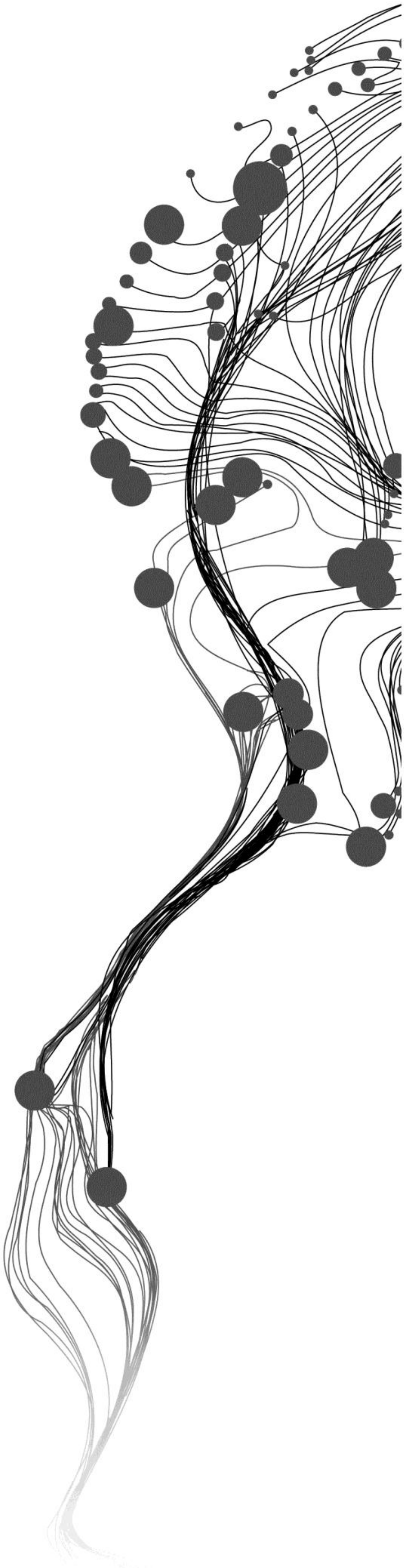
IDENTIYING AND MAPPING THE BIODIVERSITY AND OTHER ECOSYSTEM BASED MULTIPLE BENEFITS OF REDD+: THE CASE OF CHITWAN, NEPAL

GETACHEW TADDESE MERAHI
February 2013

SUPERVISORS:
MS. IR.L.M. Leeuwen
DRS. Henk Kloosterman



IDENTIYING AND MAPPING THE BIODIVERSITY AND OTHER ECOSYSTEM BASED MULTIPLE BENEFITS OF REDD+: THE CASE OF CHITWAN, NEPAL

GETACHEW TADDESE MERAHI
Enschede, The Netherlands, February, 2013

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Natural Resources Management

SUPERVISORS:
Ms. Ir. Louise van Leeuwen
Drs. Henk Kloosterman

THESIS ASSESSMENT BOARD:
Dr. Y.A. Hussin (Chair)
Dr. J.F. Duivenvoorden (External Examiner, Institute for Biodiversity and Ecosystem Dynamics (IBED) – University of Amsterdam)
Ms. Ir. Louise van Leeuwen (First Supervisor)
Drs. Henk Kloosterman (Second Supervisor)

ABSTRACT

REDD+ has the potential to conserve or protect forests and deliver multiple benefits beyond carbon. To realize these benefits, careful planning is needed and particular attention should be paid to biodiversity and other ecosystem services. This study aims to investigate where REDD+, in addition to maintaining carbon stocks, can secure benefit of biodiversity (tree species diversity) and ecosystem services of provisioning of NTFPs; identify hotspot areas (areas of importance for carbon stock, biodiversity, and NTFPs) and investigate their spatial relationships.

GIS and geospatial statistics were used for this study. Aboveground biomass map data was used to develop carbon stock map; and Shannon diversity index was calculated and used as an indicator of tree species diversity. Kriging spatial interpolation was used to map tree species diversity; and spatial relationship between tree species diversity and carbon stock of the study area was also investigated.

Non timber forest products (NTFP) were identified and mapped, spatial relationship between NTFP rich and NTFP unique places were investigated; and the accuracies of the maps were assessed through leave one out cross validation techniques.

NTFP uniqueness map for the study area was produced based on a uniqueness index developed in this study. Investigation of the effect of accessibility on NTFP extraction shows that while there may be effect of accessibility for NTFP popularity, its effect on NTFP uniqueness was not observed; but its effect on availability calls for further study.

Very weak negative correlation was obtained (Pearson's correlation = -0.05) between carbon stock and tree species diversity, and the relation was not statistically significant at 95% confidence level. But, there was obtained positive strong correlation and statistically significant relation ($\alpha = 0.01$) between NTFP rich places and NTFP unique places. Pearson's correlation obtained was 0.91, and coefficient of determination (R^2) was 0.84.

NTFP hotspots were identified and mapped by identifying NTFP richness and NTFP uniqueness based on the uniqueness index. Finally, map of hotspots and most hotspot places were identified based on set criteria for areas of importance for carbon stock, biodiversity and NTFP richness and NTFP uniqueness.

Keywords: ecosystem services, carbon stock, tree species diversity, NTFP richness, accessibility, NTFP uniqueness, uniqueness index, REDD+

ACKNOWLEDGEMENTS

I would like to express my gratitude to those who have supported me throughout my research work. First and foremost, I thank God through Jesus Christ for all things and for his presence with me in my study at ITC; thank you doesn't convey the depth of my gratitude.

I am really very much grateful to Ms. Ir. L.M. Leeuwen for her patience and continual professional guidance from the very beginning till the end, without the support of whom this research would not be complete. I will not forget your systematic way of conveying too much information with too little words. I sincerely thank also my second supervisor, Drs. Henk Kloosterman for his critical feedbacks and enthusiastic encouragement during the course of the research work. Your appreciation has helped me a lot.

I would also like to thank Dr Y.A. Hussin for his constructive comments during the proposal defence, field data collection (with me in South Asia, Nepal) and midterm presentation. I am also thankful to my course director, Dr. Michael Weir and NRM staff for their positive attitude and support in my study in ITC. I would also like to expand my thanks to Dr David Rossiter and Dr. Hein van Gils for the research skill they provided me during Module 11 course teaching, it was inspiriting.

I am also very grateful again to ITC/UT and NUFFIC (Netherlands Universities Foundation for International Cooperation) for granting me the scholarship to study in the Netherlands; oh, thank you is not enough! I thank ICIMOD and the government of Nepal, Ministry of Land Reform and Management National Land Use Project, Kathmandu and the Chitwan District Development Committee for their providing me the required data for my study. I also thank the people of Nepal and particularly the community in Chitwan for their very nice and sincere hospitality during my field data collection in Shaktikhor and Siddi VDCs.

My classmates, who were all always with me, also deserve my appreciation and acknowledgement in my stay and study at ITC. I am grateful to Pradeep Sapkota Upadhyaya for the topographic data, and Metadel Fentahun for her AGB map.

I am also indebted to Dr. Paul van Dijk and the ITC International Christian Fellowship for the spiritual encouragement and Christian brotherhood I got from the fellowship. Last but not least, I thank all my families and friends for their love and support during my study in the Netherlands, God bless you all.

Getachew Taddese Merahi
Enschede, the Netherlands
February 2013

Dedicated to my father - Taddese Merahi and his family

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATION

LIST OF APPENDICES

LIST OF ACCRONYMS

AGB	Aboveground biomass
CBD	Convention on Biological Diversity
CF	Community Forest
CS	Carbon stock
DEM	Digital Elevation Model
EBK	Empirical Bayesian Kriging
GE	Google Earth
GHG's	Greenhouse gases
GIS	Geographic Information Systems
GPS	Geographic Position System
HP	Hewlett Packard
ICIMOD	International Centre for Integrated Mountain Development
IDW	Inverse Distance Weight
ITC	Geo-Information Science and Earth Observation Faculty of the University of Twente, Netherlands
KML	Keyhole Mark-up Language
KMZ	Keyhole Markup Language, Zipped
LOOCV	Leave one out cross validation
LPI	Local Polynomial Interpolation
MAE	Mean of absolute error
ME	Mean of prediction error
MEA	Millennium Ecosystem Assessment
MLRMNLP	Ministry of Land Reform and Management National Land Use Project, Nepal
NTFPs	Non-Timber Forest Products
NUFFIC	Netherlands Universities Foundation for International Cooperation
OED	Oxford English Dictionary
OK	Ordinary Kriging
REDD	Reducing emission form deforestation and forest degradation
REDD+	Reducing carbon emission form deforestation and forest degradation and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks
RMSE	Root Mean Square Error
RS	Remote sensing
SI	Shannon index
SQS	Species quality sites
TSD	Tree species diversity
UI	Uniqueness index
UN	United Nations
UNFCCC	United Nations framework Convention on Climate Change
VDC	Village Development Committee
WofE	Weight of evidence

1. INTRODUCTION

1.1. Background

Climate change, hot issue these days, has altered the perception of people about the world. The fate of humanity, the future of all, rich and poor, in every corner of the world, have become closely intertwined (Lal et al., 2011). Many aspects of the planet are changing mainly due to human activities (Metzger et al., 2006). To create a world which is more resilient to this challenge, it is said that it is necessary to reduce the greenhouse gas emissions which drive climate change and provide populations, particularly the poor and vulnerable, with the assistance they need to adapt to climate change (Scheffran et al., 2012).

Several statistics show that deforestation and forest degradation account for about 20 per cent of global greenhouse gas emissions – which is estimated to be more than the entire global transport sector next to the energy sector (UNEP, 2011). Hence, reducing emissions from deforestation and forest degradation especially in less developed countries has become a priority for global climate change policy (Sandbrook et al., 2010).

REDD (Reducing Emissions from Deforestation and forest Degradation), is a United Nation's (UN) programme introduced in 2007 which basically reward individuals or countries that reduce greenhouse gas emissions from forests. It is said to have "the potential to achieve significant co-benefits, including alleviating poverty, improving governance, and conserving biodiversity and providing other environmental services" (Angelsen, 2008). It is also widely accepted as a "land use policy objective for mitigating climate change" (Minang & van Noordwijk, 2012). Besides its basic and initial conception, the 2007 Bali Action Plan of the UNFCCC (United Nations framework Convention on Climate Change) opened the way to broadening the scope of REDD to include three main things: conservation of forest carbon stocks, sustainable management of forests, as well as enhancement of forest carbon stocks (Swan & McNally, 2011).

The Cancun Agreement (UNFCCC Cop 16, 2010) also states that REDD+ is not only about reducing emissions, but also halting and reversing forest degradation and forest loss which is thought to be important as it emphasizes that REDD+ actions must result in preserving existing forests and carbon stocks (Swan & McNally, 2011; WRI, 2012).

REDD+ has the potential to conserve or protect forests and to deliver multiple benefits beyond carbon. UN-REDD, (2011) state the "need to have careful planning to realize these benefits and mitigate any risks and the need to pay particular attention to the biodiversity, ecosystem services, transparent and effective governance, participation, inclusion of stakeholders and indigenous people's rights". Although REDD-plus programmes focus on forests, they also affect socioeconomic and ecological outcomes at local, regional, national and global levels (Agrawal et al., 2011).

The term multiple benefits, according to the UN-REDD Programme, include both the ecosystem and social benefits of REDD (UN-REDD, 2009). Social benefits include jobs, livelihoods, land tenure clarification, carbon payments, and enhanced participation in decision-making and improved governance. Ecosystem based multiple benefits of REDD-plus are also called ecosystem services (UN-REDD, 2009).

Ecosystem services are services/benefits people obtain from ecosystems. Literatures, following the 2005 Millennium Ecosystem Assessment's definition, mainly mention four types of ecosystem services, such as (1) cultural which includes: cultural diversity, cultural heritage, spiritual and religious values, social relations, sense of place, recreation and tourism, aesthetic and inspiration, knowledge system, bequest, intrinsic and existence; (2) regulating which includes: pollination, disease regulation, air quality regulation, erosion regulation, climate regulation, pest regulation, natural hazards, water purification and waste treatment, water regulation; (3) provisioning which includes: fresh water, medicines and pharmaceuticals, biochemical, genetic resources, ornamental resources, geological resources, energy, fibre, food; (4) supporting which includes: primary production, water cycling, soil formation, nutrient cycling and photosynthesis (Raymond et al., 2009; UN-REDD, 2009).

Biodiversity, according to Millennium Ecosystem Assessment (2005), is defined as the "variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part"; it includes diversity within and between species and diversity of ecosystems. Biodiversity is said to have an important role of providing ecosystem services (MEA, 2005). As Alerts & Honnay (2011) noted restoring multiple forest functions requires multiple species.

The relationship between biodiversity and ecosystem services seems to be controversial as seen in many literatures. On the one hand, biodiversity is treated as one of the ecosystem service (Metzger et al., 2006); on the other hand, the word biodiversity is treated as a synonymous word for ecosystem services (TEEB, 2010). Some researchers assert that both biodiversity and ecosystem services mutually exist and treat them as having positive correlation (Schneiders et al., 2012; Willms et al., 2002); however, others also claim that there is no correlation between them (Naidoo et al., 2008). For some, ecosystem services are the goods and services that biodiversity provides (UN Global Compact and IUCN, 2012; F. I. UNEP, 2008). Feng et al, (2010), based on other studies, noted that high species richness is required to retain a high degree of ecosystem services; and maintaining biodiversity is considered as an efficient way to enhance ecosystem services (Feng et al., 2010). Moreover, more recent studies approach biodiversity as having multi-layered relationship, i.e., as a regulator of ecosystem processes, as a service by itself and as a good (Mace et al., 2012).

Although it may be optimal for biomass/carbon stock production, species-poor plantations will not outperform species diverse situation; and it is also asserted that complex forest ecosystems are more productive than less diverse one (Aerts & Honnay, 2011; Thompson et al., 2009). High carbon stock doesn't automatically mean high biodiversity; high carbon intervention may have huge carbon with low biodiversity and few ecosystem services. That is why "high biodiversity REDD+ approach" is advocated by researchers (Swan & McNally, 2011). Although the term has no common agreement, high-biodiversity REDD+ is designated as an "approach that, through a range of policies and positive incentives at international and national levels, leads to mitigation actions with positive outcomes for both emissions reductions and biodiversity"(Swan & McNally, 2011).

1.2. Mapping of ecosystem based multiple benefits of REDD+

Forests, especially those located in the tropics, have gained wide recognition and are regarded as important providers of ecosystem services, like biodiversity, carbon sequestration, and the regulation of water and nutrient cycles, most of which contribute to and sustain human life at all levels (Boerner et al., 2007; Metzger et al., 2006). Despite the fact that maintenance of ecosystem services is essential for the future of the planet, only the role of forests in sequestering carbon (to combat global warming) is the focus of the present international arguments, and these ecosystem services are said to be compromised (Hall, 2012).

REDD+ in its attempt to reduce the greenhouse gas emission is expected to bring much more than emissions reductions. A properly designed mechanism is expected to contribute to multiple benefits which include "poverty alleviation, indigenous rights, improved community livelihoods, technology transfer, sustainable use of forest resources and biodiversity conservation" (Murphy, 2011). In return, multiple benefits will contribute to sustainability of REDD+ programs because local people will value the forest resources and protect/conserve them.

REDD+ measures also need to be planned in such a way that ensure biodiversity (Thompson et al., 2009), which requires spatial planning at the landscape, regional, or national level (SCBD, 2011). The need to have such spatial biodiversity data is to inform "REDD-plus design and planning to improve ecological connectivity in protected areas networks, and to optimize biodiversity benefits" (SCBD, 2011). Identifying, analysing (spatially) and mapping those and other multiple benefits, carbon stock densities and other parameters can provide key information intended to support planning and decision-making on REDD+ at national and subnational levels.

Researchers also pointed out that despite the increasing consideration given to conservation projects, exhaustive and systematic methodology that include ecosystem services in the planning has not been developed (Chan et al., 2006). Although there might be methodological difficulties involved in attempting to quantify biodiversity benefits and ecosystem services, it is thought that this should also be incorporated into mitigation and adaptation strategies (Hall, 2012).

As the UN-REDD programme states, it is important that countries who wish to gain multiple benefits through REDD implementation are assisted through the development of techniques and guidance on quantifying and mapping multiple benefits that will facilitate informed decision making; which will also enable them to better understand how actions to reduce emissions can influence biodiversity and ecosystem services, both positively and negatively.

This need has encouraged organizations to develop carbon and biodiversity mapping tools, which inform decision-makers about synergies between carbon, biodiversity and ecosystem services. Studies have also been undertaken in ecosystem service conservation and mapping at all levels.

At global level, Luck et al (2009) so as to promote development strategies that integrate conservation and ecosystem service protection, developed prioritization scheme for protecting ecosystem services in the world's watersheds and compared their results with global conservation schemes. They identified watersheds in Southeast Asia and East Africa as the most crucial priorities for service protection and biodiversity conservation.

