficit quantities in both years 1992 and 2005; 21282 and 16142 kg/ha respectively. Similarly, the cultivated area also had higher fuelwood deficit quantities; 4192 and 4111 kg/ha respectively in 1992 and 2005, whereas, the bare soil and the closed to open herbaceous vegetation constituted fuelwood deficit quantities of less than 2 kg/ha in both years. During the years 1992 and 2005, the gravels, stones and boulders constituted fuelwood deficit quantities of 38.76 and 62.12 kg/ha respectively. The broad leaved forest constituted of higher quantities of fuelwood surplus in both years 1992 and 2005; 1005.68 and 1035.98 kg/ha respectively. The shrub land constituted fuelwood surplus quantities of 270.23 and 247.16 kg/hectare respectively in 1992 and 2005. The other land cover types, needle leaved forest, multilayer mixed and broad leaved forest constituted fuelwood surplus quantities between 935 and 1006, and 918 and 1035 kg/ha respectively in 1992 and 2005.

The **fuelwood deficit** per hectare decreased in the cultivated area, built up area, closed to open herbaceous vegetation and the bare soil by 1.93%, 24.15%, 29.10% and 20% respectively over the 14-year period due to the use of alternative sources such as solar panels, kerosene and electricity for cooking purposes. The fuelwood deficit increased in the gravels, stones and boulders by 60.26% between 1992 and 2005 because of the increment of the number of lodges. The quantities of the fuelwood surplus increased in the broad leaved forest by 3.01% over the 14-year period. The quantities of the fuelwood surplus decreased in the shrub land, needle leaved and the multilayer mixed forest by 8.53%, 1.79% and 2.84% respectively between 1992 and 2005 because of the growing number of hotels and lodges.



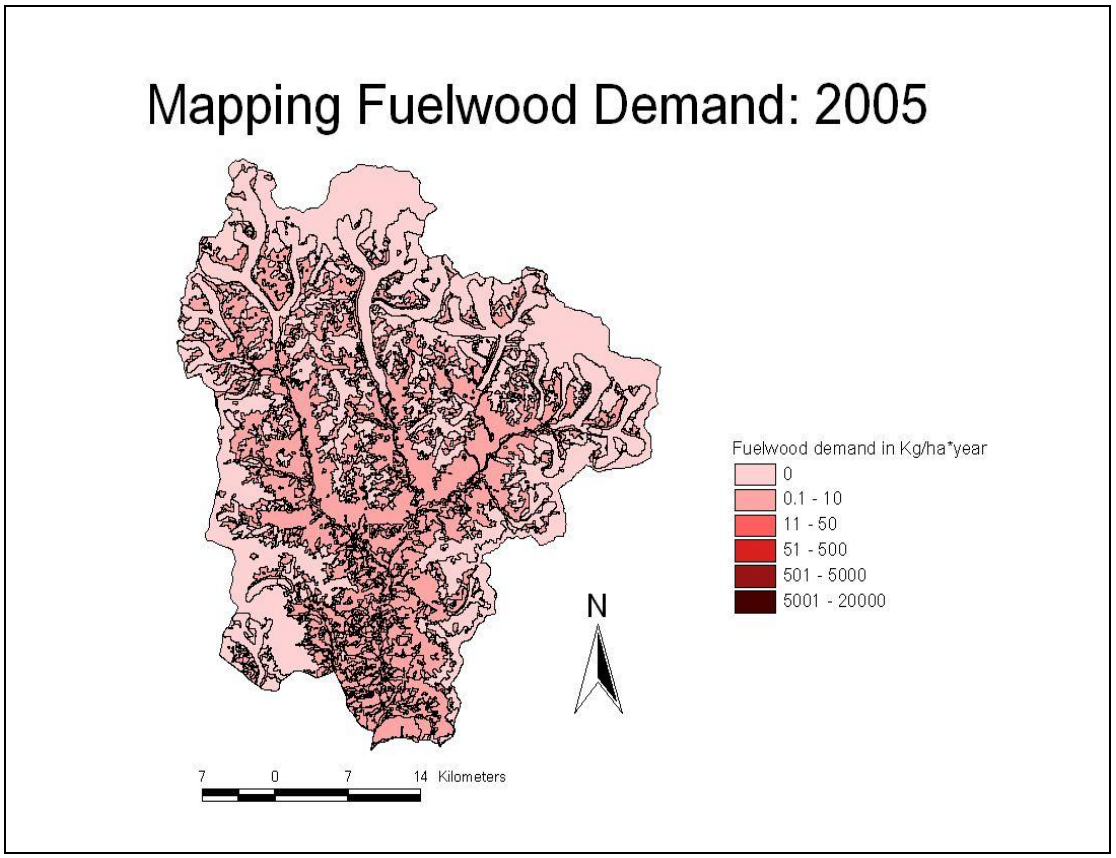


Figure 42: Mapping fuelwood demand of the years 1992 and 2005.

The total quantity of fuelwood **demand, supply and surplus** in the whole region in 1992 and 2005 are shown in figure 43. The total demand of fuelwood reached 6044 and 5882 metric tons respectively in 1992 and 2005, in which the total demand of fuelwood decreased by 2.68% over the 14-year period. Furthermore, the total quantity of fuelwood supply reached 15697.12 and 14936.39 metric tons respectively in the years 1992 and 2005, in which the total quantity of fuelwood supply decreased by 4.84% over the 14-year period. The total quantity of fuelwood demand and supply results in a fuelwood surplus of 9653 and 9054 metric tons respectively in 1992 and 2005. This surplus demonstrates that the region could offer fuelwood provision on a sustainable basis even though there has been a higher demand of fuelwood quantities as a result of the growing number of local population and tourists.

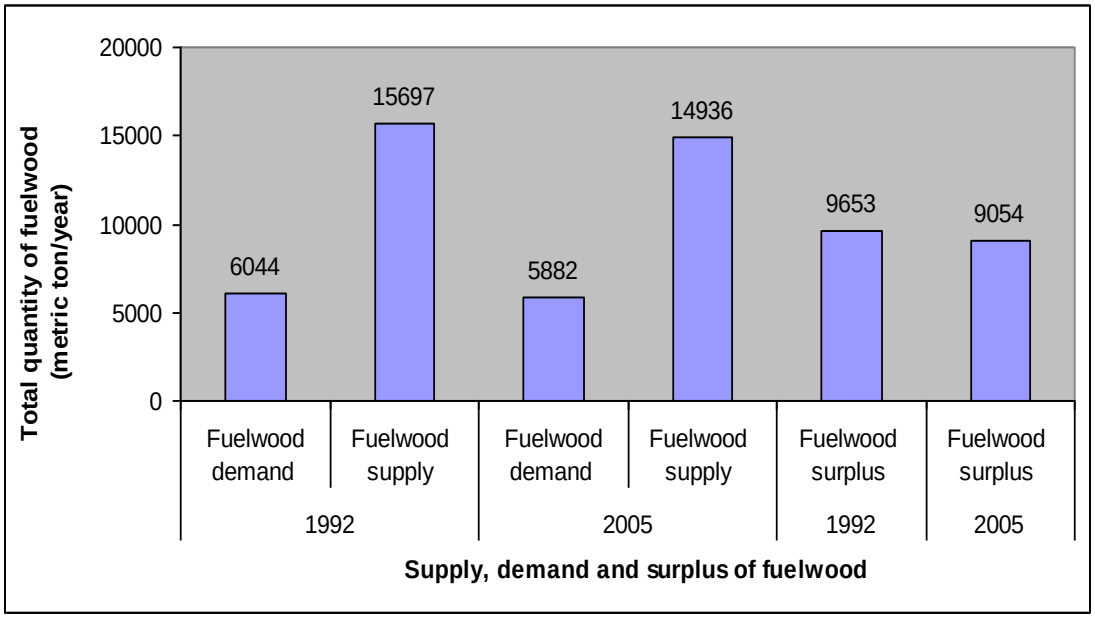


Figure 43: Total quantity of fuelwood demand, supply and surplus in the whole region in 1992 and 2005.

4.5.2 Changes in potato demand and supply

The potato demand, supply and balance maps of the years 1992 and 2005 are presented in figures 46, 47 and 48. The total **demand** and supply quantities of potatoes per land cover type are shown in figure 44. This result is based on the household survey data collection**.** Among all the land cover types, the cultivated area constituted higher quantities of potato demand; 956.34 and 981.81 metric tons in 1992 and 2005. Similarly, the shrub land and the built up area constituted high quantities of potato demand of more than 100 metric tons each in both years 1992 and 2005, whereas, the bare soil and the closed to open herbaceous vegetation constituted a demand of only 3.58 and 6.32 and, 3.74 and 5.34 metric tons in 1992 and 2005.

The other land cover types broad leaved forest, gravels, stones and boulders, multilayer mixed forest and the needle leaved forest constituted a demand between 18.56 and 56.76, and 18 and 63.44 metric tons respectively in 1992 and 2005. The total quantities of potato demand increased in the cultivated area, built up area, shrub land, broad leaved and needle leaved forest land cover type by 2.66%, 66.11%, 12.07%, 41.48% and 11.76% respectively over the 14-year period due to the demand from growing number of tourists and local population. The total demand decreased in the gravels, stones and boulders, and the multilayer mixed forest land cover type by 19.42% and 23.71% respectively between 1992 and 2005 due to the motivations of these land cover inhabitants for importing food items.

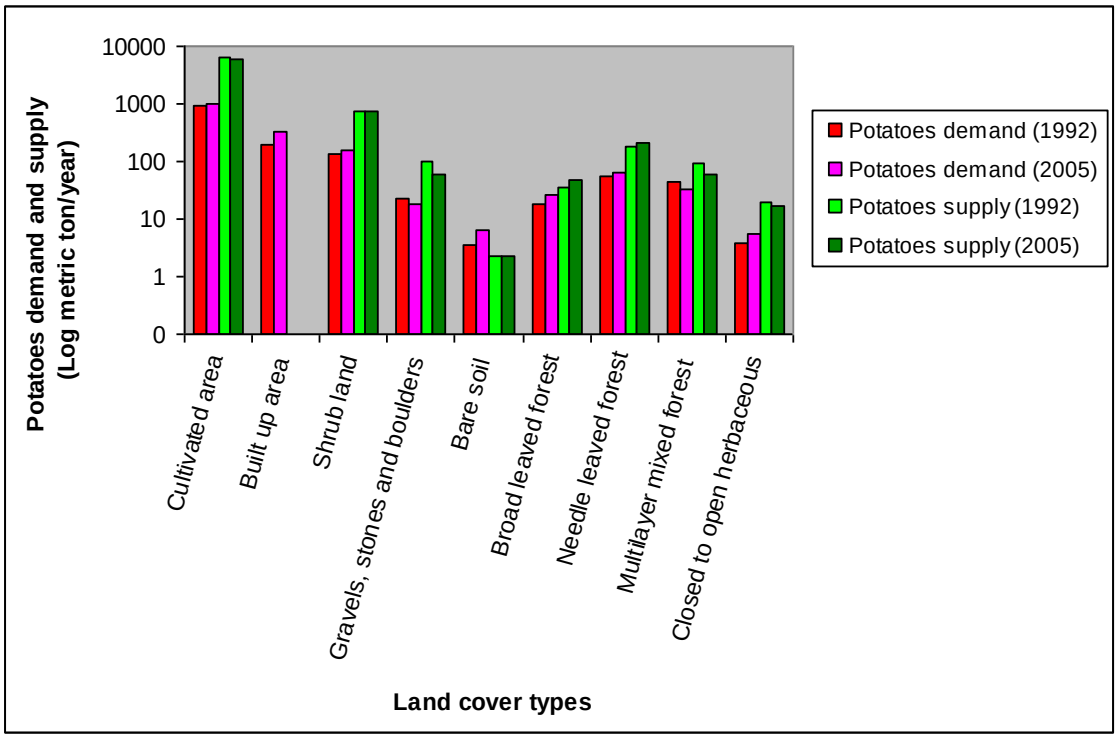


Figure 44: Total demand and supply quantities of potatoes attributed to the different land cover types in 1992 and 2005.

The cultivated area has higher quantities of potatoes **supply**; 6296.13 and 6014.4 metric tons in 1992 and 2005. The shrub land also constituted of higher quantities of potatoes supply; 757.8 and 751 metric tons respectively in 1992 and 2005, whereas, the built up area constituted null. The bare soil and the closed to open herbaceous vegetation constituted quantities of potato supply less than 20 metric tons each in 1992 and 2005. Similarly, the other land cover types; broad leaved forest, gravels, stones and boulders, multilayer mixed and the needle leaved forest constituted quantities of potatoes supply between 34.51 and 185.2 and, 48.38 to 206.2 metric tons respectively in 1992 and 2005. Furthermore, between 1992 and 2005, the total quantities of the potato supply decreased in the cultivated area, shrub land,

gravels, stones and boulders, and the multilayer mixed forest land cover types by 4.47%, 0.89%, 38.48% and 36.97% respectively due to the motivations of local people on the tourism related works rather than agriculture. This can also be seen by the growing numbers of lodges and households in the traditional potato farming fields. On the other hand, the total quantities of potato supply have increased in the broad leaved and the needle leaved forest by 40.19% and 11.33% respectively over the 14-year period due to the growing demand of potatoes in the trekking route site lodges. Most of the households of these land cover types belong to the off-site trekking site. Therefore, these households mainly dependent on agro-pastoral works to earn money by supplying potatoes to the trekking route site lodges.

The total quantities of the potato **demand, supply and surplus** in the whole region in 1992 and 2005 are presented in figure 45. The total quantity of the potato demand reached 1435 and 1609 metric tons respectively in 1992 and 2005. Similarly, the total quantity of potato supply reached 7485 and 7155 metric tons. The total quantities of demand and supply have effect that there was a surplus of 6050 and 5546 metric tons of potatoes in 1992 and 2005. The total quantity of potato surplus has decreased by 8.33% between 1992 and 2005. This surplus data represents that the potato crop has still remained a main crop of the region. It is sure that the supply of potato has also played vital role in the local people's income basing trades to the lowland communities.

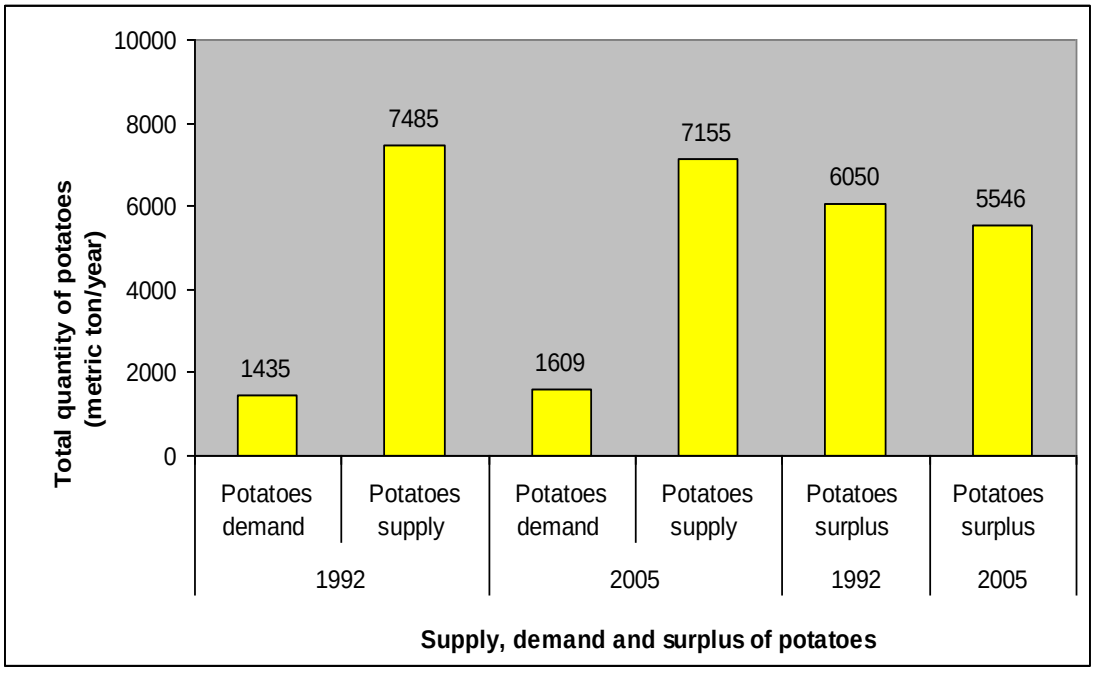
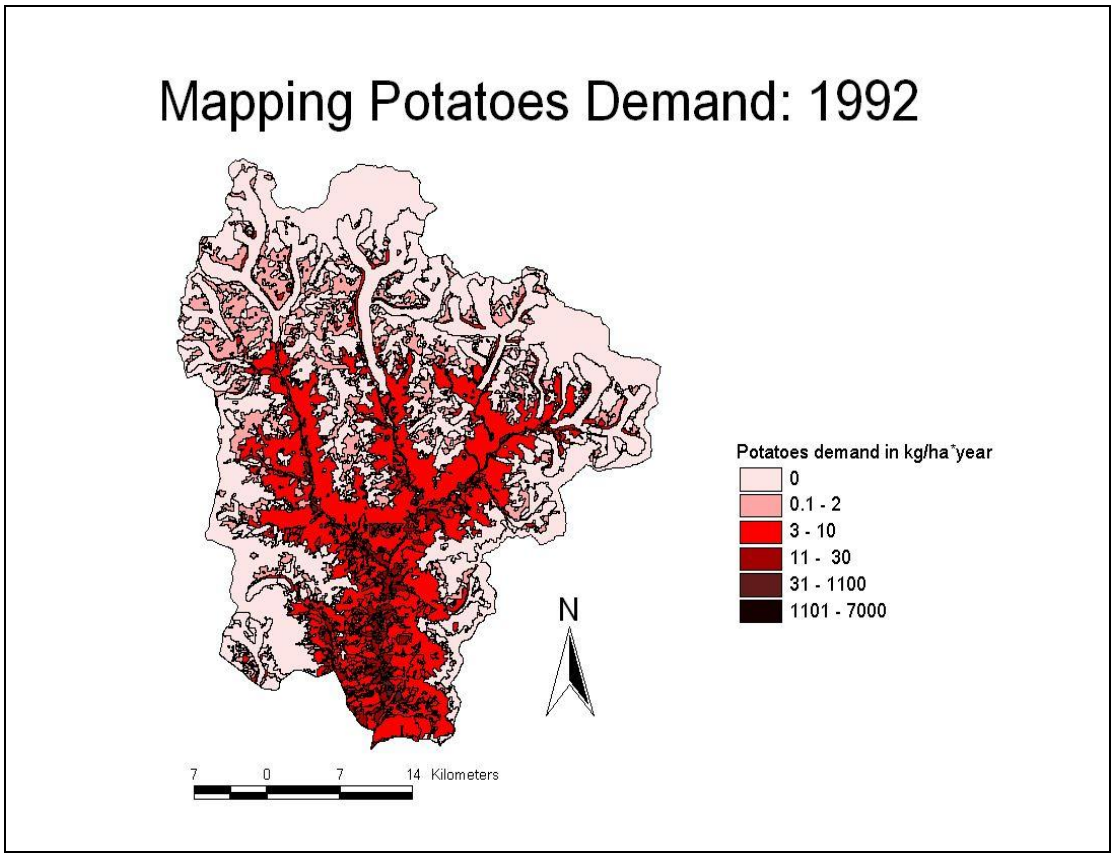


Figure 45: Total quantity of potatoes demand, supply and surplus in the whole region in the years 1992 and 2005.



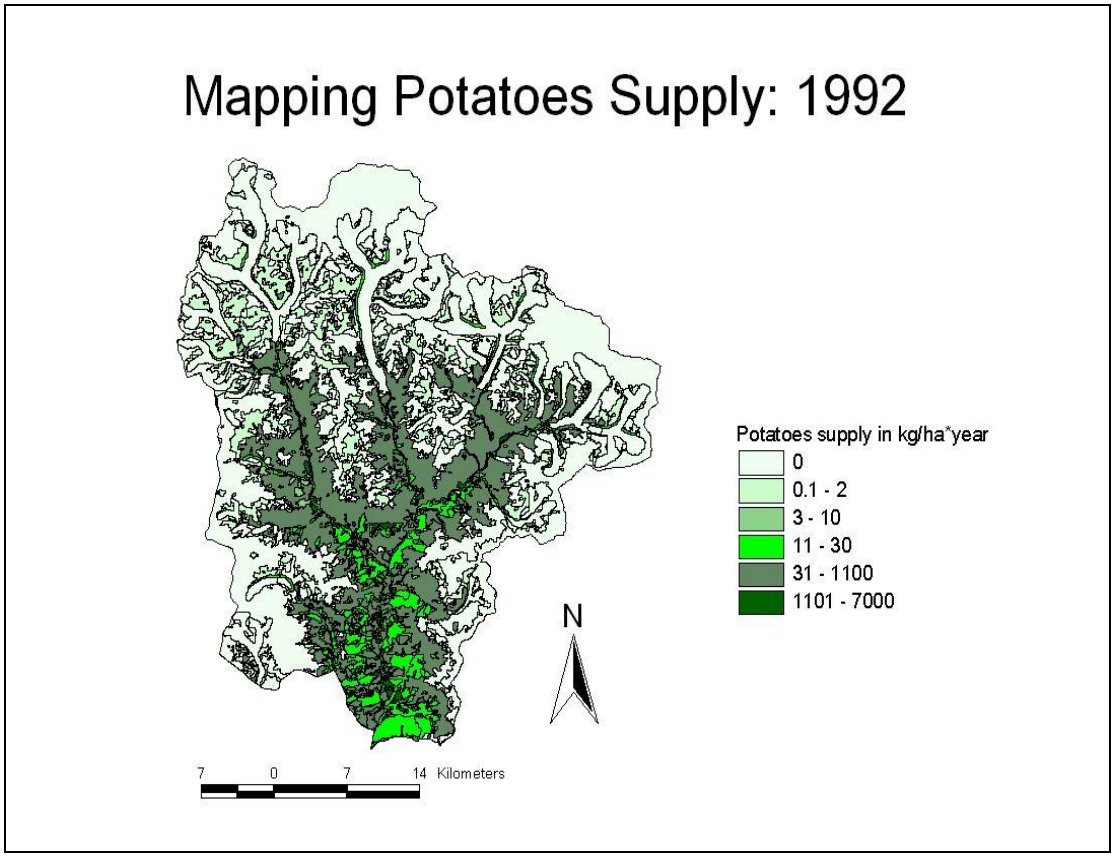
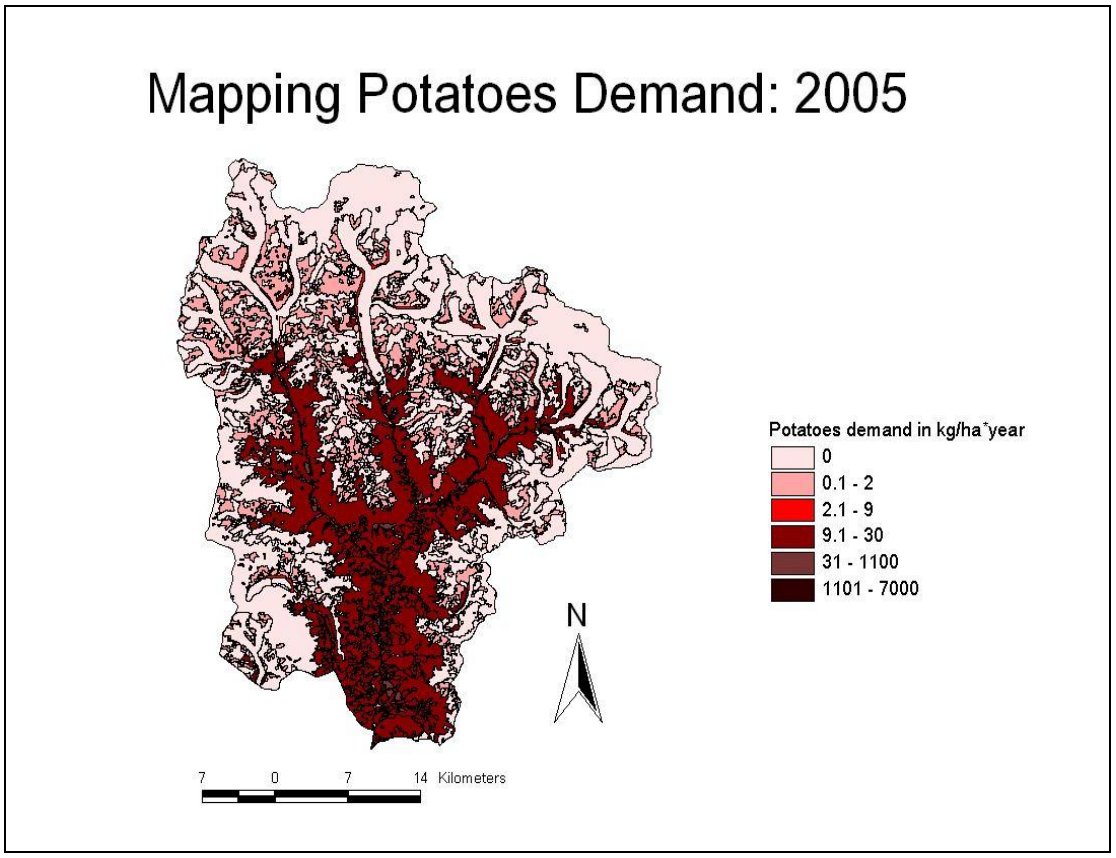


Figure 46: Mapping potatoes demand and supply of the year 1992.



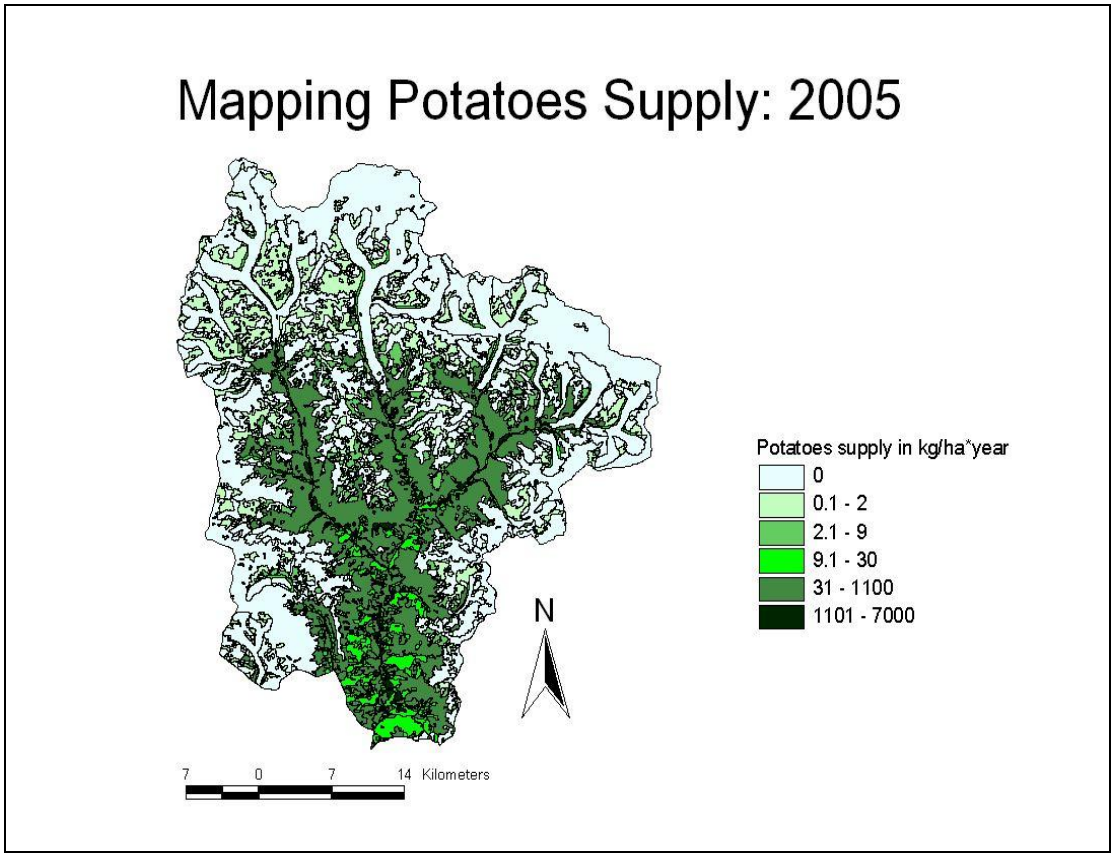
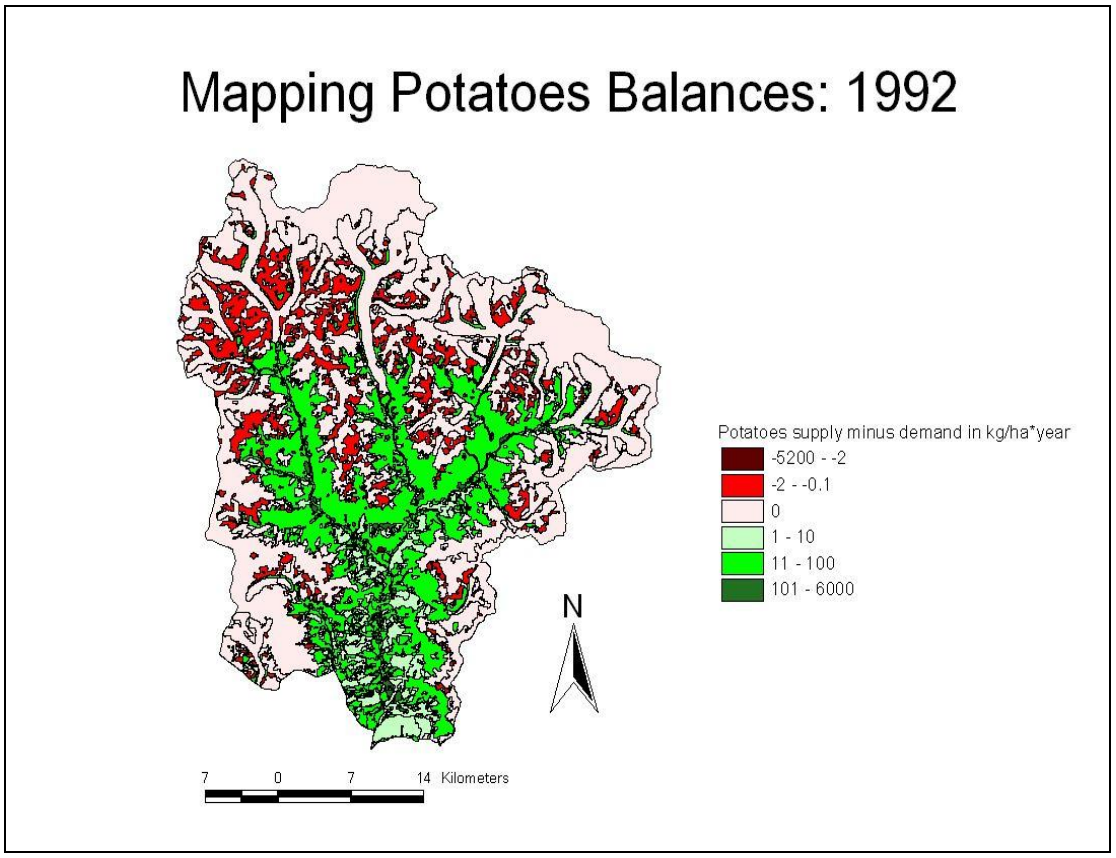


Figure 47: Mapping potatoes demand and supply of the year 2005.



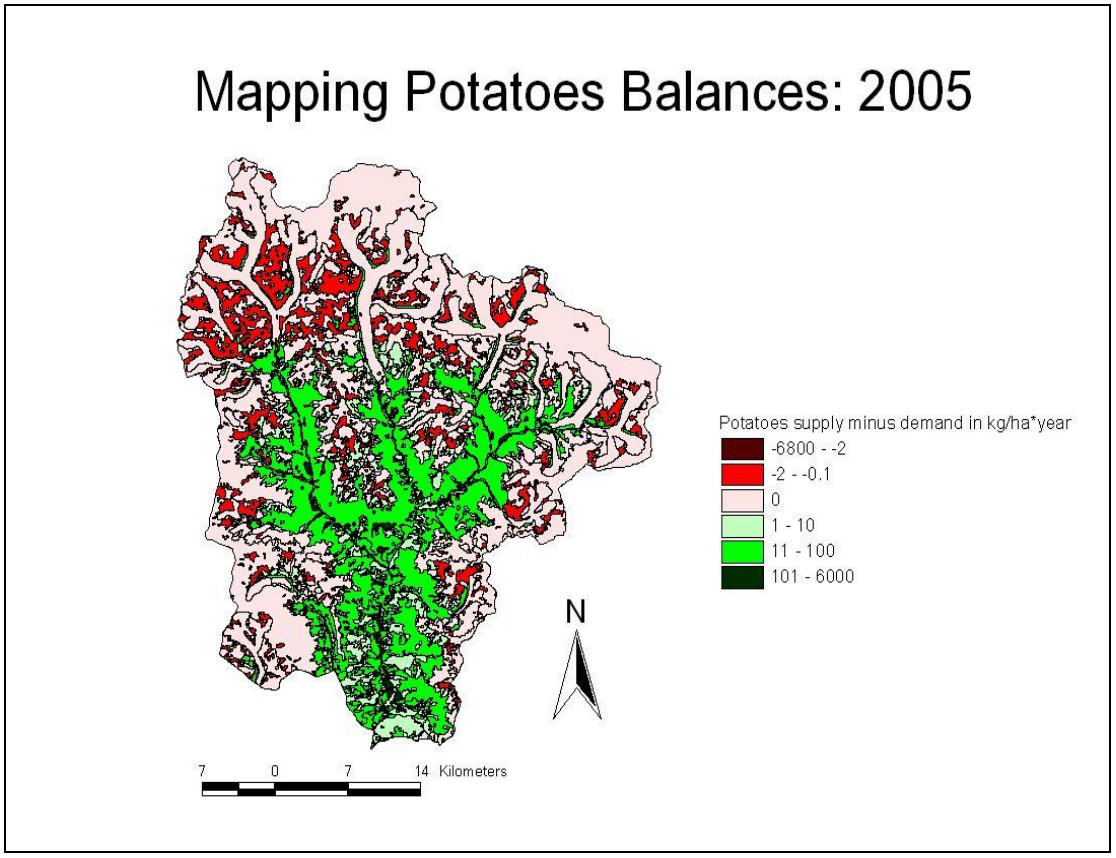


Figure 48: Mapping potatoes balances of the years 1992 and 2005.

4.5.3 Changes in milk demand and supply

The milk demand, supply and balance maps of the years 1992 and 2005 are presented in figures 50, 51 and 52. The supply and demand quantities of milk per hectare in 1992 and 2005 are presented in figure 49. This value is obtained from the household survey data collection. Among all the land cover types, the built up area constituted the highest quantities of milk **demand** in both years 1992 and 2005; 9058 and 11014 litres/hectare*year respectively. Similarly, the cultivated area also constituted high quantities of milk demand in both years; 2645 and 3430 litres/ha*year respectively, whereas the bare soil and the closed to open herbaceous vegetation constituted milk demands of less than 2 litres/ha in both years. Similarly, the other land cover types multilayer mixed forest, needle leaved forest, broad leaved forest, shrub land and the gravels, stones and boulders constituted quantities of milk demand between 15.85 and 23, and 20.6 and 26 litres/ha*year respectively in 1992 and 2005. Between 1992 and 2005, the quantities of milk demand increased in the land cover types cultivated area (29.67%), built up area (21.59%), shrub land (13.04%), gravels, stones and boulders (27.77%), bare soil (14%), broad leaved forest (15.73%), needle leaved forest (5.79%), multilayer mixed forest (48.83%), closed to open herbaceous vegetation (8.37%) and bare soil (14%).

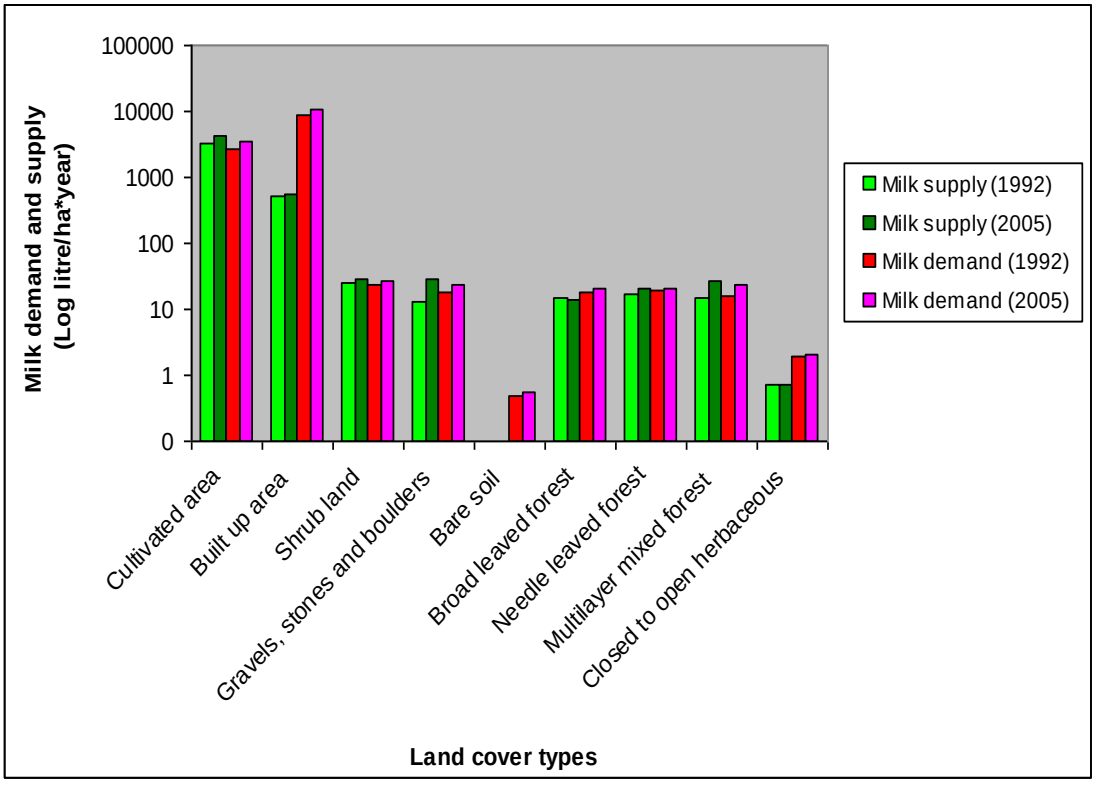
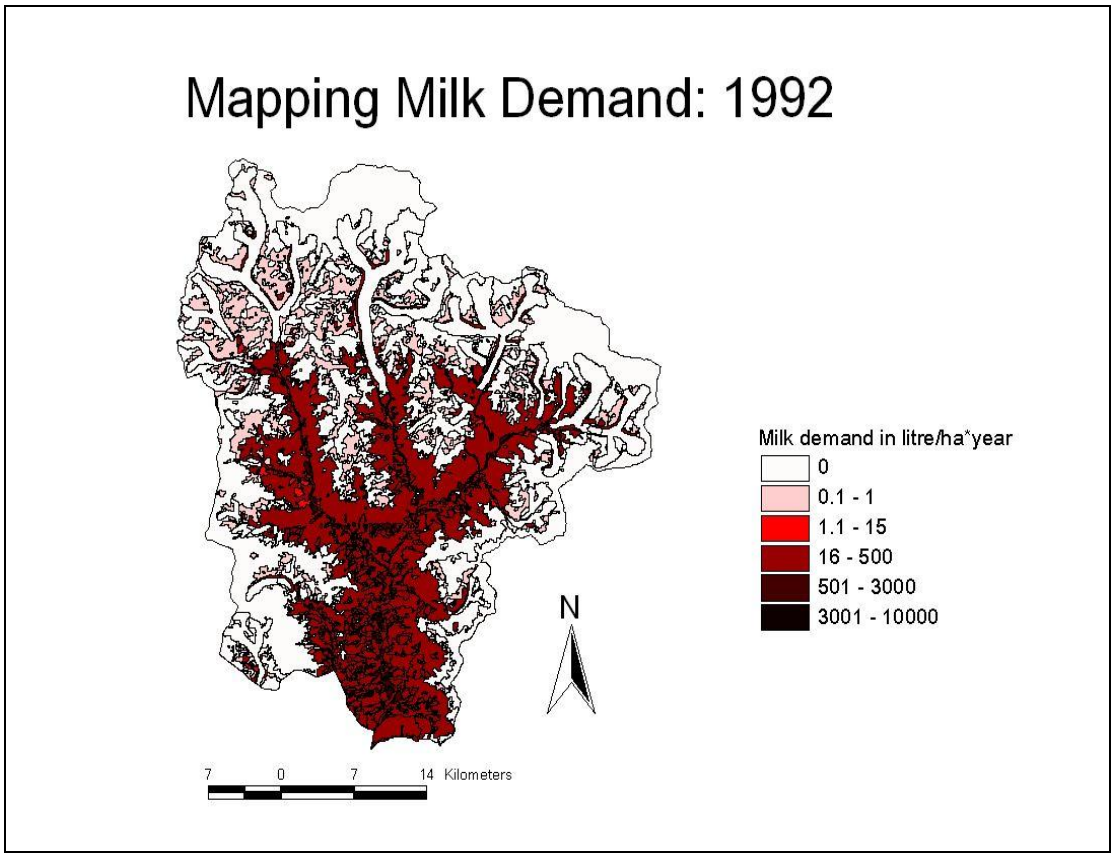


Figure 49: Demand and supply quantities of milk per hectare attributed to the different land cover types in 1992 and 2005.

Among all the land cover types, the cultivated area constituted of higher quantities of milk **supply** per hectare in both years 1992 and 2005 with 3303 and 4234 litres/ha*year respectively. Similarly, the built up area also constituted of higher quantities of milk supply of 529 and 540litres/ha*year respectively in 1992 and 2005. The bare soil constituted null and the closed to open herbaceous vegetation constituted quantities of milk supply less than 1litres/ha in the both years. The other land cover types; gravels, stones and boulders, shrub land, broad leaved forest, needle leaved and the multilayer mixed forest constituted quantities of milk supply between 12.77 and 25.55, and 14.23 and 29.2 litres/ha respectively in 1992 and 2005. Between 1992 and 2005, the quantities of milk supply per hectare increased in the cultivated area, built up area, shrub land, gravels, stones and boulders, needle leaved forest and the multilayer mixed forest by 28.18%, 2.07%, 14.28%, 127.09%, 22.22% and 75.66% respectively, whereas, the quantities of milk supply decreased in the broad leaved forest by 2.53%. However, the quantity of milk supply remained the same in the closed to open herbaceous vegetation land cover type over the 14-year period.

The **demand and supply** quantities of milk per hectare indicated that among all the land cover types, the built up area recorded the highest quantities of milk deficit in 1992 and 2005; 8529 and 10474 litres/ha*year respectively. The closed to open herbaceous vegetation, needle leaved forest, broad leaved forest and the bare soil constituted quantities of milk deficit less than 6.37 litres/ha*year in both years. The gravels, stones and boulders constituted quantities of milk deficit of 5.23 litres/ha in the year 1992, whereas, in the year 2005, it constituted quantities of milk surplus of 6 litres/ha*year. The highest quantity of milk surplus per hectare was attributed to the cultivated area in both years 1992 and 2005 with 658 and 804 litres/ha*year respectively, whereas, the lowest average quantities of milk surplus belonged to the multilayer mixed forest in both years: 0.89 and 2.69 litres/ha*year. The shrub land constituted quantities of milk surplus with 2.55 and 3.2 litres/ha*year in 1992 and 2005. Moreover, the quantities of milk surplus increased in the cultivated area, shrub land and the multilayer mixed forest by 22.18%, 25.49% and 202% over the 14-year period. The quantities of milk deficit per hectare has increased in the built up area and the broad leaved forest by 22.80% and 99.06% respectively between 1992 and 2005 due to the growing demand of tourists and the local population.



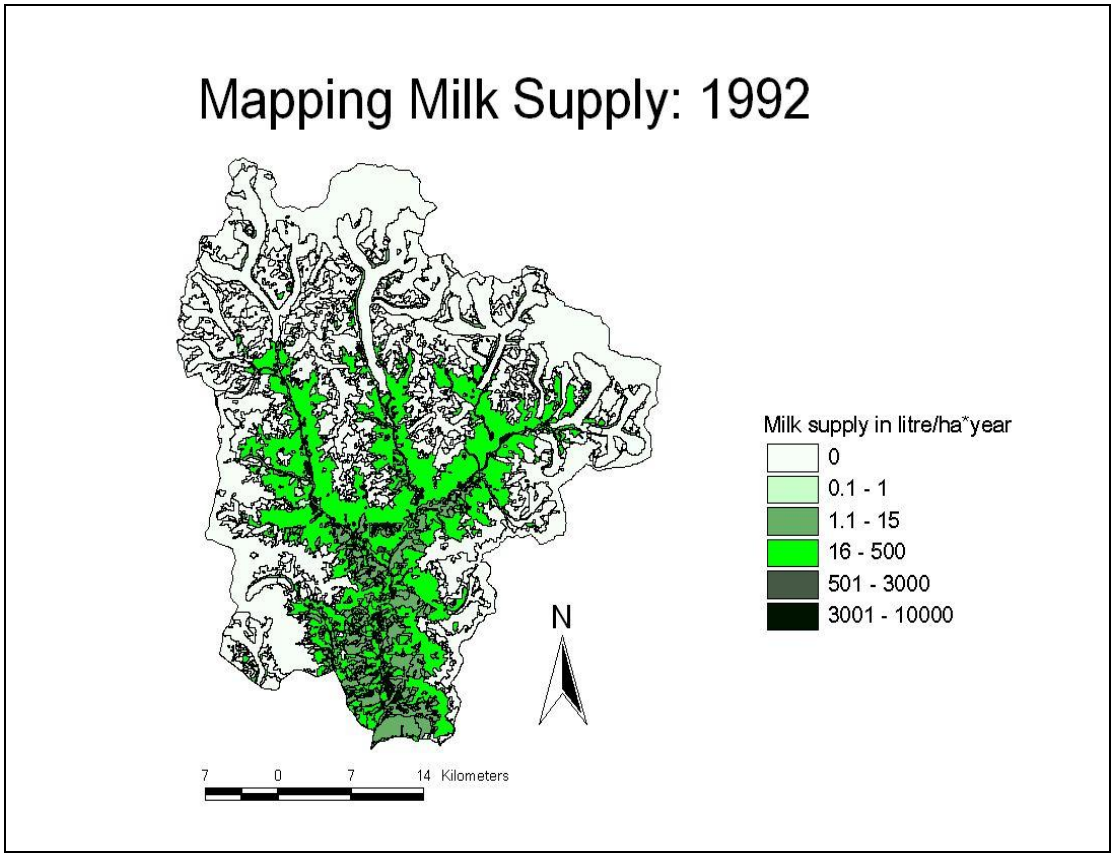
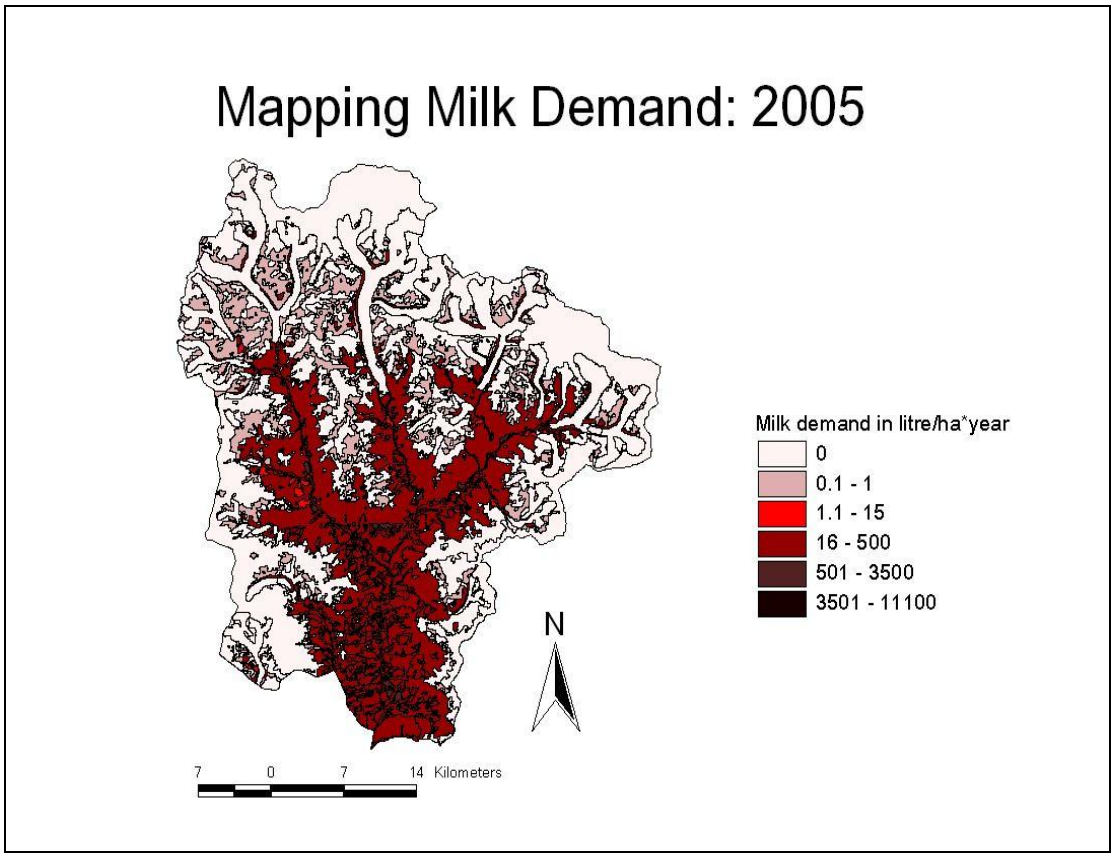


Figure 50: Mapping milk demand and supply of the year 1992.



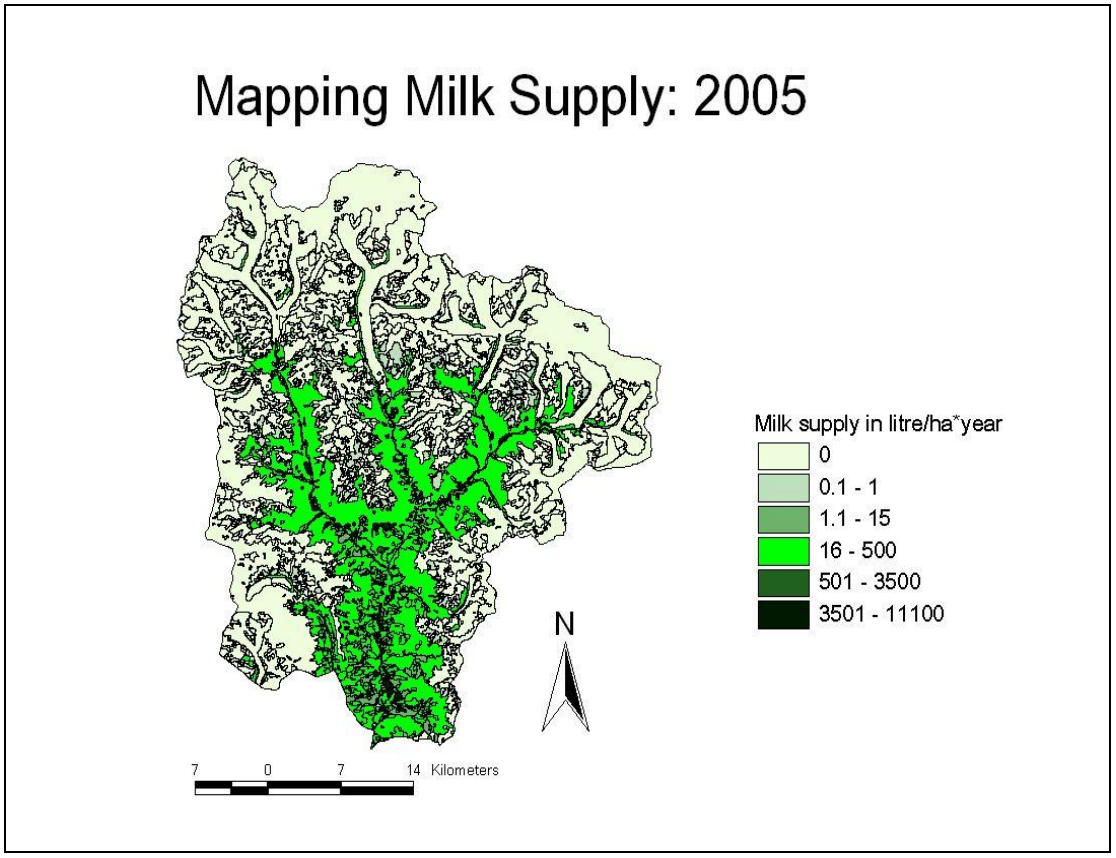
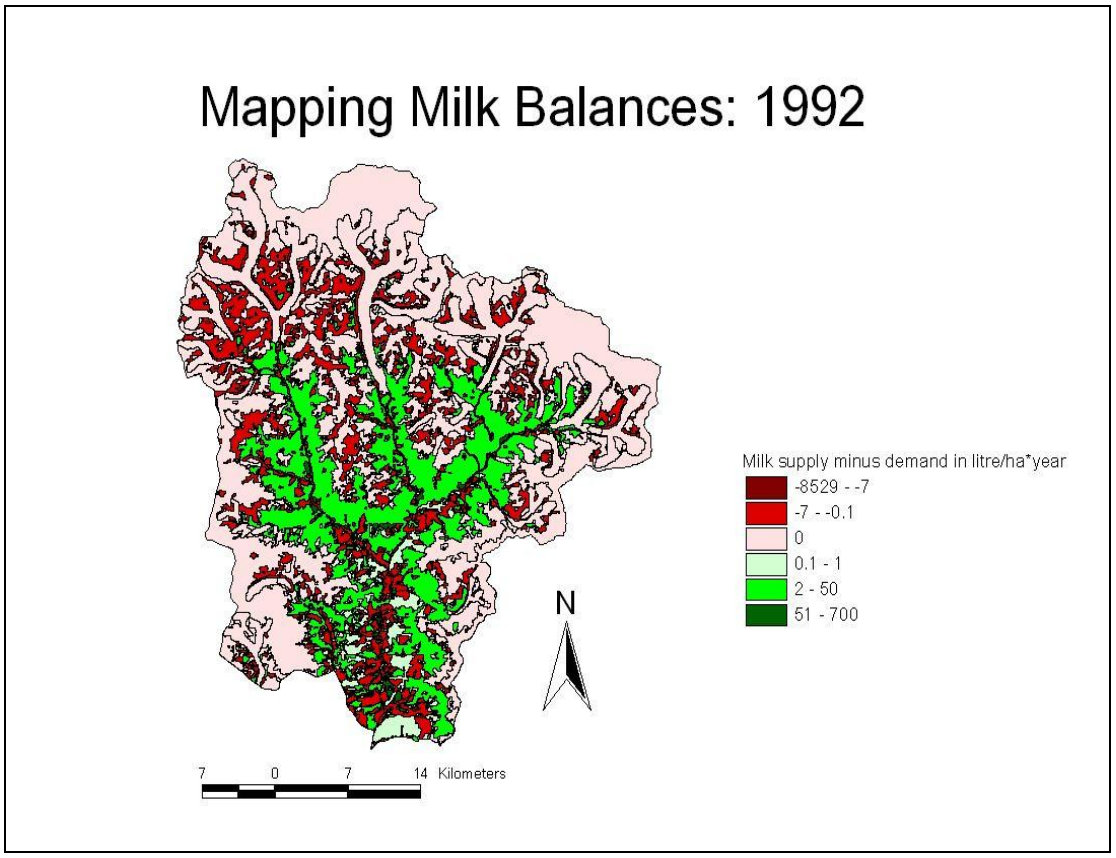


Figure 51: Mapping milk demand and supply of the year 2005.



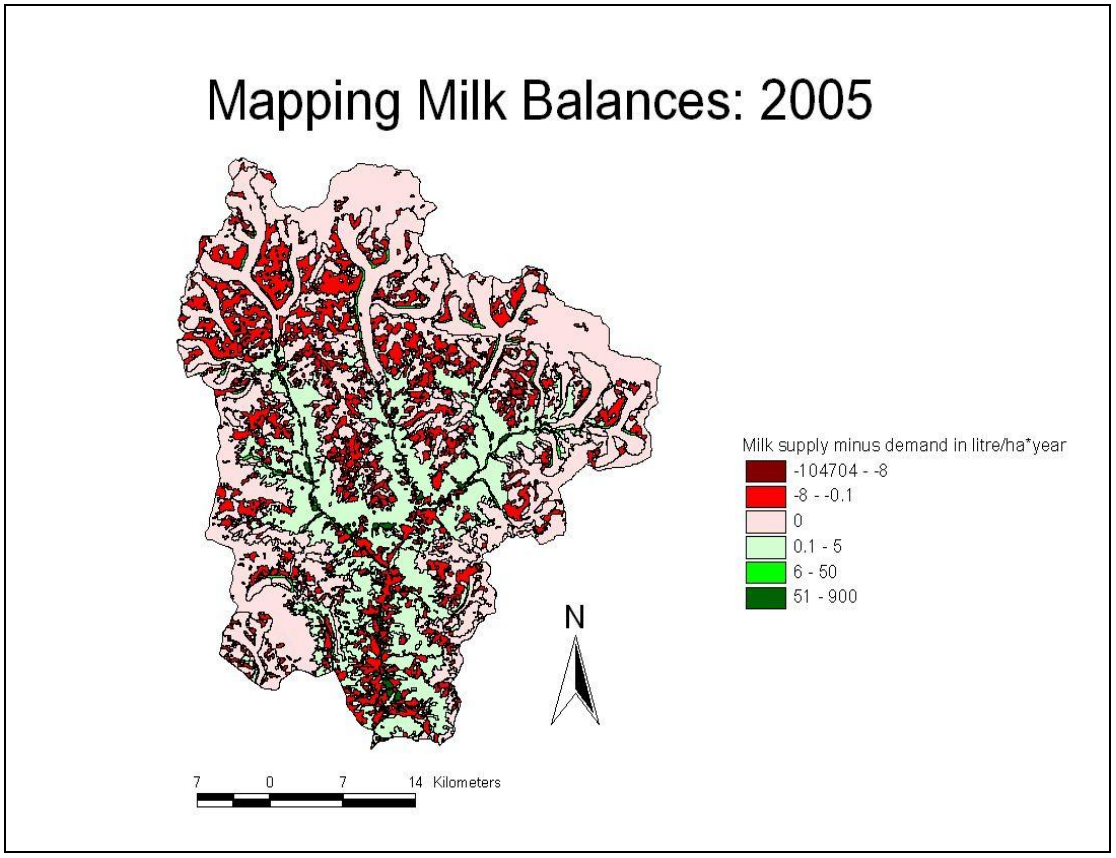


Figure 52: Mapping milk balances of the years 1992 and 2005.

The total quantities of milk **demand, supply and surplus** in the whole region of the years 1992 and 2005 are presented in figure 53. The total quantity of milk demand of 1992 and 2005 reached 3516.27 and 4039.85 cubic meters per year. The total quantity of milk supply in 1992 and 2005 reached 3698.96 and 4367.25 cubic meters per year respectively. These supply and demand data imply a surplus of milk in both years. The total surplus quantity of milk in 1992 and 2005 was 182.69 and 327.4 cubic meters per year respectively. The total quantity of milk demand and supply increased by 14.89% and 18.06% respectively over the 14-year period in which the total quantity of milk surplus increased by 79.21% between 1992 and 2005. The tourism affluence has made local people rear more cows than before. Consequently, the supply of milk has mounted up. Therefore, this service also accounts as an alternative source of income generating for the local people.

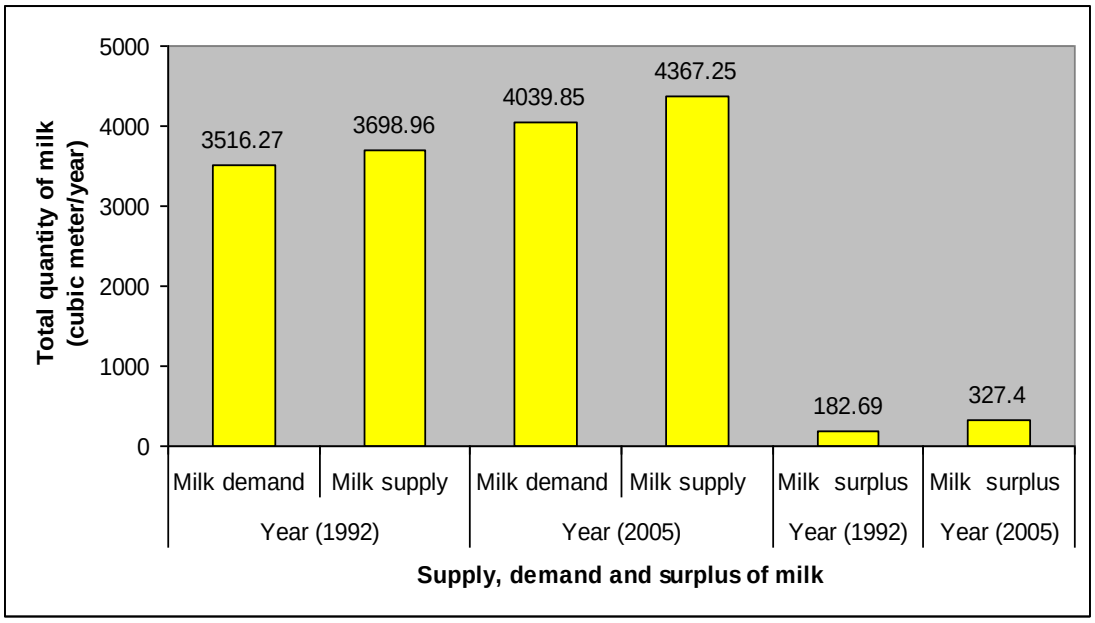


Figure 53: Total quantity of milk demand, supply and surplus of the years 1992 and 2005.

4.5.4 Changes in butter demand and supply

The butter supply, demand and balance maps of the years 1992 and 2005 are presented in figures 55, 56 and 57. The supply and demand quantities of butter per hectare of 1992 and 2005 are presented in figure 54. This value is based on the household survey data collection**.** Among all the land cover types, the built up area constituted of the highest quantities of butter **demand** per hectare in both years with values of 12500 and 13190 gram/ha*year. The cultivated area also constituted high quantities of butter demand in both years: 2010 and 8280 gram/ha*year respectively. The closed to open herbaceous vegetation and the bare soil land cover types constituted demand quantities of less than 9 gram/ha*year in both years. Similarly, the other land cover types; shrub land, needle leaved forest, broad leaved forest, multilayer mixed forest and the gravels, stones and boulders constituted demand quantities of butter between 15 and 30, and 19 and 36 gram/ha*year in 1992 and 2005. Between 1992 and 2005, the demand quantities of butter per hectare increased in the land cover types: cultivated area (25.87%), built up area (5.52%), shrub land (26.66%), gravels, stones and boulders (20%), bare soil (52.54%), broad leaved forest (5.26%), needle leaved forest (35%), and multilayer mixed forest (11.53%).

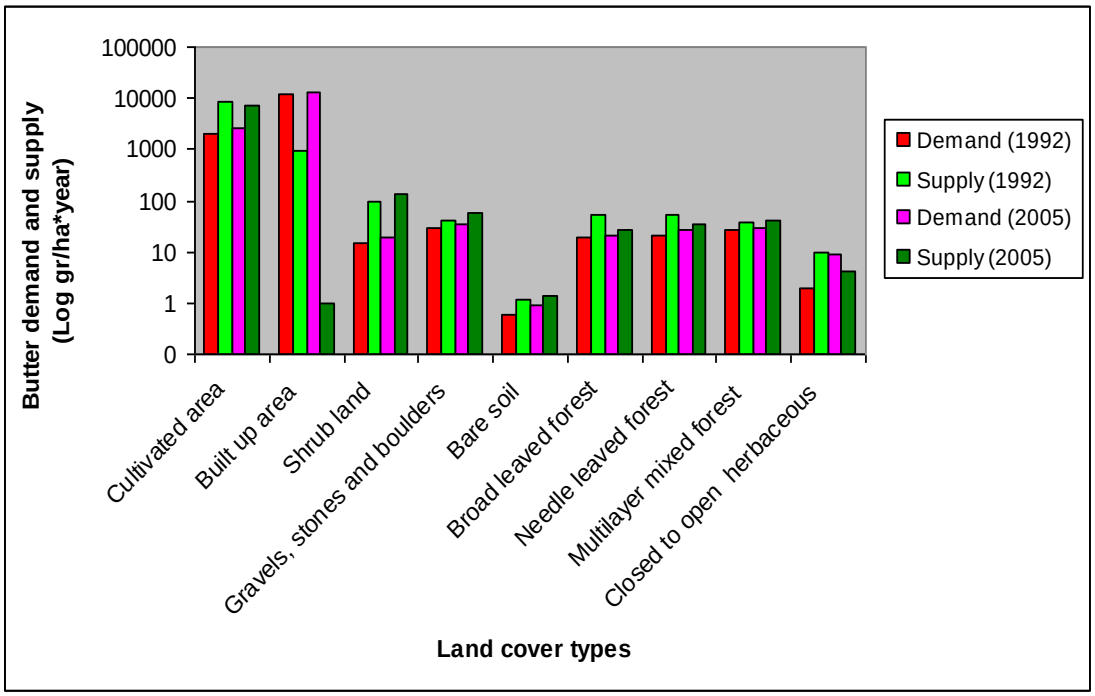
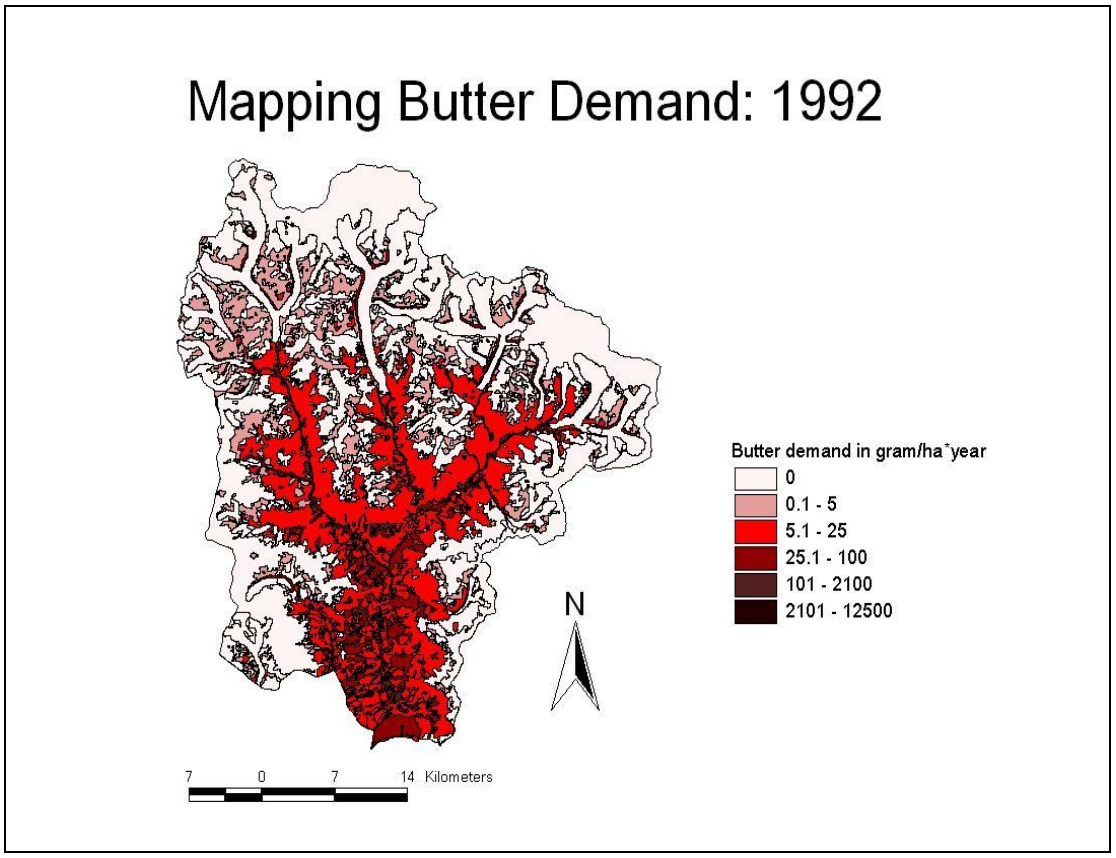


Figure 54: Demand and supply quantities of butter per hectare attributed to the different land cover types in the years 1992 and 2005.

The cultivated area constituted of higher quantities of butter **supply** per hectare in both years 1992 and 2005 with 8280 and 7040 gram/ha*year respectively. The built up area also

constituted of high quantities of butter supply: 940 gram in the year 1992, whereas, the supply quantities of butter decreased by 100% between 1992 and 2005 in the built up area due to the motivation of local people on operating hotels and lodges rather than animal husbandry. Furthermore, the bare soil and the closed to open herbaceous vegetation constituted quantities of butter supply less than 10 gram/ha*year in both years. The other land cover types multilayer mixed forest, needle leaved forest, broad leaved forest, gravels, stones and boulders, and the shrub land constituted quantities of butter supply between 37 and 98, and 28 and 133 gram/ha*year respectively in 1992 and 2005. In addition, the quantities of the butter supply per hectare decreased in the closed to open herbaceous vegetation, cultivated area, broad leaved and the needle leaved forest by 57.14%, 14.97%, 47.36% and 31.37% respectively between 1992 and 2005. The quantities of butter supply per hectare increased in the shrub land, gravels, stones and boulders, multilayer mixed forest and the bare soil land cover types by 35.71%, 33.33%, 13.51% and 16.66% respectively over the 14-year period.