At country level, Anderson et al, (2009) presented national-scale estimates of the spatial covariance in areas important for ecosystem services and biodiversity using Britain as a case study. Their study shows that one can arrive at "diametrically opposing conclusions about relationships between ecosystem services and biodiversity by studying the same question within different areas" (Anderson et al., 2009).

At regional level, Raymond et al, (2009) used community values mapping method which is based on the concept of natural capital and ecosystem services and the landscape values methodology to link local perception of place to a broader measure of environmental values at the landscape level. Based on interviews and mapping task conducted with 56 natural resource management decision-makers and community representatives, they quantified and mapped values and threats to natural capital assets and ecosystem services in the South Australian Murray–Darling Basin region. While they used GIS (Geographic Information Systems) based techniques to map the spatial distribution of natural capital and ecosystem service values and threats over the region, they also analyse the proportional differences at the sub-regional scale.

Chan et al, (2006) have characterized and mapped terrestrial biodiversity and six ecosystem services and develop networks of conservation areas for each service. They assembled these networks using an optimization algorithm called MARXAN which is said to be a widely used conservation planning software in the world that is designed for solving complex conservation planning problems in landscapes and seascapes (Watts et al., 2009). Several studies are also being undertaken globally to conserve key ecosystem services by mapping their spatial distributions (Eigenbrod et al., 2010). Their studies examine the distribution and resemblance of ecosystem services, with the goal of identifying areas that will provide multiple ecosystem services.

1.3. Problem statement

Identifying and mapping of ecosystem services can be used by decision makers as a powerful tool for the support of forest management and sustainability assessments (Swatantran et al., 2011) as well as REDD+ planning and decision making. Mapping of ecosystem services are also considered as one of the main requirements for the implementation of the ecosystem services concept into environmental institutions and local level decision making (Daily and Matson, 2008) (Daily & Matson, 2008). Nevertheless, it is a well-known fact that there is lack of such information relevant to local level decision making (Turner and Daily, 2008). In light of the significance that ecosystem service research is likely to play in linking conservation activities and human well-being, systematic approaches to identifying and mapping of ecosystem services are essential (Fisher et al., 2011).

Current global concern regarding increase of GHG (greenhouse gasses) emissions and the loss of biodiversity on the planet (Franklin, 2009) has made it clear that a scientific and policy-oriented understanding of how these issues are interrelated will be essential for developing effective solutions (Fisher et al., 2011). The UNFCCC and CBD (Convention on Biological Diversity) aim at addressing these challenges of increase in GHG and lose of biodiversity. The existence of such potential synergies between these two conventions offer opportunities for implementing practices that aim at achieving the objectives of these two conventions simultaneously (Jacquemont & Caparrós, 2002). Similarly, based on several studies Krishnaswamy et al, (2009) states that the "continuing biodiversity and ecosystem services loss urgently requires techniques to rapidly assess and monitor changes in biodiversity and ecosystem services" (Krishnaswamy et al., 2009) . Hence, studies on the relationship between ecosystem services, carbon stock and biodiversity are of great importance.

Studies show that converting degraded or agricultural land into forests with indigenous species might increase biodiversity; however, under afforestation and reforestation projects, biodiversity will likely decrease if these activities establish plantations of rapidly growing alien species (Jacquemont & Caparrós, 2002). In such cases "creating economic incentives for carbon sequestration may have negative impacts on biodiversity", and so, it is of great importance to assess the relationship between carbon and tree species diversity especially in tropical forests (Jacquemont & Caparrós, 2002).

Despite the fact that the relationship between carbon stock and tree species diversity is of immense importance for conservation management decision making, only few studies have been conducted to see the spatial relationship between tree species diversity and above ground carbon stock where both positive and negatives results are obtained. In their study, Wang et al, (2011) found a positive relationship in spruce-dominated forests in New Brunswick, Canada. Tree species, size, and height diversity indices as well as a combination of these diversity indices were used to correlate aboveground carbon stocks (Wang et al., 2011). Nakakaawa et al (2010) also found strong positive relationship in agro-ecosystems in south western Uganda (Nakakaawa et al., 2010). On the other hand, some also found weak relationship (Asase, 2011; Karna, 2012; Sharma et al., 2010).

Concerning non-timber forest products (NTFP), although there are few studies related to NTFP extraction and accessibility factors (Bista & Webb, 2006; Menton, 2003; Peres & Lake, 2003; Schaafsma et al., 2012; Widayati et al., 2010), no study has been conducted on NTFP uniqueness, which are needed for identification of hotspots.

As there is a need to identify hotspots- areas with high priorities for protection (Buchanan et al., 2011) and as the spatial analysis of the relationship between ecosystem carbon stock, biodiversity and other ecosystem services would support REDD-plus decision making, in this study it is aimed to contribute to ecosystem research by investigating where REDD-plus, in addition to maintaining carbon stocks, can secure biodiversity (tree species diversity); and where it can secure ecosystem services of provisioning of NTFP. Moreover, it is also aimed to identify hotspot areas (areas with high carbon, high biodiversity, and high NTFP provisioning) and to investigate their spatial relationships. These hotspots are areas with high value for carbon, but also important for other benefits and thus they are areas of high concern and interest for conservation planning.

1.4. Research objectives

General objectives

The general objective of the study is to identify, map and characterize the spatial relationship between ecosystem carbon stock, tree species diversity and NTFPs using GIS and spatial statistical methods in Kayerkhola watershed, Chitwan, Nepal.

Specific objectives

1. To investigate where REDD+ can secure biodiversity (tree species diversity) in addition to maintaining carbon stocks.
2. To investigate where REDD+ can secure ecosystem service of provisioning of NTFP in addition to maintaining carbon stocks.
3. To develop a method of identifying ‘unique’ places for non-timber forest products.
4. To identify hotspot areas (areas with high carbon, high biodiversity, and high NTFP provisioning)

1.5. Research questions

1. Where do areas of high carbon density coincide with areas of importance for biodiversity/tree species diversity?
2. Where do areas with high NTFPs coincide with areas of importance for tree species diversity?
3. Where do areas of high NTFP rich places coincide with areas of high NTFP unique places?
4. Where do areas of high carbon density coincide with areas of importance for provisioning of NTFPs?

a) What is the approach to be used to map unique areas for NTFPs?
b) Does accessibility affect NTFP extraction in the study area?

5. Is there any significant relation between NTFP richness and NTFP uniqueness in the study area?

6. Is there any significant relation between tree species diversity and NTFPs in the study area?

7. Is there any significant relation between carbon stock and tree species diversity in the study area?

8. Is there any significant relation between carbon stock and NTFPs in the study area?

9. Where are the hotspot areas (areas with high carbon, high biodiversity, and high NTFPs) in the study area?

1.6. Research hypotheses

1. Ha: There is no significant relationship between NTFP richness and NTFP uniqueness in the study area

2. Ha: There is no significant relationship between carbon stock and tree species diversity in the study area

3. Ha: There is no significant relationship between NTFP richness and NTFP uniqueness in the study area

4. Ha: There is no significant relationship between tree species diversity and NTFPs in the study area

2. CONCEPTS AND DEFINITIONS

2.1. Community forests

According to the 2049 (1993) Forest Act of Nepal, community forests are national forests handed over to users' group for its development, conservation and utilization. Nepal is said to be the world's first country to enact such a legislation which allows local communities to take full control of forests (Ojha et al., 2009). For each community forest there are registered users' groups for the management and utilization of the community forests.

2.2. Ecosystem services

While an ecosystem is "a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit" (Mace et al., 2012), ecosystem services are services that we get from the ecosystem. They are goods and services that we directly or indirectly get from ecosystem functions which include flows of materials, energy and information from natural capital stock (Costanza et al., 1997). Ecosystem services are mainly categorized into four groups: provisioning, regulating, cultural and supporting. Figure 1 illustrates these services well.

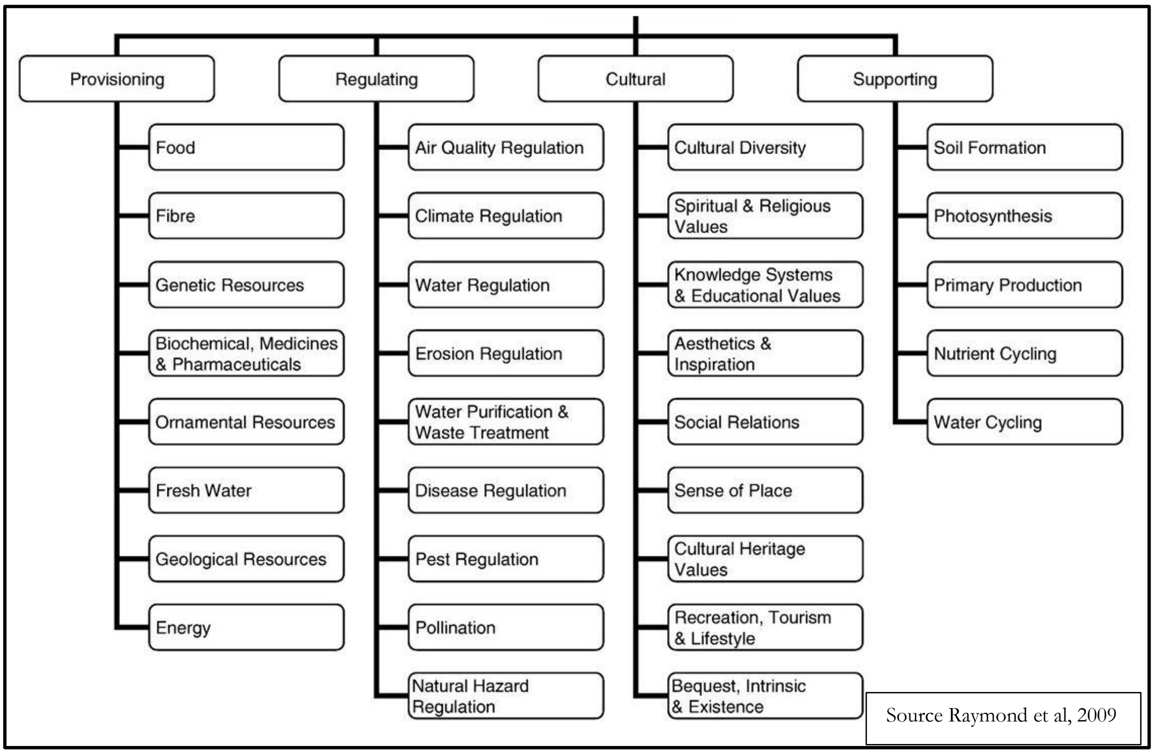


Figure 1: Types and categories of ecosystem services

These ecosystem services "support life by regulating essential processes, such as purification of air and water, pollination of crops, nutrient cycling, decomposition of wastes, and generation and renewal of soils, as well as by moderating environmental conditions by stabilising climate, reducing the risk of extreme weather events, mitigating droughts and floods, and protecting soils from erosion" (EFTEC, 2005). The life of many people in third world countries is also dependent on ecosystem services since their economies heavily depend on natural resources (EFTEC, 2005).

2.3. Biodiversity / tree species diversity

Although the word biodiversity refers to the "natural variety and variability among living organisms, the ecological complexes in which they naturally occur, and the ways in which they interact with each other and with the physical environment" (Redford & Richter, 1999), in this study it refers to only tree species diversity. The variety and abundance of tree species is considered in this study. In this study, tree species diversity refers to the index of relation between number of species and number of individuals. These two, i.e., species richness and abundance are most commonly used biodiversity indicators (Barbier et al., 2009).

- **Species richness**

Species richness is one component and an important biodiversity indicator that may or may not be correlated with patterns of species abundance (Bock et al., 2007; Franklin, 2009). Disregarding the abundance, it only takes into account the count of the species.

- **Species abundance**

Biodiversity is determined not only by the species richness, but also by the relative abundance of individuals in that community. Species abundance refers to the number of individuals per species, while relative abundance refers to the evenness of distribution of individuals among species in a community (Encyclopedia Britanica, 2013).

2.4. NTFP

Mallet (1999) defines NTFPs as all products, with the exception of timber, that can be harvested from a forest ecosystem. These include animal and plant products excluding timber (Neumann & Hirsch, 2000a). In Nepal NTFPs are used both for subsistence and trade.

- **NTFP richness**

In this study the NTFP richness refers to number of NTFPs in the identified places in each CF (Community Forest). NTFP richness was determined as the total number of NTFPs in places in each community forest.

2.5. Shannon diversity index (H)

Shannon Index, which sometimes labelled by some as Shannon Wiener's Index (or Shannon Weiner Index) and still by some other as Shannon Weaver Index, is the most commonly used species diversity index. It combines both components of the concept discussed in section 2.3: species number and their relative abundance (Pla, 2004). Shannon index is calculated with the relative abundance recorded in a plot assuming that all the species are included in the sample. The index assumes that heterogeneity depends on both the number of species in a community and their proportional abundances within this community (Pla, 2004). The general formula of the index used in this study is discussed in section 3.5.

2.6. Hotspots

Only limited resources are available for the world to address its growing environmental problems; this then requires conservationists to identify priority areas for action. The term hotspot is generally applied to "areas with high scores on any scale" (P. Williams et al., 1996) for such actions. In this study, hotspots are areas with high value for carbon, biodiversity and NTFPs and thus they are areas of high concern and interest for conservation planning as well as for the interest of the local people. As identifying priority areas for conservation within forests is essential for effective management (Newman et al., 2011), several studies have been undertaken on it. For instance, Egoh et al (2011) identified spatial priority areas for ecosystem services, where they mapped five ecosystems services with priority areas for each of them and evaluated whether priority areas for biodiversity can be aligned with those of the ecosystem services where the result found was moderate to high overlap (Egoh et al., 2011).

Hotspot areas in this study are selected based on criteria set on the basis of richness or degree of concentration (ARAÚJO, 2002) of the variables (carbon stock, biodiversity, and NTFPs).

2.7. Research theoretical framework

This research study started with reviewing literatures on main topics of the study which are related with climate change, ecosystem services, carbon stock and biodiversity. Then, fieldwork was conducted in Nepal after formulating research objectives, questions and required data. After processing and analysing the collected data, resulted were obtained which are followed by discussion, conclusion and recommendation as seen in figure 2.

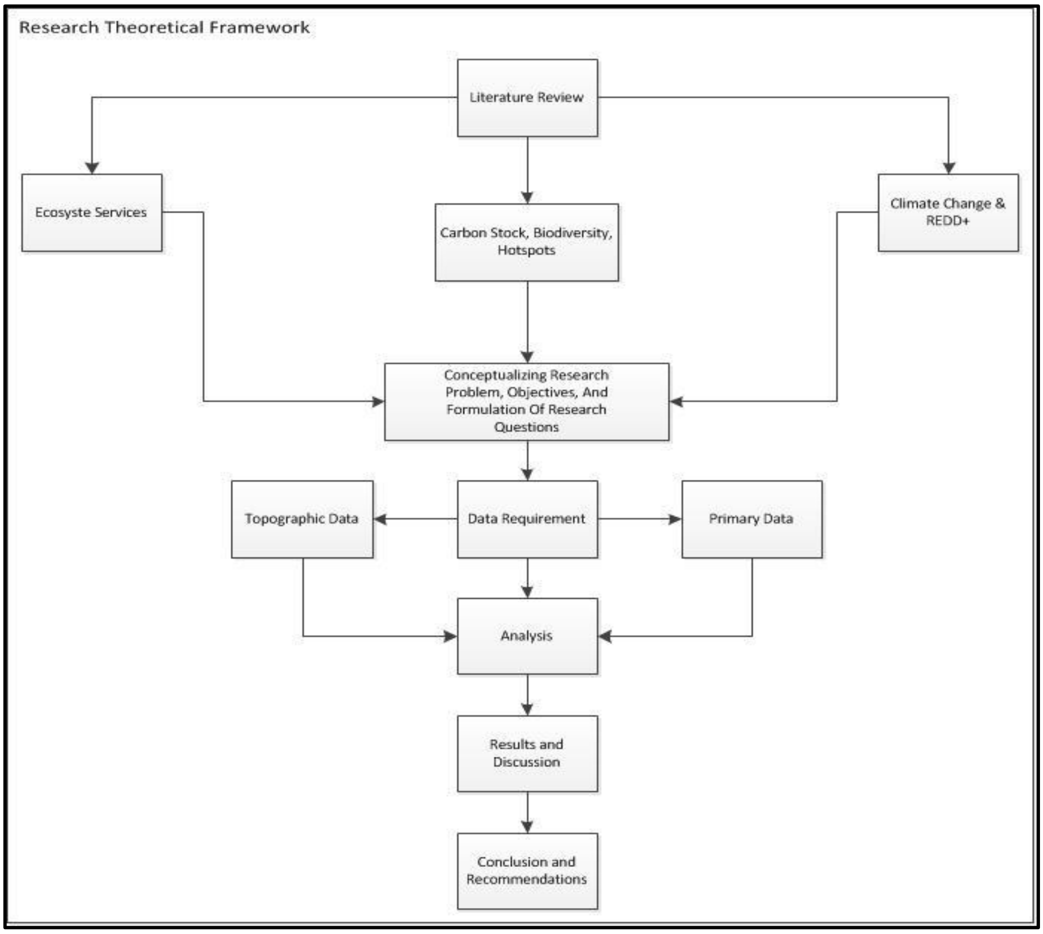


Figure 2: Research theoretical framework

3. MATERIALS AND METHODS

3.1. Study Area

3.1.1. Selection of the study area

There were some criteria for the selection of this study area: presence of forest, accessibility, presence of REDD+ project and availability of data. Kayerkhola watershed fulfilled all these criteria. Kayerkhola was one of the three watersheds where a REDD+ project is being piloted in Nepal. The project, which is being implemented by International Centre for Integrated Mountain Development (ICIMOD), emphasises on using community-based forest management for carbon sequestration. Most data required for the study was also available from ICIMOD which complements the reasons for the selection of the study area. Moreover, the selected area was accessible from nearby towns which encourages fieldwork in the forest.