The **demand and supply** quantities of butter per hectare indicates that among all the land cover types, the built up area constituted of the highest quantities of butter deficit in both years 1992 and 2005: 11560 and 13190 gram/ha*year respectively. The closed to open herbaceous vegetation constituted smaller quantities of butter deficit of 4.8 gram/ha in the year 2005. However, the cultivated area constituted of higher quantities of butter surplus in both years with 6270 and 4510 gram/ha*year respectively. The bare soil constituted less quantities of butter surplus less than 1 gram/ha*year in both years, and the closed to open herbaceous vegetation constituted quantities of butter surplus of 7.8 gram/ha in the year 1992. The other land cover types multilayer mixed forest, needle leaved forest, gravels, stones and boulders, broad leaved forest and the shrub land constituted quantities of butter surplus between 11 and 83, and 8 and 114 gram/ha*year respectively in 1992 and 2005. The butter deficit increased in the built up area by 14.10% over the 14-year period. The butter surplus has decreased in the cultivated area, broad leaved, needle leaved forest and the bare soil by 28.07%, 76.60%, 74.19% and 18.03% respectively between 1992 and 2005. The butter surplus per hectare increased in the shrub land, gravels, stones and boulders, and the multilayer mixed forest by 37.34%, 66.66% and 18.19% respectively over the 14-year period.



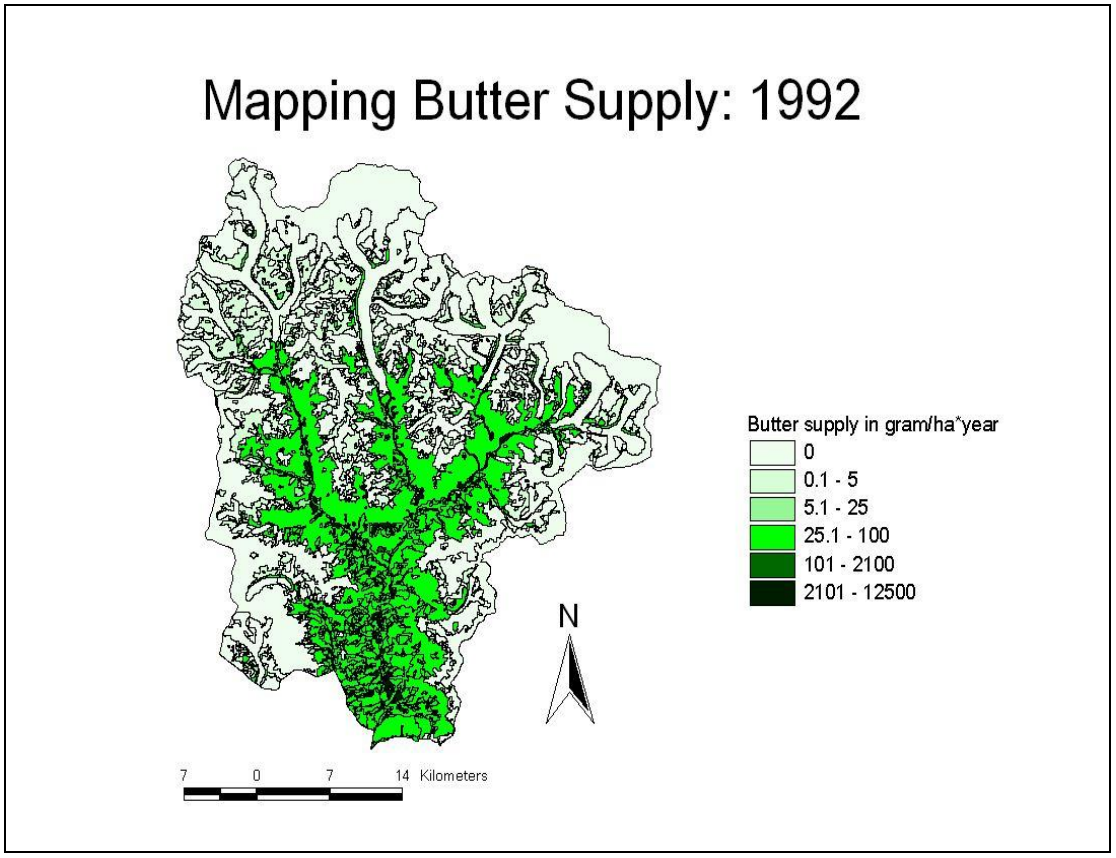
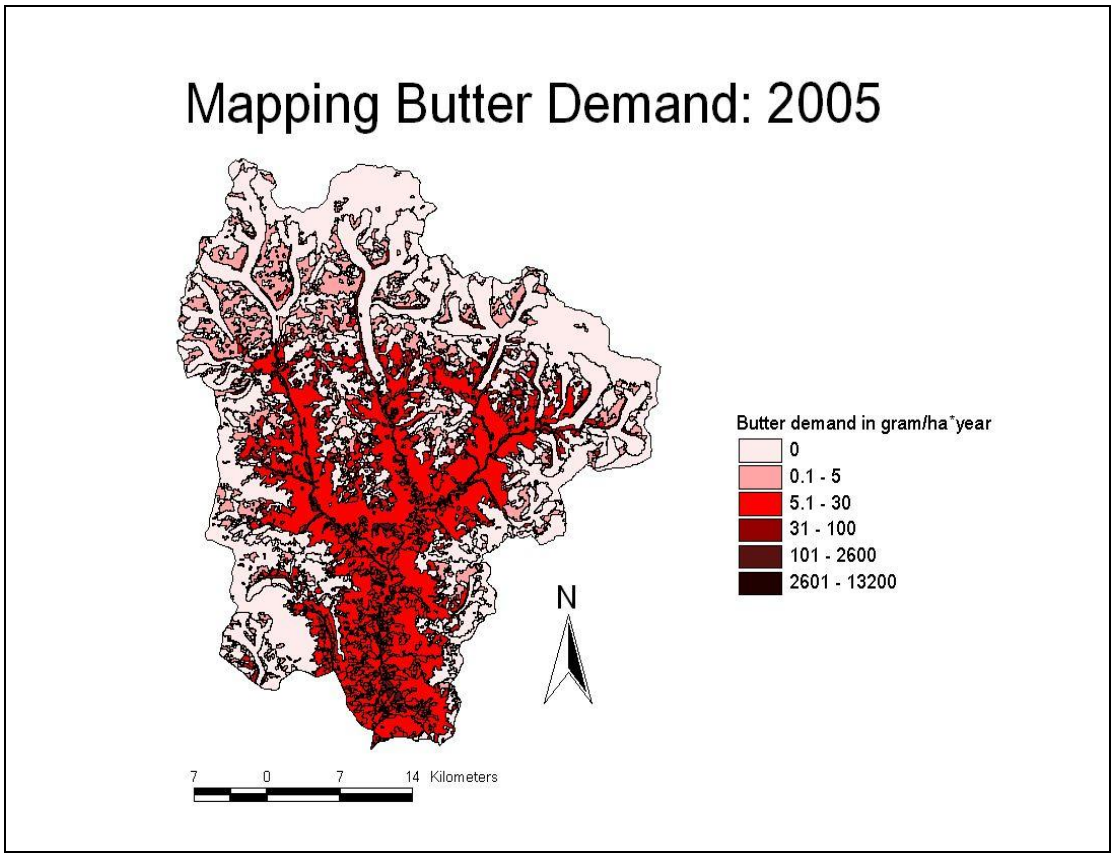


Figure 55: Mapping butter demand and supply of the year 1992.



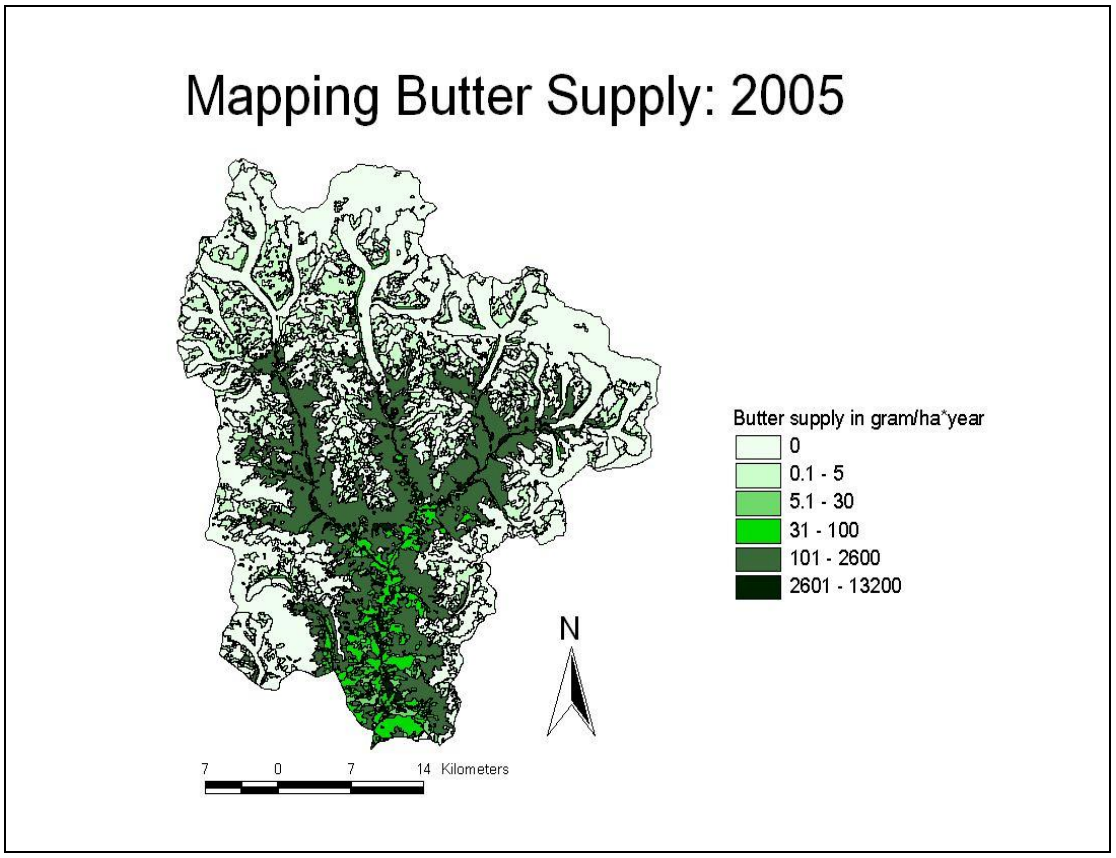
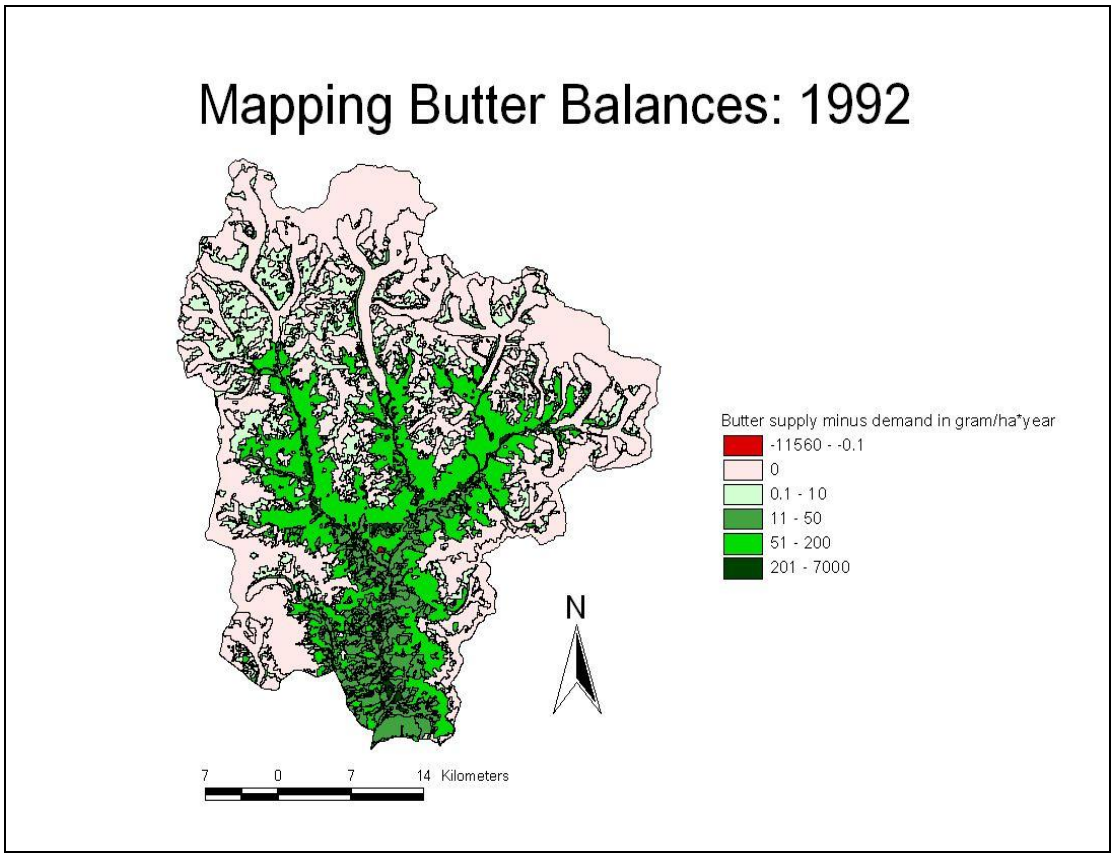


Figure 56: Mapping butter demand and supply of the year 2005.



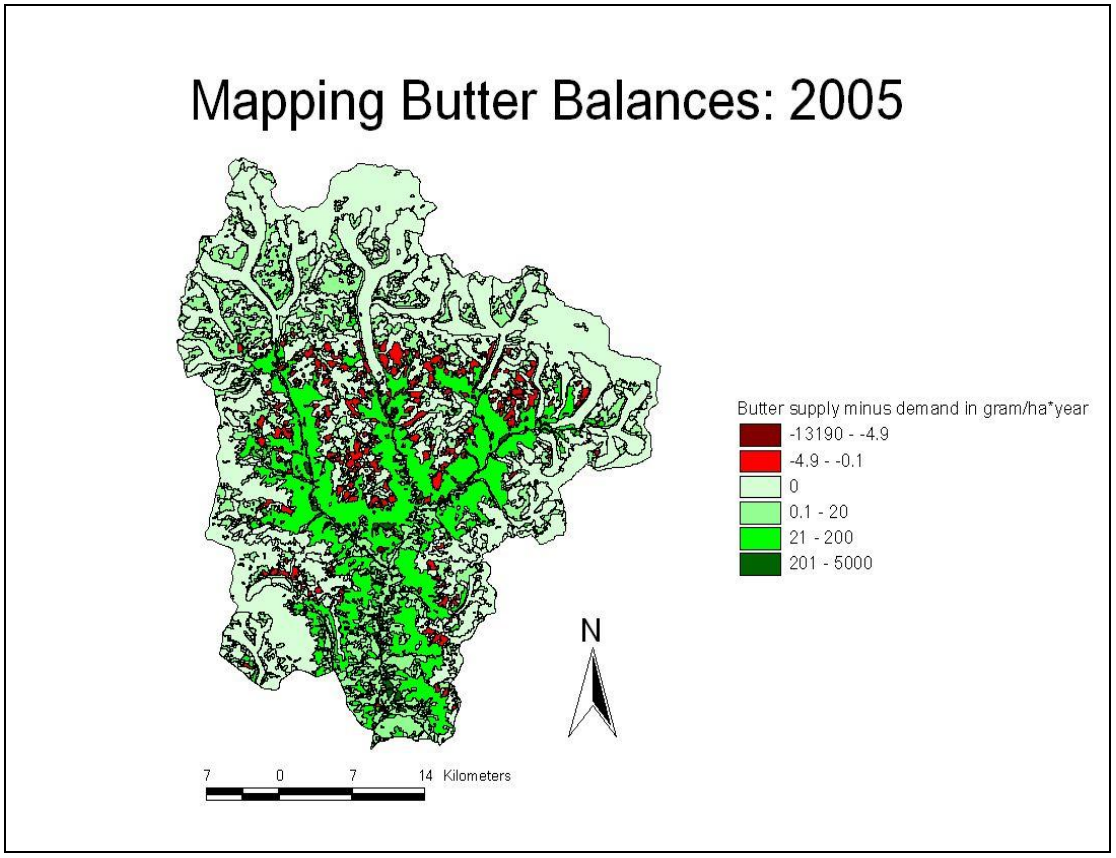


Figure 57: Mapping butter balances of the years 1992 and 2005.

The total quantity of butter **demand, supply and surplus** of the years 1992 and 2005 are presented in figure 58. The total butter demand of the years 1992 and 2005 reached 2934 and 3635kg per year respectively, while the total butter supply has been reached 10002 and 9070kg per year respectively. Consequently, have a butter surplus of 7068 and 5435kg/year respectively in 1992 and 2005. Between 1992 and 2005, the total quantity of butter demand increased by 23.89%, butter supply and surplus decreased by 9.31% and 23.10% respectively. Due to the promotion of religious events, where, butter is the main worshipping material, there has been a higher consumption of butter than before. But still the region possesses a surplus, which is e.g. used to produce butter cheese, locally named "churpi", which traded to other parts of Nepal.

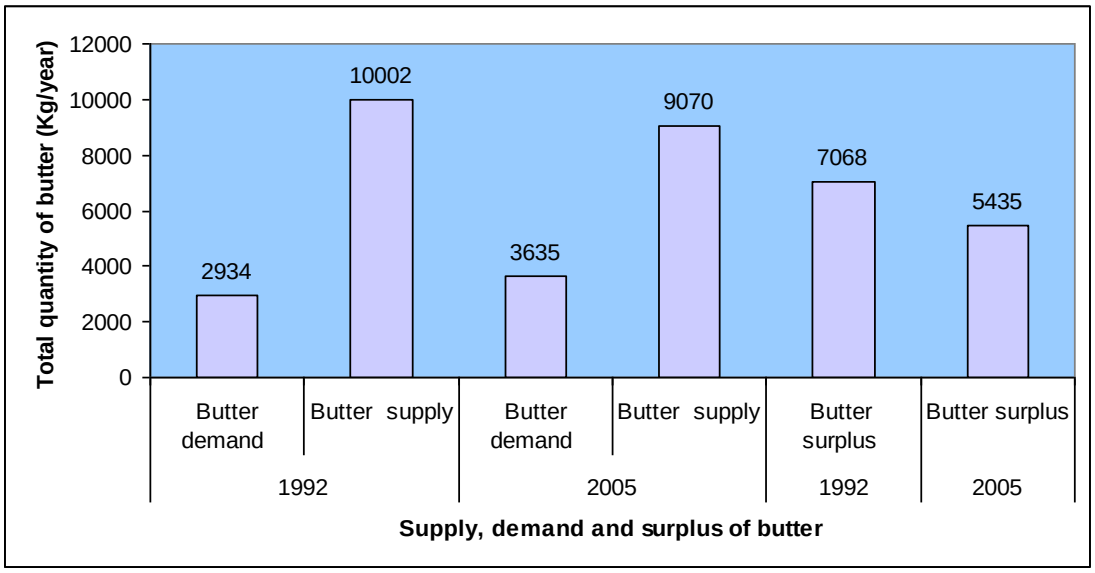


Figure 58: Total quantity of butter supply, demand and surplus in the whole region of the years 1992 and 2005.

4.5.5 Changes in the supply of transportation

The supply maps of transportation service of the years 1992 and 2005 are presented in figure 60. The income based on transportation seems to be very high because it is assumed that the total numbers of **zopkios** available in the settlements are used as a packstock for transportation. The supply of transportation in terms of income per land cover type of the years 1992 and 2005 are presented in figure 59. Among all the land cover types, the highest income was attributed to the cultivated area in both years with US*$* 149740.54 and 449222.92 per year, whereas a smaller income was attributed to the closed to open herbaceous vegetation in both years 1992 and 2005: US*$* 437.83 and 1936.30 per year respectively.

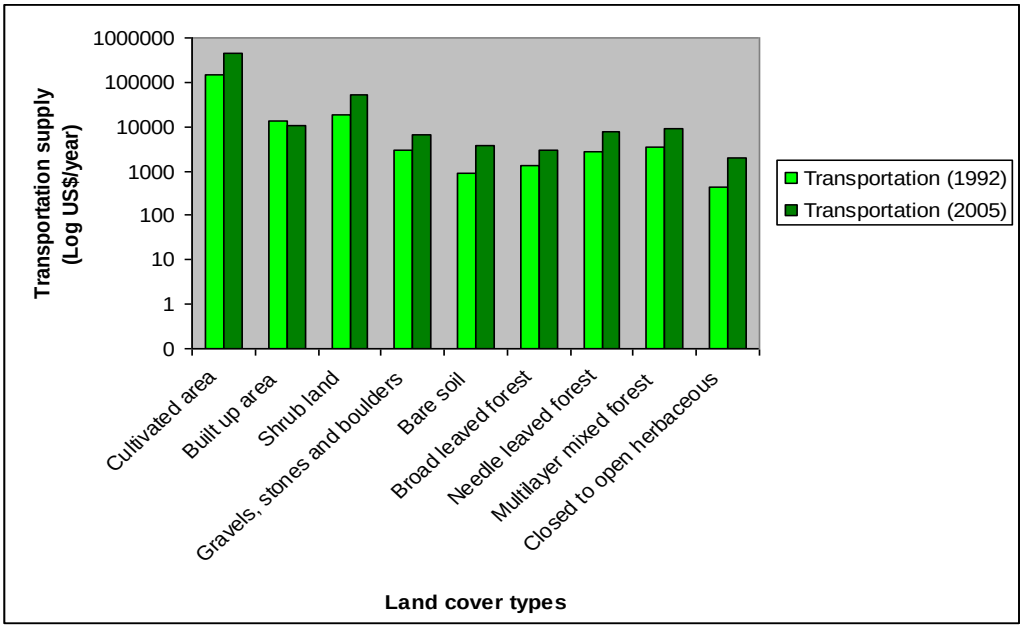
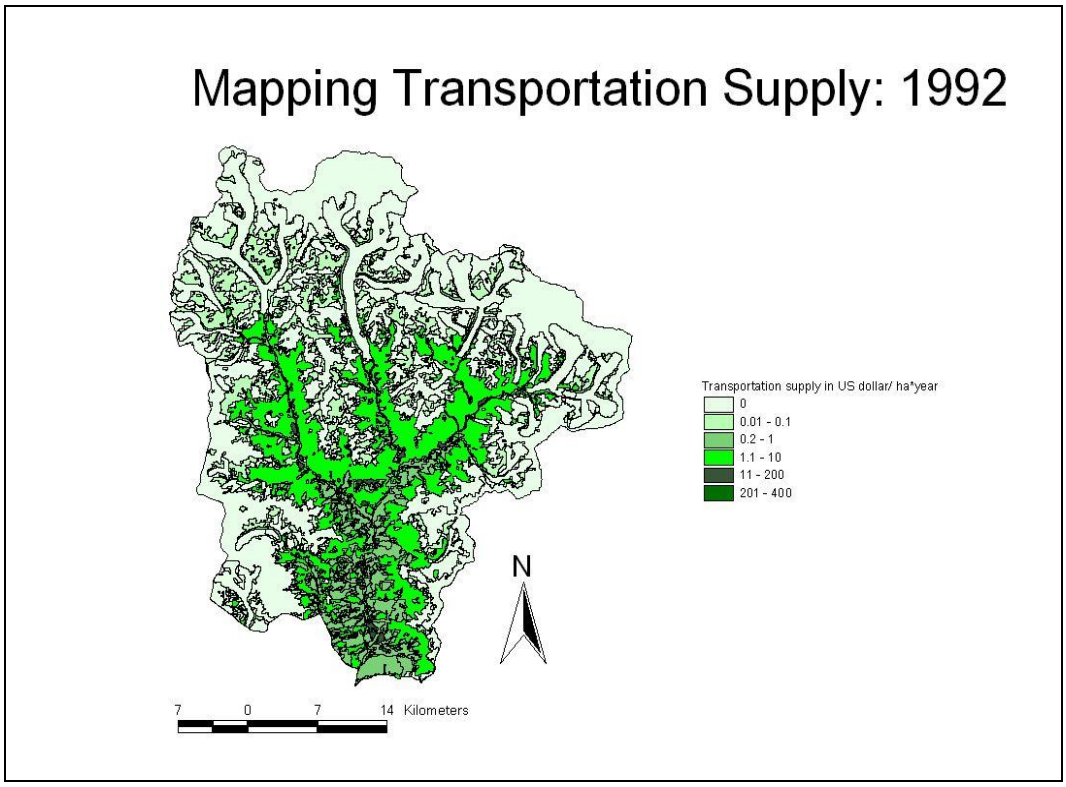


Figure 59: Total supply value of transportation attributed to the different land cover types in 1992 and 2005.

The other land cover types bare soil, broad leaved forest, needle leaved forest, multilayer mixed forest and gravels, stones and the boulders constituted incomes between US $ 875 and 3502, and 2904 and 8713 per year respectively in 1992 and 2005. The shrub land and built up area constituted incomes of US $ 18389 and 13135 respectively in the year 1992, whereas, in the year 2005, these land cover types constituted incomes of US $ 50343 and 10649 respectively. The total amount of income has only decreased in the built up area by 18.92% between 1992 and 2005. The **total income** increased in all other land cover types: cultivated area (200%), shrub land (173.76%), gravels, stones and boulders (121.12%), bare soil (342%), broad leaved forest (121%), needle leaved forest (194%), multilayer mixed forest (148%) and closed to open herbaceous vegetation (342%) respectively over the 14-year period. In addition, the total amount of income through transportation of the years 1992 and 2005 in the

whole region constituted of US $193086.44 and 542165.56 respectively. Besides the built up area in all other land cover types the total numbers of zopkios have increased. Between 1992 and 2005, the income per zopkio per day has increased by 76.31%. These factors have in been responsible for a growth of income over time.



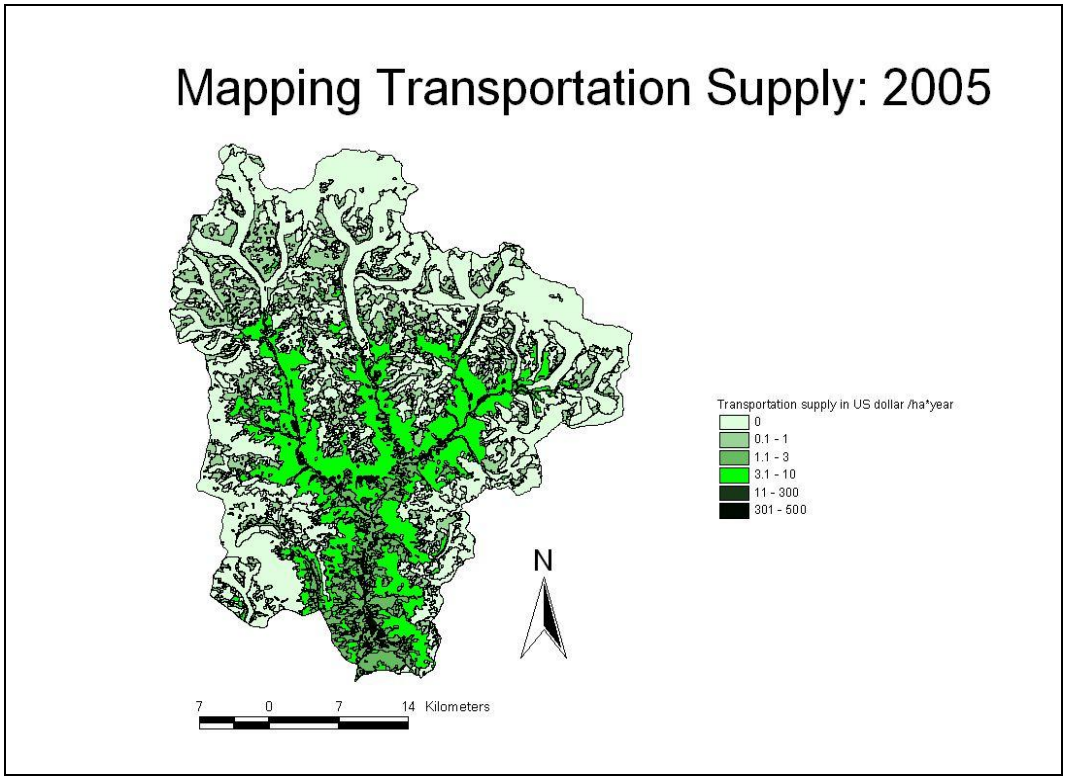


Figure 60: Mapping transportation supply of the years 1992 and 2005.

4.6 Spatial and temporal changes in the regulating services

4.6.1 Changes in the demand of soil erosion regulation

The quantity of soil loss seems to be very high in the region. This value is based on the literature reviews and field observation rating. The demand map of the soil erosion regulation of the year 1992 is presented in figure 63. The **demand** quantity of soil erosion regulation per hectare in 1992 is presented in figure 61. Among all the land cover types, the bare soil constituted a high demand in quantities of soil erosion regulation; 41 metric tons/ha*year, whereas, the broad leaved forest constituted demand quantities of soil erosion regulation of only 1 metric ton/ha*year. Similarly, the other land cover types needle leaved forest, multilayer forest, shrub land, cultivated area and closed to open herbaceous vegetation constituted demand quantities of soil erosion regulation of 2, 1.5, 4, 13 and 8 metric tons/ha*year respectively.

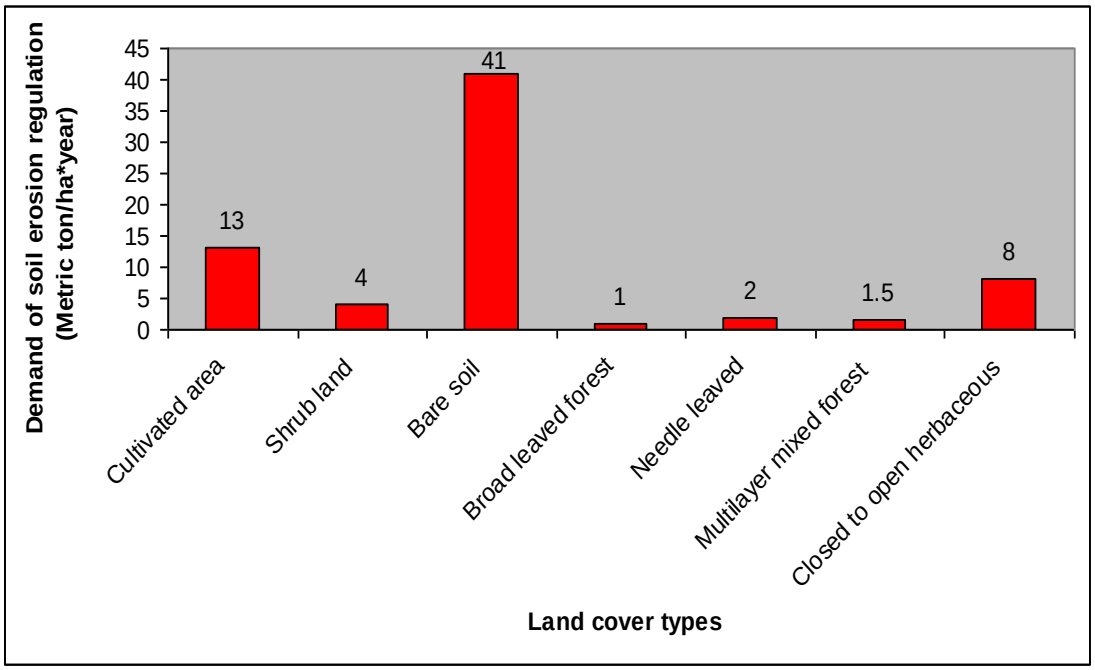


Figure 61: Demand quantities of soil erosion regulation per hectare attributed to the different land cover types in 1992.

The **total demand** of soil erosion regulation per land cover type of the years 1992 and 2005 are presented in figure 62. The bare soil land cover type constituted the highest demand quantities of soil erosion regulation in both years, 1992 and 2005: 1094946 and 1127459 metric tons per year respectively, whereas, the broad leaved forest constituted smaller demand quantities of soil erosion regulation in both years: 1952 and 2688 metric tons per year respectively. The needle leaved forest, multilayer mixed forest and the cultivated area

constituted demand quantities of soil erosion regulation in between 6300 and 12012, and 5511 and 11635 metric tons/year respectively in 1992 and 2005. The closed to open herbaceous vegetation and the shrub land constituted demand quantities of soil erosion regulation between 50736 and 65876, and 65728 and 66756 metric tons/year respectively in 1992 and 2005. The demand for soil erosion regulation increased in the broad leaved forest, needle leaved forest, shrub land, closed to open herbaceous vegetation and the bare soil by 37.70%, 9.11%, 1.33%, 29.54% and 2.96% respectively between 1992 and 2005. Whereas, it decreased in the multilayer mixed forest and cultivated area by 27.73% and 3.13% respectively over the 14-year period. The total demand of soil erosion regulation in the whole region in 1992 and 2005 reached 1239448 and 1352407 metric tons per year respectively in which the total quantity of soil erosion regulation demand increased by 9.11% between 1992 and 2005. Without doubt, this value is much higher than in other parts of the world. However, due to the special conditions of the Himalayan region this result reflects the real situation of the study site even though the field observation ratings were carried out on a qualitative basis. Thus, there is a need for further detailed scientific research on this topic.

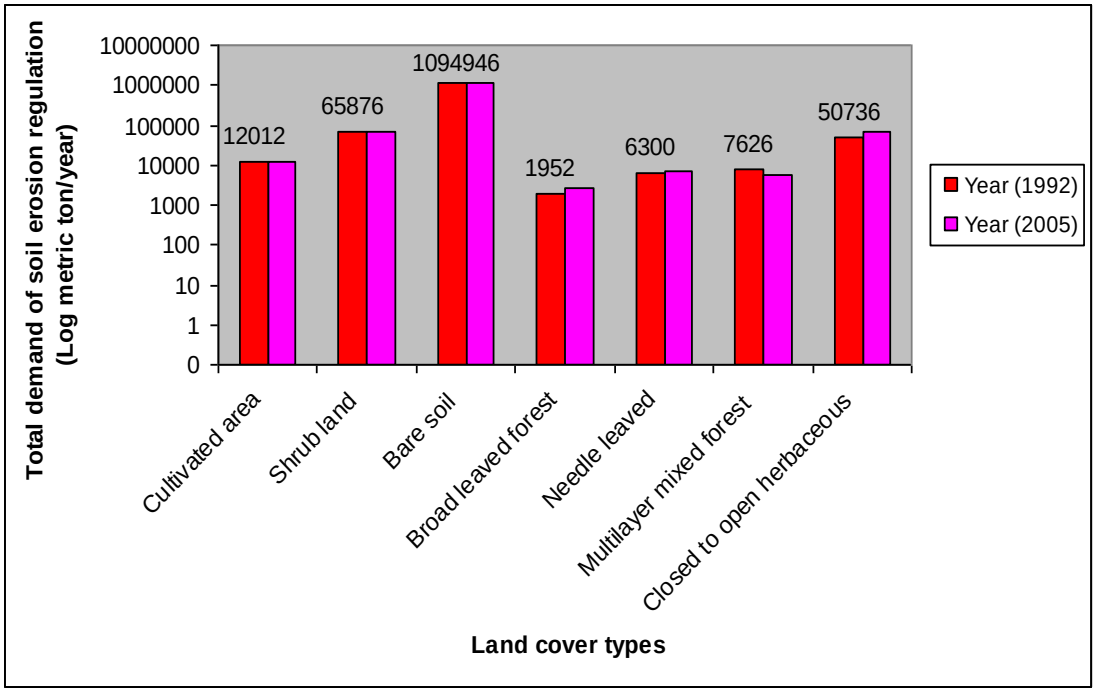


Figure 62: Total demand of soil erosion regulation attributed to the different land cover types in 1992 and 2005.

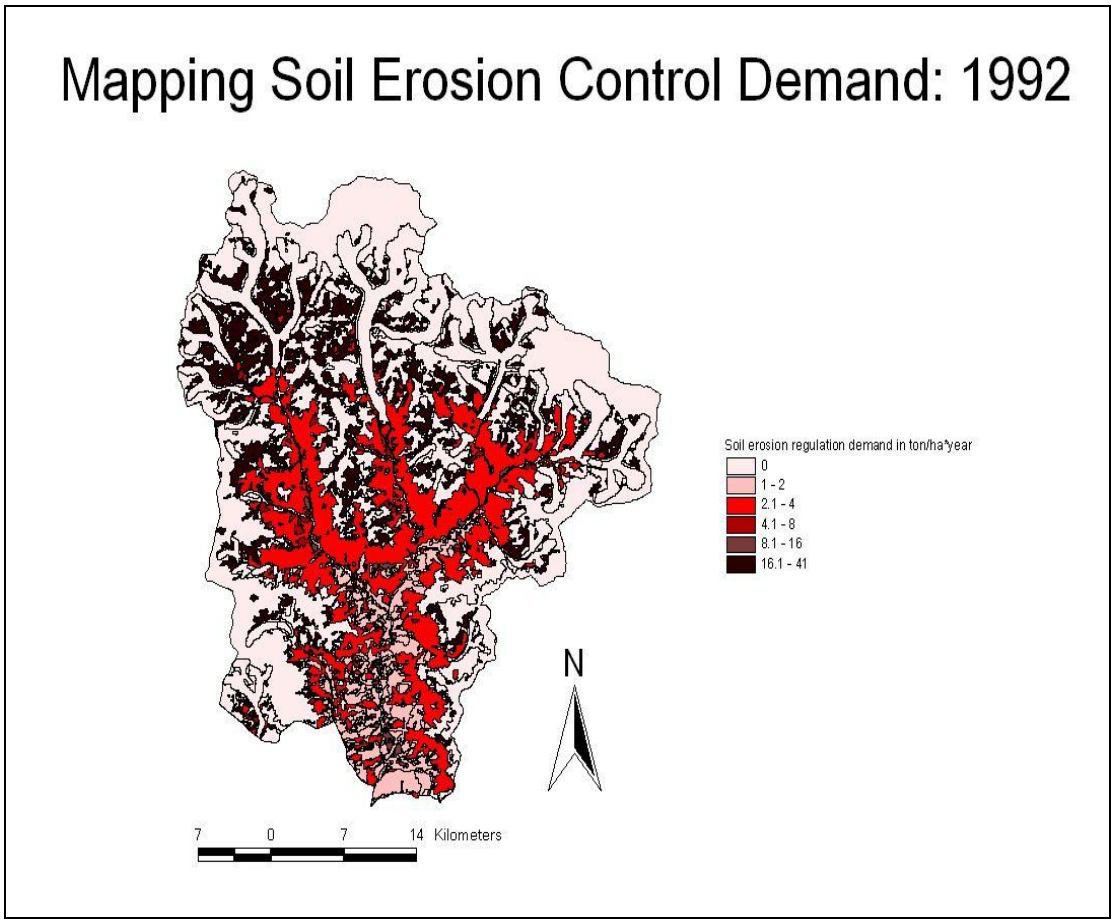


Figure 63: Mapping soil erosion regulation demand of the year 1992.

4.6.2 Changes in carbon production and sequestration

The carbon sequestration demand and supply maps of the year 2005 are presented in figure 66. The total amount of carbon supply and sequestration per land cover type of the years 1992 and 2005 are presented in figure 64. This value is based on the literature reviews and field observations ratings. Among all the land cover types, the highest amount of **carbon supply** was attributed to the cultivated area in both years 1992 and 2005: 13.47 and 12.8 metric tons respectively. The built up area and the shrub land constituted amounts of carbon supply in both years between 2.05 and 2.74, and 2.25 and 2.64 metric tons respectively in 1992 and 2005. The other land cover types constituted amounts of carbon supply of less than 1 metric ton in both years. The total amount of carbon supply decreased in the built up area, broad leaved forest, multilayer mixed forest and the cultivated area by 3.64%, 2.04%, 3.40% and 4.97% respectively between 1992 and 2005. Whereas, the total amount of carbon supply increased in the shrub land, needle leaved forest and the gravels, stones and boulders by 9.75%, 6.02% and 4.16% respectively over the 14-year period. In addition, the total amount

of carbon supply has remained the same in the bare soil and the closed to open herbaceous vegetation land cover types between 1992 and 2005.

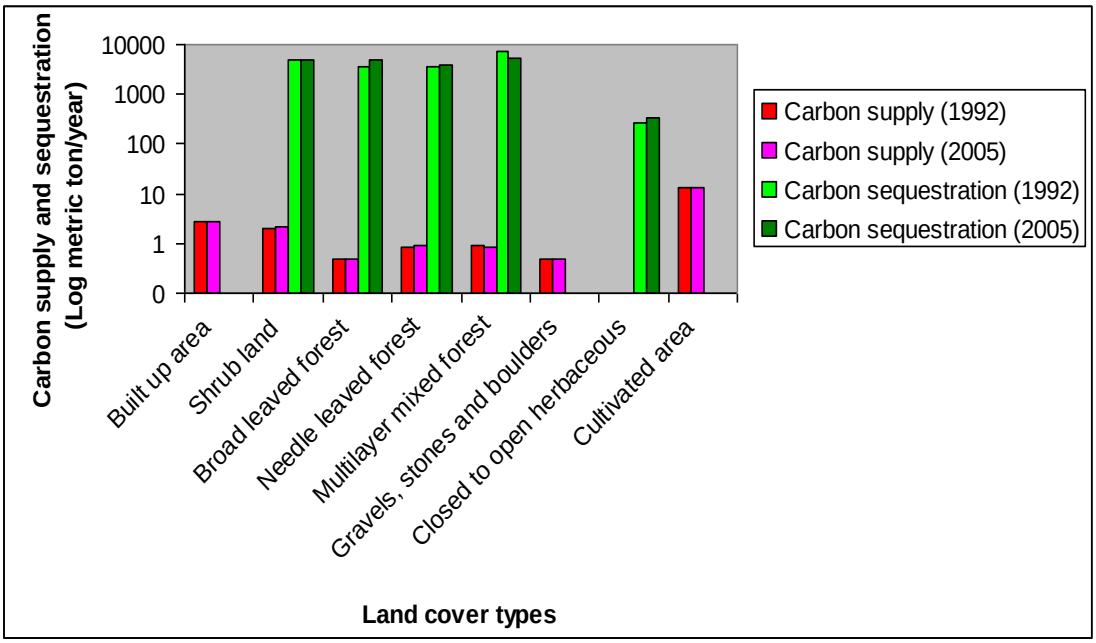


Figure 64: Total quantities of carbon supply and sequestration attributed to the different land cover types in 1992 and 2005.

Among all the land cover types, the multilayer mixed forest constituted the highest amount of **carbon sequestration** in both years 1992 and 2005: 7168.44 and 5180.34 metric tons per year respectively. The broad leaved forest, needle leaved forest and the shrub land constituted carbon sequestration between 3474 and 4842, and 3883 and 4907 metric tons respectively in 1992 and 2005. The closed to open herbaceous vegetation land cover type recorded 266.36 and 345.07 metric tons respectively in 1992 and 2005, whereas, the built up area, bare soil, cultivated area and the gravels, stones and boulders land cover types recorded null in both years. Between 1992 and 2005, the total amount of carbon sequestration decreased in the multilayer mixed forest by 27.73%. Whereas, the total amount of carbon sequestration increased in the shrub land, broad leaved forest, needle leaved forest and the closed to open herbaceous vegetation land cover types by 1.33%, 37.70%, 9.11% and 29.55% respectively over the 14-year period.

The total amounts of **carbon supply, sequestration and surplus** in the whole region in 1992 and 2005 are presented in figure 65. The total amount of carbon supply of 1992 and 2005 has reached 21.01 and 20.46 metric tons per year respectively. The total amount of carbon sequestration of 1992 and 2005 reached 19310.76 and 19100.42 metric tons per year respectively. The surplus amount of carbon supply and sequestration for 1992 and 2005 was

obtained to be 19289 and 19079 metric tons respectively. Furthermore, the total amount of carbon supply and sequestration decreased by 2.61% and 1.08% respectively over the 14-year period, in which the total surplus of carbon sinks decreased by 1.08% between 1992 and 2005. The amount of carbon storage in the region seems to be very high. Due to the lack of appropriate reference data and the use of field observation ratings, this result could be different if a high level applied research had been carried out. However, if this result reflected true conditions of the region the local people could benefit from this huge surplus by getting accreditations within carbon trading schemes.

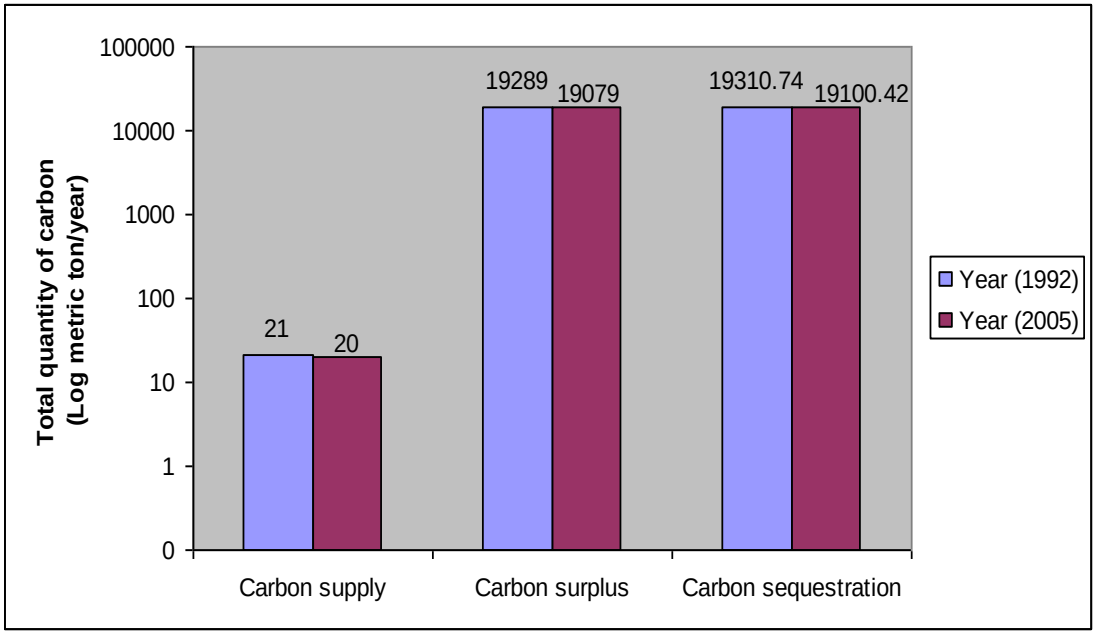


Figure 65: Total quantity of carbon supply, sequestration and surplus in the whole region in the years 1992 and 2005.

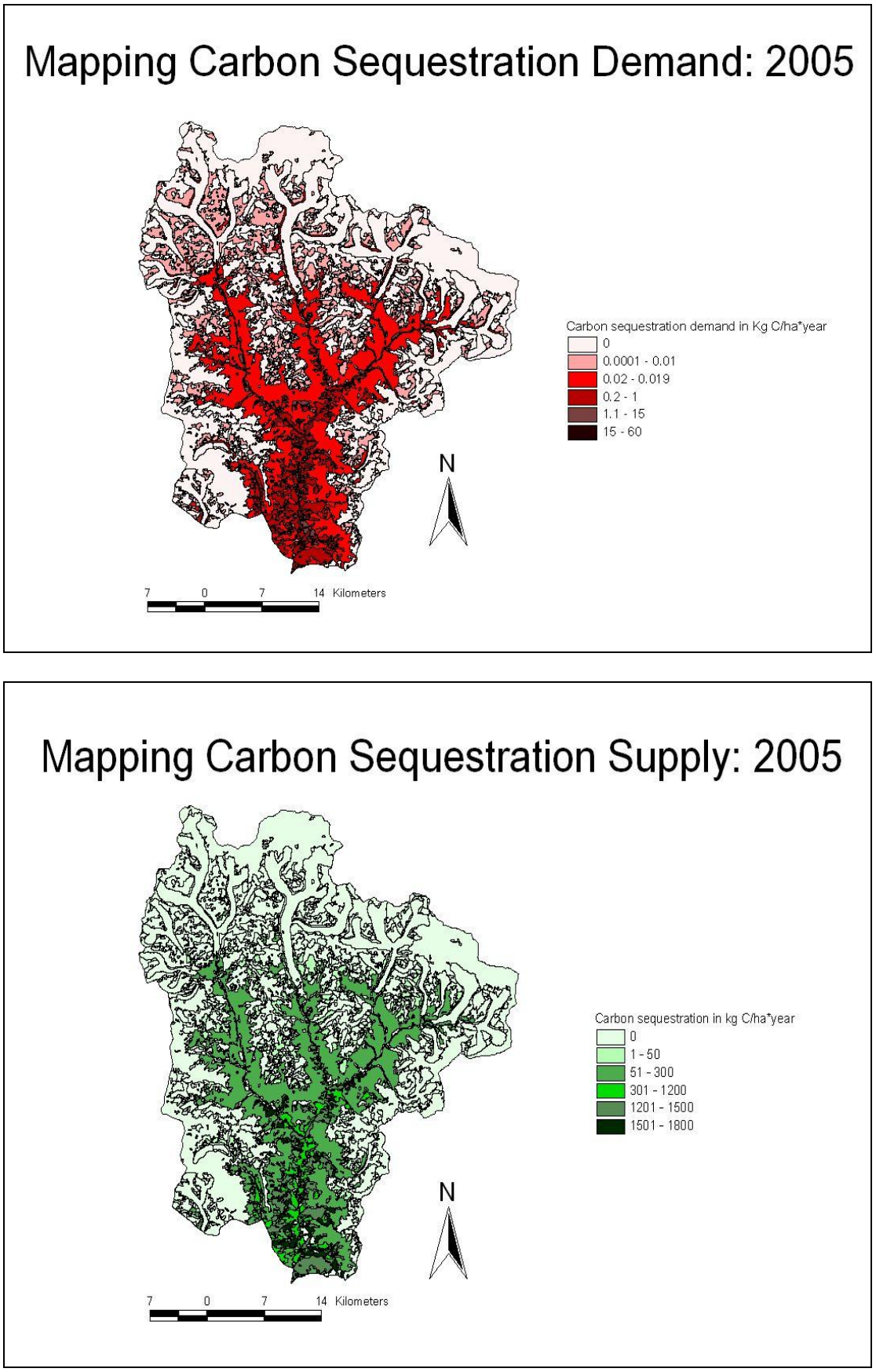


Figure 66: Mapping carbon sequestration demand and supply of the year 2005.

4.7 Spatial and temporal changes in the cultural services

4.7.1 Changes in the supply and demand of religious values

The supply and demand maps of the religious value of 1992 and 2005 are presented in figures 68 and 69. The total **supply** of religious value in terms of amount of donations received per land cover type of 1992 and 2005 is presented in figure 67. This data is obtained from the household survey data collection. The demand value has been estimated by considering the time local people spent on visiting religious sites in relation to their annual income. The supply value has been estimated based on the amount of donations received by the religious sites. The shrub land had the highest supply of religious values in both years 1992 and 2005 with US $ 62027.02 and 38235.66 per year respectively, whereas, the broad leaved forest constituted the smallest supply of religious values in both years: US $ 756.75 and 481.24 per year respectively. The other land cover types constituted supply values between US $1500 and 10000 in both years. Between 1992 and 2005, the total supply of religious values decreased in all the land cover types; shrub land (38.35%), cultivated area (36.86%), multilayer mixed forest (17.70%), built up area (40.25%), needle leaved forest (34.82%) and broad leaved forest (36.40%). The increased costs of the Everest trip have made tourists reduce the donations. Global economic recession and changes in the hosting environments are the reasons for the decrease of the respective supply values.

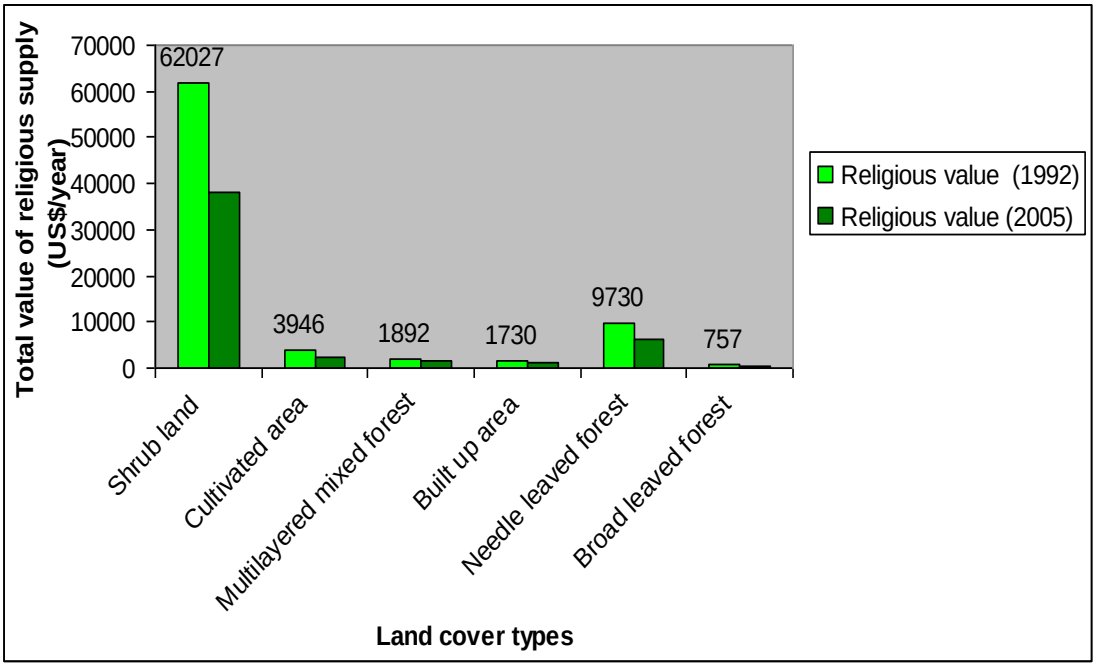
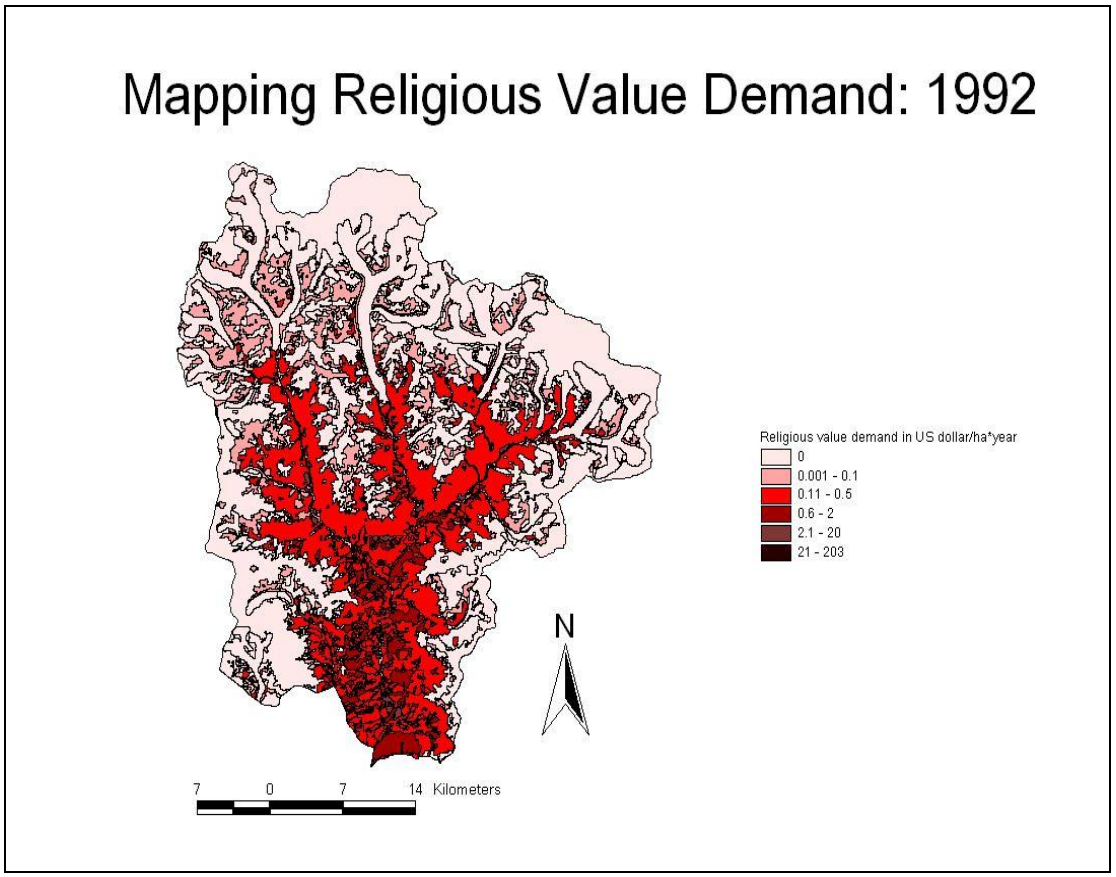


Figure 67: Total value of religious supply per land cover type in 1992 and 2005.



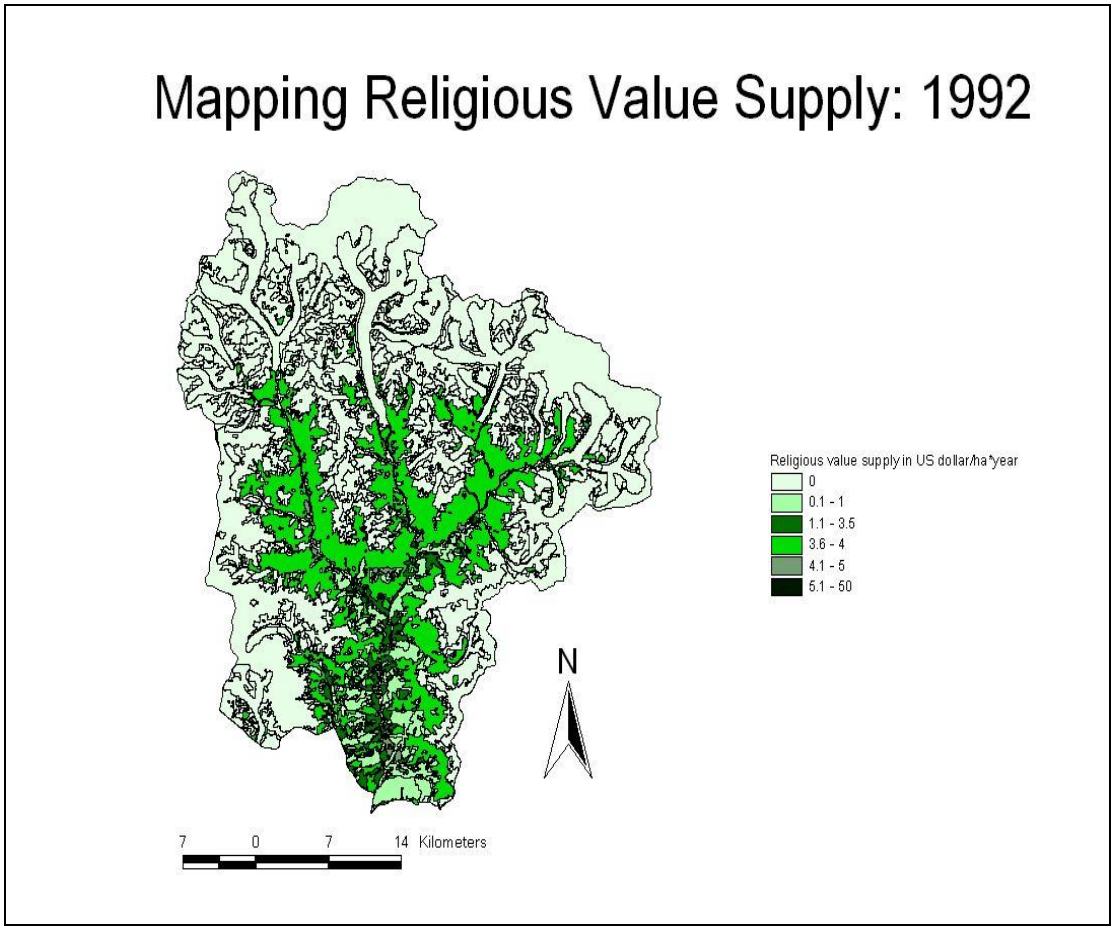
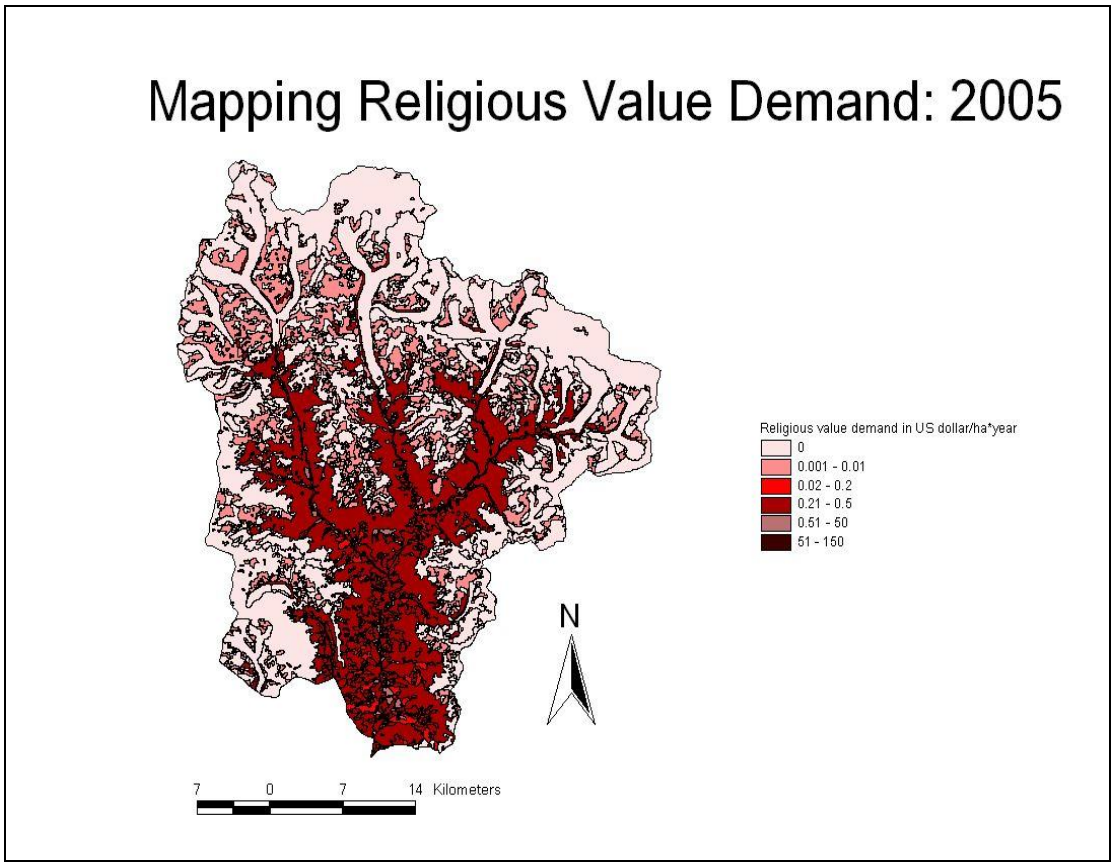


Figure 68: Mapping religious value demand and supply of the year 1992.



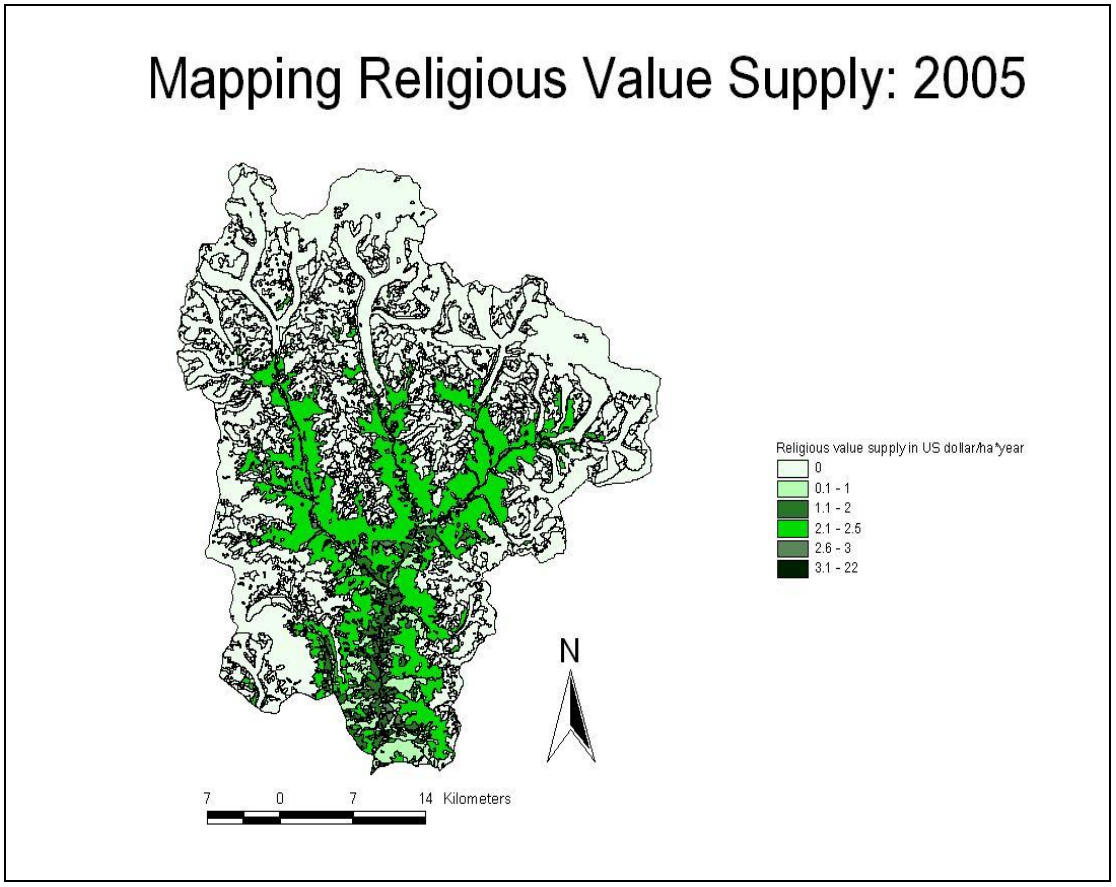


Figure 69: Mapping religious value demand and supply of the year 2005.

The **total demand** for religious values per land cover type of 1992 and 2005 are presented in figure 70. Among all the land cover types, the cultivated area constituted of the highest demands for religious values in both years 1992 and 2005: US $ 18072.51 and 36825 per year respectively. The built up area also constituted of higher demands of religious values in both years with US $ 7496 and 6879 per year respectively. In the same vein, the shrub land constituted a high demand of US $ 6141 in the year 2005, whereas this same land cover type was attributed a value of only US $ 2419 in the year 1992. The total numbers of hotels and lodges have increased along with the growing number of tourists in the region. This tourism affluence has enabled lodge owners and hotel owners to afford employees to do their household works. Thus the owners can use more time to make a visit to the religious sites. Therefore, the tourism affluence was the main reason to derive a high demand of religious values in shrub land and other land cover types besides the built up area. The total demand of religious value has decreased only in the built up area because the settlements of this land cover type are the tourist hub centres, where almost all households remain busy with tourism related works. Due to the higher flow of visitors, people hardly managed time to visit religious sites, thus the demand of religious value decreased. Similarly, the closed to open herbaceous vegetation land cover type constituted smaller demands of US $ 20 and 23 respectively in 1992 and 2005. The other land cover types bare soil, broad leaved forest, needle leaved forest, multilayer mixed forest and the gravels and stones and boulders constituted demands between US $ 120 and 1191 and, 144 and 6879 per year respectively in 1992 and 2005. Furthermore, the total demand of religious values increased in the cultivated area, shrub land, bare soil, needle leaved forest, broad leaved forest, multilayer mixed forest, closed to open herbaceous vegetation and the gravels, stones and boulders land cover types by 103.76%, 153.86%, 19.83%, 17.28%, 82.45%, 56.17%, 15% and 66.85% respectively between 1992 and 2005. The total demand has decreased in the built up area by 8.23% over the 14-year period.

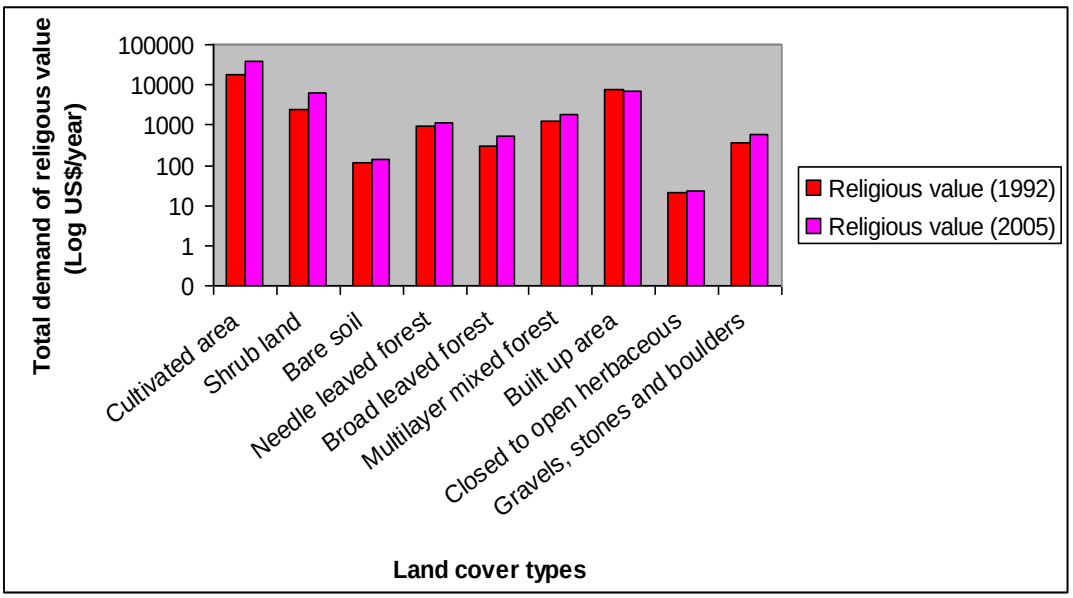


Figure 70: Total demand of religious value per land cover type in 1992 and 2005.