3.1.2. Overview of Chitwan district

The study area, located in Chitwan district, Nepal, encompasses about 2,218m km2. Nepal is a land locked country in South Asia bordered by India and Tibetan region of China. Chitwan, being one of the seventy-five districts in the country, is specifically situated between 27040'07" to 27046'37" northern latitude and 84033'25" to 84041'48"eastern longitude. It is located about 148km southwest of the capital city, Kathmandu. The district has a total population of 566,661 (2011 National Housing & Population Census) and population density of 213 persons/km2.

3.1.3. Climate

Chitwan has a subtropical type of climate with an average maximum and minimum temperature of 30.3 and 16.6 degree Celsius respectively, and an average rainfall of 1510 mm/year (Kandel, 2004). The area has also four seasons (autumn, monsoon, summer and winter) with an average daily temperature of 14.5 degree Celsius.

3.1.4. Vegetation

Chitwan District, which is well known for its high quality timber and medicinal plant, has three types of vegetation: tropical evergreen forest, tropical deciduous forest and mixed forest (Shrestha et al., 2005). One dominant tree species is *Shorea robusta*, locally known as Sal.

3.1.5. Overview of Kayerkhola watershed

Kayerkhola watershed is situated in two of the forty VDCs (Village Development Committee) in the district, namely, Shaktikhor and Siddi. There are about 15 CFs in Kayerkhola watershed, but the study area includes three CFs (see Figure 3) namely, Devidhunga, Janapragati B, and Nibuwatar. Table 1 summarizes the location and area (in hectare) of these specific CF.

S.N	Name of CF	Location (VDC)	Area (ha)
1	Devidhunga	Shaktikhor - 8	253.86
2	Janapragati B	Shaktikhor - 5	78.57
3	Nibuwatar	Siddi - 2 & 3	871.07

Table 1: Location & area of the selected community forests

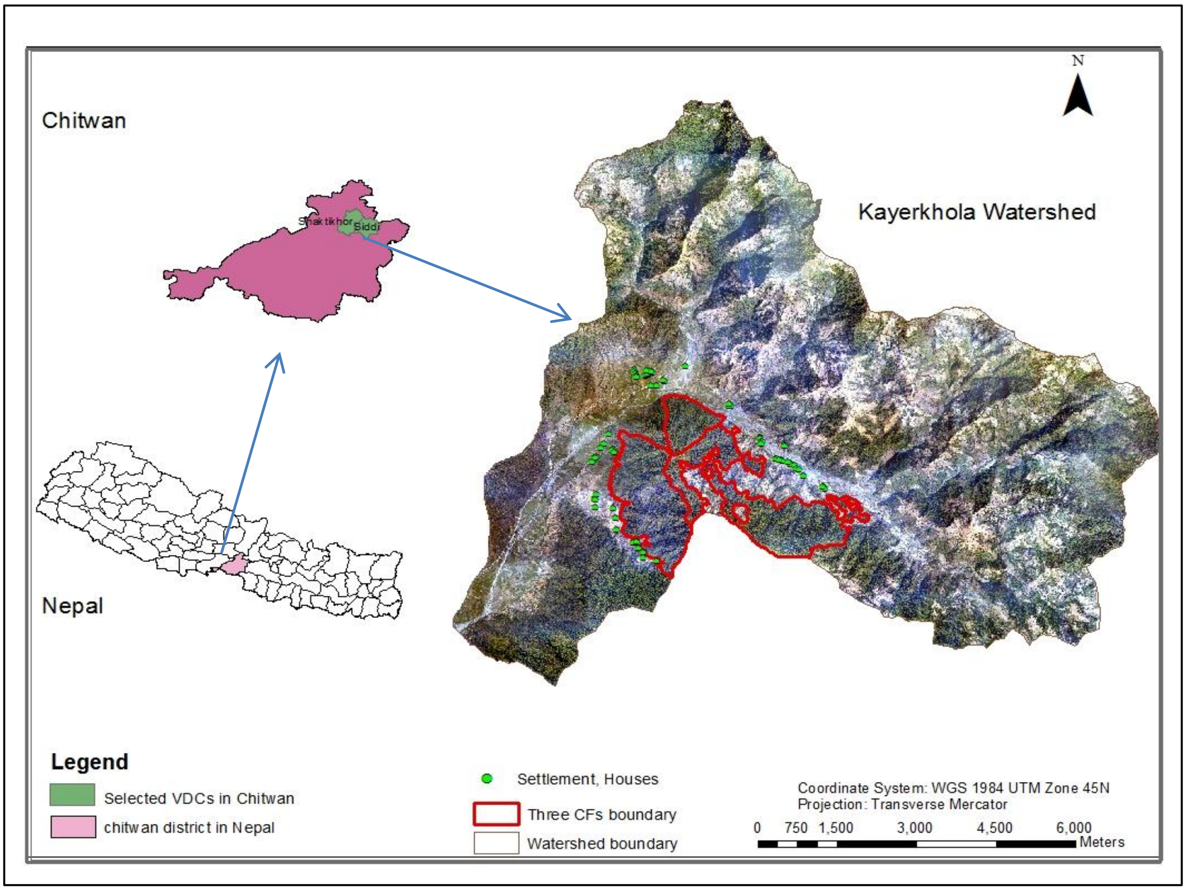


Figure 3: Location map of the study area

3.2. Materials

This study is based on primary and secondary data. The secondary data (106 tree species plot data) were collected by MSc students (2011 & 2012) of ITC (Geo-Information Science and Earth Observation Faculty of the University of Twente, Netherlands) which was available from NRM department, ITC, Enschede.

3.2.1. Topographic data

Topographic data with a scale of 1:50000 which include: land cover, road network, and contour data used for this study were obtained from the National Land Use Project, Ministry of Land Reform and Management, Government of Nepal.

These data has a Horizontal Datum with:

Spheroid:	Everest 1830
Projection:	Modified Universal Transverse Mercator
Origin:	Longitude 84^0 East, Latitude 0^0 North
False Coordinates of Origin:	500000m. Easting
Scale factor at Central Meridian:	0.9999

Moreover, shapefile (watershed, district and country boundary) and World View-2 satellite image obtained on 25th October 2010 and other topographic data such as topographic maps (2784-03C, 2784-03D, 2784-07A and 2784-07B) were also obtained from ITC and ICIMOD.

3.2.2. Field instruments, software and tools

The two main field equipment used during field work were HP (Hewlett Packard) EliteBook 8560w laptop with Google Earth to collect data on NTFP places; and iPAQ 2470 with GPS (Geographic Position System) to collect GPS coordinates of some places and all interviewee houses. Software used in this study and their specific uses are listed in Table 2.

No.	Software	Purpose
1	ERDAS Imagine 2011	Image processing
2	ArcGIS 10.1	GIS analysis
3	SPSS 21	Statistical Analysis
3	Microsoft Excel	Statistical analysis
4	Endnote X5	Citation and reference
5	Microsoft Visio	Diagrammatic representation
6	Microsoft PowerPoint	Research presentation
7	Microsoft Word	Thesis writing
8	Adobe Acrobat	

Table 2: List of software used

3.3. Methods

3.3.1. Pre-fieldwork

Before starting field work, World view-2 pan sharpened images and shapefiles of the study area were collected and used to identify the study area; and arc map layers were converted to Keyhole Mark-up Language (KML) to display shapefiles on Google Earth. Layer to KML of ArcGIS version 10.1 conversion tools was used to convert the ArcGIS layer (i.e., shapefiles) to KML. This tool converts a feature or raster layer into a KML file where the file is compressed (and has a .kmz extension) which can be read by ArcGIS Explorer, ArcGlobe, and Google Earth. Six A3 size maps of the study area were also printed which depict settlements surrounding the three CFs. All shapefiles were then uploaded to the iPAQ for navigation. Before uploading the files, the iPAQ was cleaned and installed with its original ArcPad software. Finally, a questionnaire was prepared and printed to collect data related to NTFPs.

3.3.2. Sampling design

Based on the available time and accessibility of the area three CFs were selected among the 15 CFs found in Kayerkhola watershed. Then, through non proportional quota sampling 20 people from each CFs (totally 60 questionnaires were planned) were allocated to undertake a structured interview concerning the NTFPs collected in these CFs. No population list is used in assigning the minimum number of sample size in non-proportional quota sampling (Elder, 2009; Smith, 2010).

Before selecting the type of sampling technique and determining the sampling size for this study sampling sizes of other studies were examined. While there are other factors (e.g. the scope of the study, the nature of the topic) that affect sample size in qualitative studies, researchers that have used interviews as their source of data collection, generally use saturation as a guiding principle during their data collection (Mason, 2010). Saturation is reached when no further new information is added after taking interview with some number of interviewees. For instance, this idea of saturation was also observed during the field interview where all types of NTFPs were clearly visible after undertaking the interview for about twenty interviewees of the total sixty five interviews.

Three steps were taken in this study. First, the study area was stratified into three based on the respective community forests in the area. Second, a total of 20 interviewees were assigned for each stratum (CF), and finally, an interview was undertaken in each CF until the quota for each stratum is met. People everywhere in the rural village were not invited to the interview, but, particular attention was gives to people living in the houses surrounding each CF. This was done by going to the houses and taking GPS locations and pictures when interviewing.

3.3.3. Fieldwork

In the field, data were collected with the help of a local translator during the structured interview using a printed questionnaire. In order to identify the places where the NTFPs were collected, mapping on Google Earth was carried out during the interview. Figure 4 shows how the data on NTFP places were collected.

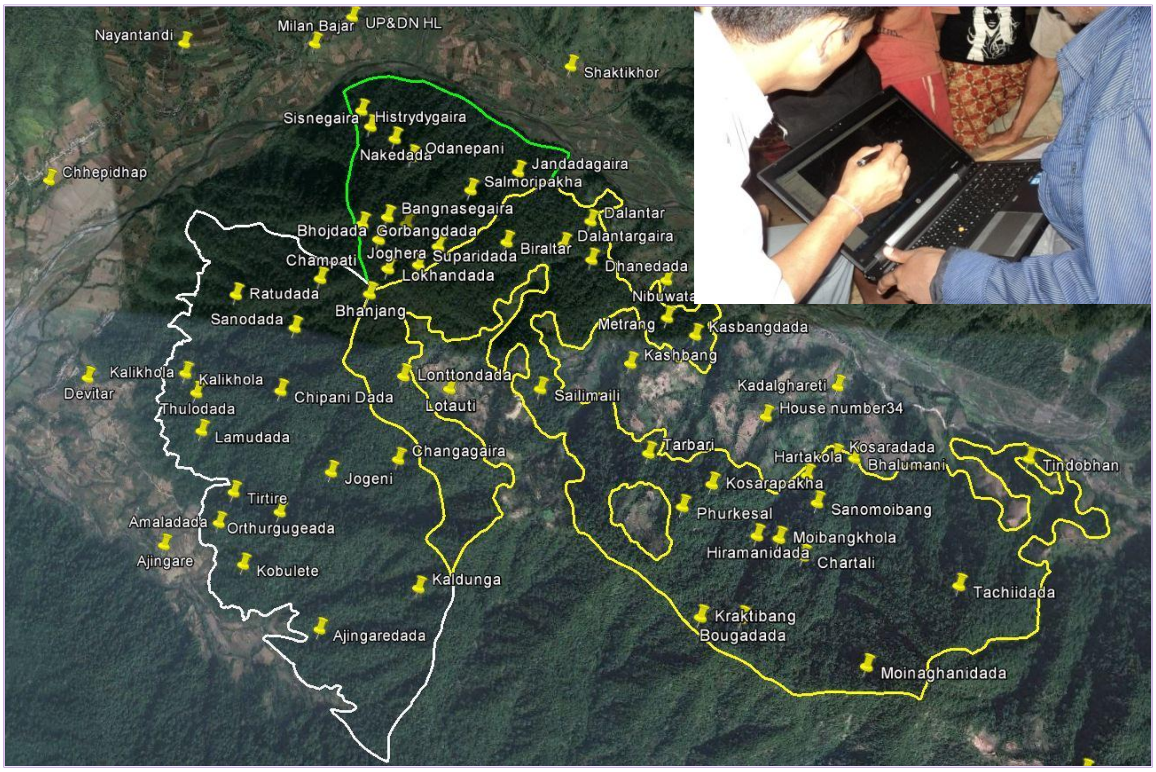


Figure 4: Community mapping on Google Earth

Each point on the map (figure 4) actually represents an area in each community forest. Although for outsiders each CF is known by one name (CF name), the local community identifies several places (identified by name) in each CF.

3.4. Post fieldwork

3.4.1. Land cover map

The land cover map was developed from the topographic data (topographical base map) with a scale of 1:25000 (accuracy factor 1:5000) which was obtained from Ministry of Land Reform and Management National Land Use Project, Nepal (MLRMNLP). The data contained GIS polygons together with a separate feature codes (in excel format). A field, land cover types, was then added based on those feature codes. The boundary of the land cover map which actually becomes the boundary for the study area was made to include the three CFs, the settlements/houses surrounding the forests and road network in the area.

3.5. Shannon's diversity index

There are several types of diversity measurements. Magurran (1988) categorises diversity measurements into three groups: species richness indices, species abundance models and indices that are based on the proportional abundances of species. The first one, species richness indices, is indices which essentially measure the number of species in a defined sampling unit. Whereas the second one species abundance models describe the distribution of species abundances, the third one that are based on the proportional abundances of species takes into account species richness and evenness as an alternative to the species abundance models. Among those several types of species diversity measurements, an index which falls on the third category, i.e., Shannon index was used in this study.

Although there were several, specifically about 27 (Yue et al., 2005) individual diversity measures, Shannon index is the most common one (Chao & Shen, 2003; Diker et al., 2004; Pla, 2004; Spatharis et al., 2011; Spellerberg & Fedor, 2003; Yue et al., 2005) and it was used to determine the diversity of tree species in the study area.

Shannon index uses species number and their relative abundance in determining the diversity. In this study, first, Shannon diversity index per plot was calculated, and then the average for each CF was calculated. The data used were 106 plot data collected by ITC (2011 and 2012 MSc. students). Shannon index is calculated by taking into account the relative abundance of the total number of individuals for each species where the proportion or relative abundance of each species is multiplied by its natural logarithm; then the result is again to be multiplied by the proportion or relative abundance. Finally, the sum for all species is taken. But, since this is a negative number, the negative of this sum is taken. Tree diversity index in the study area was calculated using this formula which is described in equation 1.

$$H = -\sum_{i=1}^{n} pi \ln pi$$ .... Equation 1: Shannon diversity index

Where,
H = Shannon diversity index
Pi = Relative abundance of each group of species
ln = natural logarithm
Σ = Sum from species 1 to species n.

3.6. NTFP uniqueness and uniqueness index

In this study the word uniqueness refers to the number of NTFPs in a place and the degree of occurrence of these NTFPs in other places, or, in other words, their rarity.

For example, a place has a high uniqueness when one or more NTFPs are found there that are not found anywhere else; the more 'rare' NTFPs with no occurrence elsewhere, the higher the uniqueness of the place. The place is 'unique' for this specific NTFP. If NTFPs occur in more than one place, so if they are less rare, the uniqueness of these places reduces accordingly.

Every place can be assigned with a value or degree of uniqueness. When identifying hotspot areas related to NTFPs, such place i.e., places with high uniqueness are important and demand management priority, similarly to NTFP rich areas.

No question that an NTFP rich place demands high priority; in addition, NTFP unique places, i.e., places which are found with rare products that are not found in other places should also be given management priorities. Hence, it is of high importance to identify such places for hotspot analysis. The idea of uniqueness in this sense is adopted from other studies related to wildlife site quality assessment (Booth et al., 2011; Paul Williams, 2000).

The data related to the NTFP in the study area which were collected during the fieldwork were all recorded and analysed on Microsoft excel 2010 sheet. Places which are rich in NTFPs, popularity of places for NTFPs, and most collected NTFPs were identified and displayed using several types of charts (such us column charts, bar charts, and pie charts). Then both NTFP places and products were also analysed on a table (excel sheet) to see if a patter exists. It was possible to see some places with relatively rare products. Then the next task was to mathematically express the rarity of NTFPs in the uniqueness of the place to map the situation. Subsequently, a uniqueness index was developed. Since all places and products are known, the accuracy of the index was also easily attested. This index was developed by adopting the idea of wildlife site quality assessment index where a combination of sites (species poor sites but with rare species) were used (Paul Williams, 2000). In his study Paul Williams states that in animal wildlife animal "species lists for sites are often compared for rarities using an index of the average or mean national range size of the species (species quality score)", this idea was adapted to NTFP species/product lists for NTFP sites (places identified in the study area).