The **total demands, supplies and surplus/deficits** of religious value in the whole region in 1992 and 2005 are presented in figure 71. The total demand reached US $ 30926 and 54115 per year respectively, and the total supply of the years 1992 and 2005 reached US $ 80081 and 50139 per year. The demand and supply budget recorded a surplus of US $ 49155 in the year 1992 and a deficit of religious value of US $ 3976 in the year 2005. Due to the increase of households' incomes from tourism as well as the increased time for religious purposes in the semi-trekking route households a deficit budget of religious values has resulted.

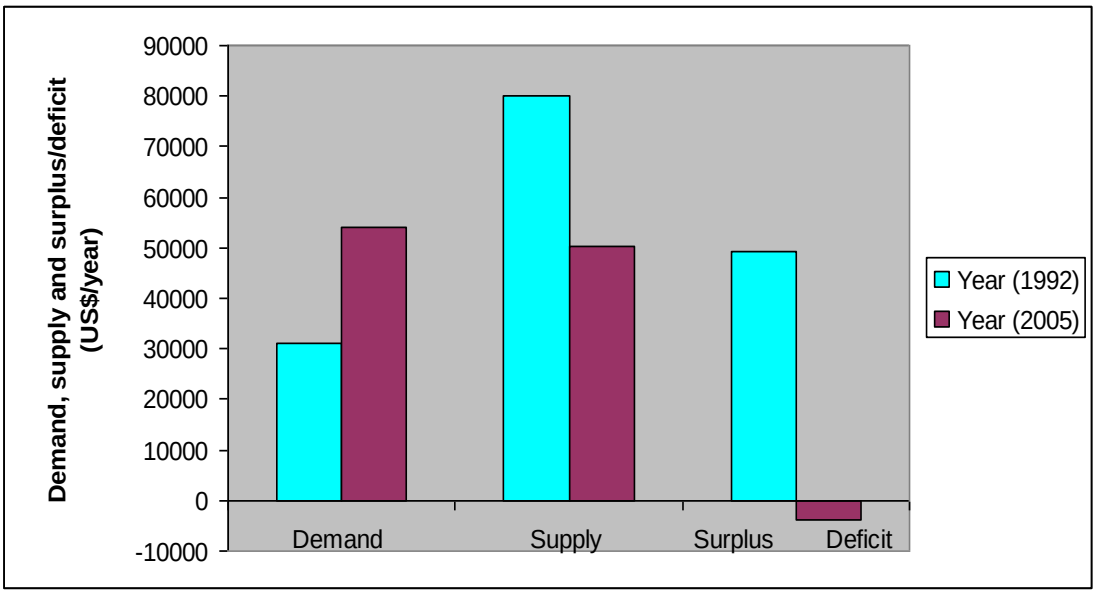


Figure 71: Total demand, supply and surplus/deficit of religious value in the whole region in 1992 and 2005.

4.7.2 Changes of the aesthetic value

The supply maps of the aesthetic value of the year 1992 and 2005 are presented in figure 73. The total **supply** of aesthetic value per land cover of the years 1992 and 2005 are presented in figure 72. These values were determined through tourist surveys by providing photographs of land cover types to rank their satisfaction level derived from the particular land cover type out of their total expenditure. The snow land cover type showed the highest supply of aesthetic values in the both years: US $ 2534157 and 8698010 per year respectively. The built up area, shrub land and the glacier constituted supply ratios between US $ 1044597 and 1698878, and 4006415 and 6521836 per year respectively in 1992 and 2005. This result illustrates that the higher alpine areas are the main destination sites for the tourists. The glacial lake, broad leaved forest, needle leaved and the multilayer mixed forest constituted supplies values between US$ 712803 and 835842, and 2731332 and 3225332 respectively in 1992 and 2005. The other land cover types cultivated area and closed to open herbaceous vegetation constituted supply values of US $ 299309 and 331448 respectively, and US $ 1115470 and 1229922 respectively in the year 2005. The bare rocks, bare soils and the gravels, stones and boulders land cover types constituted supply of aesthetic values less than US $ 100000 in the year 1992 and US $ 350000 in the year 2005. The total supply of aesthetic values based on all the land cover types in the whole region amounted to US $ 10270777 and 38637867 respectively in the years 1992 and 2005. It increased by 276.19% over the 14-year period due to the increased number of tourists as well as their increasing costs per trip to the Everest.

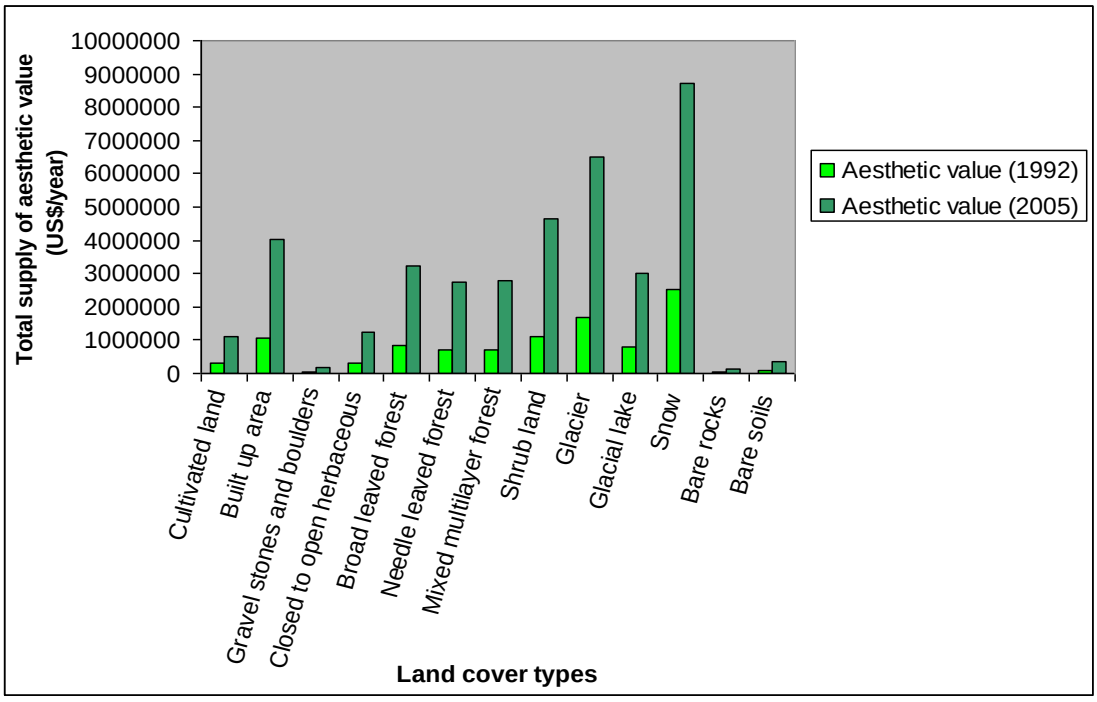
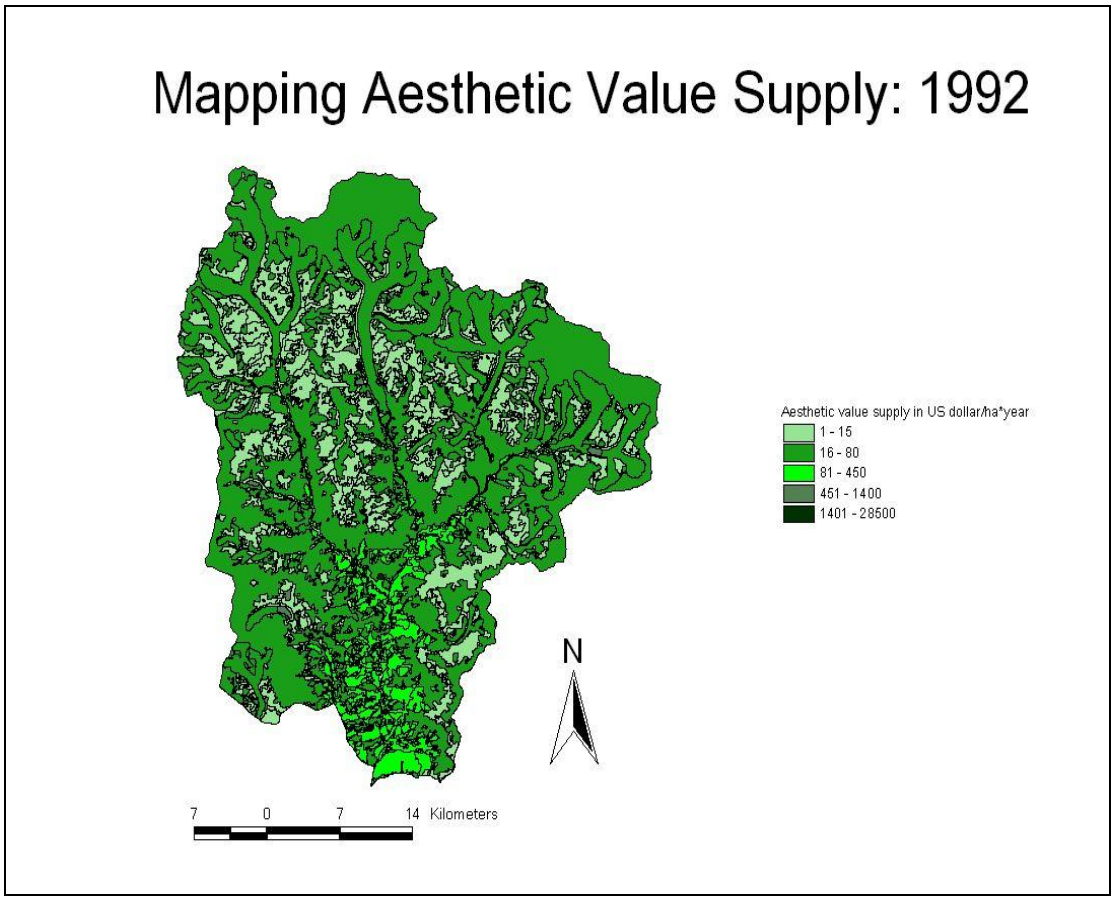


Figure 72: Total supply of the aesthetic value attributed to the different land cover types in the years 1992 and 2005.



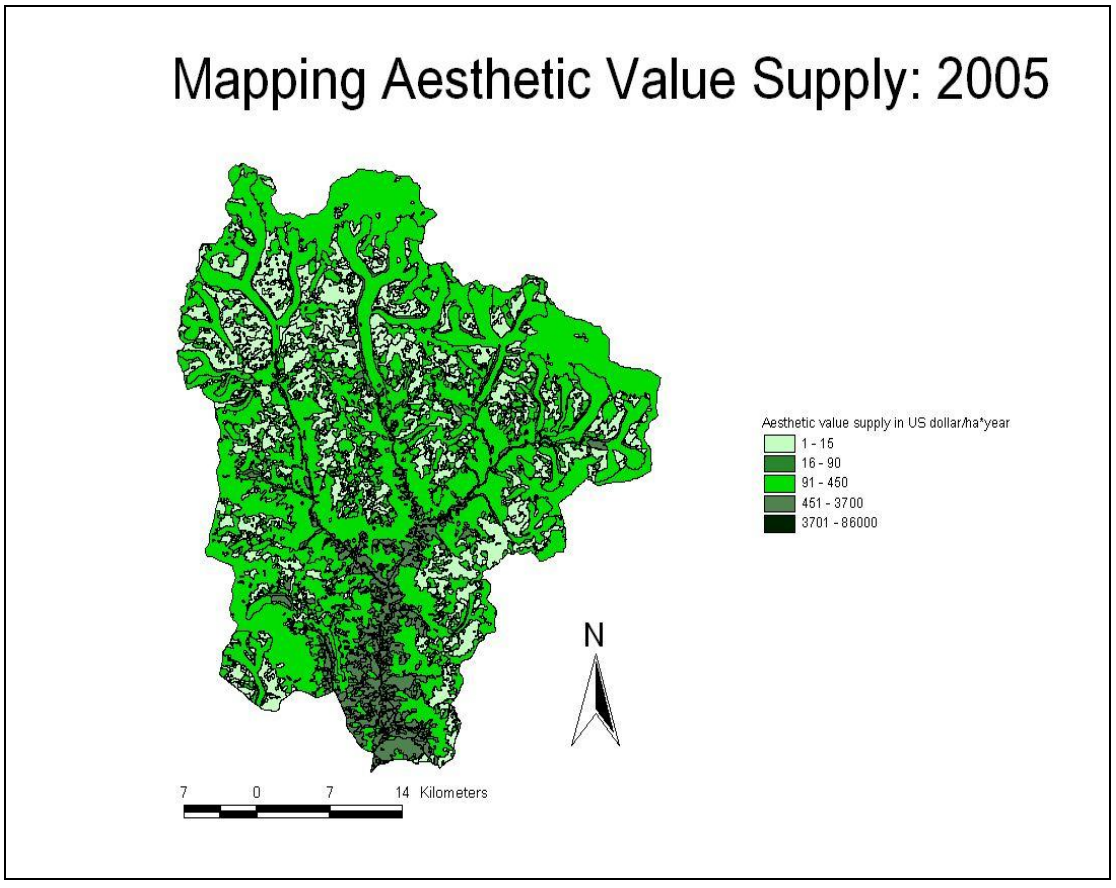


Figure 73: Mapping aesthetic value supply of the years 1992 and 2005.

4.8 Integration of the results concerning ecosystem services

The results about **provisioning services** show that the region has experienced both surplus and deficit quantities of fuelwood, potatoes, milk and butter in 1992 and 2005. Considering the total supply and demand of the whole region, all indicators of provisioning services provided surplus quantities in both years. However in the case of each land cover type, the built up area recorded the highest deficits in the quantities of all provisioning services, while, the broad leaved forests and the multilayer mixed forests showed higher quantities of fuel wood surplus. The cultivated areas recorded a high surplus in the quantities of potatoes, milk and butter in both years and a high supply of the transportation provisioning service in both years, whereas, the closed to open herbaceous vegetation constituted smaller provisions of transportation services. In addition, in terms of demand, the built up area and the cultivated area recorded high demands in provisioning services in both years 1992 and 2005. The bare soil and closed to open herbaceous vegetation land cover types had a small demand in quantities of provisioning services in both years.

With regards to **regulating services**, the highest supply of regulating services was attributed to the broad leaved forest, multilayer mixed forest and the needle leaved forest land cover types. A high demand of regulating services was attributed to the bare soil, built up area and cultivated area. Similar to the provisioning services, the region also attributed both surplus and deficit areas of regulating services. For example, the broad leaved and multilayer mixed forest recorded a high surplus in the quantities of carbon sequestration, whereas the built up area, bare soil and the cultivated area show deficit amounts of this service in both years.

The built up area, cultivated area and the shrub land constituted the highest demands of **cultural services**, whereas, the bare rocks, bare soils and the closed to open herbaceous vegetation land cover types constituted small demands of cultural services in both years. The snow, glacier, built up area and the shrub land constituted a high supply of cultural services in both years, whereas, the bare rocks, bare soils and gravels, stones and boulders have only small supply ratios of cultural services. Moreover, the supply of cultural services has seen both increasing and decreasing trends.

To sum up, the built up area and cultivated area constituted a **high demand** of all kinds of services. Similarly, the shrub land also constituted a higher demand of most of the services. The close to open herbaceous vegetation, bare rocks and gravels, stones and boulders constituted less demand as well as less supply of all kinds of services. Besides the regulating service, bare soil also constituted a small demand of all kinds of services. The cultivated area

provided a **high supply** of provisioning services, and the broad leaved forest also shows high supply rates of some of the provisioning services and regulating services such as fuelwood supply and carbon sinks. In addition, the snow, built up area and glacier land cover types constituted high supply values of cultural services.

Considering the **multilayer mixed forest** values as a reference, the result shows that the demand is highest in the shrub land as well as the supply side in both years 1992 and 2005. Similarly, the broadleaved forest constitutes low demand as well as supply in both years, which can be observed in figures 75 and 76. The needle leaved forest seems to provide similar patterns as the multilayer mixed forest besides the religious values. The supply of religious values is higher in the needle leaved forest than in the multilayer mixed forest. This land cover type holds surplus values of religious services in both years. The demand of butter is lowest in the shrub land where as it constituted the highest supply values in 1992. This surplus value has decreased in 2005. Similarly, this land cover type attributed a high surplus of milk in 1992, whereas this value has highly decreased in 2005. Furthermore, this land cover type constituted of a deficit value of fuelwood service in both years. In the case of other services such as carbon sequestration and fuelwood supply, very similar patterns among the needle leaved forest, multilayer mixed forest and the shrub land can be observed. In an overall assessment, the supply of milk has highly increased, whereas religious value and butter has decreased. The demands of butter, milk and religious values have increased (see figure 74) in which the religious service constituted the highest value. The two services (butter and religious value) are depending on the same drivers because both of them are totally dependent on the functions of the gumpas. The highest increases are attributed to the shrub land because of the tourists' interferences. The demand of potato service also increased in a small number. The demand of other services carbon sequestration and fuelwood remains same. The supply of butter and religious services decreased in which the religious service attributed the highest decreased value. The milk service increased slightly due to the tourism based affluence. The supply of the others services potato, fuelwood and carbon sequestration remains the same. There was a deficit of religious value and butter services in the year 2005, whereas the milk service attributed a surplus value.

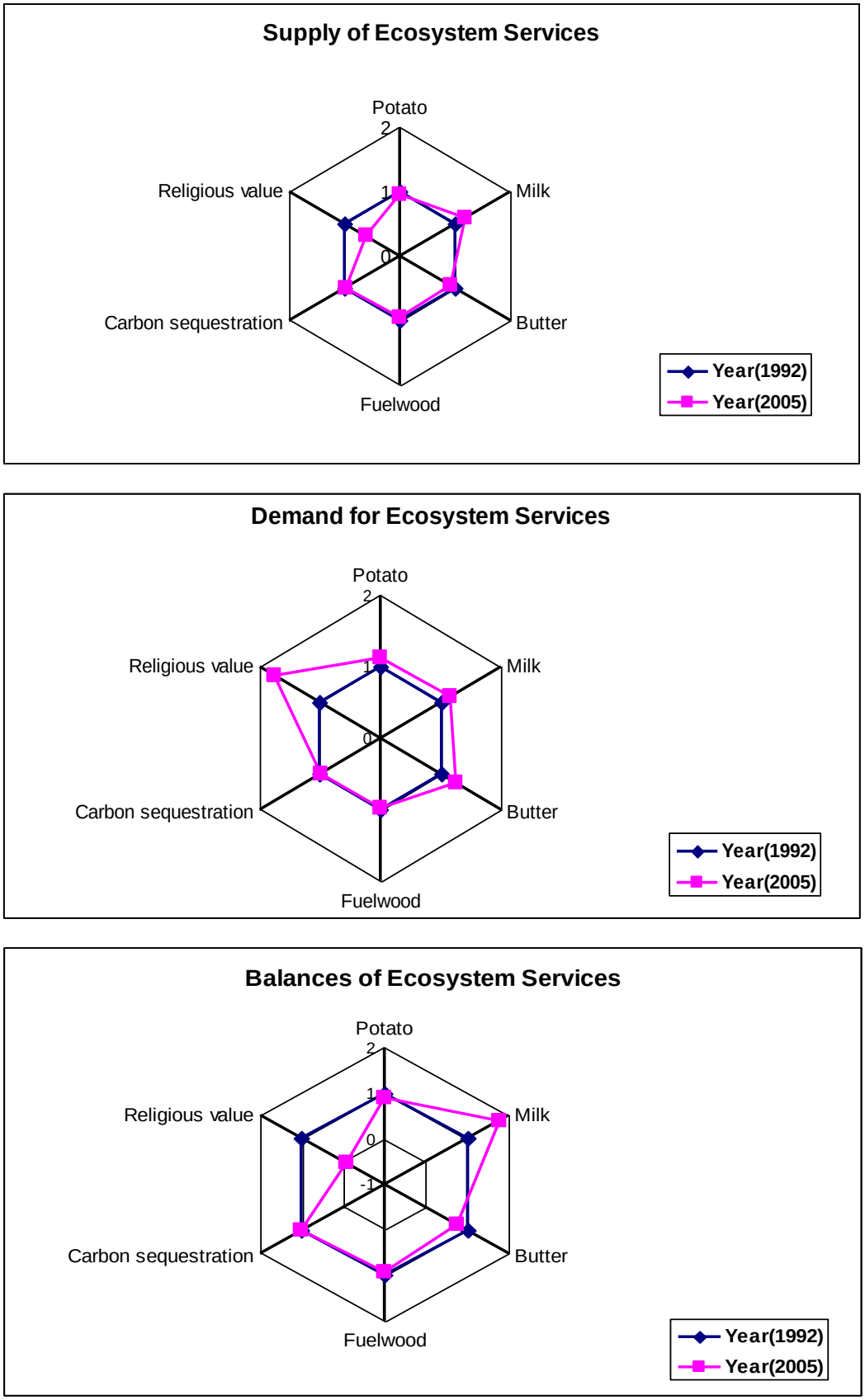
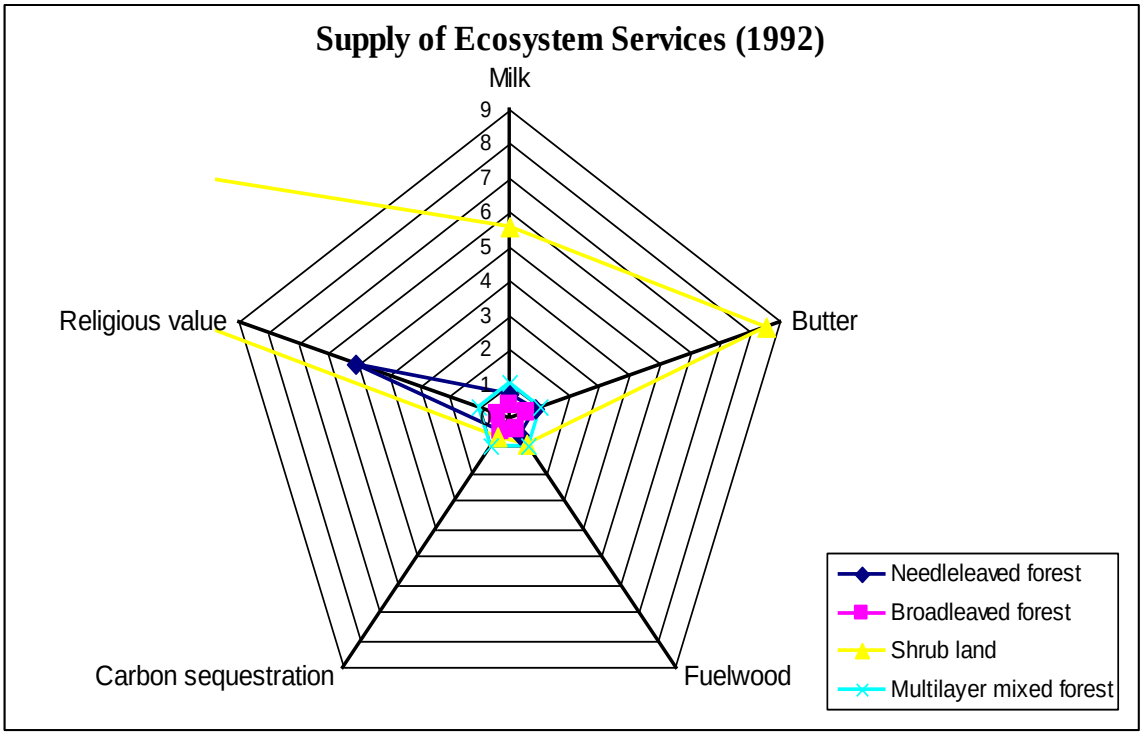


Figure 74: Comparisons of the supply, demand and balances of selected ecosystem services of 1992 and 2005. (The multilayer mixed forest is set=1 as a reference).



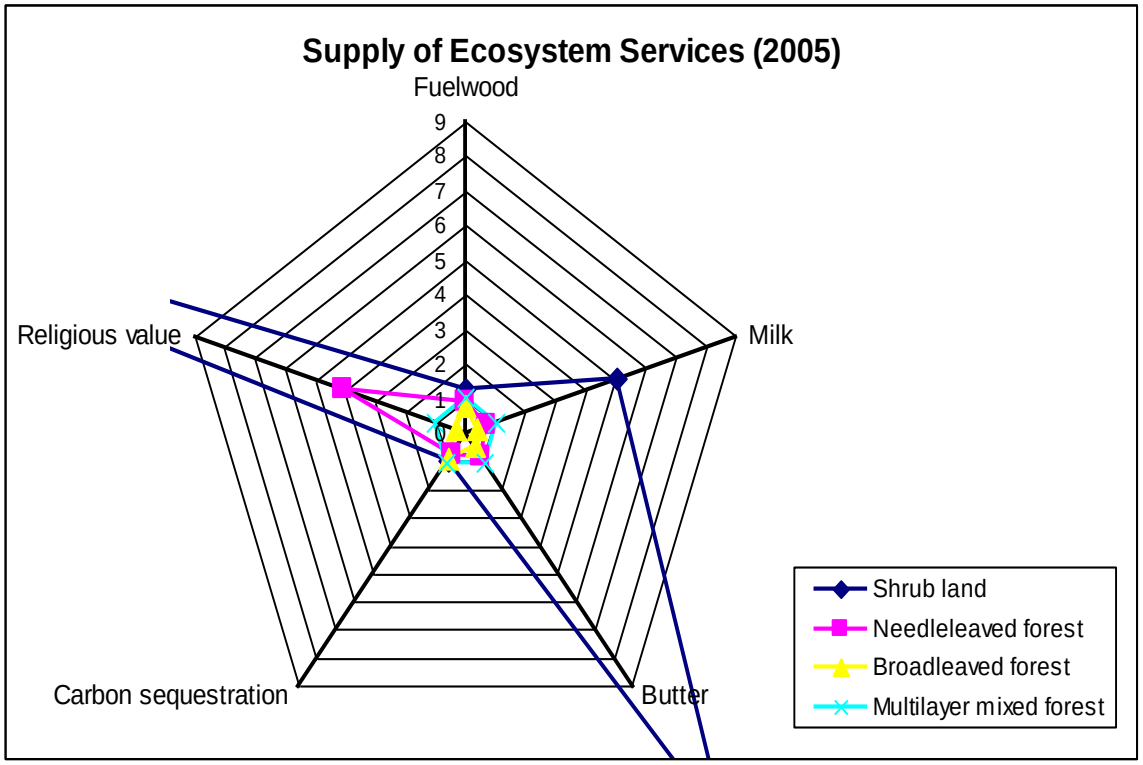
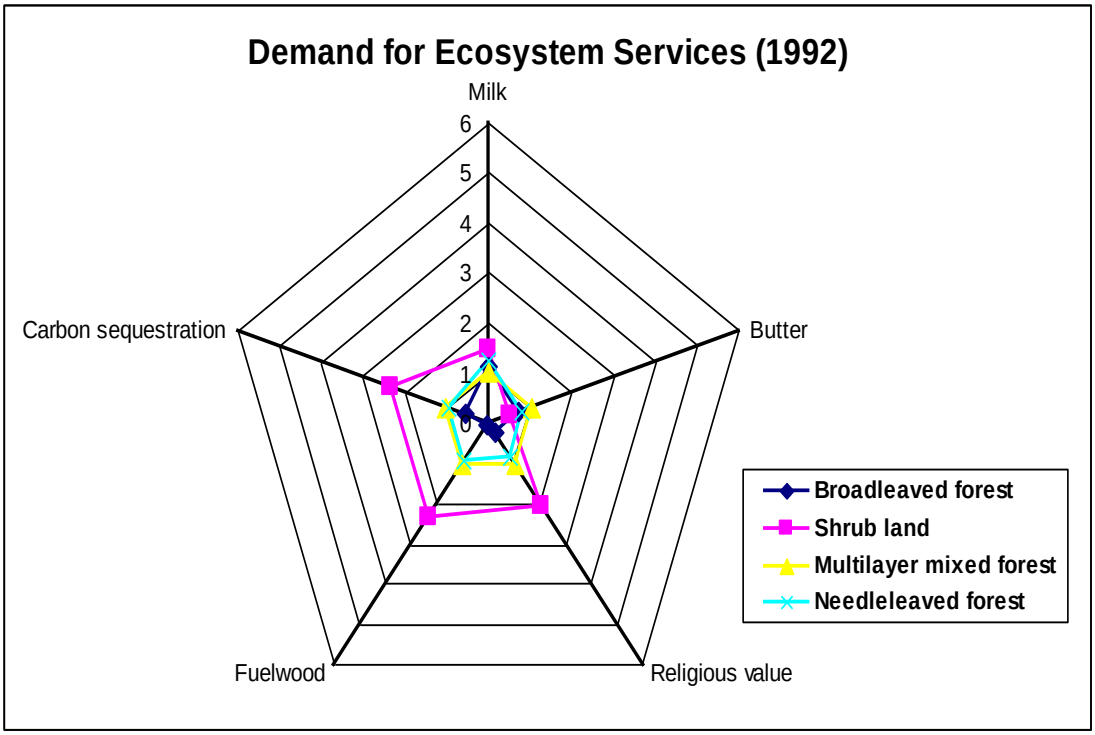


Figure 75: Supply of ecosystem services in 1992 and 2005.



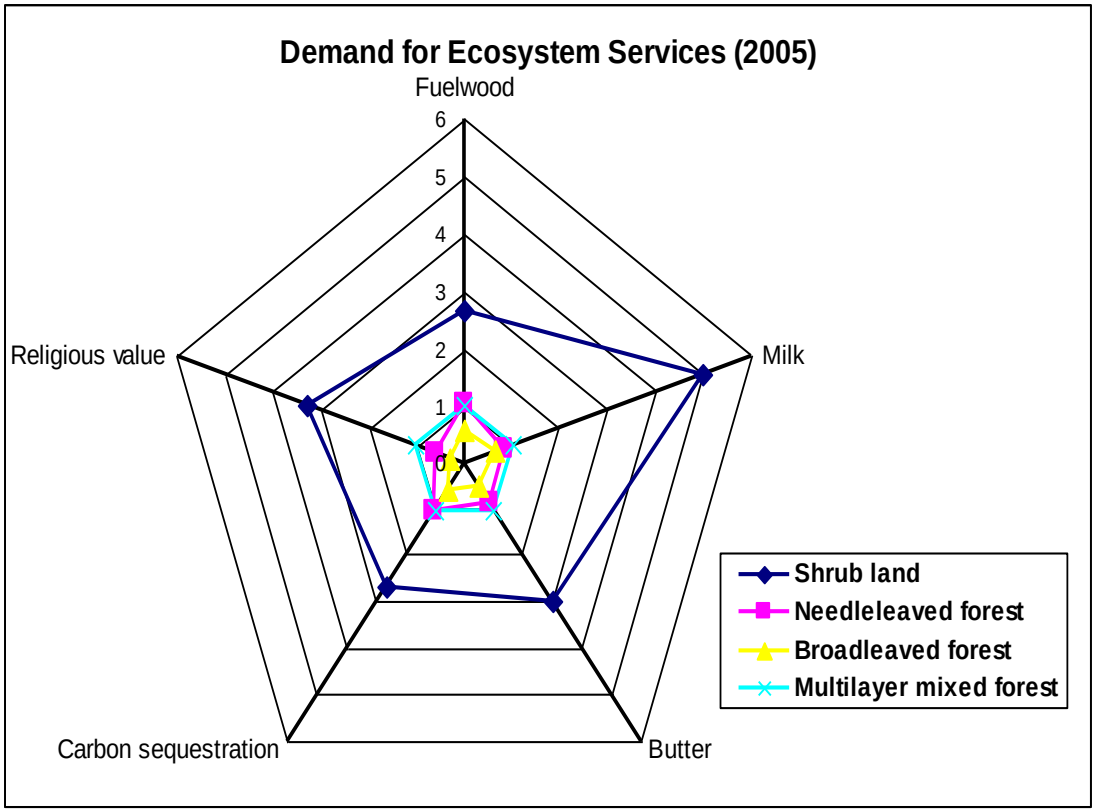


Figure 76: Demand of ecosystem services in 1992 and 2005.

5 Discussion

In this chapter the collective results concerning the landscape dynamics of the Everest and their consequences are discussed in relation to the drivers of land use and land cover change, and their impacts on the provision of ecosystem services. Moreover, the challenges of the land cover types concerning the future provision of ecosystem services in the study site are described.

Landscapes differ in their capacities to provide ecosystem goods and services. The services are altered by human activities in the human-environment system. In this study a **mapping approach** of ecosystem services based on land use and land cover data, field observations and literature reviews is used to evaluate the influences of human activities on the ecosystem structures, functions and their services supplies in the Khumbu environment. The result shows that the Khumbu ecosystems and their supply capacities of services are changing. The research concept and methodological framework used in this study have initially been applied in some other studies. To improve the methodological framework, it should be developed further to capture the nature supply of multiple goods and services in the complex human-environmental system. Main objects of that improvement should be

- an integration of other parameters than land cover items,
- a stronger integration of physical values such as vegetation characteristics, soil characteristics, landscape features (elevation, slope, geomorphologic indicators) and concrete land use activities,
- a better balancing capacity to interlink social, economic and environmental items,
- a clear distinction of values that can be monetarized and values which can not,
- a stronger quantification of the interlinkages between land cover and services, e.g. including models or response functions instead of the expert guided classification,
- a stronger inclusion of the indigenous knowledge of local people,
- a more detailed inclusion of psychological aspects to measure cultural values,
- an applicable user interface.

This study has evaluated some of the services of the study site. However, there are many important services to be quantified in more detail such as biodiversity, fresh water and flood controls. The study has adapted only literature reviews to make a quantification of soil erosion, carbon sequestration services and the supply of fuelwood. To make a better conclusion on the behaviour of these services, there is before all a need of **comprehensive**

studies focusing on climate change impacts and their consequences for the ecosystem services of the region. The results concerning religious values could be stronger if other indicators could have been considered. For example along with the gumpa it could be useful to consider indicators such as forest, agriculture and livestock issues. These indicators could produce stronger results because the daily activities of the local people are bounded by the religious norms and values, i.e. the production of agricultural goods, wood from forests and livestock products which are dependent on the religious component of the environment. A more intensive social mapping based on the participation of local people could supplement the results of aesthetic values.

5.1 Causes of land cover changes and their consequences

5.1.1 Glaciers/snows land cover

The observed trend of the decreasing area of the glacier cover in the study site showed that the Everest glaciers have already experienced high retreats. The **global warming** phenomenon has provoked extreme and rapid changes in this high altitude area. The earlier studies of Byers (2007), Yamada (1992) and World Wildlife Fund-Nepal (2009) have also pointed out that the Khumbu landscape has been altered due to the high rate of the depletion of the snow cover area. Based on the ongoing climate change, it can be predicted that the increasing rate of depletion in the snow cover area will even more increase in the future, which will have severe impacts on the hydrological regime, and consequently, the existing provision of ecosystem services will be affected in an even greater extent.

Among the alteration of the Everest National Park land cover, the decreased area of **lakes** could be explained on the base of earlier studies which reported about several GLOF events; Nare and Cholatse GLOFs (Glaciers Lake Out Burst Floods) in 1977, avalanches in Phortse and Thanga village in 1988 and the Digscho flood in Pangboche in 1985. This time period probably saw most of the large lakes burst out and after 1992 a formation of new lakes took place. The findings of the Central Department of Hydrology and Meteorology of Tribhuvan University (2007) has also documented that the number of moraine dammed lakes has increased. In future these lakes will increase in sizes due to the melting snow. In addition, many of these tiny lakes which are formed within the Nozumpa glacier in the central part of the national park might merge up and increase the threat of bursting in the future. This will result in severe impacts on the provisioning of ecosystem services in forests, shrub lands,

closed to open herbaceous vegetation and gravel, stone and boulders land cover types. Moreover, based on the increasing rate of melting ice, it can be predicted that the provision of ecosystem services such as fresh water supplies, food production, biodiversity and tourism could be strongly impacted in the future. For example the Koshi River basin, which provides a significant source for fresh water for the local life and economy, will be highly impacted from the decreased area of the snow clad peaks and glaciers of the Everest. Therefore, the consequences of the disappearance of the glaciers in the Himalaya could be of greatest significance for the local people who depend on tourism.

5.1.2 Vegetation land cover types

The obtained result concerning the stable condition of the vegetation cover from the satellite imaging showed that the establishment of the Everest National Park in 1976 and the traditional forest management system of local people has played a great role to preserve the vegetation. Furthermore, the religious faith of the Sherpas to consider the forest around religious sites as sacred places also played a major role to keep the condition of the vegetation cover stable. The findings of Byers (1987) based on the comparison of past and present-day photographs of the forest covers of the Imja Khola-Namche-Everest, Khumjung-Phortse-Phunki Tenga and Phortse-Tengboche also show that the forests cover is basically intact. Similarly, several earlier studies such as Ledgard (2002a, 2002b), Baker (1993, 1995) have revealed that the forest condition has been remained rather healthy. But, even though the vegetation cover of the Sagarmatha National Park seems more or less stable in the overall condition, the land use maps of the years 1972, 1992 and 2000 showed that the pattern of the vegetation cover has been changed in the local level including a decrease in the northern part and an increase in the southern region. This result shows that there has been a localized **forest clearing** in the northern part of the national park due to the growing number of tourist related firewood use in the lodges. Similarly, the findings of Stevens (2003) have underlined that there has been a localized forest clearing in some parts of the national park. Therefore, it can be predicted that there may be a remarkable increment of vegetation cover in the southern part in future because of a small number of tourist related firewood use in the lodges, whereas, the decreasing trend of the vegetation cover mostly around the Imja Lake may exacerbate the present condition of this site from the higher demand of fuelwood. These relations could even lead to shortages of fuel wood in the local vicinity.

5.1.3 Bare rock and bare soil land cover types

The obtained results concerning the increase of the area of bare rocks and bare soils in the study site show that **climate change** induced impacts and the local people's activities have changed the landscape to a great extent. The intensified pressures related to tourism-use of firewood have resulted in harvesting juniper shrubs in the high alpine areas. This has extended the area of the bare soils and accelerated the rate of soil erosion. Byers (2005) also reveals that soil erosion has been taking place at a higher rate in these areas. The climate change induced impacts such as landslides, GLOFs (Glacier Lake Out Burst Floods), and melting of snow have also altered the area of the land cover types glacier/snow cover, bare rocks, bare soils and gravels, stones and boulders. Based on this result, it could be pointed out that the ecological equilibrium that existed in the Everest region for centuries is under increasing strain from tourism demands and climate change. Furthermore, it is sure that the alteration of landscapes has changed the trends of ecosystem services provision. For example the aesthetic value of the Everest might decrease because of the decrease of the snow cover area. The study of Beza (2010) in the Everest region also shows that the high alpine areas, especially shrub land and snow cover possesses higher aesthetic value than others. Therefore, the increasing trends of the bare rocks and soils areas and the decreasing trends of snow cover areas could be one of the greatest challenges for the long-term development of the Everest tourism.

5.2 Causes of settlement changes and their consequences

5.2.1 Houses and lodges

The Sherpas have shaped and reshaped the landscapes around their settlements in order to build more houses and lodges as a result of local population growth and tourism development. The flourishing of tourism in the region has resulted in a highly increased number of houses and lodges, mainly in the **on-route trekking** sites of the cultivated area, shrub land and the built up area land cover types. This has amplified the pressures in the local forest areas from the higher demand of tourists related fuelwood uses. In addition, the area of potato farming fields has decreased in the settlements due to the set up of new houses and lodges in the traditional potato fields such as Khunde, Lukla, Namche and Khumjung villages. Moreover, the forest around the Tengboche settlement has been cleared to set up new houses due to the influx of Tibetan refugees. Based on this fact, it is sure that the provision of ecosystem services based on different land cover types has been impacted due to the additional demand of fuelwood and timber and the decreased area of farming fields. Therefore, it is indispensable to extend the provision of alternative sources of energy supply across the whole national park

and buffer zone area to preserve the local forest near to the on-route trekking sites from the loss of valuable flora and fauna, in order to preserve services such as fuelwood supply, soil erosion regulation and carbon sequestration. In addition, it is also necessary to enforce the regulations pertaining to the cutting of juniper and birch to prevent further accelerations of soil erosion in the high alpine areas.

5.2.2 Fuelwood

The result of fuelwood consumption shows that the lodges in the on-route trekking sites of the settlements consumed still very high quantities of fuelwood. The findings of Nepal (2003) and Rogers (1997) also show that the lodges in the **on-route trekking** sites villages consume high quantities of fuelwood. Even though, the fuelwood consumptions by the lodges have been growing, the good side is that that there has been an overall decreasing trend of fuelwood consumption. The promotion of hydroelectricity in some of the settlements is one of the reasons for reducing the total amount of fuelwood consumption of the region. Therefore, a promotion of hydroelectricity in all settlements might be helpful to reduce the fuelwood demand.

5.2.3 Tourism based income

The result of household income shows that there has been a high increase through tourism development in the region. The earlier studies such as Mountain Spirit (2002), Stevens (1993) and Nepal (2003) have also traced out that the opening of tourism in the region has enhanced the local people's wellbeing through the increase of household income. The tourism based income has resulted in the transformation of traditional architecture such as promotion of multi-storey buildings, wood panelling, celling instead of open-beam constructions, glass windows rather than translucent paper ones in the region. Consequently, the **cultural landscape** of the region has been impacted. Moreover, the promotions of multi-room houses in the region have increased the demand for timber and this has put pressure mainly in the multilayer mixed forest. This is one of the main reasons that the buffer zone multilayer mixed forest has been deteriorated in its condition. Furthermore, the increased number of family members shows that the overall demand of provisioning ecosystem services has increased putting challenges on the fragile and sensitive Everest landscapes through land fragmentation and intensive agricultural farming. Earlier studies such as Mountain Spirit (2002), Sherpa (2007) and Rogers (1997) have also reported that the agricultural lands have been more fragmented than before. Therefore, the growing local population is also one of the main

drivers in changing the existing patterns of supply and demand of ecosystem services of the study site.

5.2.4 Religious practices

The result concerning the household time spent on religious purposes shows that the religious practices have been promoted along the development of tourism because of having enough money to purchase the worshipping goods and organization of different religious events. The religious practices such as respecting the **natural landscapes,** mountains, lakes, trees and rocks as abodies of spirits and deities have played a vital role in preserving the landscapes from further degradation. Based on these religious practices, it can be interpreted that the Sagarmatha National Park and Buffer Zone provides a high quantity of cultural services, performing a backbone for other services. For example, the soil erosion regulation, carbon sequestration, biodiversity and aesthetic values of the region have been promoted from the preservation of forests, lakes and other sites. Therefore, the promotion of religious practices among the local people could have supplemented the provision of ecosystem services to a great extent.

5.2.5 Livestock

The results of livestock numbers and compositions shows that there has been an increase in the total numbers of cows and horses, and relatively stable numbers of naks, whereas, the numbers of yaks have been scaling down mainly in the on-route trekking settlements such as Namche, Khumjung and Khunde. The earlier studies of Sherpa and Bajracharya (2009) and Rogers (1997) have found similar trends of decreasing numbers of yaks in the on-route trekking sites. As **tourism** created many employment opportunities with substantial income, people of tourist on-route sites have gradually scaled down yak farming. Consequently, the total numbers of yaks of the region decreased, whereas, the total numbers of cows have been increased in the region due to the tourist related milk demand, and horses are used as pack animals to transport the tourist load as well as household load. Based on this result, it can be pointed out that tourism is one of the main drivers of the changing livestock patterns in the different land cover types. It can be taken as a fact that the supply of provisioning ecosystem services such as livestock products and transportation has certainly increased due to the growing numbers of cows and horses. Even though climate change has been evident in the region, tourism related activities have actually outweighed the impacts on livestock. However, as global warming continues, changing climatic patterns could possibly affect high altitude

indigenous breeds like yak, by creating shortages of water, fodder and increases in pests and diseases.

Concerning the total number of **livestock**, its relative stability reflects that the supply of provisioning services such as water and fodder is still sufficient for animal husbandry due to the Sherpa's indigenous livestock management system. They practice transhumance, which is a system of migrating with livestock up and down the slope (up slope in summer settlements called years and down-slope to lower elevation in winter settlements called ghunsa). This system is regulated by the community to facilitate rotational grazing within the region. This traditional system ensures an effective management of pastureland and conservation of natural resources. The earlier studies of Stevens (1993), Brower (1991) and Sherpa (2007) have also argued that this system establishes a rotational grazing pattern which distributes livestock impacts over time and space. Based on this indigenous pastoral management system, it could be suspected that if the region increases the total number of livestock in the future, the rangeland could also provide necessary diets for livestock. Therefore, the supply of provisioning services (livestock products) could remain high in the study area.

5.3 Drivers and their impacts on provisioning services

5.3.1 Fuelwood

The result concerning the supply and demand ratios of fuelwood shows that the forest of the Sagarmatha National Park and Buffer Zone has satisfied the demand of fuelwood on a **sustainable** basis even though there has been a higher demand of fuelwood quantities as a result of the growing number of local population and tourists. The finding of Ledgard (2002a) also shows that the total regional firewood use constitutes only about 20% of the region s potential annual supply. Based on this study, the total regional firewood use constitutes about 38% and 40% respectively in the year 1992 and 2005. The region consists of large quantities of fuelwood surplus because of decreased fuelwood consumption from the promotion of alternative energies. Even though there has been a large quantity of fuelwood surplus in the overall condition in both years 1992 and 2005, the region has possesses both surplus and deficit areas for fuelwood. Similarly, the study of Ghilardi (2007) in the Combodia, found that a region with an overall positive balance may include deficit areas. Looking at Everest, the built up area and cultivated area land cover types possess large quantities of fuelwood deficits because of many on-route trekking sites are placed in these land cover types. The numbers of lodges and households have been set up on trekking on-route settlements such as Namche, Khumjung and Lukla. This has affected a higher demand of fuelwood in on-route settlements,

resulting in deficit areas. Most of the off-route trekking sites settlements such as Tika, Bakong Dinma, Kusum Tsanga and Pakhepani of the broad leaved and multilayer mixed forest land cover types constituted of less quantities of fuelwood demand because of the small number of lodges and houses. This has resulted in large quantities of fuelwood surplus in the off-route settlements. Based on this pattern the deficit fuel wood quantities of tourist on-route settlements have been balanced by the surplus quantities of off-route settlements. Therefore, the fuelwood demand is site-specific and totally dependent on tourist. Moreover, there has been a fuelwood traded between on-route and off-route trekking sites within and between the land cover types.

The results concerning the supply and demand of fuelwood also shows that the total supply has slightly decreased due to the overharvesting of juniper shrubs in the high alpine areas. In addition, the tourist related firewood use pressures and the necessary demand of timber wood to build new lodges and households in the whole region has left the Pharak **multilayer mixed forest** areas in deteriorated conditions. Based on this fact, it can be pointed out that the region has suffered from a loss of biodiversity because the mixed forest supports the richest avifauna in the region (Laiolo, 2003) and provides good habitat conditions for musk deer (Buffa et al., 1998). Therefore, the intensified pressures of tourist related firewood use have over-exploited their habitats.

5.3.2 Potatoes

The results of demand and supply of potatoes show that the potato crop has still remained a **main crop** of the region, even though, earlier studies have predicted that along the increase of tourism-based income, the diet of the local people could be changed. Based on the result, the total demand for potatoes has slightly increased due to the growing number of local population and tourists. It is also a fact that along with the increase of tourists and the local population, there should be a high increase of potatoes demand but the preamble of new crops such as vegetables in the Lukla, Phakding, Ghat, Chaurikharka and other settlements and the adaptation of alternative food items such as rice or noodles could have played a role in keeping the demand for potatoes more or less stable. Despite, the role of vegetables and import foods, it is also sure that the regional production of potatoes could easily meet the necessary demand of local peoples' diets because the region has produced a large potato surplus. The total amount of potatoes surplus in the region clearly hints that there has been a trade of potatoes with other regions. The studies of Stevens (1993) and Spoon (2008) have also reported that a large amount of potatoes has been a traded to the lowland living people

and to Tibet. Therefore, beside tourism, the supply of provisioning services (potatoes) has also played a vital role in the local peoples' income. Furthermore, the supply of potatoes has even supplemented other services such as the growing tourists' diet demands has meet by the regional production; otherwise, there could be challenges to run the tourism industry because other types of crop farming are very limited in the region due to the climatic conditions.

The results also show that there has been a slight decrease in the supply side of potatoes in the region. The fragmentation of agricultural land size attributed to the growing number of local population and the introduction of vegetables in the potato fields especially in the buffer zone areas of the cultivated land cover types has resulted in slight decrease of the total supply of potatoes. Based on this result, it can be also interpreted that negative **climate change** impacts have not shown up in the agricultural conditions of the region. But the agricultural aspects of the Khumbu seem to be quite different from other Himalayan regions. The studies of Sharma and Xu (2007) and Alam and Tshering (2004) based on Central Himalayan and Bhutan areas have reported that the crop production will be highly decreased and even there could be food insecurity in the Himalayan region in the future. Looking at Khumbu, the production of potatoes remains in more or less stable conditions, also because the local people mainly stuck to the traditional crop farming supply with the manure derived from livestock and forest litter.

The supply and demand patterns of potatoes among the land cover types showed that the cultivated areas provided a high surplus even though it possesses higher demands. Bare soil land cover types have a small supply as well as a small demand, whereas, the built up area shows a large deficit of potatoes due to the increased number of lodges. Therefore, the supply and demand patterns are guided by the **location of tourists** and the mostly visited sites. For example, the increased numbers of lodges and households on the tourist on-route sites have resulted in an increased demand of potato quantities in the shrub land, the cultivated area and the built up area and there has been a decrease in the supply of potatoes in those land cover types because of the introduction of vegetables on tourist on-route sites. The studies of Mountain Spirit (2002) and Sherpa (2007) have also reported that the production of potatoes has decreased in the on-route trekking sites villages. Thus there is a potato trade between these zones.

5.3.3 Livestock products

The result of the supply and demand analysis of **livestock products** (milk and butter) shows that both demand and supply have increased in the region. The land cover types with

preferred tourist sites such as cultivated area, shrub land and built up area constituted higher quantities of milk demand. Similarly, the tourist on-route sites constituted an increased supply of milk quantities. Based on this result, it can be interpreted that the income based on tourism has made local people of tourist on-route sites to rear more cows than before. Therefore, it can be understood that **tourism** has played a vital role in the increase of both demand and supply of milk.

Furthermore, the increase of the number of **cows** shows that the availability of fodder is so far sufficient in the region. Based on this result, it could be argued that the pasture land has not been impacted from climate change like other Himalayan regions. The study of Smith et al. (1996) reported that there could be 40 to 90 percent reduction in grassland productivity with temperature also rising between 2-3 degrees centigrade combined with low precipitation. Moreover, based on the trade of milk between the land cover types the necessary demand of the built up area and the broad leaved forest land cover types have been met by the surplus quantities of milk of other land cover types. In addition, the supply of provisioning services (milk) might mount up in future due to the increasing number of cows so that this service could be one of the alternative sources of income generation.

The result of supply and demand of butter shows that there has been a high increase of the demand for butter in all land cover types. This increased demand has been driven directly and indirectly by tourism and growing local population, i.e. due to the demand of butter for **religious** events and tea. Along with the promotion of religious practices based on the tourism income, the demand of butter has been increased because butter is the main worshipping material. Without it in the Buddhist culture, the religious events do not function. For example, the deficit quantity of butter has even increased in the built up areas because of the promotion of religious events. They afforded a higher quantity of butter from their tourism based income to organize religious events which has resulted in higher demand quantities. Along with the tourism development the local people have also replaced their traditional subsistence practices such as rearing of naks. Consequently, this has resulted in a decrease in the supply amount of butter. Nevertheless, the increased butter deficit quantities of the built up area and the closed to open herbaceous vegetation land cover type's households have been balanced by the surplus quantities of other land cover types mainly from the cultivated area and shrub land. Therefore, considering the total surplus of butter of the region, it can be predicted that the future increase of butter demand will be met the regional production focusing on trade between different land cover types. Moreover, it can be argued that the provisioning services

(livestock products) are not only parts of local people's diet but also provide important meanings for other services such as the promotion of cultural services.

5.3.4 Transportation

The obtained result concerning the supply of the transportation services show that the **income** based on transportation has highly increased in all the land cover types besides the built up area. It is sure that the increased incomes have been an even more influential source for local people's livelihood. Based on this result, it can be predicted that the supply of transportation will be enhanced in future due to the lack of other means in transporting tourist loads. The demand of male animals such as zopkios and horses will even increase along the increase number of tourists because these animals make twice the income of a human porter. Sherpa and Bajracharya (2009) have also found that the total numbers of the male animals have increased in places like Fortse and Thamicho. Therefore, it can be assured that the male animal numbers will highly dominate the livestock compositions in the future because female cattle breeds have meagre returns. Based on this result, it can be traced out that cultural services and provisioning services are strongly interrelated. For example; in the absence of tourism, the supply of transportation will be highly decrease, and similarly, without transportation based on livestock, the number of tourists in the region will also decrease due to the lack of other means for transporting tourist loads. Therefore, the supply and demand patterns of transportation have strongly depended on the trends of the tourist numbers.

5.4 Drivers and their impacts on regulating services

The results of soil erosion and carbon sequestration show that there is a high amount of **soil erosion** as well as high potential of carbon sequestration in the region. But considering the limitations of the data collection, the results could be different if high tech research methodologies had been used. There has been an increase in the total demand of soil erosion regulation. The tourist related fuelwood uses have accelerated soil erosion in the high alpine areas due to the over-harvesting of juniper shrubs. Similarly, the areas of bare soil land cover types, which attributed higher demands of soil erosion regulation, have increased as a consequence of climate change induced impacts such as snow melting, floods and landslides. Furthermore, the demand of soil erosion regulation has also increased in the closed to open herbaceous vegetation land cover types due to the trampling effect and seedling damage from the growing number of the cows, zopkios and horses, whereas, the demand of soil erosion regulation has decreased in the cultivated area due to the creation of new households and

lodges in the traditional farming fields. Therefore, the trends of increased and decreased demand of soil erosion regulation in different land cover types have been mostly driven by tourism and climate change induced impacts. Based on this result, it can be predicted that the demand of soil erosion regulation will be even more increase in the future because of the increment in the area of the bare soils land cover types from the ongoing climate change. Similarly, it could increase in the closed to open herbaceous vegetation due to the impacts of the increasing number of livestock via trampling and foraging (Laiolo, 2003). Some of the high altitude locations of bare soils and open to closed herbaceous vegetation, and low altitude locations of gravels, stones and boulders and cultivated land cover types such as the main trails between Lukla-Namche, Namche-Gorakshep etc. possess higher demands of soil erosion regulation because of increasing trampling and erosion of vegetation cover adjacent to the main trails from the growing number of visitors movements. Consequently, the region might experience many consequences such as a decrease of the aesthetic value from the increment area of the bare soils. Similarly, there will be impacts on the availability of herbs because the habitats of herbs have been mostly placed on the open to closed herbaceous vegetation and upper alpine shrub land (WWF-N, 2005). Furthermore, the increase of soil erosion in the different land cover types such as broad leaved forest, needle leaved forest and the shrub land has impacted fragile ecosystems and their wildlife's, i.e. endangered species such as snow leopard, musk deer and impeyan pheasant. Therefore, it is an urgent consequence to carry out measures of soil erosion protection in order to keep the trend of ecosystem services provision in existing patterns. Otherwise, there could be more threats to very sensitive ecosystems, agricultural lands, pastures and to the tourism of the region. The focal controlling measure could be a reduction of fuel wood consumption. The provision of alternative energy sources such as kerosene, electricity and livestock dung could ease the pressure on the forest. Another control measure will be increasing vegetation covers on sites as well as controlling grazing by implementing the rotational grazing system.

In parallel to the higher demand of soil erosion regulation, the Everest region has attributed a higher supply of the provisioning of regulating services such as **carbon sequestration**. The region provides a very low amount of carbon production because the emission of carbon is only related to the fuelwood consumption by lodges and households. This emission has even slightly decreased because of adapting alternative energies for cooking. Based on the assessment, it can be predicted that the region possesses a large surplus of carbon even though the fuelwood consumption might grow in the future. Therefore, the local people could benefit

from this carbon surplus in present and future time if there could be realized an accreditation of carbon trading scheme.

5.5 Drivers and their impacts on cultural services

5.5.1 Religious values

The result concerning the supply and demand of religious values shows that there has been an increasing demand in all land cover types besides the built up areas. The income based on tourism has promoted the religious activities in the region. The local people spend more time in religious activities than before because most of households employ the low land people for their mundane activities based on tourism, and consequently they are having more spare time. This spare time was mostly used in the religious function in the on-route and semi-route trekking sites located households. Therefore, the land cover types such as shrub land and cultivated area which attributed most of the main tourist on-route sites have constituted a higher increase in demand for religious value. Whereas, the tourist hub centre "Namche" – the built up area land cover type shows a decreasing demand for religious values because most of the households' members of this land cover type remain totally busy in providing services for tourists, so that they very rarely have spare time. Moreover, the off-route trekking sites settlements such as Thame, Tika, Bakong Dinma, Kusum Tsanga and Pakhepani also posses a slightly increased demand of religious values because these settlements' households have also been benefiting from the tourism industry directly or indirectly: for example, the selling of the potato surplus and livestock products in the weekly market to the consumer of on route sites lodges and households, and the involvement as tourist guides or any other positions in the tourism sector. Based on this income, these household members are also engaged in religious activities because they can afford the necessary worshipping materials and even hire household workers in some of the households. Therefore, it can be suggested that the provision of ecosystem services of the region could be enhanced with respect to the increased time spend in the **monasteries**, i.e. because the monasteries are the "heart of the communities and foundations of local culture and religion" (Sherpa, 2007). This will result in even stronger relations between the religious practices and the landscapes, and consequently, enhance the provision of ecosystem services. For example, landscapes such as mountains, forests, rivers and lakes will be highly treated as sacred places. The recognitions of the values of trees and forests by the Sherpa religion will be highly enhancing the biodiversity (Bratton, 1994). In addition, the Gokyo lake, respected as the place of the snake god, and a temple of Vishnu and

Shiva provides the faith of no harm to the birds in the lake which could result in more wetland birds (WWF-Nepal, 2005).

Furthermore, the result concerning the **supply of religious values** reflects that the highest supply has been attributed to the shrub land because most of the famous gumpas have been place in this land cover type. The other land cover types such as cultivated area and needle leaved forest, where most of the on-route and semi on-route trekking sites have been placed, also is related to a higher supply of religious values. Whereas, the land cover types which are situated mostly in off-route trekking sites have a lower supply of the religious values. Based on this fact, it is clear that the on-route trekking site settlements comprise of both higher demand and supply of religious values. Therefore, the tourism force could be seen as a driving factor for the changes in the trends of religious values.

Furthermore, normally with the increase of the number of tourists, the supply of **religious values** has increased due to the high amount of donation collections but the region possesses a decreased trend, even though it has experienced a growing number of tourists. There could be many reasons for the decreasing trends, for example, the increased costs of the Everest trip could have caused tourists to reduce the donations. In addition, the decline of global economic power could have a hand in reducing the amount of donations. Furthermore, there might be changes in the hosting environment such as lama behaviour and changes in the aesthetic beauty of the surrounding arena which could have made tourists unsatisfied and consequently gaining fewer amounts of donations. Based on this result, it can be predicted that along with the increasing number of tourists, the demand for religious values will increase and that the supply of religious values will decrease or remain the same, because, the increased income will be diverted to the religious sides to a greater extent. Therefore, the promotion of religious aspects along the escalating number of tourists will definitely escort the provision of ecosystem services in a sustainable way, because the Sherpas' religious practices contribute an array of resources that are absolutely essential to the survival of local people in such harsh environmental conditions. However, the promotion of religious values can not be interpreted as always having positive effects on the provision of ecosystem services in each society. Due to the specific characteristics of the Buddhism religion such as high interconnection of local peoples' daily works in the landscape has a significant role for the ecosystem functions. Consequently, the number of benefits such as tourism, carbon sequestration and aesthetic value has increased stronger than before in the Khumbu society.

The **concept of cultural ecosystem services** has so far been limited in its application due to the difficulties which arise from measuring the intangible benefits. There is also a disputation among scientists concerning quantifications of cultural services. However, the efforts of the monitarization process will potentially increase their visibility. For e.g., this process could relate the incremental changes in services of different types of ecosystems of the Khumbu region with the promotion of religious values from tourism affluence.

It is a fact there are difficulties around an identification of reliable indicators of religious values and it is hard to convince groups of people who do not favour **(monetary) quantifications** of ethical benefits which derive from the value system of a society. These groups for example argue that the values of the ethical benefits depend upon individual preferences, i.e. the value of any items for the person A is different from the value for B. Therefore, opponents might state that it does not make any sense to quantify cultural benefits. However, all persons are parts of their societies. Therefore, in most of the cases the values of ecosystems and their benefits are depended upon the societal consensus. This can be experienced e.g. in the homogenous Indian society, which attributes religious values on cows, or the value of wildlife in the Khumbu region, which will always remain high due to the cultural benefits of a religion and the local sense of place. Therefore, one can also say that the conditions of the cultural services are functioning as a mirror of the society referring to the perception of the meaning of ecosystems and their benefits. I.e. it has an important meaning to make quantifications of these services in human-environmental systems because this step can provide a way to tackle the issues of public goods. However, concerning reliable indicator methodologies, there is a need of depth studies about the entire society so that the indicators can reflect both, historical and current conditions and even future developments of the society. For example, the local peoples' worshipping places, the "gumpas", have been considered as an indicator to quantify the religious values in my study. This indicator reflects the past, present and future development of the society because the implementation of the principles reflected in the gumpas have always guided the daily works of the local people, which consequently have an important influence on ecosystem functions.

5.5.2 Aesthetic value

The result concerning the aesthetic values shows that the region can be characterized by a high attractions because of the high **alpine** landscapes such as shrub land, snow peaks mountains, glaciers and glacial lakes. Beza (2010) also found that the high alpine sites of the Everest possess high aesthetic values than the low land areas in terms of attracting more

tourists. Based on this result, it can be predicted that the region could fail to attract more tourists in the future because of the alteration of the high alpine landscapes from ongoing climate change and human induced impacts such as melting of snows, glaciers lakes outburst floods and over-harvesting of juniper shrubs. Therefore, it is necessary to take respective management steps soon for the long-term security of the tourism industry of the region. Otherwise, the local people and the Nepal government will suffer from the loss of one of the greatest income generating sources in the near future.

Furthermore, it can be predicted that the growing demand of tourist related fuelwood uses might introduce some changes in the **aesthetic value** because of the alteration of different forest land cover types. In addition, the seedling and trampling impacts from the growing number of livestock could change the existing conditions of open to closed vegetation types and shrub land which may result in a loss of the aesthetic value. The extension of physical structure especially setting up new religious sites such as monasteries, chorten and temples based on the contributions of tourists in the different land cover types could enhance the aesthetic value of the region. Consequently, these cultural destinations could attract more tourists to the region. Therefore, it can be explained that besides climate change, tourism force is one of the agents for the long-term supply of the aesthetic value of the region.

5.6 Challenges and significances of land cover types

The result of the ecosystem services analysis show that the snow/glacier land cover types are the most important land cover types which provide higher cultural services such as aesthetic value, recreation and tourism in the region. Based on the result concerning decreasing trend of the area of ice cover, it can be assured that there is a **challenge** to secure tourism for long term in the region because climate change and human induced impacts such as glacier retreat and soil erosion are taking place with a greater extent in the higher alpine areas. This will definitely spoil the scenic beauty of the higher alpine areas. The consequences could be a failure to capture higher numbers of tourists. In addition, the supply of provisioning services such as fresh water and herbs will also be one of the main challenges. The study of Sherpa (2007) has also mentioned that many rare medicinal and flowering plants which are abundant for a short period during the summer monsoon are affected. Similarly, the supply of provisioning of ecosystem services such as fuel wood, timber, herbs and carbon sequestration based on the shrub land and different types of forest land cover types are in decreasing trends, whereas, the demand for these services is increasing at the same time. Based on these trends, it can be predicted that different plants and animal species which inhabit those land cover

types could be affected. Furthermore, the growing demand for provisioning ecosystem services in relation to the growing number of tourists in the region could result in forest and shrub land degradation conditions. The consequences will be meeting the regulating services such as a decrease in the carbon sequestration rate and an increase of soil erosion.

The results also show that the open to closed herbaceous vegetation land cover types are **important** for the supply of provisioning ecosystem services such as herbs and livestock grazing. The study of Sherpa (2007) has also mentioned that these land cover types are important for collecting fodder, wild foods, medicinal and aromatic plants, livestock dung, farm manure and fuel. The cultivated land cover types supply higher religious values and provisioning services related to crops, livestock products and transportation. Based on these trends, it can be assured that the demand of all services will even go higher in the future because most of the on-route trekking sites villages are located in this land cover types. The growing number of tourists will even result in a decrease in the area of cultivated land cover types due to the setting up of new houses and lodges. The consequences will be enormous, e.g. for the supply of provisioning services such as food and livestock products which will have to be managed from a decreasing area of farming land. In addition, the consequences will be high for the provision of cultural services: people might be trying to capture key ridge tops and key scenic spots for the development of hotels and lodges as around the Gokyo village in the cultivated area. This will have an effect on the religious value of the Gokyo lake due to the disposal or wastes from the growing settlements. Also the demand for almost all services in the built up area land cover types will go higher than now following the increased number of houses and lodges. But, based on the total quantities of demand and supply of different services in the region, it can be assured that the increasing demand of all services in the built up area will be supported based on trades with other land cover types such as fuelwood and timber from different forest land cover types, crops from cultivated areas and livestock products from both cultivated area and shrub land.

The supply of cultural services has shown a great **achievement** in the region. The development of tourism has provided both direct and indirect employment opportunities such as hotels and lodges operations, the pottering of food and material supplies to lodges, the collection of fuelwood, carpentry, decoration and maintenance of lodges. Other areas of employment include: cooks, tourist guides, porters and trekking agents. Educational, health facilities as well as basic necessities such as water and energy supply have also improved in the area. Consequently, the standard of living of the local people has improved.

However along with the good sides, the flow of tourism in the region has also put some **challenges** for the provision of ecosystem services through fragmentation of relatively large areas of habitats by encroachment during the expansion and development of settlements. This has resulted in challenges for the protection of rare and endangered species located at multilayer mixed forests, shrub lands, closed to open herbaceous vegetation areas and other forest land cover types. Furthermore, the village architecture has been rapidly changed, referring to colour, size, shape and décor as a consequence of the tourism affluent. This has altered the provision of aesthetic values of the region. Moreover, there are some places which have a high biodiversity of valuable medicinal plants, such as Khumjung and Porche for Panch aunle (*Dactyaloriza hattazeriya*), Kongde for Kutki (*podophyllum sp.*) Pakhan Bhed (*Bergenia ciliate*), and Panch aunle, and Thame for Laghupatra. These areas are threatened by tourists' movements because most of the main tourist trails are located in these villages. Similarly, Phorche and Tyangbochae, which are important habitats for musk deer and Thadakoshi areas for red pandas and Bhir Mouri (wild honey bee) at Toktok areas, have also chances to be impacted from tourist movements. Along with the tourism development the pastoral settlements such as Pheriche, Dingboche, Gokyo and Lobuche, which were traditionally used on a seasonal basis, have been transformed into major tourist locations. This could have impacts in the provision of livestock products. Despite some challenges, the region offers a high scientific value for research opportunities because of its extreme elevation, globally important flora and fauna, culture and environment. It provides a source of inspiration, education and recreation. Furthermore, the study area provides high religious and cultural values which make Sherpa people respect their home land as a sacred hidden valley and refrain from hunting and slaughtering, performing different religious practices such as respecting forests, mountains and lakes as god living places. These indigenous belief systems and practices have provided an important cultural basis for the enhancement of ecosystem services and environmental qualities in the region.

6 Conclusions

There is an ongoing change observable in the landscape of Everest resulting from different drivers such as national park activities, influx of Tibetan refugees, climate change and growth of tourism. It is clearly noticed from the result of satellite images that the different land use types have changed their forms and degrees in different time periods. Examples are the decreased glacier cover, and increase of bare soils and rocks area. This is also supported by different authors' findings. Considering the changes in land use form such as vegetation covers and glacier covers linked with **ecosystem services**, proved that the provision of ecosystem services especially in the on-route trekking sites villages and higher alpine areas seems to be in a decreasing condition. This is due to the depletion of local forests due to the tourists' fuelwood demand, glacier retreat and soil erosion being influenced by both climate change and direct human induced impacts. Despite some service degradations on the local level, the provision of most ecosystem services such as fuelwood, potatoes, milk, carbon sequestration etc. seems to be of good conditions in the regional level. The existing provision of services in the off-route trekking sites villages remains more or less the same pattern, holding surplus quantities in most of the cases. Therefore, the decreasing trend of ecosystem services provision in the tourist on-route sites villages is balanced by the ecosystem services of the tourist off-route sites villages. For example, there is a trade of potatoes, milk and butter between Namche (built up land cover type) and Thame village (cultivated land cover type). Regional budgeting exercises' have proved that the whole system of the Everest region is sustainable, because the regional supply of ecosystem services meets the necessary demands of the society.

The result referring to glacier cover recommends an **adaptive approach** to avoid extreme risks and uncertainties. This approach would try to enable the system to be maintained in the long term and stabilize the system's integrity. Adaptive management to attain these targets are well known issues; glacier retreating must be driven by explicit goals, policies, practices and research based on an understanding of the ecological interactions and processes to give continuity to life of the region. With such as management, the human-environmental system could be strengthened against the disturbances by specifying the future outcomes, out of which, the most important achievements could be the security of tourism and the availability of fresh water in long term.

The assessments of the ecosystem services in relation to landscape dynamics were done on the basis of "mapping supply and demand of ecosystem services" ecosystem research

instrument. This instrument was applied by the identification of different indicators of ecosystem services based on the focus group discussions. Furthermore, the conditions of ecosystem services were also qualitatively assessed through the **assessment matrix** incorporating the knowledge of expert and local people. Based on this assessment, it is seen that the supply of the cultural services is higher than other services, whereas, the provisioning services are relatively higher than other services in terms of demand. Furthermore, among the nine land cover types, the cultivated area and built up area constitute a higher demand in most of the services cases, whereas, the bare soil and the closed to open herbaceous vegetation constitutes minor demands. In addition, it is also noticed that the multilayer mixed forest, broad leaved and needle leaved forest constitute of higher regulating services, snow/glacier cover and the built up area provides a higher supply of cultural services, and cultivated and shrub land constitutes a high supply of provisioning services. Therefore, based on the above information, supply and demand are site specific features, mostly depended on the location of on-route and off-route trekking sites.