Finally, NTFP uniqueness map was developed using this uniqueness index (which is somewhat similar to rarity index in wildlife studies) which serves as a magnitude value for mapping using kriging geostatistical interpolation. Among the several NTFPs identified in several places in the study area, there were some products which were found only in one or few places. Equation 2 shows the formula for this uniqueness index where the uniqueness index (UI) was calculated as the ratio of the sum of the existence of one or more product in one place to the sum of the existence of one or more places for each product multiplied by the number of products in each place.

In deriving the formula the following two steps were taken:

1) First, dividing the number of products at a location by the sum of the locations where these products occurs; an average product rarity fraction for that particular location is then calculated. If the number of products increases, the fraction value gets higher and if the number of places decreases, the value of the fraction increases.

2) Second, in order to come up with the uniqueness index for the location as a whole the fraction is multiplied by the number of products occurring in that location.

Which is expresses as,

$$UI = \frac{\text{the sum of the existence of one or more products in one place}}{\text{the sum of the existence of one or more places for each product}} * n'$$

Where n' is the sum of products in one place;

Mathematically this is then expressed as:

$$UI = \left(\frac{\sum_{i=1}^{n} A}{\sum_{i=1}^{n} N} \right) * n'$$ ....Equation 2: Formula for UI

Where,

UI refers to uniqueness index
A1 to An refers to NTFPs in one place
N1 to Nn refers to other places for each NTFP or its rarity
n' refers to sum of products in one place

In order to illustrate this formula, let' take a sample (Table 3). In this sample area, we have 8 specific places and 13 specific products as displayed in Table 3. The last column under places, "total" refers to the sum of the number of places for one product; and the second last row, "total", refers to the sum of the number of products in one place. The last row, "UI" refers to the uniqueness index calculated for each places using this UI formula. According to this UI formula, UI for each place in this sample is calculated as:

UI for place 1 = (4/ (5+3+2+2)) * 4= 1.33

UI for place 2 = (3/ (5+3+2+)) * 3 = 0.9

UI for place 3 = (4/ (1+1+1+1)) * 4 = 4
UI for place 4 = (1/5) * 1= 0.2

UI for place 5 = (2/ (5+3)) * 2 = 0.5

UI for place 6 = (1/5) * 1 = 0.2

UI for place 7 = (5/ (1+1+1+2+1)) * 5 = 4.17

UI for place 8 = (1/1) * 1 = 1

In this sample, place 8 has got an index of 1. This shows that there is one product which is only found in place 8, i.e., a product which is not found anywhere else. This product is found only in one place-place 8.

Then, we can say that place 8 is perfectly unique for one NTFP but with only one product- product 12, so its UI value is only 1.

On the other hand, place 7 has the highest UI (4.7) in this sample. Place 7 contains 4 products (product 2, 5, 7 and 10) that are found only in it, and one product (product 9) which is also found in one other place (place 1). Hence, relatively it has higher UI, about four times as much as place 1. Please note that place 1 has one perfectly unique product while place 7 has 4 perfectly unique products.

Based on their degree of uniqueness, these places will have the following priority sequences from highest to lowest: place 7, place 3, place 1, place 8, place 2, place 5, and place 4 & place 6. Place 3 and place 8 are perfectly exclusive, but, place 3 is 4 times greater in uniqueness than place 8. Place 1 is not perfectly exclusive, but it has a higher degree of uniqueness, because the index takes into consideration the importance of the number of products in calculating their respective place uniqueness.

Products (NTFPs)	Places								
	place 1	place 2	place 3	place 4	place 5	place 6	place 7	place 8	Rarity
Product 1	x	x		x	x	x			5
Product 2							x		1
Product 3			x						1
Product 4			x						1
Product 5							x		1
Product 6	x	x			x				3
Product 7							x		1
Product 8	x	x							2
Product 9	x						x		2
Product 10							x		1
Product 11			x						1
Product 12								x	1
Product 13			x						1
Total	4	3	4	1	2	1	5	1	
UI	**1.33**	**0.9**	**4.00**	**0.20**	**0.50**	**0.20**	**4.17**	**1.00**	

Table 3: sample uniqueness index

3.7. Accessibility

Besides topography and infrastructure land cover types also have their own influence on accessibility (A.G. Toxopeus & Bakker, 1992; Verburg et al., 2004). Different places in the study area have different types of land cover. Its effect on travelling speed was taken into consideration and included in accessibility mapping.

Availability of roads is another factor which facilitates movement to forests. Roads increase the ease by which people tend to move to forests (Peres & Lake, 2003). Toxepeus (1994) also states that the easier to access, the sooner people tend to go to a target area. Hence, the existence of infrastructure (primary, secondary and other road types) in the study area has been included in the accessibility mapping for these reasons.

Slope has also its own influence on accessibility to the forest. The steeper the slope, the more it reduces the travelling speed to walk to the forest (A.G. Toxopeus & Bakker, 1992).

A map of accessibility to forest was developed based on travelling speed per land cover and road type with their respective slope correction factor. Then cost weighted distance was calculated from the surrounding settlements/actual houses whose GPS point was taken during the field data collection. Figure 5 shows the flowchart for developing the accessibility map and the detailed explanation is followed thereafter.

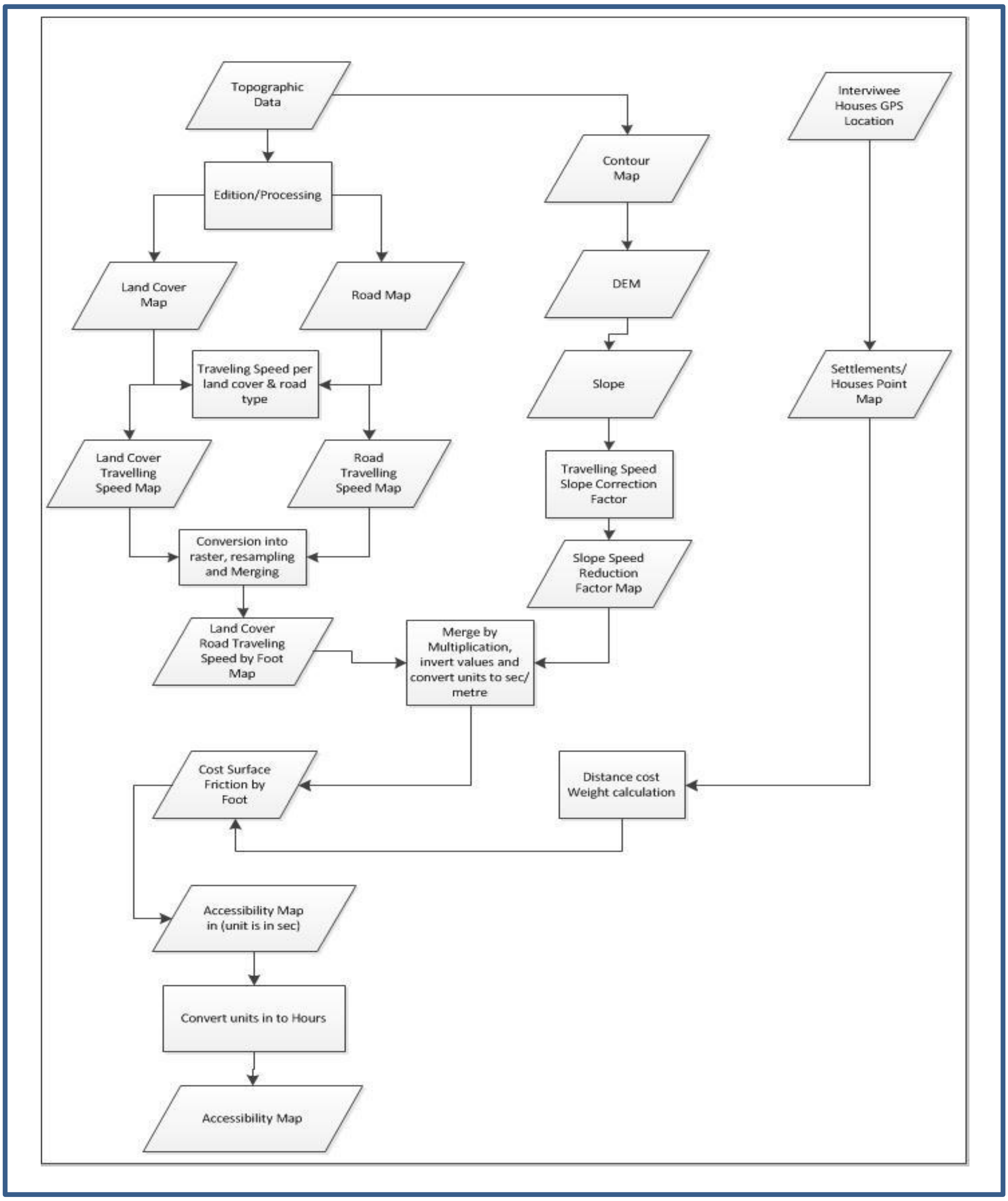


Figure 5: Flow diagram for mapping accessibility

- **Travelling speed per land cover type**

After the land cover map was produced (refer 3.4.1), the corresponding on foot traveling speed per land cover type based on Toxopeus (1996) (see Table 4) was applied so as to produce a preliminary map of travelling speed per land cover type. For ease of working with raster map algebra calculations, the land cover vector map was converted to raster and resampled to a 5m X 5m cell size/resolution since all maps have to be of the same cell size/resolution and the same coordinate system.

S.N.	Land Cover Type	Travelling Speed (km/hr)	Remark
1	Bare	3	
2	Bush	0.7	
3	Cultivation	2	
4	Forest	1	
5	Grass	2	
6	Sand	3	
7	Water/River	0	Lowest value 0.01 was taken

Table 4: Travelling speed per land cover type

- **Travelling speed per road type**

A road network map was then produced using the topographic data which was obtained from Ministry of Land Reform and Management National Land Use Project, Nepal (MLRMNLP). The data contained GIS polygons together with a separate feature codes (in excel format). A field, road types, was then added based on those feature codes. Then the extent of the map was clipped to fit to the boundary of the study area. Thereafter, travelling speed per road type based on other studies – Toxopeus (1996) (refer Table 5) was applied so as to produce a road travelling speed map. Again, for ease of working with raster map algebra calculations, the road vector map was converted to raster and resampled to a 5m X 5m cell size/resolution since all maps has to be of the same cell size/resolution and the same coordinate system.

S.N.	Road Type	Travelling Speed (km/hr)
1	District road	6
2	Trails/cart track	3
3	Tracks/main trail	3
4	Footpaths	2
5	Ford/crossing	3

Table 5: Travelling speed per road type

- **Land cover – roads travelling speed map**

The land cover travelling speed map and the roads travelling speed map were converted into raster of the same resolution and geographic coordinate system, and made to be mosaicked/merged together. This resulted in the land cover – roads travelling speed map.

- **Slope speed reduction factor**

A digital elevation mode (DEM) was produced from a contour lines which were obtained from Ministry of Land Reform and Management National Land Use Project, Nepal (MLRMNLP). Then, a slope steepness map (in percentage) was produced from the DEM, which was then reclassified into seven classes (see Table 6) based on Toxopeus (1996). The classification of the slope steepness was based on the expected influence on the travelling speed which is called travelling speed slope correction factor (A.G Toxopeus, 1992).

S.N.	Slope Steepness	Slope correction
1	0% - 5%	1.00
2	5% - 10%	0.96
3	10% - 20%	0.82
4	20% - 30%	0.65
5	30% - 45%	0.50
6	45% - 65%	0.41
7	65% and higher	0.29

Table 6: Slope steepness classes and correction factors

- **Land cover – road – slope map**

The slope steepness map including a slope speed reduction factor was multiplied by the land cover – roads travelling speed map and values were inverted in order to get the final estimated travelling speed per land cover and road type. The land cover-road-slope map leads to the friction surface (friction by foot) which takes into account the land cover, roads and slope.

- **Cost weighted distance**

The input raster cell (the cost surface friction by foot map) defines the resistance or cost to move through each cell; and the value at each cell location represents the cost per unit distance for moving through the cell. The costs may be based on several variables like slope, the type of road and the character of the area being traversed (zoning or land use, natural vegetation) (OCW, 2004).

Coordinate points of the actual houses were taken during the structured interview period and then point map of the houses was prepared showing the source points for the cost weighted distance function in ArcGIS version 10.1. This function calculates the least accumulative cost distance for each cell to the nearest source (the houses) over the cost surface (the cost surface friction by foot map). The cost distance tool in ArcGIS version 10.1 are more or less similar to Euclidean distance tool, but the difference is that instead of calculating the actual geographic distance from one location to another, the cost distance tools determine the shortest weighted distance, i.e., the accumulated travel cost from each input raster cell to the nearest source location of the houses. It takes into consideration obstacles to travels. The tool applies distance in cost units, not in geographic units.

After obtaining the friction surface (friction by foot), the cost surface friction by foot was obtained using raster calculator by inverting the values and then multiply by 3.6 (km/hr = 1000m/3600s) to get a unit of second/metre. Then, the accumulated cost of travel from the surrounding villages to the forest area was calculated.

- **Accessibility map**

After the cost weighted distance calculation, the distance map - accessibility (in seconds) was obtained, which was, then, in raster calculator made to be divided by 3600 to get accessibility in hours. Finally, when producing the map the units (in the legend) were changed to minutes for ease of understanding.

- **Travel time zone**

Finally, extraction of area coverage and accessibility travel time zone map was produced by reclassifying the raster map (accessibility in travel time map) into four time zones. Reclassification was necessary since it is not possible to add an attribute table to a pixel type of 32-bit floating point. Reclassification was done using the reclassify tool on the floating point raster map of the accessibility map.

3.8. Spatial interpolation method used for tree species diversity and NTFPs mapping

Tree species diversity and NTFP richness and uniqueness maps were produced using Kriging interpolation method. Kriging is an advanced geostatistical procedure based on regression that generates an estimated surface from a scattered set of measured point values (Bohling, 2005). This method of interpolation weights the surrounding measured values to derive a prediction for an unmeasured location. The general formula for Kriging is shown in equation 4.

Kriging now has become a generic name for geostatisticians as one of the minimum-error-variance estimation techniques (Yamamoto, 2000). It has been widely used as an alternative (to traditional survey method) to predict spatial distribution of species richness (Hernandez-Stefanoni et al., 2011). Among all types of kriging OK (ordinary kriging) is by far the most type of kriging in practice, although not the only one (Oliver & Webster, 2008).

Although kriging is the most commonly used interpolation method, there is no single general method for all situations, or no single method better than the others in all situations (Karydas et al., 2009; Sluiter, 2009). Hence, testing of several interpolation methods was done for better results in this study the result of which is depicted in Appendix 5.

There are several types of Kriging (simple, indicator, universal, ordinary, probability and disjunctive), but best result was obtained when using ordinary kriging (OK). Moreover, other geostatistical interpolation methods such as Spline, Inverse Distance Weight (IDW), Empirical Bayesian Kriging (EBK), Local Polynomial Interpolation (LPI) were also tested for better results (see Appendix 5: B-G). But, still ordinary kriging was better than the rest of the interpolation methods.

The test was done by comparing the cross validation report of all methods. Leave one out cross validation (LOOCV) statistics was also performed for two of the interpolation methods: EBK (Empirical Bayesian Kriging) and OK (Appendix 5: A). The reason for doing so was since EBK was found to be close to the result of OK method when the cross validation report was seen. Appendix 5 shows results of the comparison. Finally, tree species diversity, NTFP richness and uniqueness maps were produced using OK interpolation method. The kriging interpolation was done using the software ArcGIS version 10.1 where Equation 3 is used for the interpolation.

$$\hat{Z}(s_o) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$ .... Equation 3: Kriging general formula

Where,
$Z(s_i)$ = the measured value at the i^{th} location

λ_i = an unknown weight for the measured value at the i^{th} location
s_0 = the prediction location
N = the number of measured values

3.9. Statistical analysis

Correlation is a statistical procedure used to see the association between two variables where the value of correlation is numerically shown by a coefficient of correlation while the significance of the coefficient is expressed by p value (Udovicic et al., 2007). Correlation was used in this study to see the association of carbon stock with tree species diversity and NTFPs, tree species diversity with NTFPs, and NTFP richness with NTFP uniqueness in the study area. Correlation coefficient (r), and coefficient of determination (R^2) which measures the goodness of fit of the regression model by its ability to predict the response variable (Renaud & Victoria-Feser, 2010) were also calculated.

One way ANOVA was also used so as to test whether there was statistically significant relations two variables (from carbon stock, tree species diversity and NTFPs).

For instance, to see the correlation of carbon stock with tree diversity map, their corresponding raster values were extracted into dbf (dBase files) format which was then opened in Microsoft excel and SPSS 21 to calculate those statistics. First, the raster map of the tree species was converted to point map, and then the values to the corresponding points were added to the attribute table of the tree species diversity map by extracting the raster values of the carbon stock map to the point feature of the tree species diversity map in ArcGIS spatial analyst tool ("extract raster values to points"). This tool extracts the cell values of a raster based on a set of point features, and records the values in the attribute table of an output feature class.

Then, 200 samples (for tree species diversity and carbon stock) and 75% of NTFP richness and NTFP uniqueness since values were actual field values) of the observations were randomly selected to do the statistics. Correlation (Pearson's) and one way ANOVA tests were also done using SPSS version 21.

Additionally, to see the correlation of one map with the other map (carbon, tree species diversity, NTFP richness and NTFP uniqueness maps), spatial Spearman's correlation (SSC) based on related works by Skidmore et al (2011) were also calculated using band collection statistics tool of ArcGIS 10.1 (Skidmore et al., 2011). Since all maps were raster (carbon feature/vector map was converted to raster), ArcGIS 10.1 band collection statistics which calculates statistics for a set of raster bands was used. The tool calculates values of min, max, mean covariance, and correlation of raster maps.

3.9.1. Map accuracy validation

In order to assess the accuracy of the tree species diversity, NTFP richness and uniqueness maps which were made using geostatistical method- ordinary kriging interpolation, leave one out cross validation statistics as outlined in Skidmore – Knox et al (2012) was used (Knox et al., 2012). Leave one out cross validation method is used when there is no additional dataset for validation.

Cross validation statistics of mean of error (ME), mean of absolute error (MAE), root mean squared error (RMSE), percentage root mean squared error (%RMSE), and percentage mean of absolute error (% MAE) were calculated as outlined in equation 4 - 9. For tree species diversity map 106 observations, for NTFP richness map 47 and for NTFP uniqueness map 47 observations were used. For instance for tree species diversity which has 106 observations, the procedure is that each times one observation is removed from the data set, and the remaining sampling values (i.e. 105 observations) are used to predict the variable.

Then, this cross validation yields a list of predicted/estimated values paired to those obtained from the observed sampling units.

Then, the diagnostic statistics ME, MAE, RMSE, %RMSE and %MAE were calculated by relating the predicted values to the observed values and finally the average values were taken. While the mean of absolute error (MAE) gives the bias; root mean square gives an indication on the precision of the prediction (Utset et al., 2000). RMSE indicate precision and accuracy of the prediction. Several studies focus on these diagnostic statistics (ME, MAE, RMSE) (Oliver & Webster, 2008).

$$ME = \frac{1}{n}\sum_{i=1}^{n}(Kp - Ko)$$ .... Equation 4: Mean error of prediction

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|Kp - Ko|$$ .... Equation 5: Absolute error of prediction

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Kp - Ko)^2}$$ .... Equation 6: Root mean square error

$$\%RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Kp - Ko)^2} * \frac{100 * n}{\sum_{i=1}^{n} Ko}$$ .... Equation 7: Percentage root mean square error

$$\%MAE = \frac{1}{n}\sum_{i=1}^{n}\frac{|Kp - Ko|}{\sum_{i=1}^{n} Ko} * 100$$ .... Equation 8: Percentage mean absolute error

Where;

Kp is predicted value

Ko is measured or calculated values

n is number of observations/samples

ME is mean of prediction error

MAE is mean absolute error

RMSE root mean square error

%MAE is percentage of mean of absolute error

3.10. Hotspots analysis

Combine tools in ArcGIS version 10.1 was used to combine two maps so as to identify priority areas.

- **NTFP richness and NTFP unique places**

In order to identify hotspot areas or areas of importance for NTFPs, the two maps i.e., NTFP richness and NTFP uniqueness maps were first reclassified and then combined.

- **Biodiversity and NTFPs**

Hotspot areas or areas of importance for biodiversity and NTFPs were identified in two stages. First, areas of importance for NTFP richness and NTFP uniqueness were produced. Then this map was combined with the reclassified tree species diversity map. Hence areas of importance for biodiversity and NTFPs were identified by taking into consideration the area of importance for tree species diversity and NTFP richness and NTFP uniqueness.

- **Carbon stock and NTFPs**

Hotspot areas or areas of importance for carbon stock and NTFPs were identified in two stages. First, areas of importance for NTFP richness and NTFP uniqueness were produced. Then this map was combined with the reclassified carbon stock map. Hence areas of importance for carbon stock and NTFPs were identified by taking into consideration the area of importance for carbon stock and NTFP richness and NTFP uniqueness.

- **Final Hotspot areas**

Finally, the hotspot area which takes into consideration all maps (carbon stock, tree species diversity, NTFP richness & NTFP uniqueness maps) were identified by combining the two combined maps, i.e., combined map of NTFP richness & NTFP uniqueness, and combined map of tree species diversity and carbon stock. Finally, the set criteria were used to identify the most hotspot places in the study area.

4. RESULTS

4.1. Ecosystem boundaries - Land cover

Appendix 7 shows the land cover map which was developed from the topographic data (topographical base map) with a scale of 1:25000 (accuracy factor 1:5000). Six classes: bare, cultivation, forest, grass, sand and water/river were distinguished which show that most of the area is covered by forest (68.40%) and cultivation (26.65%). The area for each land cover type is shown in Table 7.

Land Cover Type	Area (KM^2)	Percentage
Bare	0.0047	0.03
Cultivation	4.4357	26.65
Forest	11.3822	68.40
Grass	0.0072	0.04
Sand	0.6632	3.99
Water/River	0.1483	0.89
Sum	16.6413	100.00

Table 7: Area per land cover type

4.2. Shannon's diversity index

Figure 6 shows the Shannon diversity index calculated for the three CFs from the 106 plot data. Devidhunga is found to be the most diverse CF with 1.28 diversity index and 4.04 species richness, while the other two CF has more or less similar diversity index and species richness.

Community Forest	Tree Diversity Index	Species Richness	No. Of Plots ($500m^2$)	No. of Species
Devidhunga	1.28	4.04	47	22
Janapragati_B	1.05	3.18	11	18
Nibuwatar	1.07	3.55	48	19

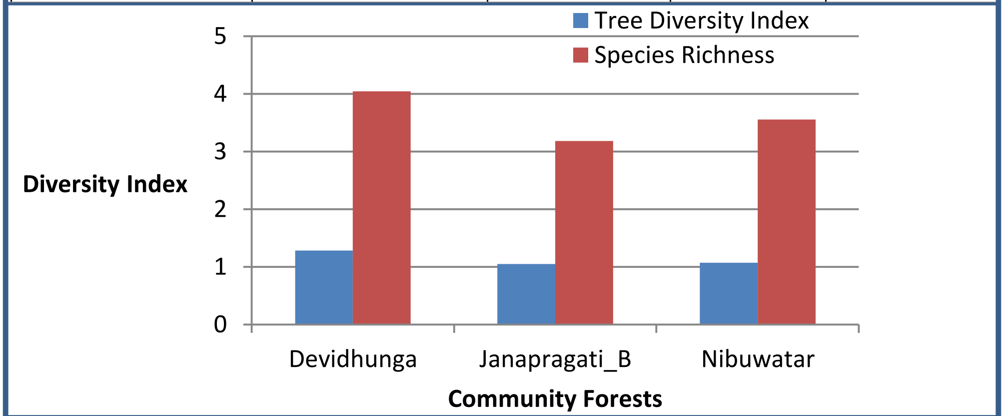


Figure 6: Tree species richness and diversity index

4.3. Tree Species diversity map

The tree species diversity map was developed using ordinary kriging spatial interpolation method with calculated Shannon tree diversity index as a magnitude value for the interpolation. Figure 7 shows the tree species diversity map for the study area. According to the map, the grey area shows higher tree species diversity values and the dark area shows areas with lower diversity values in the study area. According to the map, central and southern Devidhunga CF and eastern and southern part of Nibuwatar CF have high tree species diversity. On the other hand the central part of the study area is found to be low in diversity.

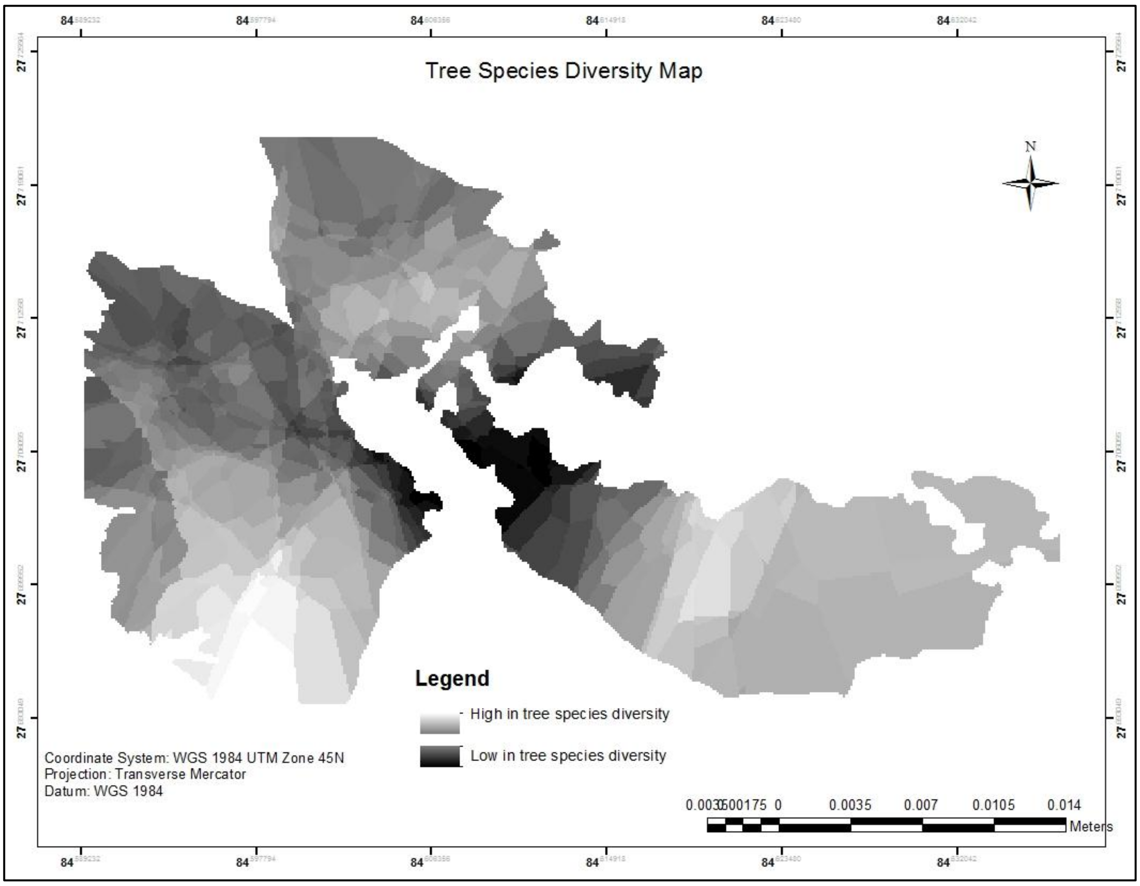


Figure 7: Tree species diversity map

4.4. Accuracy assessment

In order to assess the validity of the prediction the kriging interpolation, leave one out cross validation statistics was calculated and the result is shown in Table 8 (see section 3.9.1 for method). According to the summary statistics the mean prediction errors approach zero and no bias is shown. The other parameters also show lower prediction errors. For %RMSE and %MAE values see the discussion (section 5.4).

Cross validation statistics	Value
ME	-0.01
MAE	0.47
RMSE	0.47
%RMSE	47.48
%MAE	47.48

Table 8: LOOCV accuracy assessment of the tree species diversity map

4.5. NTFP - products

Appendix 2 shows the list of NTFPs (with local names and scientific names) identified in the study area. 41 products were identified where the majority (78.05 %) are found to be medicinal plants followed by edible fruits and food items (14.63%) as categorized in Figure 8.

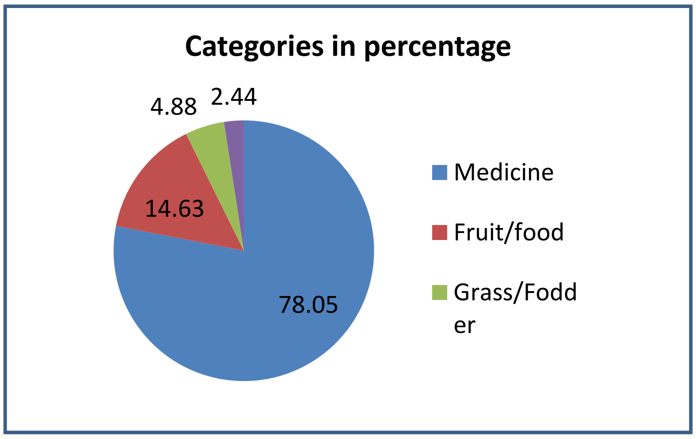


Figure 8: Categories of identified NTFPs

The result shows that while Amala (Phyllanthus emblica), Harra (Terminalia chebula), Barra (Terminalia belerica), Kurilo (Asparagus racemosu), Bel (Aegle marmelos) and Argeli (Edgeworthia gardneri) are most collected NTFPs in Devidhunga CF, Chau (Pleurotus sps.), Barra (Terminalia belerica), Harra (Terminalia chebula), Amala (Phyllanthus emblica), Bhorla (Bauhinia vahlii), and Ghitta (Dioscorea bulbifera) are the most collected one in Janapragati_B CF. In the third CF, Nibuwatar, the most collected one are: Barra (Terminalia belerica), Harra (Terminalia chebula), Amala (Phyllanthus emblica), Ginderi (Premna integrifolia), Khirro (Sapium insigne), Kurilo (Asparagus racemosu). Overall, Amala (Phyllanthus emblica), Harra (Terminalia chebula), Barra (Terminalia belerica), are the most collected NTFPs in the study area.

4.6. NTFP – popularity of places

Popularity of places for NTFPs refers to the place where people go mostly to collect NTFPs. Due to some reasons the local community go to mostly to some particular places. According to the result of this study (see

Figure 9) Jogeni, a place in Devidhunga is found to be most popular place for NTFPs; on the other hand Amaladada, Kalikhola and Tirtire are least popular places. Appendix 3 shows all NTFP places identified in the study area.

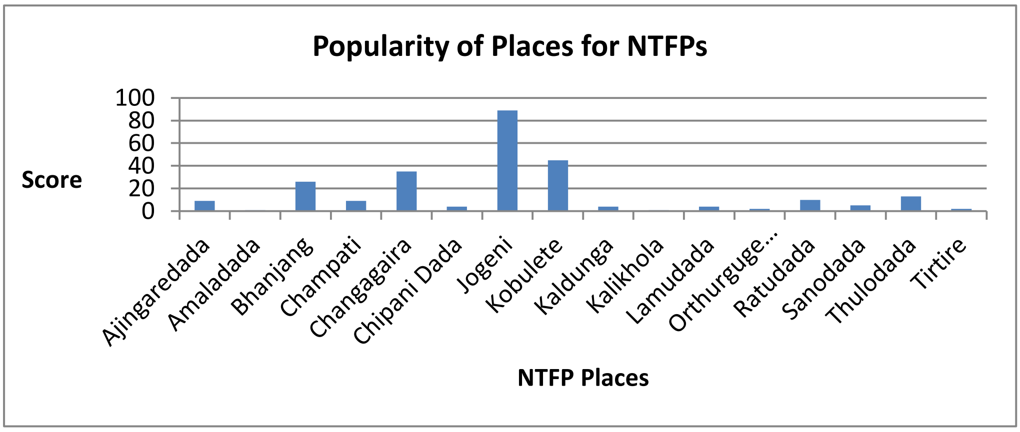


Figure 9: Popularity of places for NTFPs in Devidhunga CF

4.7. NTFP richness map

Figure 10 shows the result of the NTFP richness map. According to the map central and eastern Devidhunga CF and southern and eastern Nibuwatar are found to be high in NTFP richness. On the other hand, western Devidhinga CF and majority part of Janapragati_B CF are found to be low in NTFP richness. High and low values of NTFP richness refer to the number of NTFPs found in the area. In the map areas with dark colour indicates low values of NTFPs and areas with grey colour indicate high values. The values indicate the relative NTFP richness or number of NTFPs found in that location.