Furthermore, the results based on **mapping** supply and demand of ecosystem services illustrated that the provision of ecosystem services of the Everest has not been degraded despite some services such as soil erosion. Most of the services seem to be in better conditions, holding surplus quantities on the regional level. Even some of the services such as religious value, supply of milk and transportation are enhancements of the tourism affluent. However, there has been a change in the trends of supply and demand of ecosystem services especially in the cultivated area, built up area and the shrub land because of the increase numbers of houses and lodges. This has resulted in deficit areas for some services in the on-route trekking sites villages even though the region is holding surplus quantities in the overall level. Therefore, the intervention of tourism has effected both surplus and deficit areas for different services around the Everest. This could be a reason for several earlier authors who have concluded that the environmental and societal carrying capacities of tourism in the Nepal Himalaya have already been exceeded (Shackley, 1996; Brown et. al., 1997)**.** But, the present author does not support that view. Based on this study, it is clearly illustrated that the regional supply of ecosystem services can adjust even more numbers of tourists. It may be true that the main on-route trekking sites villages could fail to hold higher numbers of tourists in the future, but this is not valid for the whole region. Therefore, it is indispensable to regard future extensions of settlements in the off-route trekking sites villages rather than only on-route trekking sites villages.

There have been both positive and **negative impacts** of tourism such as the promotion of education and infrastructure, employment opportunities and on the other side environmental degradation. The requirements of tourists and their porters have placed additional pressures in the natural resources of Everest. Other pressures on the resources are as a result of the changing lifestyles of the Sherpas. These additional demands have affected local resource and land-use practices which have resulted in deficit areas of provisioning and regulating ecosystem services mainly in the on-route trekking sites villages. Furthermore, there has been a deterioration of the cultural landscape by changing the traditional architecture with import materials and new architectural styles. In addition, the extension of houses and lodges in the potato farming fields have raises questions about the future demand of potatoes. Similarly, the extension of ribbon shape settlements mainly in the on-route trekking sites such as the areas between Lukla and Namche, which are located very near to the river banks have put challenges on peoples' life and their properties.

However despite these challenges, the tourism based wealth has also put new opportunities for the provision of ecosystem services. It is seen that related with the development of tourism, the religious value of the region has been promoted based on the tourism income. Local people have been stronger diverted to the religious aspects. The religious events have been more systematic than before also promoting other cultural services. For example, forest ecosystem services are enhanced due to the religious belief considering forest areas as sacred areas, and the respect of the whole valley as a hidden valley. This is the reason why the system of the Everest is self sustainable because every day activities of the local people are guided by environmental friendly **cultural practices**. These practices are highly interlinked with landscape such as forest preservation from monasteries, worshipping of mountains and lakes etc. Therefore, it can be argued that the cultural service is a main pillar that helps the Everest system to remain sustainable. Furthermore, it can be also guarantee that the future increase in the number of tourists will not be a problem on the regional potential of ecosystem service provision if the religious beliefs and their traditional practices will continue. Many earlier authors' findings reported a loss of many ecosystem services in other Himalayan regions. But concerning Everest, due to its specific cultural value and the traditional land use practices, this loss might be avoided.

It is also noted that new stock-keeping practices of larger numbers of urang zopkio, zhum, and cows, have changed after tourism has started in this region. This alteration of livestock compositions has enhanced the supply of provisioning ecosystem services (livestock products

and transportation). At the same time, the demands for these services have also increased along with the increased number of tourists. Therefore, **tourism** has been a factor which has a role in the enhancement of both supply and demand of most of the provisioning ecosystem services. Tourism has had adverse effects on regional forest and alpine vegetation due to the high demand of firewood by camping groups and the need to construct more inns and lodges. The continuing use of firewood by inns, however, has contributed to the thinning of local forests and depletion of shrub juniper in the most heavily visited alpine regions. If current trends continue in same manner affecting ecosystem services from land use change then the services which are used freely today will become more costly in the near future. Therefore, the promotion of alternative energies such as electricity or kerosene is necessary in all settlements to prevent further degradation. Otherwise, the present quantities of fuelwood demand could even go higher in future due to the growing number of lodges and households. And consequently, there could be severe impacts such as loss of biodiversity from habitats destruction, increase of soil erosion, loss of aesthetic value, fuelwood and timber shortages nearby the tourist on-route settlements local forests such as Lukla-Namche route, Namche and vicinity areas and Gokyo or Goraksheep.

The landscape of Everest was also experiencing **climate change**. This change has led to the formation of glacial lakes, which places the local people at risk in case of an unexpected outburst of the lake. Furthermore, the ongoing increasing rate of melting of ice illustrates the insecure availability of fresh water in the long term and challenges of agro-pastoral farming in the future. If this trend continues, the aesthetic beauty of the region will be spoiled which will insecure the tourism in the long term. Furthermore, the valuable flora and fauna which live in the higher alpine areas could become extinct in the future. Thus, the development and changes of ecosystems and their services should be considered in the context of a changing landscape of the region**.** A lot of effort is needed to understand the process in dynamic landscape to make the system more resilient and adaptable for the provision of ecosystem services in a sustainable manner. The assessment of ecosystem services from this study can be used to develop a clearer understanding of landscape dynamics and the consequences on ecosystem services within the region.

Summarizing, the following points are emphasized from this study:

1. Climate change and human induced impacts have changed the existing landscapes and the trends of supply and demand of ecosystem services. These impacts have put

challenges such as soil erosion regulation, availability of fresh water and continuation of agro-pastoral farming in the long term;

2. Considerable thinning of highland juniper and local forest degradation has taken place in the northern part due to tourists related fuelwood demand. This has resulted in an increase of soil erosion in high alpine areas and a decrease of the aesthetic beauty of the region;
3. There has been a strong socio-economic change on a grand scale, provoking both positive and negative effects. The transition from a subsistence farming economy to a trekking-tourist dominated way of life has had several effects;
4. There is unequal distribution of wealth among the Sherpas due to the proximity of some villages to the main trekking routes;
5. Tourism has increased the number of houses and lodges mainly in the on-route trekking sites villages. This has resulted in an increased demand of most ecosystem services;
6. Among the nine land cover types the built up area, cultivated area and the shrub land comprise of higher demand quantities of most services, whereas, the cultivated area comprises of higher supply ratios of provisioning services, forest land cover types constitute of higher supply of the regulating services, and the snow/glacier land cover type comprises of a higher supply of the cultural services;
7. The supply and demand of ecosystem services is site specific, based on the distinction of mostly visited sites and off-sites villages, which has resulted in a trade of ecosystem services between on-route and off-route trekking villages;
8. Most of the services hold higher supply quantities than demand quantities i.e. the Everest system can be denoted to be sustainable. There are even chances of enhancement of most of the services in the future because of the strong cultural aspects of the Everest people;
9. The Everest includes both deficit and surplus areas in local level for different kinds of services even though the region constitutes of surplus quantities in the regional level;
10. The Everest environment has provided many important ecosystem services from which the local people benefit in great extent, even though the Everest land use and land cover systems are fragile and sensitive.

An adaptive management approach is demanded in order to strengthen the human-environmental system of Everest by reducing future risks and uncertainties. The **adaptive**

management to cope with the problems driven by climate change and tourism should be based on the consideration of the following points:

- There is the need for interaction among scientists, managers, and the local people to give insight on ongoing problems;
- The participation of stakeholders is very important;
- Continual improvement of management policies and practices by learning from the outcomes of operational programs;
- The roles amongst the three actors (tourism, protected areas and local communities) should be balanced to ensure mutual benefits;
- Creating awareness of climate change and its relation to land use and to the local people;
- Continuation of the traditional forestry management system and the traditional livestock grazing system;
- Promotion of electricity in all villages and establishing a kerosene and stove depot as alternative fuel for tourists and lodges;
- Building high-altitude nurseries and enclosures to rejuvenate vegetation on the hill slopes;
- Expansion of houses and lodges in the off-route trekking sites rather than at already crowded places;
- Promotion of new houses based on traditional architectures to preserve the cultural landscape;
- Social Resilience: strengthen the traditional practices and values to preserve the existing provision of ecosystem services in the context of landscape dynamics;
- Economic Resilience: blending the traditional income generating sources with the tourism industry. This will provide space to the local people who are not involved in the tourism sector to get economic benefit directly and indirectly;
- Biological Resilience: Planting of native vegetation and controlling the harvest of juniper shrubs;
- Hazard Resilience: implementation of programs to minimize and cope with the risks Glacial Lake Outbursts, landslides, and floods. And encouragement of high scientific research.

In conclusion, the Everest region has gone under tremendous transformations after tourism started flourishing in the region due to mountaineering and trekking activities. Economic,

social, ecological, cultural systems have been changed, and in turn, also the supply and demand of ecosystem services have been modified. The determination of these trends through the ecosystem service **mapping instrument** guides human behaviours as well as policy makers towards a sustainable use of the natural resources. Therefore, the technique is a very simple but efficient approach to address the supply and demand ratios in both spatial and temporal contexts. The ratios which are evaluated considering the biophysical variations of the region including land cover and land use data, intensive field observations and literature reviews can well be used to illustrate the system's sustainability. The mapping approaches therefore present the assessment of the relations between ecosystem structures, ecosystem functions and service supply within the human-environmental system. Using this approach in the assessment of the study site proved that the supply and demand trends are shaped by **climate change and tourism development.** Due to these factors, the region has experienced some environmental problems such as local forest degradation, soil erosion in higher alpine areas and glacier retreat. So far, these problems have not altered the potential of ecosystem services in a regional level. Up to now, the people of the Khumbu have been able to gain substantial economic wealth through tourism without losing ecosystem services. Nevertheless, climate change has become the main issue of the region. This will continue in future, and consequently, there could be huge impacts on the provision of ecosystem services. Therefore, to address this challenge there is the need of **comprehensive studies** focusing on climate change impacts and their consequences for ecosystem services of the region. Furthermore, there are many important services of the Khumbu which remain to be quantified in detail concerning supply and demand aspects, for example, biodiversity, fresh water, flood control, education and research. But, only quantifications are not enough, if a clear picture about the climate change induced impacts on the provision of these ecosystem services cannot be drawn. Furthermore, it is necessary to trace out the local peoples' adaptation practices in relation to climate change impacts. Therefore, it is important to identify the services and the respective levels of risk both in present and future conditions. No doubt, it is most challenging but can be acquired through extensive research, incorporation of both experts and local people knowledge and the use of adequate tools of ecosystem service research.

References

Adams, V. (1992) TOURISM AND SHERPAS, NEPAL: Reconstruction of Reciprocity. ***Annals of Tourism Research*** 19: 534-554

Alam, M. and Tshering, D. (2004) Adverse impacts of climate change on development of Bhutan: Integrating adaptation into policies and activities. Working paper No.2, Bhutan CLACC (Capacity Strengthening in the Least Developed Countries (LDCs) for Adaptation to Climate Change), pp. 38. Dhaka: International Institute for Environment and Development, and Bangladesh Centre for Development Studies

Ale, S.B. and Lovari, S. (2005) Ecology and conservation of the snow leopard and the Himalayan tahr in Sagarmatha National park (Nepal). Report submitted to EV-K2-CNR, Nepal

Bajracharya, B. and Shrestha, B. (2007) Impact of climate change on Himalayan glaciers and glacial lakes. International Centre for Integrated Mountain Development, Kathmandu

Bajracharya, B., Uddin, K. and Shrestha, B. (2009) Land cover mapping in the HKKH region: cases from three mountain protected areas. HKKH partnership for ecosystem management project, ICIMOD, Kathmandu

Baker, G.C. (1993) *Nepal- Sagarmatha Forestry Report 1993 Visit*. Rangiora: New Zealand Forest Research Ltd

—

(1995) *Nepal- Sagarmatha Forestry Report 1995 Visit*. Rangiora: New Zealand Forest Research Ltd

Baskota, K., Karky, B.S. and Skutsch, M. (2007) Reducing Carbon Emissions through Community – Managed Forests in the Himalaya. International Centre for Integrated Mountain Development, Nepal

Basnet, K. (1993) Sagarmatha National Park: Conservation for Sustainable Development. ***Contribution to Nepalese studies*** 19: 121-127

Bauer, K. and Poudel, K. (1995) Pharak community forestry project. Unpublished report, World Wildlife Fund Nepal Program report series 15

Bennett, E.M., Peterson, G.D. and Levitt, E.A. (2005) Looking to the future ecosystem services. *Ecosystems* 8: 125-132

Beza, B. (2010) The aesthetic value of a mountain Landscape: A study of the Mt. Everest Trek. ***Landscape and Urban Planning*** 97: 306-317

Bjonness, I. M. (1980a) Animal husbandry and grazing, a conservation and management problem in Sagarmatha (Mt. Everest) National Park, Nepal. ***Norsk Geografisk Tidsskrift*** 34: 59-76

—

(1980b) Ecological conflicts and economic dependency on tourist trekking in Sagarmatha (Mt. Everest) National park, Nepal: an alternative approach to park planning. ***Norsk Geografisk, Tidsskrift*** 34: 119-38

—

(1983) External Economic Dependency and Changing Human Adjustment to Marginal Environment in the High Himalayas, Nepal. ***Mountain Research and Development*** 3: 263-272

Boyd, J. and Banzhaf, S. (2007) What are ecosystem services? The need for standardized environmental accounting units. ***Ecological Economics*** 63: 616–626

Bratton, S. (1994) Monks, Temples and Trees: The Spirit of Biodiversity. In: Meffe, G.K. and Carroll, C.R. (Eds), Principles of Conservation Biology. Sinauer Associates, Sunderlands, Massachussetts, USA

Brower, B. (1987) Livestock and Landscape: The pastoral system of Sherpas in Sagarmatha National Park, Nepal. A Ph.D. dissertation, Department of Geography, University of California, Berkeley

—

(1991) *Sherpa of Khumbu: People, Livestock and Landscape*. Oxford University Press, New Delhi

Buffa, G., Ferrarai, C. and Lovari, S. (1998) The upper subalpine vegetation of Sagarmatha National Park (Khumbu Himal area, Nepal) and its relationship with Himalayan tahr, musk deer and domestic yak. An outline In: Baudo, R., Tartari, G. and Munawar, M. (Eds), Top of the world Environmental Research: Mount Everest-Himalayan Ecosystem. Ecovision World Monograph Series, Backhuys Publ., Leiden, The Netherlands, pp. 167-175

Burkhard, B., Kroll, F., Müller, F. and Windhorst, W. (2009) Landscapes' capacities to provide ecosystem services - a Concept for Land-Cover Based Assessments**. *Landscape Online*** 15: 1-22

Burkhard, B. and Kroll, F. (2010) Maps of ecosystem services, supply and demand. ***Encyclopaedia of Earth***

Byers, A. (1987b) An assessment of landscape change in the Khumbu region of Nepal. ***Mountain Research and Development*** 7(1): 77-80

—

(1987c) Landscape change and man-accelerated soil loss: the case of Sagarmatha (Mt. Everest) National Park, Khumbu, Nepal. ***Mountain Research and Development*** 7: 209-16

—

(2005) Contemporary Human Impacts on Alpine Ecosystems in the Sagarmatha (Mt. Everest) National Park, Khumbu, Nepal. ***Annals of the Association of American Geographers*** 95(1): 112-140

—

(2007) An assessment of contemporary glacier fluctuations in Nepal, Khumbu Himal using repeat photography. ***Himalayan Journal of Sciences*** 4: 21-26

Carpenter, S.R., Mooney, H.A., Agard, J., Capistrano, D., DeFries, R.S., Díaz, S., Dietz, T., Duraiappah, A.K., Oteng-Yeboah, A., Pereira, H.M., Perrings, C., Reid, W.V., Sarukhan, J. and Scholes, R.J. (2009) Science for managing ecosystem services: Beyond the millennium ecosystem assessment. ***Proceedings of the National Academy of Sciences*** 106: 1305-1312

Central Department of Hydrology and Meteorology Tribhuvan University (2007) Integrated studies on hydrology and meteorology of Khumbu region with climate change perspectives. Unpublished report prepared for WWF-Nepal and UNESCO Nepal, Kathmandu

Chalise, S.R. (1997) Erosion processes and their implications in sustainable management of watersheds in Nepal Himalayas: *FR1END'97-Regional Hydrology: Concepts and Models for Sustainable Water Resource Management* (Proceedings of the Postojna, Slovenia, Conference, September-October 1997). IAHS Publ. no. 246

Chan, M.K., Shaw, M. R., Cameron, D. R., Underwood, E.C. and Daily, G.C. (2006) Conservation planning for ecosystem services. ***Public Library of Science Biology*** 4(11) pp. 379

Chandra, A., Kandari, L.S., Payal, K.C., Maikhuri, R.K., Rao, K.S. and Saxena1, K.G. (2010) Conservation and Sustainable Management of Traditional Ecosystems in Garhwal Himalaya, India. ***New York Science Journal*** 3(2)

Chaudhary, R. P., Aase, T.H., Vetaas, O.R. and Subbedi, B.P. (2007) Local effects of Global Changes in the Himalayas: Manang, Nepal. Tribhuvan University, Nepal and University of Bergen, Norway

Chettri, R.B. (2005) Sacred Himalayan Landscape, Nepal: A socio-economic assessment. Unpublished report submitted to WWF Nepal

Coburn, B. (1984) Sagarmatha: Managing a Himalayan World Heritage Site. ***Parks*** 9(2):10-13

Corbetta, P. (2003) Social Research; Theory, Methods and Techniques. Sage Publications, London

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, O.V., Paruelo, J.M., Raskin, R.G., Sutton, P. and van den Belt, M. (1997) The value of the world's ecosystem services and natural capital. ***Nature*** 387: 253–260

Costanza, R. (2008) Ecosystem services: multiple classification systems are needed. ***Biological Conservation*** 141: 350–352

Daily, G.C. (1997) Introduction: What are ecosystem services? In G. Daily, editor. Nature Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C

Daily, H. E. and Farely, J. (2004) Ecological Economics: Principles and Applications. Island press, Washington D.C

Daily, G.C., Soderquist, T., Aniyar, S., Arrow, K., Dasgupta, P., Ehrlich, P.R., Folke, C., Jansson, A.M., Jansson, B.O., Kautsky, N., Levin, S., Lubchenco, J., Maler, K.G., David, S., Starrett, D. and Tilman, D. (2000) The value of nature and the nature of value. ***Science*** 289: 395–396

de Groot, R.S., Wilson, M.A. and Boumans, R.M. (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. ***Ecological Economics*** 41: 393–408

de Groot, R.S. (2006) Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes. ***Landscape and Urban Planning*** 75: 175-186

de Groot, R.S., Alkemade, R., Braat, L. and Hein, L. (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. ***Ecological Complexity*** 7: 260–272

Egoh, B., Rouget, M., Reyers, B., Knight, A.T., Cowling, R.M. and van Jaarsveld, A.S. (2007) Integrating ecosystem services into conservation assessments: a review. ***Ecological Economics*** 63: 714-721

Egoh, B., Reyers, B., Rouget, M., Richardson, D.M., Le Maitre, D.C. and van Jaarsveld, A.S. (2008) Mapping ecosystem services for planning and management. ***Agric. Ecosyst. Environ.*** 127: 135–140

Ehrlich, P.R. and Ehrlich, A.H. (1981) Extinction: The Causes and Consequences of the Disappearance of Species. Random House, New York, NY

Eigenbrod, F., Armsworth, P.R., Anderson, B.J., Heinemeyer, A., Gillings, S., Roy, D.B., Thomas, C.D. and Gaston, K.J. (2010) The impact of proxy-based methods on mapping the distribution of ecosystem services. ***J. Appl. Ecol***. 47(2): 377–385

Engel, S. (2008) Designing payments for environmental services in theory and practice: An overview of the issues. ***Ecological Economics*** 65(4): 663-674

Farber, S., Costanza, R. and Wilson, M. (2002) Economic and ecological concepts for valuing ecosystem services. ***Ecological Economics*** 41: 375–392

Fisher, J. (1986) Tourists and Sherpas. ***Contributions to Nepalese studies*** 14: 37-61

—

(1990) Sherpas: reflection on change in the Himalayan Nepal. Oxford University press, New Delhi

Fisher, B., Turner, K., Zylstra, M., Brouwer, R., de Groot, R., Farber, S., Ferraro, P., Green, R., Hadley, D., Harlow, J., Jefferiss, P., Kirkby, C., Morling, P., Mowatt, S., Naidoo, R., Paavola, J., Strassburg, B. and Yu, D. (2008): Ecosystem services and economic theory: Integration for policy-relevant research. ***Ecological Applications*** 18(8): 2050-2067

Fisher, B., Turner, R.K. and Morling, P. (2009) Defining and classifying ecosystem services for decision making. ***Ecol. Econ.*** 68(3): 643–653

Furer-Haimendorf, C. (1975) Himalayan traders, life in highland Nepal. John Murray, London

—

(1964) The Sherpas of Nepal; Buddhists Highlanders. Oxford Book Co., New Delhi

(1984) The Sherpas transferred: social change in a Buddhist society of Nepal. Sterling Publishers, New Delhi

Garratt, K.A. (1981) Sagarmatha National Park Management Plan. Department of National Parks and Wildlife Conservation, Kathmandu

Gautam, A.P., Webb, E.L. and Shivakoti, G.P. (2003) Land use dynamics and landscape change pattern in a mountain watershed in Nepal. ***Agriculture, Ecosystems and Environment*** 99: 83-96

Gee, K. and Burkhard, B. (2010) Cultural ecosystem services in the context of offshore wind farming: A case study from the west coast of Schleswig–Holstein. ***Ecological Complexity*** 7(3): 349-358

Ghilardi, A., Guerrero, G. and Masera, O. (2007) Spatial analysis of residential fuelwood supply and demand patterns in Mexico using the WISDOM approach. ***Biomass and Bioenergy*** 31: 75–491

Gimona, A. and Van der Horst, D. (2007) Mapping hotspots of multiple landscape functions: a case study on farmland afforestation in Scotland. ***Landsc. Ecol.*** 22: 1255–1264

Goldman, R.L., Thompson, B.H. and Daily, G.V. (2007) Institutional incentives for managing the landscape: inducing cooperation for the production of ecosystem services. ***Ecological Economics*** 64(2): 333-343

Government of Nepal (2000) "*Nepal Tourism Statistics*". Unpublished data

Government of Nepal (1991) Statistical Year Book of Nepal. Central Bureau of Statistics, Kathmandu, Nepal

Government of Nepal (1997) Statistical Year Book of Nepal. Central Bureau of Statistics, Kathmandu, Nepal

Greenwood, G. (2008) Why Mountains Matter. International Human Dimensions Programme Issue 2 "Mountain Regions: Laboratories for Adaptation", pp. 4-6

Haines-Young, R., Watkins, C., Wale, C. and Murdock, A. (2006) Modelling natural capital: The case of landscape restoration on the South Downs, England. ***Landsc. Urban Plann.*** 75: 244–264

Hardie, N., Benecke, U. and Gorman, P. (1987) Nepal- New Zealand project for forest management in Khumbu-Pharak. Unpublished report, Himalayan Trust and Volunteer Service Abroad, Wellington, New Zealand

Harmon, D. and Worboys, G. (2004) Managing Mountain Protected Areas: Challenges and Responses for the 21st Century. IUCN Publication

Hein, L., van Koppen, K., de Groot, R. S. and van Ierland, E. C. (2006) Spatial scales stakeholders and the valuation of ecosystem services. ***Ecological Economics*** 57: 209-228

HMG/ADB/FINIDA (1988) Master Plan for the Forestry Sector Nepal. Main Report, Ministry of Forests and Soil Conservation, Kathmandu, Nepal

Hu, H., Liu, W. and Cao, M. (2008) Impact of land use and land cover changes on ecosystem services in Menglun, Xishuangbanna, Southwest China. ***Environ. Monit. Assess.*** 146 (1–3): 147–156

Huntington, S.P. (1993) The clash of civilizations? ***Foreign Affairs*** 72(3): 22–49

—— (1996a) The Clash of Civilizations and the Remaining of the World Order. Simon and Schuster, New York

—— (1996b) The west unique, not universal. ***Foreign Affairs*** 75(6): 28–34

—— (1997) The clash of civilizations-response. ***Journal of International Studies*** 26(1): 141–142

Inglehart, R. and Flanagan, S. (1987) Value change in industrial societies. ***American Political Science Review*** 81(4): 1289–1319

Inglehart, R. (1995) Public support for environmental protection: objective problems and subjective values in 43 societies. ***Political Science & Politics*** 28(1): 57–72

—— (1997) Modernization and Post modernization: Cultural, Economic, and Political Change in 43 Societies. Princeton University Press, Princeton, NJ

Inglehart, R. and Baker, W.E. (2000) Modernization, cultural change, and the persistence of traditional values. ***American Sociological Review*** 65(1): 19–51

Ives, J.D. (1989) Deforestation in the Himalayas: the cause of increased flooding in Bangladesh and Northern India. ***Land Use Policy*** 6: 187-193

—— (2004) *Himalayan Perceptions: environmental change and the wellbeing of mountain peoples*. Routledge, London

Jefferies, B. (1982) Sagarmatha National Park: the impact of tourism in the Himalaya. ***Ambio*** 11: 274-81

—— (2004) Sagarmatha National Park: A world Heritage Site in Crises In: Harmon, D. and Worboys, G. (editors), Managing Protected Areas: Challenges and Responses for the 21st Century. IUCN Publication pp. 42-53

Kadota, T., Fijita, K., Seko, K., Kayastha, R.B. and Ageta, Y. (1997) Monitoring and prediction of shrinkage of a small glacier in Nepal Himalaya. ***Annals of Glaciology*** 24: 90-94

Kline, J.D. (2007) Defining an economics research program to describe and evaluate ecosystem services. USDA Forest Service, Pacific Northwest Research Station. Gen. Tech. Rep. PNW-GTR-700

Körner, C. and Ohsawa, M. (2005) Mountain systems. Chapter 24 In Hassan et al. (eds.) Ecosystems and Human Well-being: Current State and Trends, Volume 1, Island Press, Washington DC: pp 681-716

Kremen, C., Williams, N.M. and Thorp, R.W. (2002): Crop pollination from native bees at risk from agricultural intensification. ***Proceedings of the National Academy of Sciences*** 99: 16812-16816

Kreuter, U., Harris, H.G., Matlock, M.D. and Lacey, R.E. (2001) Change in ecosystem service values in the San Antonio area, Texas. ***Ecol. Econ.*** 39(3): 333–346

Krueger, R.A. (1994) Focus Groups: A Practical Guide for Applied Research. Sage Publications, California

Krueger, R.A. and Casey, M.A. (2000) Focus Groups: A Practical Guide for Applied Research (3rd edition). Sage Publications, Thousand Oaks, CA

Kumara, M. and Sharma, C.M. (2009) Fuelwood consumption pattern at different altitudes in rural areas of Garhwal Himalaya. ***Biomass and Bioenergy*** 33: 141 3 –1418

Kuniyal, J.C. (2003) Analysis of regional imbalances and sustainable crop farming in the Uttaranchal Himalaya, India. ***Ecological Economics*** 46: 419-435

Laiolo, P. (2003) Diversity and structure of the bird community overwintering in the Himalayan subalpine zone: is conservation compatible with tourism? ***Biological Conservation*** 115: 251-262

Lal, M. (2005) Implications of climate change on agricultural productivity and food security in South Asia. In Key vulnerable regions and climate change-identifying thresholds for impacts and adaptation in relation to Article 2 of the UNFCC. European Climate Forum

Lautenbach, S., Kugel, C., Lausch, A. and Seppelt, R. (2010) Analysis of historic changes in regional ecosystem service provisioning using land use data. ***Ecological Indicators*** xxx: xxx–xxx

Ledgard, N. (2002a) Forest in Sagarmatha (Everest) National Park, Nepal. Papers presented at the international symposium for the international year of mountains 2002, Innsbruck

—

(2002b) Nepal-Sagarmatha forestry report 2002. Unpublished report prepared for the Himalayan Trust, New Zealand and the Sir Edmund Hillary foundation of Canada forest research, Christchurch, New Zealand

Li, R., Dong, M., Cui, J.Y., Zhang, L.L., Cui, Q.G. and He, W.M. (2007) Quantification of the impact of land-use changes on ecosystem services: a case study in Pingbian County, China. ***Environ. Monit. Assess.*** 128(1): 503–510

Liu, X. and Chen, B. (2000) Climatic warming in the Tibetan Plateau during recent decades. ***International Journal of Climatology*** 20: 1729-1742

Marion, J.L. (1994) "An Assessment of Trail Conditions in Great Smoky Mountains National Park". Final Research Report, US Department of Interior, National Parks Service, Southeast Region. Atlanta, Georgia

Marsh, G.P. (1864) Man and Nature. Reprint, Harvard University Press, Cambridge, MA, pp. 1965

Masera, O., Drigo, R. and Trassero, M.A. (2003) Woodfuels integrated supply/ demand overview mapping (WISDOM): a methodological approach for assessing woodfuel sustainability and support wood energy planning. FAO-EC partnership programme; wood energy programme-FAO Forestry Department, Rome

Messerschmidt, D.A. and Navin, R.K. (1992) Readings in social forestry and Natural resource Management for Nepal. Report prepared to Ministry of Agriculture-Winrock, Nepal

Meyer, B.C. and Grabaum, R. (2008) MULBO-model framework for multi criteria landscape assessment and optimisation: A support system for spatial land use decisions. ***Landsc. Res.*** 33: 155–179

Millennium Ecosystem Assessment (2003) Ecosystems and Human Well-being- A framework of assessment. Millennium Ecosystem Assessment (MA), Island Press, Washington D C

—

(2005) Ecosystems and Human Well-being – General Synthesis. Millennium Ecosystem Assessment (MA), Island Press, Washington D.C

Morgan, D. L. (1997) Focus Groups as Qualitative Research (2nd ed.). Qualitative Research Methods Series 16

Moseley, R.K. (2006) Historical landscape change in northwestern Yunnan, China: Using repeat photography to assess the perceptions and realities of biodiversity loss. ***Mountain Research and Development*** 26: 214-219

Mountain Spirit (2002) Successful community initiatives project document Sagarmatha region: Chaurikharka, Namche and Khumjung VDC, solukhumbu, Nepal. Unpublished report

Müller, F. and Burkhard, B. (2007) An ecosystem based framework to link landscape structures, functions and services. In: Mander, Ü., Wiggering, H. and Helming, K. (eds.): Multifunctional Land Use – Meeting Future Demands for Landscape Goods and Services pp. 37-64, Springer. Berlin-Heidelberg -New York

Munic, J. (1997) Influence of tourist activities on mountain regions. Paper presented to the Mountain Forum E-Conference on Community-Based Mountain Tourism. Mountain Forum

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R.E., Lehner, B., Malcolm, T.R. and Ricketts, T.H. (2008) Global mapping of ecosystem services and conservation priorities. ***Proceedings of the National Academy of Sciences*** 105(28): 9495–9500

Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D.R., Chan, K.M.A., Daily, G.C., Goldstein, J., Kareiva, P.M., Lonsdorf, E., Naidoo, R., Ricketts, T.H. and Shaw, M.R. (2009) Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. ***Front Ecol Environ*** 7(1): 4–11

Nepal, S.K. (1997) "Sustainable tourism, protected areas, and livelihood needs of local communities in developing countries". ***Int. J. Sustain. Dev. and World Ecol*** (4): 123-35

—

(1999) "Tourism-induced environmental changes in the Nepalese Himalaya: A Comparative analysis of the Everest, Annapurna, and Mustang regions". A Ph.D. dissertation, Faculty of Natural Sciences, University of Bern, Switzerland

—

(2003) Tourism and the Environment (PERSPECTIVES FROM THE NEPAL HIMALAYA). Himal Books and STUDIEN VErlag Innsbruck-Wien-München

New, M., Lister, D., Hulme, M. and Makin, I. (2002) A high-resolution data set of surface climate over global land areas. ***Climate Research*** 21: 1-25

Norris, P. and Inglehart, R. (2003) Islamic Culture and Democracy: Testing the 'Clash of Civilizations'. Thesis In: Inglehart, R. (Ed.), Human Values and Social Change. Brill, Leiden, Boston

Ortner, S.B. (1978) Sherpas through their rituals. Cambridge University Press, Cambridge

—

(1989) High Religion: A Cultural and Political History of Sherpa Buddhism. Princeton University Press, Princeton

Palni, L.M., Maikuri, R.K. and Rao, K.S. (1998) Conservation of the Himalayan agroecosystem: issues and priorities. Technical Paper-V in Ecoregional Co-operation for Biodiversity Conservation in the Himalaya, United Nation Development Programme, New York, pp. 253-290

Pawson, I.G. (1984) Growth of Tourism in Nepal s Everest Region: Impact on the Physical Environment and Structure of Human settlements. ***Mountain Research and Development*** 4: 237-246

Paudel, K.P. and Andersen, P. (2010) Assessing rangeland degradation using multi temporal satellite images and grazing pressure surface model in Upper Mustang, Trans Himalaya, Nepal. ***Remote Sensing of Environment*** 114: 1845–1855

Pederson, G.T., Gray, S.T., Fagre, D.B. and Graumlich, L.J. (2006) Long-duration drought variability and impacts on ecosystem services: a case study from Glacier National Park, Montana. ***Earth Interact***.10: 1–28

Philip, G. and Shah, M.P. (2004) Mapping repeated surges and retread of glaciers using IRS-1C/1D data: a case study of Shaune Garang glacier, northwestern Himalaya. ***International Journal of Applied Earth Observation and Geoinformation*** 6: 127–141

Pradhan, S., Bajracharya, B. and Shrestha, B. (2009) Decision Support Toolbox User Manual. HKKH Partnership Project, ICIMOD, Kathmandu

Price, M., Wachs, T. and Byers, E. (1999) Mountains of the World: Tourism and Sustainable Mountain Development. Centre for Development and Environment, Institute of Geography, University of Bern, Bern, Switzerland, pp. 4–5

Rao, K.S. (1997) Natural Resource Management in Himalaya: A Recourse to Issues and Strategies. ENVIS Monograph, G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora, India

Rasul, G. (2009) Valuing Ecosystem Services for Promoting Sustainable Agricultural Land Use Systems in Hills and Mountains". Unpublished report, International Centre for Integrated Mountain Development, Kathmandu, http://www.openmeeting2009.org/pdf_files/Pdf%20papers/Golam%20rasul%20paper.pdf

Reiger, H.C. (1983) Floods and droughts: the Himalaya and the Ganges plains as an ecological system, quoted by Maithani, B.P. (1983). In: Environmental Planning for Hill Area Development: A study of Nadaun Tahsil, Himanchal Pradesh, Project Report, National institute of Rural Development, N.E. Regional Centre, Guwahati, India, pp. 14

Ries, J. B. (1993) Soil erosion in the high mountain region, eastern central Himalaya. A case study in Bamti/Bhandara/Surma area, Nepal. A Ph.D. Dissertation, Geowissenschftlichen Fakultat, Albert-Ludwigs-Universitàt, Freiburg I Br

Rogers, P. (1997) Tourism, Development and Change in the Sagarmatha National Park and its Environs. A Ph.D. dissertation, University of Wales, Aberystwyth

Rowell, G. (1980) Many people come, looking, looking. The Mountaineers, Seattle

Sacherer, J. (1977) The sherpas of Rolwaling, North Nepal: A study in Cultural Ecology. A Ph.D. dissertation, Ecole Des Hautes Etudes en Sciences Sociales