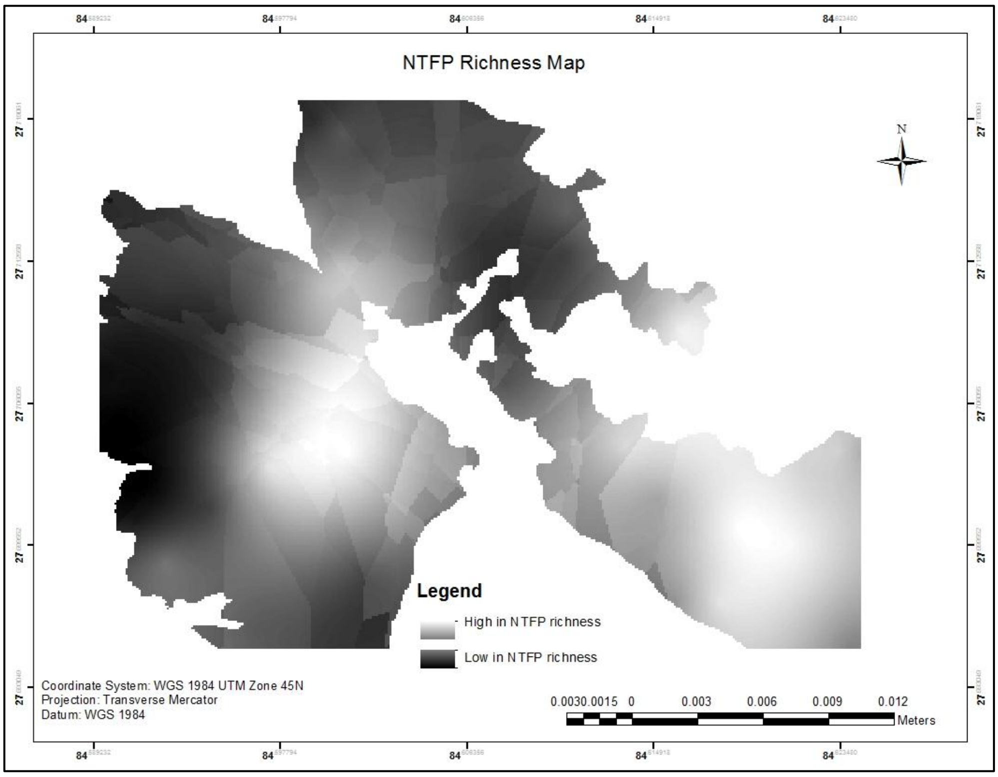


Figure 10: NTFP richness map

4.8. Accuracy assessment

In order to assess the validity of the prediction leave one out cross validation statistics was calculated and the result is shown in Table 9 (see section 3.9.1 for methods). According to the summary statistics the mean prediction errors approaches to zero and no bias is shown. The other parameters also show lower prediction errors.

Cross validation statistics	Value
ME	-0.15
MAE	5.74
RMSE	5.74
%RMSE	134.93
%MAE	125.19

Table 9: LOOCV accuracy assessment of the NTFP richness map

4.9. Uniqueness index

The result of the uniqueness index (UI) analysis of the NTFP places in the three CF (Figure 11) shows that Kalikhola, Tirtire, Jogeni, Histrydygaira, Changagaira, Kobulete, Suparidada, Sailimaili have relatively higher values of uniqueness.

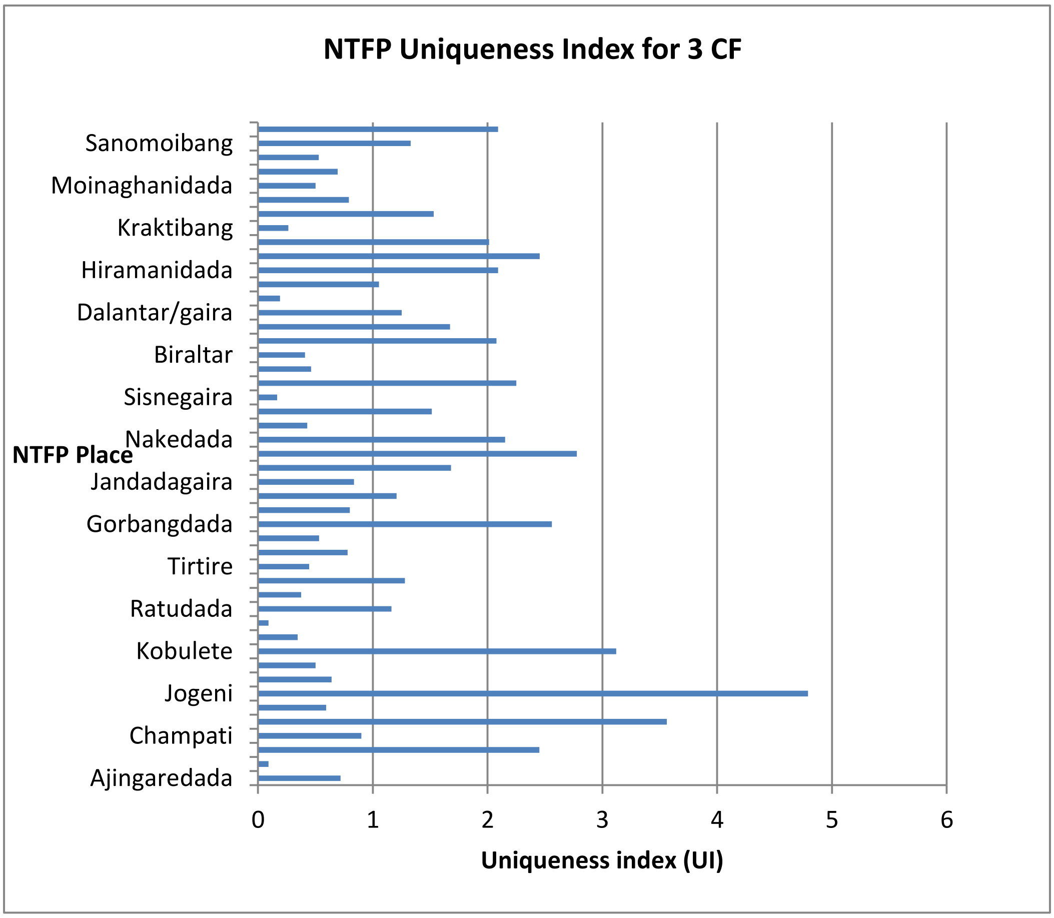


Figure 11: Uniqueness index analysis results

4.10. NTFP uniqueness map

Figure 12 shows the uniqueness map for NTFPs in the study area. Areas with grey colour indicate high uniqueness values for NTFPs; for instance places with high uniqueness value include Jogeni and Changagaira (centre of Devidhunga CF). These places are places where some NTFPs are located that are not found in other places. On the other hand places with low uniqueness include Sisnegaira Amaladada, and Orthurgugedada (areas with dark color in the three CF). These places have no uniqueness value, because all NTFPs that are found in these places are also found in several other places, i.e. they are common, not very special. The values indicate the degree of uniqueness for a location.

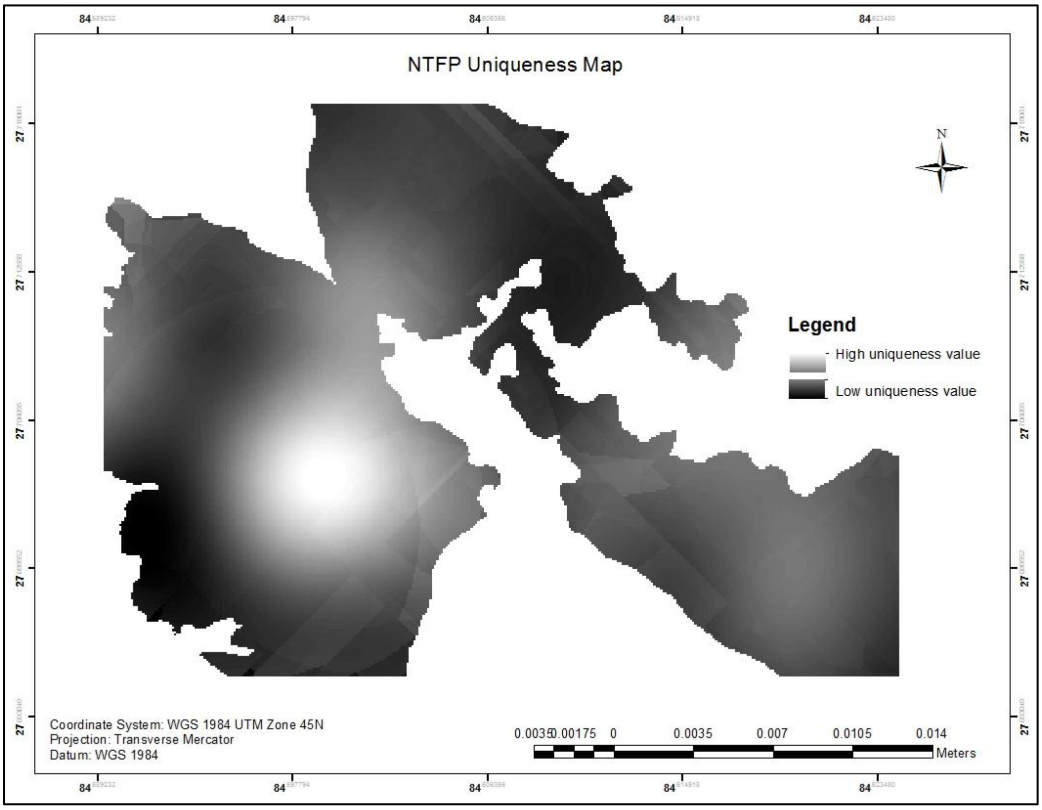


Figure 12: NTFP uniqueness map

4.11. Accuracy assessment

In order to assess the validity of the prediction leave one out cross validation statistics was calculated and the result is shown in Table 10 (see section 3.9.1 for the methods). According to the summary statistics the mean prediction errors approaches to zero and no bias is shown. The other parameters also show lower prediction errors. For %RMSE and %MAE values see the discussion (section 5.4).

Cross validation statistics	Value
ME	0.01
MAE	0.57
RMSE	0.57
%RMSE	109.7
%MAE	109.7

Table 10: LOOCV accuracy assessment of the NTFP uniqueness map

4.12. Accessibility map

Figure 13 shows the accessibility map in travel time from the settlements surrounding the forest. This accessibility analysis which was based on literatures that gave values for travelling speed per land cover and road type with their respective slope steepness correction factor agrees (with little fluctuation) with the data collected during the structured interview period. Table 11 shows the average minimum and maximum hours travelled to collect NTFPs in their respective CF.

CF	Minimum average	Maximum average
Devidhunga	0.53	1.80
Janapragati_B	0.50	1.50
Nibuwatar	0.37	1.45
Average	**0.46**	**1.59**

Table 11: Minimum and maximum hours travelled to collect NTFPs

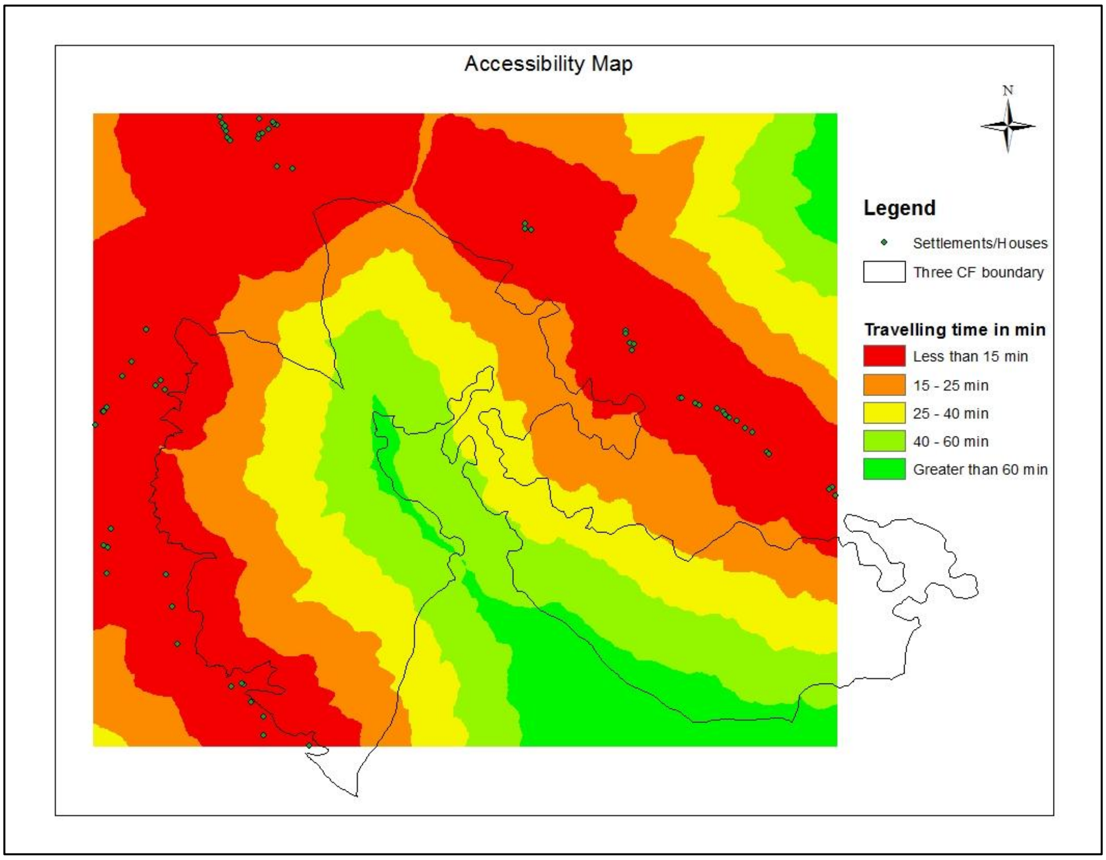


Figure 13: Map of accessibility

As can be seen from Table 12, 44.25% of the forest area is accessible within 0.25 hr (15 minutes) from the surrounding villages. Only 3.39 % of the area is accessible between 1 and 1.50 hr (60 – 90min) from the villages surrounding the forest.

Time Zone-min	Class	Area m²	Percentage
0 - 15	1	7,344,006.92	44.25
15 - 30	2	3,718,866.07	22.41
30 -60	3	4,970,169.06	29.95
60 - 90	4	562,651.96	3.39
Sum		**16,595,694**	**100**

Table 12: Travel time zone classification

Figure 14 shows the result of travel time zone classification of the area. The map has four zones: travel time zone 1, 2, 3, and 4. All NTFP places and settlements/houses (compare with Figure 13) are classified based on this travel time zone. Travel time zone 1 include places that are accessible within 0 to 15 min, travel time zone 2 between 15 – 30 min, travel time 3 between 30min – 1 hr, and travel time zone 4 above 1 hr (compare with (Table 12). According to the map Jogeni and Kasbangdada are located in travel time 2; both are the most NTFP rich place. Kalikhola and Tirtire are located in travel time 1; both have high NTFP uniqueness. Lockhantapadada is located in travel time zone 3 and has medium uniqueness index, and Kraktibang is located in travel time zone 4 and has low uniqueness index. From these results we see that the higher the accessibility the more the uniqueness value.

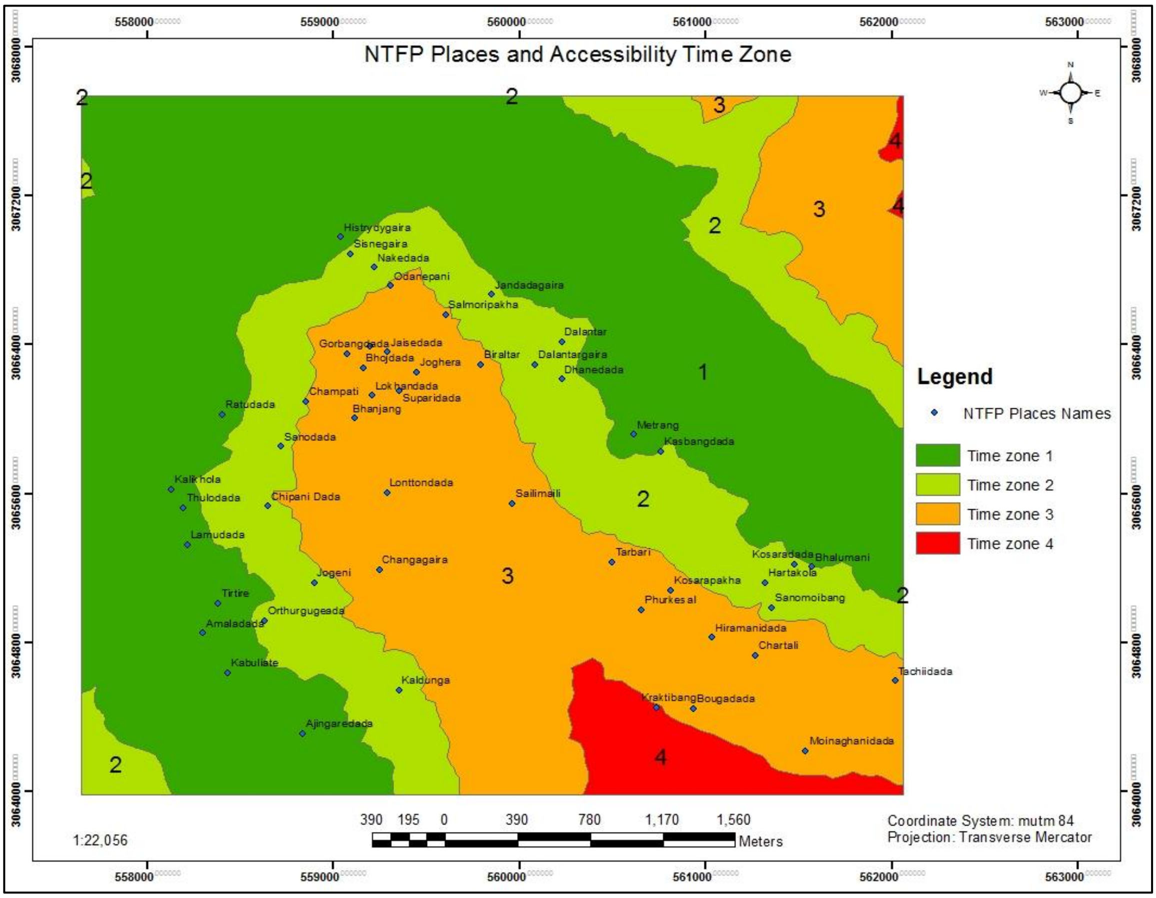


Figure 14: Travel time zone map

4.13. Relationships

4.13.1. Relationship between NTFP richness and NTFP unique places

Pearson product moment correlation coefficient was calculated using SPSS 21 to analyse the strength of linear relationship between the variables (NTFP richness index and NTFP uniqueness index). As seen in Table 13, Pearson's r (0.917) was very strong and which was also statistically significant at 99% confidence level. Coefficient of determination (R^2) was also found to be 0.84. This implies that NTFP richness and NTFP uniqueness have very strong and statistically significant relation.