Salerno, F., Buraschi, E., Bruccoleri, G., Tartari, G. and Smiraglia, C. (2008) Glacier surface-area changes in Sagarmatha national park, Nepal, in the second half of the 20th century, by comparison of historical maps. ***Journal of Glaciology*** 54(187)

Saunders, P.R. (1981) Casting Recreation Demand in the Upper Savannah River Basin. ***Annals of Tourism Research*** VIII(2)

Schaffner, R. (1987) Vegetation of stabilizing and eroding slopes in eastern Nepal. A Ph.D. Dissertation, Swiss Federal Institute of Technology, Zurich

Schneider, S. H., Semenov, S., Patwardhan, A., Burton, I., Magadza, C.H.D., Oppenheimer, M., Pittock, A.B., Rahman, A., Smith, J.B., Suarez, A. and Yamin, F. (2007) Assessing key vulnerability and the risk from climate change. Contribution of Working Group 2 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge UK, pp. 779-810

Schröder, B. and Seppelt, R. (2006) Analysis of pattern–process interactions based on landscape models-overview, general concepts, and methodological issues. ***Ecol. Modell.*** 199(4): 505–516

Shackley, M. (1996) "Too much room at the inn?" ***Annals of Tourism Research*** 23: 449-462

Sharma, K.P., Adhikari, N.R. and Karbuja, R.G. (2002) Vulnerability and adaptation of water resources to climate changes in Nepal. Interim Report prepared for the United Nations Framework Convention on Climate Change (UNFCCC) Initial National Communication, Central Department of Hydrology and Meteorology, Tribhuvan University, Kathmandu

Sharma, K.P. (2003) "Impact of climate change on water resources of Nepal*". In Proceedings of the consultative workshop of climate change impacts and adaptation options in Nepal's hydropower sector with a focus on hydrological regime changes including GLOF*, 5-6 March 2003, Kathmandu. Department of Hydrology and Meteorology and Asian Disaster Preparedness Centre

Sharma, E. and Xu, J. (2007) Land-use, landscape management and environmental services in the Mountain Mainland Asia: Introduction. ***Tropical Ecology*** 48(2): 129-136

Sharma, E., Chettri, N., Tsering, K., Shrestha, A. and Jing, F. (2009) Climate Change Impacts and Vulnerability in the Eastern Himalayas. Report published by ICIMOD, Kathmandu

Shastri, C. (1999) Developing U.P. hills: notes of "fifty years of up-hill tasks". Paper Presented in the National Seminar on Economy of Uttrakhand in the context of Separate Uttaranchal State, Department of Economics, Kumaon University, Nainital, India

Sherpa, A.R. (2001) Tourism Potential in Thame Valley Sagarmatha National Park, Khumbu Region. Report prepared for Mountain Spirit, Kathmandu, Nepal

Sherpa, L.N. (1979) A report on fire wood use in Sagarmatha National Park, Khumbu region. Unpublished report, Department of National Parks and Wild life Conservation, Kathmandu

—

(2007) Sagarmatha National Park Management and Tourism Plan. Department of National Parks and Wildlife Conservation and Tourism for Rural Poverty Alleviation Program, Kathmandu

Sherpa, L.N. and Bajracharya, B. (2009) View of a high place/Natural and Cultural Landscape of Sagarmatha National Park. Report, ICIMOD/HKKH, Kathmandu

Sherpa, Y.D. (2009) A study of livestock Management patterns in Sagarmatha National park, Khumbu region: trends as affected by socio-economic factors and climate change. Kathmandu University, ***Journal of Science, Engineering and Technology*** 5( ): 110-120

Shrestha, A.B., Wake, C.P., Mayewski, P.A. and Dibb, J.E. (1999) "Maximum temperature trend in the Himalayas and its vicinity: An analysis based on temperature records from Nepal for the period 1971-94". ***Journal of Climate*** 12: 2775-2786

Singh, S. (1981) Soil conservation and afforestation for moderating/mitigating floods. In: The Proceedings of International Conference on Flood Disasters, Indian National Science Academy, New Delhi, p. 114

Singh, S.P. (2007) Himalayan Forest Ecosystem Services: Incorporating in national accounting. Central Himalayan Environmental Association, Nainital, Uttarakhand, India

Smith, J.B., Bhatti, N., Menzhulin, G., Benioff, R., Campos, M., Jallow, B., Rijsberman, F., Budyko, M.I. and Dixon, R.K. (1996) Adapting to climate change: Assessment and issues. New York: Springer-Verlag

SPCC (1997/1998) Annual progress report for the Fiscal Year 1997-1998. Report submitted to HMG/NP, WWF NP and NAP-J. Sagarmatha Pollution Control Committee (SPCC) Board, Namche

Spoon, J.D. (2008) Tourism in a Sacred Landscape: Political Economy and Sherpa Ecological Knowledge in Beyul Khumbu (SNP, Nepal). A Ph.D. dissertation, Graduate Division of the University of Hawaii, Hawaii

Stevens, S.F. (1993) Claiming the high ground: Sherpas, subsistence, and environmental change in the highest Himalaya. A Ph.D. dissertation, Berkely, University of California press

—

(1997) Conservation through cultural survival: indigenous peoples and protected areas. Island Press, Washington

—

(2003) Tourism and deforestation in the Mt. Everest region of Nepal. ***The Geographical Journal*** 169(3): 225-277

—

(2008) The Mount Everest Region as an ICCA: Sherpa Conservation Stewardship of the Khumbu Sacred Valley, Sagarmatha (Chomolungma/ Mt. Everest) National Park and Buffer Zone. Unpublished report, IUCN, Kathmandu

Study of Critical Environmental Problems (1970) Man's Impact on the Global Environment. MIT Press, Cambridge, MA

Sutton, P.C. and Costanza, R. (2002) Global estimates of market and non-market values derived from night time satellite imagery, land cover, and ecosystem service valuation. ***Ecol. Econ.*** 41: 509–527

Tallis, H. and Polasky, S. (2009) Mapping and Valuing Ecosystem Services as an Approach for Conservation and Natural-Resource Management. ***Annals of the New York Academy of Sciences*** 1162: 265-283

TEEB (2008) The economics of ecosystem and biodiversity (TEEB) - An Interim Report. Welzel+Hardt, Wesseling, Germany

Tiwari, P.C. (1995) Natural Resources and Sustainable Development in Himalaya. Shree Almora book Depot, Almora, U.P., India, pp. 147-168

—

(1997) Wildlife in the Himalayan Foothills: Conservation and Management. Indus Publishing Company, New Delhi, India, pp. 143

Toky, O.P. (1983) Secondary succession following slash and burn agriculture in North-eastern India. ***Journal of Indian Biomass Litterfall and Productivity*** 72: 735-745

Top, N., Mizoue, N., Ito, S., Kai, S., Nakao, T. and Ty, S. (2006) Re-assessment of woodfuel supply and demand relationships in kampong Thom Province, Cambodia. ***Biomass and Bioenergy*** 30: 134–43

Troy, A. and Wilson, M.A. (2006) Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer. ***Ecological Economics*** 60: 435-449

Turner, R.K. and Daily, G.C. (2008) The ecosystem services framework and natural capital conservation. ***Environ Resources Econ*** 39: 25-35

Valdiya, K.S. (1985) Accelerated erosion and landslide prone zones in the central Himalayan region. In: Singh, J.S. (Ed.), Environmental Regeneration in Himalaya. Gyanodaya Prakashan, Nainital, U.P., India, pp. 12-38

Vandewalle, M., Sykes, M.T., Harrison, P.A., Luck, G.W., Berry, P., Bugter, R., Dawson, T.P., Feld, C.K., Harrington, R., Haslett, J.R., Hering, D., Jones, K.B., Jongman, R., Lavorel, S., Martins da Silva, P., Moora, M., Paterson, J., Rounsevell, M.D.A., Sandin, L., Settele, J., Sousa, J.P. and Zobel, M. (2009) Review paper on concepts of dynamic ecosystems and their services. http://www.rubicode.net/rubicode/RUBICODE_Review_on_Ecosystem_Services.pdf

Vejre, H., Abildtrup, J., Andersen, E., Andersen, P., Brandt, J., Busck, A., Dagaard, T., Hasler, B., Huusom, H., Kristensen, L., Kristensen, S. and Praestholm, S. (2007) Multifunctional agriculture and multifunctional landscapes-landuse as an interface. In: Mander, Ü., Helming, K. and Wiggering, H. (Eds), Multifunctional Land Use: Meeting Future Demands for Landscape Goods and Services. Springer Heidelberg, Berlin, pp. 93-104

Wackernagel, M. and Galli, A. (2007) An overview on ecological footprint and sustainable development: a chat with Mathis Wackernagel. ***International Journal of Ecodynamics*** 2(1): 1–9

Wallace, K.J. (2007) Classification of ecosystem services: problems and solutions. ***Biological Conservation*** 139(3–4): 235–246

Watanable, T. (1994) Soil erosion on yak-grazing steps in the Langtang Himal, Nepal. ***Mountain Research and Development*** 14(2): 171-179

Water and Energy Commission Secretariat-Nepal (2001) Wood Energy Planning. Kathmandu

Westman, W.E. (1977) How much are nature's services worth? ***Science*** 197: 960– 964

Wiedmann, T. (2009) Carbon Footprint and Input-Output Analysis- An Introduction. ***Economic Systems Research*** 21(3): 175-186

Willemen, L., Verburg, P.H., Hein, L. and van Mensvoort, M.E.F. (2008) Spatial characterization of landscape functions. ***Landscape and Urban Planning*** 88: 34-43

Winkler, R. (2006) Valuation of ecosystem goods and services Part 1: An integrated dynamic approach. ***Ecological Economics*** 5 9: 8 2-9 3

World Wildlife Fund-Nepal (2003) Sagarmatha community agro-forestry project: A retrospective (1996-2002). Unpublished report

—

(2005) An overview of Glaciers, Glaciers Retreat, and Subsequent Impacts in Nepal, India and China. Report prepared by WWF-Nepal Program, Kathmandu

—

(2009) Melting Water Towers: Sagarmatha National Park and Buffer Zone. Report, Kathmandu

Wunder, S., Engel, S. and Pagiola, S. (2008) Taking Stock: A Comparative Analysis of Payments for Environmental Services Programs in Developed and Developing Countries. ***Ecological Economics*** 65(4): 834–52

Xu, J., Fox, J., Melick, D., Fujita, Y., Jinttrawet, A., Jie, Q., Thomas, D. and Weyerhaeuser, W. (2006) Land use transition, livelihoods and environmental services in Montane Mainland Southeast Asia. Mountain Notes- ***Mountain Research and Development*** 26: 278-284

Yamada, T. (1992) Fluctuation of the glaciers from the 1970s to 1989 in the Khumbu, Shorung and Langtang regions, Nepal Himalayas. ***Bulletin of Glacier Research*** 10: 11-19

ANNEXES

Annex I--------Average ranking per tourist according to the country origin.

Annex II-------Photographs used in tourist survey.

Annex III------Photographs during field survey.

Eidesstattliche Erklärung zu meiner Promotion mit dem Titel
"An Assessment of Ecosystem Services of the Everest Region, Nepal"

Hiermit erkläre ich, dass ich die vorliegende Dissertation selbständig verfasst und keine anderen als die angegebenen Hilfsmittel benutzt habe.

Die Dissertation ist bisher keiner anderen Fakultät vorgelegt worden.

Ich erkläre, dass ich bisher kein Promotionsverfahren erfolglos beendet habe und dass keine Aberkennung eines bereits erworbenen Doktorgrades vorliegt.

Bikram Tamang Kiel, den 26.5.2011

ANNEX I

Average ranking per tourist according to the country origin

Land cover types	UK		Japan		Germany		USA		France	
	1992	2005	1992	2005	1992	2005	1992	2005	1992	2005
Cultivated land			16	25	44	73	85	130	35	57
Built up area	203	334	94	146	146	240	170	260	140	230
Gravel stones and boulders										
Closed to open herbaceous vegetation	25.45	41.81	65.45	89	45	73	85	130	35	57
Broad leaved forest	89.09	146.36	61	95.45	95	157	127	195	204	345
Needle leaved forest	70	115	49	76.36	70	115	127	195	140	230
Mixed multilayer forest	70	115	61.36	95.45	70	115	106	162	140	230
Shrub land	140	209	122	190	159	261	212	325	175	287
Glacier	286.36	470	176	273	299	491	191	292	140	230
Glacial lake	165.45	272	57	89	95.45	157	127	195	35	57
Snow	350	575	225	350	350	575	390	596	481	791
Bare rocks					25.45	42				
Bare soils							42	65		

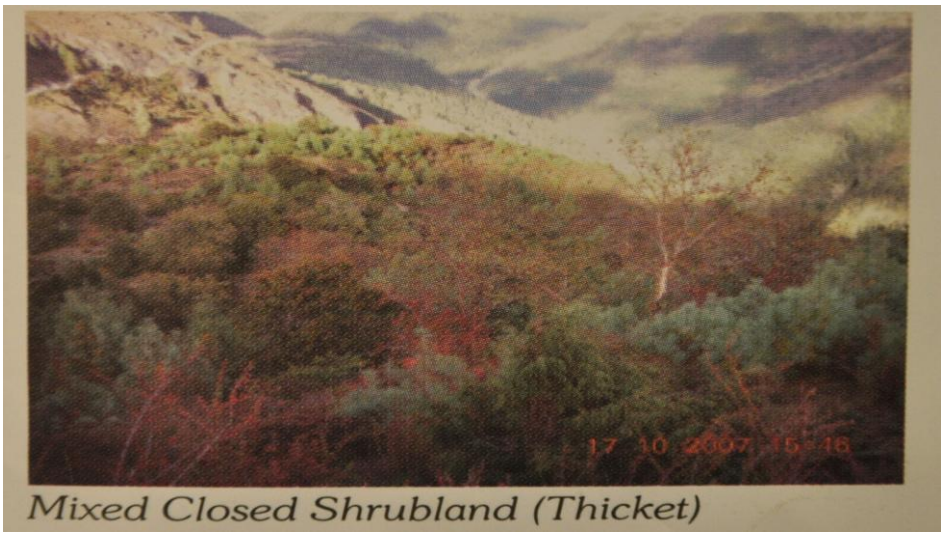
Land cover types	Australia		Netherland		Switzerland		Canada		Austria	
	1992	2005	1992	2005	1992	2005	1992	2005	1992	2005
Cultivated land			70	115	35	57.5	42.5	65	70	115
Built up area	97	157	140	230	175	287.5	127.5	195	140	230
Gravel stones and boulders	33	53					42.5	65		
Closed to open herbaceous vegetation	33	53			70	115	42.5	65		
Broad leaved forest	97	157	140	230	105	172.5	127.5	195	105	172.5
Needle leaved forest	97	157	140	230	70	115	127.5	195	70	115
Mixed multilayer forest	97	157	140	230	70	115	127.5	195	70	115
Shrub land	162	262	140	230	210	345	212.5	325	175	287.5
Glacier	211	341	210	345	175	287.5	255	390	350	575
Glacial lake	130	210	70	115	140	230	85	130	70	115
Snow	447	722	350	575	350	575	425	650	350	575
Bare rocks							42.5	65		
Bare soils	32	52					42.5	65		

Land cover types	Italy		Denmark		Spain		Russia		Other European countries	
	1992	2005	1992	2005	1992	2005	1992	2005	1992	2005
Cultivated land	23	38	70	115	35	57.5	110	180	87.5	144
Built up area	186	307	70	115	140	230	55	90	87.5	144
Gravel stones and boulders			70	115					17.5	29
Closed to open herbaceous vegetation	93	153	70	115	35	57.5	55	90	17.5	29
Broad leaved forest	117	192	140	230	105	172.5	110	180	114	187
Needle leaved forest	117	192	140	230	105	172.5	55	90	96	158
Mixed multilayer forest	117	192	140	230	105	172.5	55	90	131	215
Shrub land	187	307	140	230	140	230	110	180	175	287
Glacier	187	307	140	230	245	402.5	165	270	245	402
Glacial lake	23	38	70	115	105	172.5	110	180	157	259
Snow	350	575	350	575	350	575	275	450	315	517
Bare rocks										
Bare soils					35	57.5			9	14

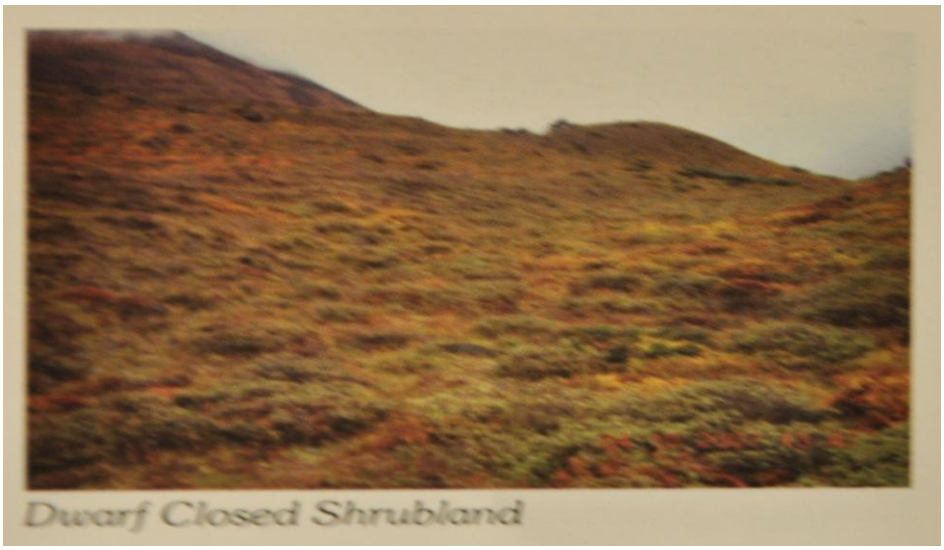
Land cover types	Other Asian countries		SAARC countries	
	1992	2005	1992	2005
Cultivated land	22.5	35	22	37
Built up area	93.21	145	75	128
Gravel stones and boulders				
Closed to open herbaceous vegetation	16	25	22	37
Broad leaved forest	77	120	65	110
Needle leaved forest	64	100	65	110
Mixed multilayer forest	64	100	65	110
Shrub land	93.21	145	65	110
Glacier	164	255	119	202
Glacial lake	67.5	105		
Snow	225	350	162	275
Bare rocks				
Bare soils	6	10		

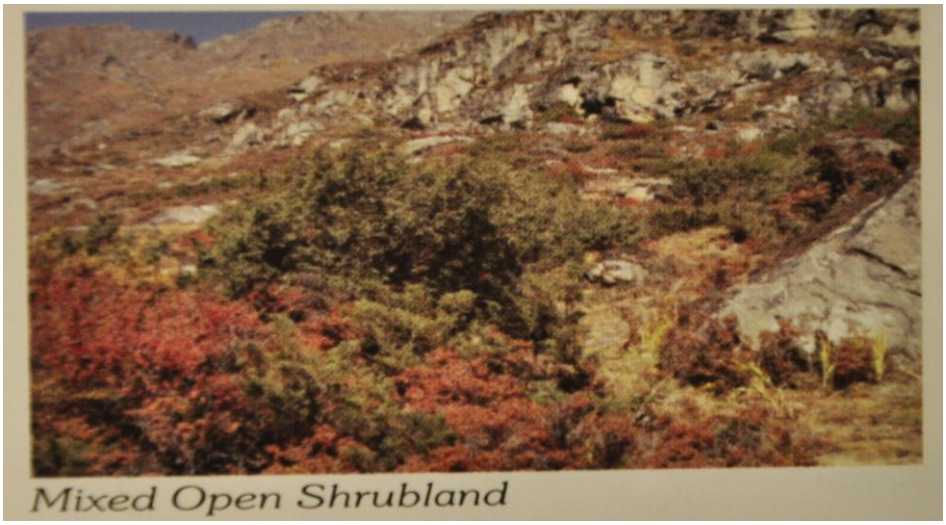
ANNEX II

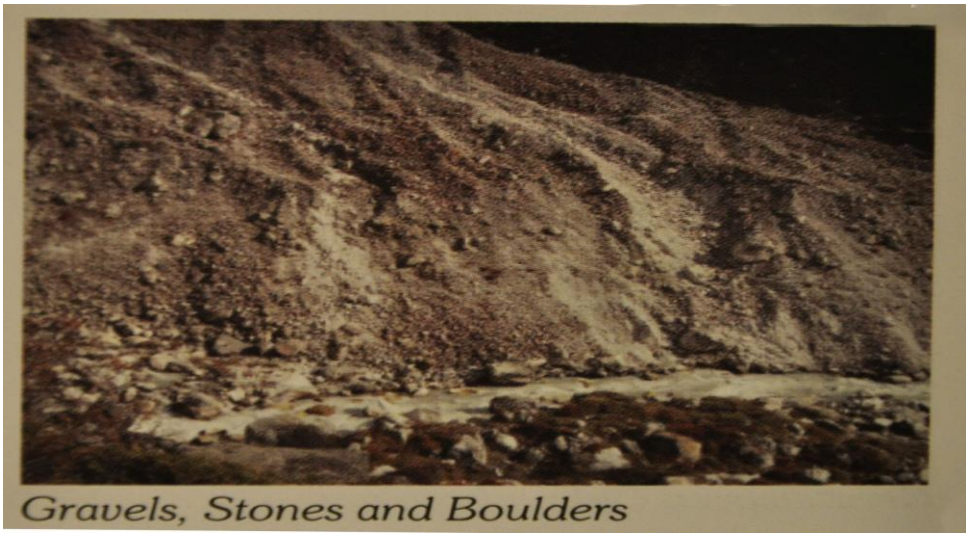
Photographs used in tourist survey



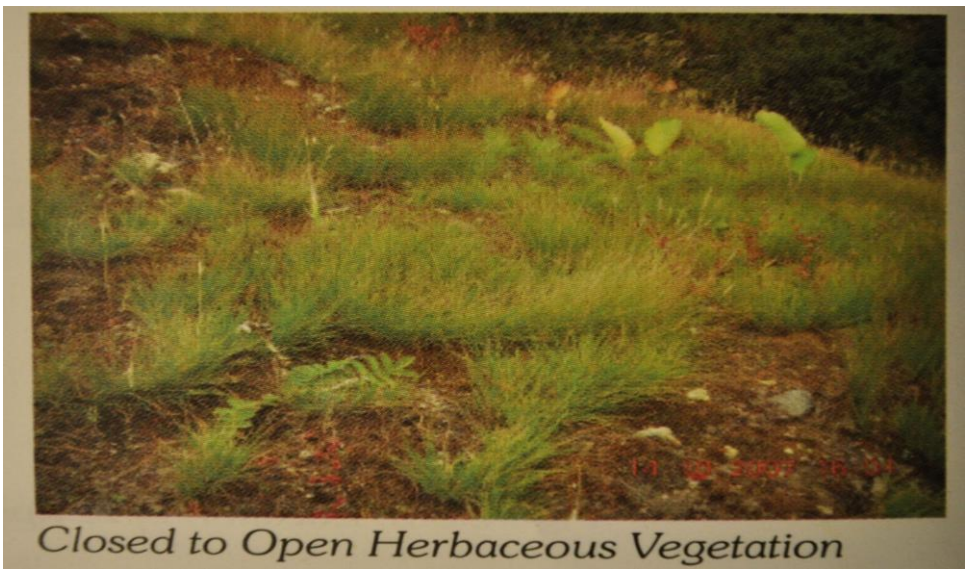
Mixed Closed Shrubland (Thicket)


Dwarf Closed Shrubland

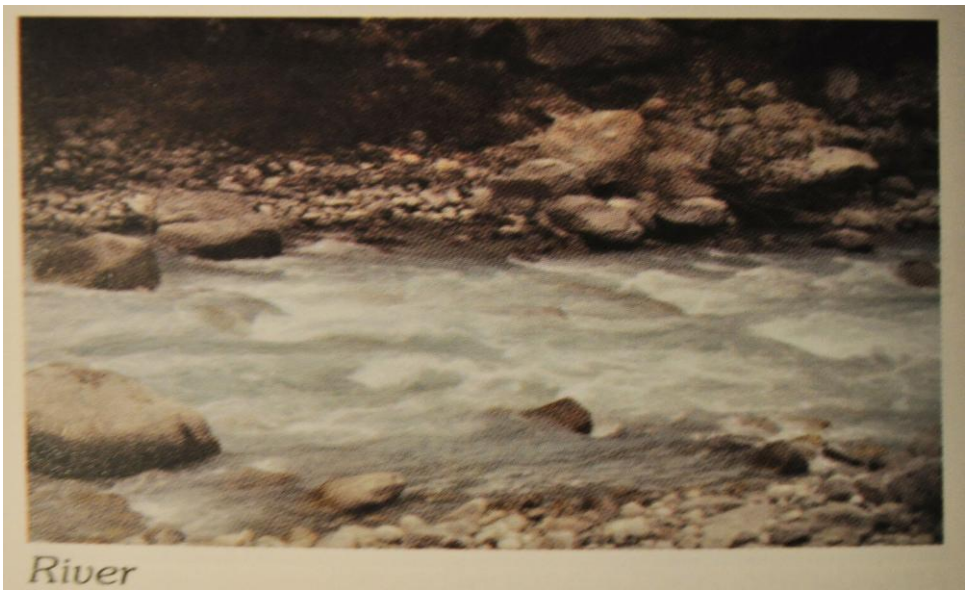

Mixed Open Shrubland



Gravels, Stones and Boulders



Closed to Open Herbaceous Vegetation

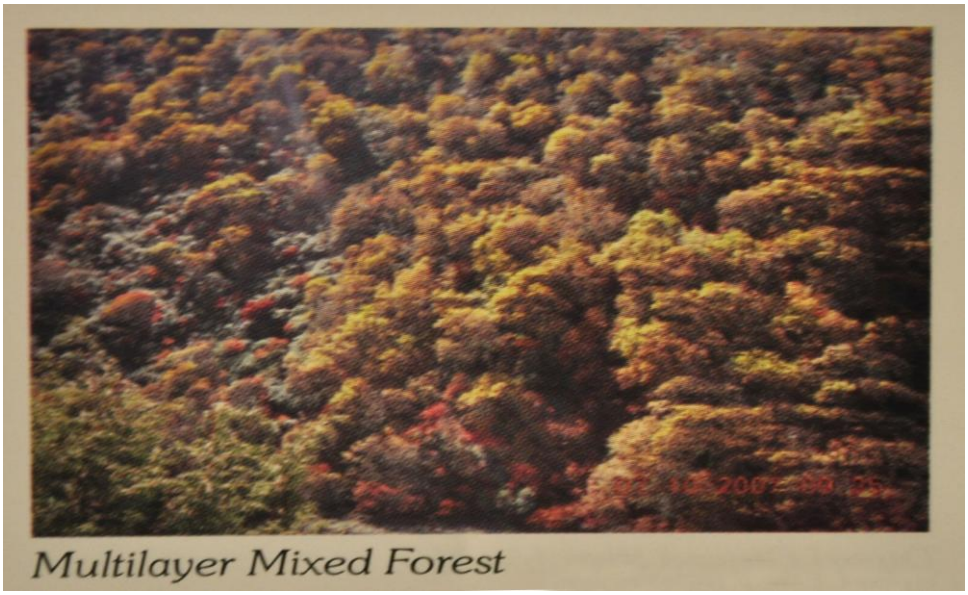


River

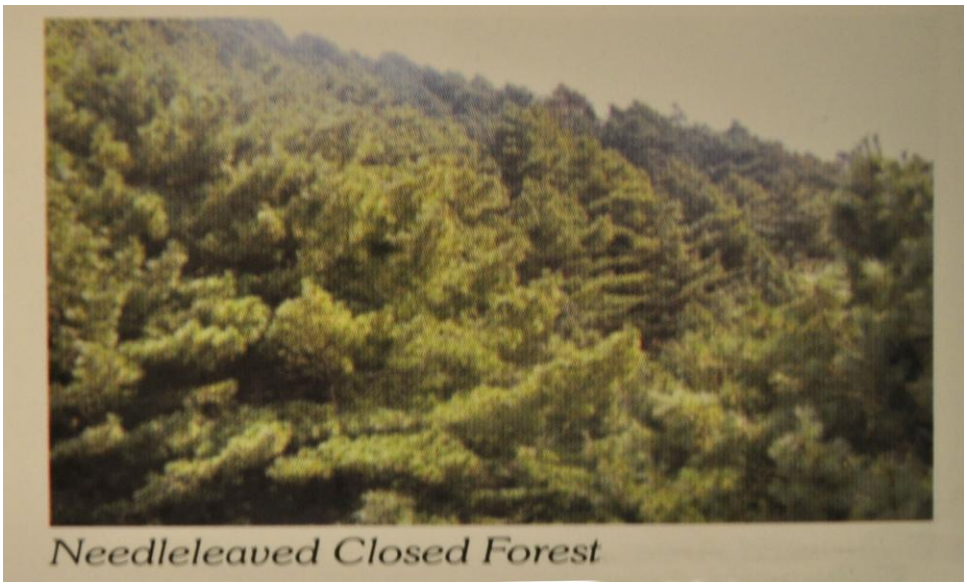
Glacial Lake

Glacier

Snow

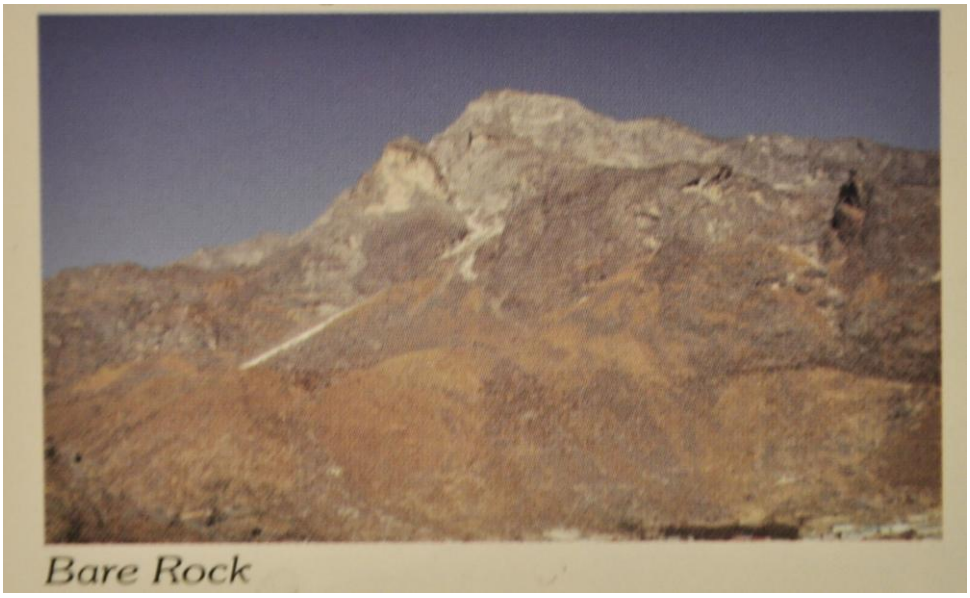


Multilayer Mixed Forest

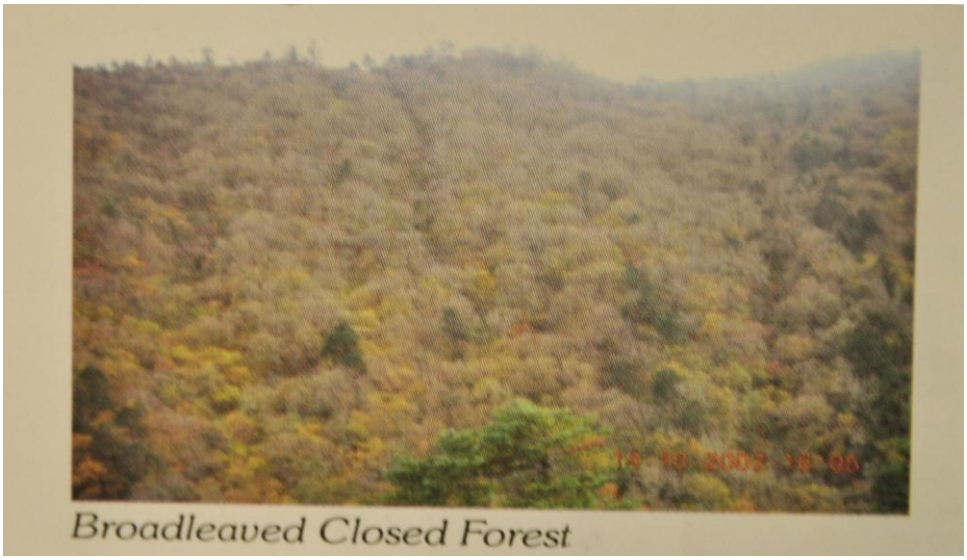


Needleleaved Closed Forest

Needleleaved Open Forest

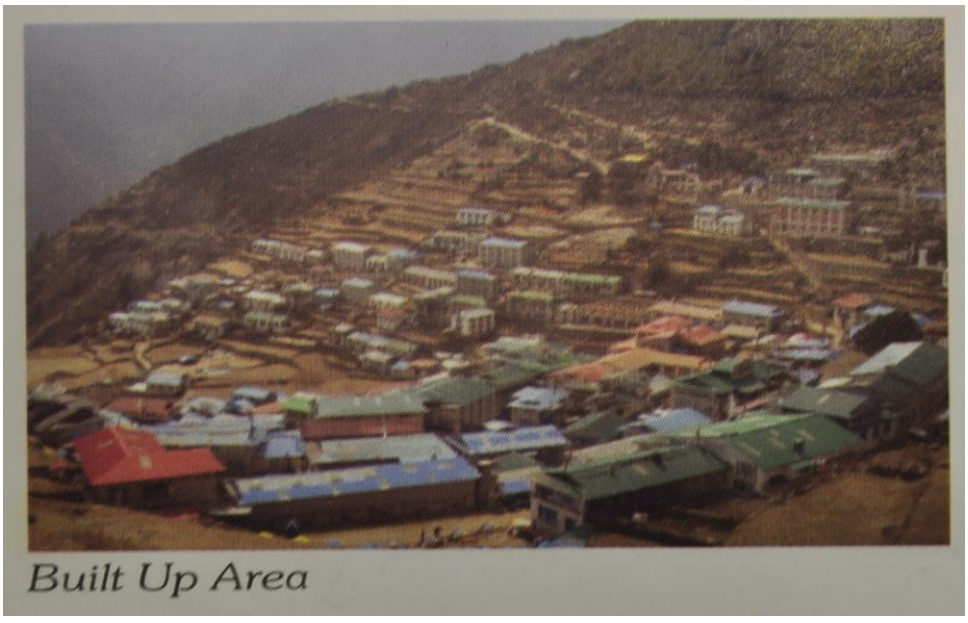

Bare Rock


Bare Soil


Broadleaved Closed Forest

Broadleaved Open Forest

Cultivated Area



Built Up Area

ANNEX III

Photographs during field visit

Focus group participants in upper Thame village

Interview with Doctor of the Khunde hospital

Interview with Everest Summitter in the Khunde village


Interview with Headmaster of the Khumjung School

Interview with local people in the Khumjung village


Interview with Lama of the Kumjung Monastery

Bishwokarma family working in stone supply in Namche village


Focus group participants in Namche village

Interview with local business person in Namche weekly market


Local business person selling livestock products (butter, cheese, ghee and churpi) in Namche weekly market

Focus group participants from government and non-government organization

Improved cooking stove use in Thame lodge