Correlations

		NTFP Richness	NTFP_UI
NTFP Richness	Pearson Correlation	1	.917**
	Sig. (1-tailed)		.000
	N	37	37
NTFP_UI	Pearson Correlation	.917**	1
	Sig. (1-tailed)	.000	
	N	37	37

**. Correlation is significant at the 0.01 level (1-tailed).

Table 13: Correlation between NTFP richness and NTFP uniqueness index

The strength of the relationship is also shown after plotting them in scatterplots as seen in Figure 15.

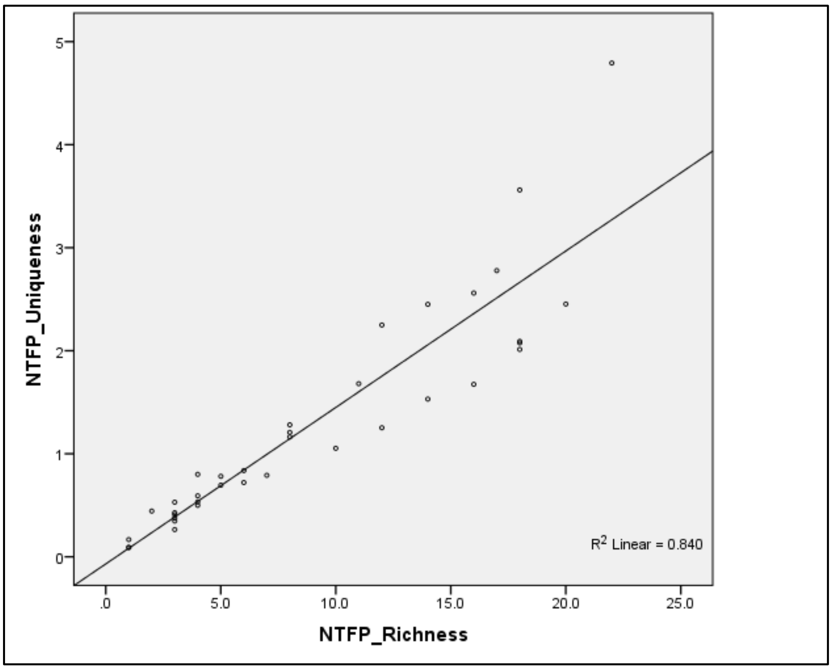


Figure 15: Scatterplot of NTFP richness and NTFP uniqueness

The test of one way ANOVA as shown in table 14 also indicated that there is statistically significant relationship between NTFP richness and NTFP uniqueness in the study area at $P < 0.001$.

One way ANOVA					
NTFP_UI					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	37.009	16	2.313	14.827	.000
Within Groups	3.120	20	.156		
Total	40.130	36			

Table 14: One way ANOVA - NTFP richness and NTFP uniqueness

The spatial Spearman's correlation result between the maps of NTFP richness and NTFP uniqueness maps is also resulted in somewhat similar result i.e., correlation value of 0.66215 between NTFP richness and NTFP uniqueness (see result in Appendix 4).

Appendix 9 – A shows the result of the areas of importance for NTFP richness and NTFP uniqueness where the grey areas indicate places with high value for both richness and uniqueness, while the dark areas indicate areas with low values for both. Combination of the two maps was necessary so as to identify hotspots for NTFPs; the grey areas are hotspots based on NTFP richness and NTFP uniqueness.

4.13.2. Relationship between tree species diversity and NTFP richness

Pearson product moment correlation coefficient was calculated to analyse the strength of linear relationship between tree species diversity index and NTFP richness. The result is shown in Table 15 which shows that there is no correlation (very weak correlation) between tree species diversity and NTFP richness. Pearson's r was 0.1.

Correlations			
		NTFP Richness	Tree diversity
NTFP Richness	Pearson Correlation	1	.101
	Sig. (1-tailed)		.078
	N	200	200
Tree diversity	Pearson Correlation	.101	1
	Sig. (1-tailed)	.078	
	N	200	200

Table 15: Correlation between NTFP richness and tree species diversity

One way ANOVA as shown in Table 16 indicated that there is statistically significant difference between the mean values of NTFP richness and tree species diversity at $P < 0.05$. Therefore, there is no statistically significant relationship between NTFP richness and tree species diversity in the study area.

Tree diversity and NTFP richness Correlations			
		NTFP Richness	Tree diversity
NTFP Richness	Pearson Correlation	1	.101
	Sig. (1-tailed)		.078
	N	200	200
Tree diversity	Pearson Correlation	.101	1
	Sig. (1-tailed)	.078	
	N	200	200

Table 16: One way ANOVA - NTFP richness and Tree diversity

According to the spatial Spearman's correlation statistics, tree species diversity and NTFP richness have somewhat stronger correlation (negative direction, -0.37). But, this result is not similar to the result of Pearson correlation (0.1), see appendix 4.

Appendix 9 – B shows the result of the map of area of importance for tree species diversity and NTFPs in the study area. High values (areas with grey colour) indicate places that are found relatively high in NTFPs and tree species diversity. Low values (areas with dark colour) indicate places that are found to be low in both NTFPs and tree species diversity.

4.13.3. Relationship between carbon and biodiversity

Pearson product moment correlation coefficient was calculated to analyse the strength of linear relationship between carbon stock and tree species diversity in the study area. The result (Table 17) shows that there was no correlation (very weak correlation) between carbon stock and tree species diversity; Pearson's r was -0.05.

The spatial Spearman's correlation statistics result between the maps of carbon stock and tree species diversity also resulted in somewhat similar results i.e., correlation value of -0.002 between carbon stock and tree species diversity (see appendix 4).

Carbon & Tree diversity Correlations			
		Carbon	Tree Diversity
Carbon	Pearson Correlation	1	-0.049
	Sig. (1-tailed)		0.245
	N	200	200
Tree Diversity	Pearson Correlation	-.049	1
	Sig. (1-tailed)	.245	
	N	200	200

One way ANOVA					
Carbon and Tree diversity					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	103534309.427	119	870036.214	0.920	0.663
Within Groups	75637450.093	80	945468.126		
Total	179171759.520	199			

Table 17: Pearson's correlation and one way ANOVA test carbon stock and tree species diversity

Appendix 9 – C shows the result of areas of importance for carbon stock and tree species diversity in the study area. Central and southern Devidhunga CF and central Nibuwatar CF are found to be relatively with high values for carbon and tree species diversity. These could be areas of importance for REDD (carbon) while at the same time biodiversity is conserved as one of the multiple benefits. On the other hand Janapragati-B CF is found to be low in carbon and tree species diversity.

4.13.4. Relationship between carbon and NTFPs

The map used for analysis of carbon and NTFPs correlation is the NTFP richness map, but for the visual display of the areas of importance for carbon and NTFPs, the map used is that of the NTFP hotspots, i.e., a combination of NTFP richness and NTFP uniqueness map. Pearson product moment correlation coefficient was calculated to analyse the strength of linear relationship between carbon stock and NTFP richness using SPSS 21. The result shows that there is very weak correlation between the two variables; Pearson's r was 0.05, and one way ANOVA test also shows that they have no statistically significant relation at 95% confidence level (see Table 18).

Correlations NTFP Richness and Carbon Stock			
		NTFP Richness	Carbon Stock
NTFP Richness	Pearson Correlation	1	0.049
	Sig. (1-tailed)		0.243
	N	200	200
Carbon Stock	Pearson Correlation	0.049	1
	Sig. (1-tailed)	0.243	
	N	200	200

One way ANOVA NTFP Richness and Carbon stock					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1313.507	180	7.297	1.213	0.324
Within Groups	114.313	19	6.016		
Total	1427.820	199			

Table 18: Pearson's correlation and one way ANOVA test for NTFPs and carbon stock

The spatial Spearman's correlation statistics between the maps of carbon stock and NTFP richness map resulted in very low correlation but in different direction i.e., correlation value of -0.026 between carbon stock and tree species diversity (see appendix 4).

Appendix 9 – D shows the result of areas of importance for carbon stock and NTFPs in the study area. Central and western Devidhungs CF and central and south eastern Nibuwatar CF are found to be relatively with high values for carbon and NTFPs. On the other hand Janapragati-B CF is found to be relatively with low values in carbon and NTFPs.

4.14. Hotspot Areas – areas of importance for carbon, biodiversity, NTFPs

As discussed in section 25, hotspot areas include areas that are relatively high in carbon stock, tree species diversity, NTFP richness and NTFP uniqueness in the study area. Appendix 9 – E shows the result of hotspot areas, i.e., areas of importance for carbon and other ecosystem benefits. Grey areas indicate high values and dark indicate low values. According to the result, central and western Devidhunga CF is found to be with high values, while Janapragati-B CF is found to be relatively with low values of the four components of the hotspot analysis in this study.

5. DISCUSSION

5.1. Shannon diversity index and tree species diversity map

In this study, tree species diversity of the study area was mapped and places with high and low diversity were identified; and its correlation with carbon stock was made. Among the three CF in the study area, Devidhunga CF was found to be most diverse. The study area has more than 36 tree species (see Appendix 6) including 5 pioneers: Sal (Shorea robusta), Botdhairo (Lagerstromia parviflo), Chilaune (Schima wallichii), Bhalayo (Semicarpous anacardium), and Kummi (Careya arborea); Sal (Shorea robusta) is the most dominant species.

The tree species diversity map (Figure 7) shows low diversity at the centre of the study area; this was not expected: it is unusual to get higher diversity at the edges and lower at the centre of a forest area which is quite remote and not easily accessible. But, there might be several reasons for such a result; for instance the area could be rocky and even as some studies indicate elevation might have also its own effect on species diversity (Mackey & Currie, 2001). But, in this study the main effect observed was the distribution of sample points. Only few samples were taken at the centre of the area and their SI value was zero.

Some studies mention influence of human factors on species diversity (Hoang et al., 2011) but, in this study the distance of the houses/villages in the surrounding area of the forests seems to have no relation with the species diversity map. This may be due to the fact that the area is relatively small and all parts can be reached in less than two hours.

Analysis and mapping of tree species diversity was necessary to investigate where REDD+ can secure tree species diversity in addition to maintaining carbon stocks; the result of which can support REDD+ decision making in that they can be adopted to specific regional or local priorities and needs for information. It can assess the distribution of tree species at local level easily and rapidly.

High biodiversity REDD+ is being promoted internationally. High-biodiversity REDD+ approach is essential due to its contribution to reduction of forest ecosystem dysfunction (Swan & McNally, 2011). The positive correlation between ecosystem services and biodiversity is also one reason (Chan et al., 2007; Naidoo et al., 2008; Schneiders et al., 2012). When compared with artificial forests, old-growth forests maintain and continue to accumulate and sequester much more carbon from the atmosphere (Luyssaert et al., 2008; Sharma et al., 2010). Such conditions depict the potential of REDD+ in providing conservation of biodiversity together with conservation of forests.

5.2. NTFPs richness of places

Besides its contribution to rural livelihood, knowledge of NTFPs is essential for biodiversity and forest conservation and management activities (Jones et al., 2004). This case study has demonstrated among others how NTFPs can be identified and mapped for hotspot analysis for conservation priorities. Among the 41 products identified in this study (see Appendix 2), the majority (78.05 %) are found to be medicinal NTFPs followed by edible fruits and food items (14.63%). The dominance of medicinal type NTFPs in the region is also reported in many other studies (Dangol & Maharjan, 2012); even for such reason the area is internationally well known for ethno botanical studies (Rijal, 2011). Especially, three of the medicinal types of NTFPs (see section 4.5) are most collected in all the three CFs. This was also reported in other studies where even they reported that these three NTFPs have been identified as potential NTFPs for processing and marketing purposes (Magar, 2008).

As seen in this case study, NTFPs in the study area are mostly extracted as wild products for personal uses and the nature of extraction is manual and small scale. It can be observed from the study that NTFPs in the area contribute a lot to the livelihood of the forest fringe local communities; however, the extent of their dependence on the NTFPs may result in ecological costs. Other studies also show that NTFP in Nepal is an integral part of the rural community (Bista & Webb, 2006).

The NTFP richness map shows that villagers from two of the CFs (Devidhunga and Janapragati-B) have to travel longer distance to reach NTFP rich places. Especially for Devidhunga CF, NTFP rich places are located at distant places; for this reason Jogeni, the most accessible place is the most popular place for NTFPs in the area (section 5.5).

5.3. NTFP uniqueness of places

Beside NTFP rich places, identification and mapping of unique places for NTFPs was necessary for NTFP hotspot analysis which eventually contribute to identification of areas of importance for conservation planning. In this study, NTFP uniqueness of places was able to be identified as well as mapped using an index developed in this study the idea of which is basically adopted from wildlife studies. Such an attempt will trigger our further studies in this field.

The study also shows that NTFP rich places were also found to be more or less NTFP unique areas. But, this was not the case for all places. Some very rich places (e.g. place Jogeni) were also NTFP unique places; some NTFP poor places (e.g. Kalikhola) were found to be high in NTFP uniqueness, in other words, NTFPs were found there that occur nowhere else.

The result of NTFP uniqueness map (section Figure 12) shows somewhat similar result as that of the NTFP richness map (section Figure 10). This was because most NTFP rich places also have high values for NTFP uniqueness.

Management and conservation planning should also take into consideration not only rich places for NTFPs, but also poor places where rare products are located. In such instances such seemingly poor places should be distinguished from other really poor places that have no significant area of importance.

5.4. Accuracy assessment

Tree species diversity, NTFP richness and NTFP uniqueness maps were developed using ordinary kriging (see section 3.8), and the accuracy assessment was performed using leave one out cross validation (see section 4.4). This method is used where there are no enough observations for training and validation dataset. As seen from the result of the accuracy assessment ME as low as ± 0.01 and MAE as low as 0.5 show the mean prediction errors, the values of which are closer to zero which indicate that there was no bias in prediction. Of course %RMSE and %MAE show high values, but this doesn't mean that there were severe bias in prediction. As several observation values were close to zero, those parameters tend to show biased figures, because divisions by numbers close to zero results in very large figures; similarly Hyndman and Koehler, (2005) reported that where observation values were close to zero and negative, %RMSE and %MAE tend to be biased (Hyndman & Koehler, 2005).

5.5. Accessibility

Accessibility is one factor which affect extraction of NTFPs (Neumann & Hirsch, 2000b). In this study this effect can be observed from the accessibility map, where most popular places for NTFPs are located in the most accessible locations. Places can be rich for NTFPs but not popular; one factor for such difference may be accessibility.

The result of the travelling time of the accessibility map is not far from the average of the actual travel time recorded in the field interview. The little difference may be due to the difference of the size of some roads and footpaths which may be smaller than the 5m x 5m resolution or cell size of the road map which may have an effect on the cost weighted distance calculations in deriving the traveling time.

Travel time zone classification of the area shows that Jogeni is fairly most accessible; the high accessibility of Jogeni, hence, may account for its popularity. On the other hand the effect of accessibility on NTFP uniqueness is not observed. In Devidhunga CF, places like Kalikhola and Tirtire have high uniqueness index, nevertheless they are located in the most accessible travel time zone (Figure 14), which possibly show that accessibility has no effect on uniqueness in the study area. Rather, it shows that those places are really unique places for NTFPs. Despite the fact that these places are most accessible which favours popularity, we rather see rare products, not popular products. But, still there is another possibility; if people go to most accessible places to collect rare products, they do not have to search further; availability (which was not the focus of present study) has to be studied for such a conclusion.

5.6. Relation of NTFP richness and NTFP uniqueness

In this study very strong correlation (Pearson's $r = 0.91$) and statistically significant relation (at $P = 0.01$) was obtained for NTFP richness and NTFP uniqueness maps. This implies that areas of importance for NTFP richness are also related to areas of importance for NTFP uniqueness. Mechanisms for conserving NTFP rich areas could also result in conserving NTFP unique areas. As there was found no study on NTFP uniqueness, it was not possible to compare and contrast the result of this study with other studies on the correlation of NTFP richness and NTFP uniqueness. However, it was possible to find somewhat similar result in wildlife studies, where a Spearman rank correlation (r_s) = 0.44 at $P < 0.001$ was obtained for SQS (species quality sites for rarity) and species richness of bumble bees (Paul Williams, 2000).

5.7. Relation of tree species diversity and NTFPs

The relationship between NTFP richness and tree species diversity was found very weak (Pearson's $r = 0.1$). This result is not unexpected; as most were medicinal herbs and there were also products that grow independently of the tree species (e.g. Chau, Pleurotus sps.), and as there were some NTFPs extracted from one tree species (e.g. the leaf and bark of Cinnamomum tamala for food and medicine), strong relationship could not be obtained.

One thing which should also be mentioned regarding relation analysis is the somewhat different results of the spatial Spearman's correlation ($r_s = -0.37$) and Pearson's correlation ($r = 0.1$). Although in both cases the correlation is weak, results are not similar. This may be due to the effect of the several no data values on the carbon map when extracting values for correlation analysis.

5.8. Relation of carbon and biodiversity

In this study the correlation of carbon stock with tree species diversity was found to be very weak (correlation coefficient of -0.05). This can be compared with other studies with similar result; Karna, (2012) obtained correlation coefficient of 0.056 (for the three CF in the same area), Sharma et al (2012) also obtained a correlation coefficient of -0.25. Others also obtained no significant relation between tree species diversity and total carbon stock (Asase et al., 2012). Kirby and Potvin, (2007) also asserted that they found no evidence for a positive relationship between tree species diversity and aboveground biomass either in forests or agro-forests (Kirby & Potvin, 2007). This means that such results could not support the expectation that mechanisms for conserving biomass carbon stock would have co-benefit for biodiversity at very local level. On the other hand, the study of Nakakaawa et al., (2010) resulted in a strong positive correlation between carbon stock and tree species diversity in Uganda (Nakakaawa et al., 2010).

But, the result of this study is not without limitations. One reason for such low correlation between biomass carbon stock and tree species diversity may be the nature of the carbon map in which there was no sufficient number of observations extracted from the remote sensing data for the aboveground biomass map from which the carbon map was derived (see Appendix 8 for the carbon map).

5.9. Relation of carbon and NTFPs

The result of this study shows that there was very weak correlation between carbon stock and NTFP richness. This result is also not unexpected; as there were NTFPs growing independently of any trees (like Chiau, Pleurotus sps.), and as there were several NTFPs collected from a single tree, strong correlation may not be obtained with aboveground carbon stock where the carbon stock was calculated per trees.

5.10. Hotspot areas

In this study hotspot areas are areas with high value for management and conservation planning. Places that are found to be high in carbon stock, tree species diversity, NTFP richness and NTFP uniqueness were regarded as hotspots. Based on the criteria set for hotspot in this study, Jogeni was found to be most hotspot for the study area. Tree species diversity was highest; it was also most NTFP rich and with regard to uniqueness it has a value of 4.7. Hence, high conservation priority has to be given to this special place. Other studies also treat hotspots as areas of high priority for conservation where these areas were also selected on the basis of their local richness or degree of concentration of products or species (ARAÚJO, 2002).

Variables	Maximum value	Minimum value	Average value	Set value for hotspot selection		Value for Jogeni
				% (of max.)	value	
Average carbon stock (kg/tree)	5,212	243	2,982.28	75	3909	4132 (79%)
Tree species diversity (SI)	2.29	-1.36	1.13	75	1.72	1.65 (72%)
NTFP richness (no of NTFPs)	22	1	8.83	75	16.5	22 (100%)
NTFP uniqueness (UI)	4.79	0.09	1.28	75	3.59	4.79 (100%)

Table 19: Criteria for most hotspot area selection

For the final most hotspot selection, Table 19 shows the criteria for selection of the most hotspot area. In this criteria the average values for the corresponding variables was taken into consideration. It was very clear and easy to set the values for NTFP richness and NTFP uniqueness since the corresponding coordinate values for all places were known. But, for carbon stock which was measured in kg per tree, and tree species diversity which was taken the Shannon diversity index the corresponding pixel values (average in the area) was taken. As seen in Table 19, Jogeni with a score of 100% for NTFP richness and NTFP uniqueness, 79 % for carbon stock and 72 % (little less than the criteria) for tree species diversity was found to be the most hotspot area in the study area. For other places it was not possible to get higher values beyond two variables. But, Jogeni was found to be rich and unique in NTFPs, diverse in tree species as well as most dense in carbon stock -that is why it was selected as the most hotspot in the area.

Finally, for a better and fuller analysis of hotspots, it would have been better to adopt the use WofE (weight of evidence) as seen in other studies (Otero et al., 2006). It is also worth to try Getis-Ord Gi* (Spatial Statistics) which is being used for hot and cold spot analysis.

5.11. Limitation of the research

1. The investigation of the relationship between tree diversity and carbon stock suffers much due to the insufficient number of samples extracted from remote sensing data for the comparison.
2. There was some confusion on the identification of NTFPs (which is which?) e.g. Dalchini, (Cinnamomum zeylanicum) and Tejpat (Cinnamomum tamala)
3. Enough number of people to undertake mapping on Google Earth – real community mapping on GE
4. Some NTFPs were said to be found everywhere, e.g. Amala ((Phyllanthus emblica)
5. Some NTFPs were very local and it was not possible to recognize them with their scientific name (e.g. Dumarai, Kusmuro and Quinete).
6. Some of the research questions have to do with identification of areas of importance (hotspots) and better results would have been obtained if other methods (e.g., WofE) would have been used.

6. CONCLUSSIONS AND RECOMMENDATIONS

6.1. Conclussions

The general objective of the study was to identify, map and characterize the spatial relationship between ecosystem carbon stock, tree species diversity and NTFPs in Kayerkhola watershed. With this respect, following conclusions were derived from this study in relation to the research questions.

1. Where do areas of high carbon density coincide with areas of importance for tree species diversity?

In the study area, among the three CF, Devidhunga is found to be with high values for carbon and tree species diversity. Specifically, central and southern Devidhungs CF and central Nibuwatar CF are found to be relatively with high values for carbon and tree species diversity. In these areas high carbon density was found to be coincided with areas of importance for tree species diversity. Specifically, place Jogeni was found to be a hotspot area based on areas of importance for carbon density and tree species diversity.

2. Where do areas of importance for NTFPs coincide with areas of importance for tree species diversity?

The result of this study shows that west of Devidhunga CF (locally known as Lamudada, Tulodada and Tirtire), central Devidhunga CF (Jogeni, Changagaira & Lottondada) and south east Nibuwatar CF (Hiramenidada and Chartali) are places where areas of importance for NTFPs coincided with areas of importance for tree species diversity; again of all the places Jogeni was found to be hotspot based on areas of importance for NTFPs and tree species diversity.

3. Where do areas of importance for NTFP richness coincide with areas of importance for NTFP uniqueness?

Western and Central Devidhunga CF (especially places locally known as Jogeni, Changagaira & Tirtire); and southern Janapragati_B CF (locally known as lokhandada); northern Nibuwatar CF (Kasbangdada), as well as south east Nibuwatar CF (Hiramenidada and Chartali) are found to be as places rich both in NTFP richness and NTFP uniqueness.

4. Where do areas of high carbon density coincide with areas of importance for provisioning of NTFPs?

Central and western Devidhungs CF and central and south eastern Nibuwatar CF are found to be with high values for carbon and NTFPs. In these places areas of high carbon density coincided with areas of importance for NTFPs.

a. What is the approach to be used to map unique areas for NTFPs?

Unique areas for NTFPs were mapped by developing an index which serves as a magnitude value for mapping. The index (see Equation 2) takes into consideration the occurrence of an NTFP in only one or few places in reference to its occurrence in other places that have other products; an idea adopted from wildlife rarity and common species indices.

b. Does accessibility affect NTFP extraction in the study area?

The result of the study shows that accessibility may be one factor for the popularity of places for NTFP. This was based on the result that most NTFP popular places were also most accessible places. Nevertheless, there was seen no relation or effect of accessibility on NTFP unique places.

5. ***Is there any significant relation between NTFP richness and NTFP uniqueness in the study area?***
   The result of the study shows that there is a strong correlation and statistically significant relation between NTFP richness and NTFP uniqueness in the study area. The result of Pearson's correlation (r = 0.91) and one way ANOVA test indicate that there is statistically significant relation between them at 99% confidence interval level.

6. ***Is there any significant relation between tree species diversity and NTFPs in the study area?***
   The result of this study shows that there is no statistically significant relation between tree species diversity and NTFPs (very weak correlation). The result of Pearson's correlation (r = 0.01) and one way ANOVA test indicate that there is no statistically significant relation between them at 95% confidence level.

7. ***Is there any significant relation between carbon stock and tree species diversity in the study area?***
   The result of this study shows that there was no statistically significant relation between carbon stock and tree species diversity (very weak correlation). The result of Pearson's correlation (r = -0.05) and one way ANOVA test indicate that there is no statistically significant relation between them at 95% confidence level.

8. ***Is there any significant relation between carbon stock and NTFPs in the study area?***
   The result of Pearson's product moment correlation shows that there was very weak correlation between carbon stock and NTFPs; Pearson's r was 0.05, and one way ANOVA test also shows that they have no statistically significant relation at 95% confidence level.

9. ***Where are the hotspot areas (areas of importance for carbon stock, tree species diversity, NTFP richness and NTFP uniqueness)?***
   The result shows that western and central Devidhunga and eastern Nibuwatar are hotspot areas that are found to be with high values in carbon stock, biodiversity and NTFPs richness and NTFP uniqueness in the study area, but place Jogeni was found to be most hotspot in the study area based on the criteria set for areas of importance for carbon stock, tree species diversity, NTFP richness and NTFP uniqueness.

6.2. Recommendations

The study shows that the use of GIS and RS (remote sensing) method is useful in identifying, mapping and characterising ecosystem services but following recommendations are noted for further study.

- Sufficient number of observation or samples and taking care on sampling techniques for tree species diversity mapping
- Intensive community mapping on Google Earth
- Application of NTFP uniqueness index on other areas with enough number of training and validation datasets

LIST OF REFERENCES

Aerts, R., & Honnay, O. (2011). Forest restoration, biodiversity and ecosystem functioning. *BMC Ecology, 11*(1), 1-10. doi: 10.1186/1472-6785-11-29

Agrawal, A., Nepstad, D., & Chhatre, A. (2011). Reducing Emissions from Deforestation and Forest Degradation. In A. Gadgil & D. M. Liverman (Eds.), *Annual Review of Environment and Resources, Vol 36* (Vol. 36, pp. 373-396).

Anderson, B. J., Armsworth, P. R., Eigenbrod, F., Thomas, C. D., Gillings, S., Heinemeyer, A., . . . Gaston, K. J. (2009). Spatial covariance between biodiversity and other ecosystem service priorities. *Journal of Applied Ecology, 46*(4), 888-896. doi: 10.1111/j.1365-2664.2009.01666.x

Angelsen, A. (2008). *Moving ahead with REDD : issues, options and implications, design options for REDD in a global climate regime*. Bogor Barat: Centre for International Forest Research (CIFOR).

ARAÚJO, M. B. (2002). Biodiversity Hotspots and Zones of Ecological Transition. *Conservation Biology, Pages 1662–1663, Volume 16, No. 6, December 2002*.

Asase, A. (2011). Impact of land-use change on plant diversity and carbon storage in the Bia biosphere reserve in Ghana. *Department of Botany, University of Ghana The Division of Ecological Sciences, UNESCO (MAB) Young Scientist Research Award Scheme, Paris Cedex 15, France*.

Asase, A., Asitoakor, B. K., & Ekpe, P. K. (2012). Linkages between tree diversity and carbon stocks in unlogged and logged West African tropical forests. *International Journal of Biodiversity Science, Ecosystems Services and Management, 8*(3), 217-230. doi: 10.1080/21513732.2012.707152

Barbier, S., Chevalier, R., Loussot, P., Berges, L., & Gosselin, F. (2009). Improving biodiversity indicators of sustainable forest management: Tree genus abundance rather than tree genus richness and dominance for understory vegetation in French lowland oak hornbeam forests. *Forest Ecology and Management, 258*, S176-S186. doi: 10.1016/j.foreco.2009.09.004

Bista, S., & Webb, E. L. (2006). Collection and marketing of non-timber forest products in the far western hills of Nepal. *Environmental Conservation, 33*(3), 244-255. doi: 10.1017/s0376892906003195

Bock, C. E., Jones, Z. F., & Bock, J. H. (2007). Relationships between species richness, evenness, and abundance in a southwestern Savanna. *Ecology, 88*(5), 1322-1327. doi: 10.1890/06-0654

Boerner, J., Mendoza, A., & Vosti, S. A. (2007). Ecosystem services, agriculture, and rural poverty in the Eastern Brazilian Amazon: Interrelationships and policy prescriptions. *Ecological Economics, 64*(2), 356-373. doi: 10.1016/j.ecolecon.2007.03.001

Bohling, G. (2005). Kriging. *Kansas Geological Survey, USA*.

Booth, J. E., Gaston, K. J., Evans, K. L., & Armsworth, P. R. (2011). The value of species rarity in biodiversity recreation: A birdwatching example. *Biological Conservation, 144*(11), 2728-2732. doi: 10.1016/j.biocon.2011.02.018

Buchanan, G. M., Donald, P. F., & Butchart, S. H. M. (2011). Identifying Priority Areas for Conservation: A Global Assessment for Forest-Dependent Birds. *Plos One, 6*(12). doi: 10.1371/journal.pone.0029080

Chan, K. M. A., Pringle, R. M., Ranganathan, J., Boggs, C. L., Chan, Y. L., Ehrlich, P. R., . . . Macmynowski, D. P. (2007). When agendas collide: Human welfare and biological conservation. *Conservation Biology, 21*(1), 59-68. doi: 10.1111/j.1523-1739.2006.00570.x

Chan, K. M. A., Shaw, M. R., Cameron, D. R., Underwood, E. C., & Daily, G. C. (2006). Conservation planning for ecosystem services. *PLoS Biology, 4*(11), 2138-2152. doi: 10.1371/journal.pbio.0040379

Chao, A., & Shen, T.-J. (2003). Nonparametric estimation of Shannon's index of diversity when there are unseen species in sample. *Environmental and Ecological Statistics, 10*(4), 429-443. doi: 10.1023/a:1026096204727

Costanza, R., dArge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., . . . vandenBelt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*(6630), 253-260. doi: 10.1038/387253a0

Daily, G. C., & Matson, P. A. (2008). Ecosystem services: From theory to implementation. *Proceedings of the National Academy of Sciences of the United States of America, 105*(28), 9455-9456. doi: 10.1073/pnas.0804960105

Diker, K., Heermann, D. F., Bausch, W. C., & Wright, D. K. (2004). Shannon-Wiener's diversity index for linking yield monitor and remotely sensed data for corn. *Transactions of the American Society of Agricultural Engineers, 47*(4), 1347-1354.

EFTEC. (2005). The Economic, Social and Ecological Value of Ecosystem Services: A Literature Review. *Report for the Department for Environment, Food and Rural Affairs, eftec, 16 Percy Street, London W1T 1DT.*

Egoh, B. N., Reyers, B., Rouget, M., & Richardson, D. M. (2011). Identifying priority areas for ecosystem service management in South African grasslands. *Journal of Environmental Management, 92*(6), 1642-1650. doi: 10.1016/j.jenvman.2011.01.019

Eigenbrod, F., Armsworth, P. R., Anderson, B. J., Heinemeyer, A., Gillings, S., Roy, D. B., . . . Gaston, K. J. (2010). The impact of proxy-based methods on mapping the distribution of ecosystem services. *Journal of Applied Ecology, 47*(2), 377-385. doi: 10.1111/j.1365-2664.2010.01777.x

Elder, S. (2009). Sampling Methodology. *ILO School -to-Work Transition Survey: A Methodological Guide, International Labour Office, Geneva.*

Encyclopedia Britanica. (2013). Components of species diversity: species richness and relative abundance. *2013 Encyclopaedia Britania, Inc.* http://www.britannica.com/EBchecked/topic/558668/species-abundance

Feng, X. M., Fu, B. J., Yang, X. J., & Lu, Y. H. (2010). Remote Sensing of Ecosystem Services: An Opportunity for Spatially Explicit Assessment. *Chinese Geographical Science, 20*(6), 522-535. doi: 10.1007/s11769-010-0428-y

Fisher, B., Turner, R. K., Burgess, N. D., Swetnam, R. D., Green, J., Green, R. E., . . . Balmford, A. (2011). Measuring, modeling and mapping ecosystem services in the Eastern Arc Mountains of Tanzania. *Progress in Physical Geography, 35*(5), 595-611. doi: 10.1177/0309133311422968

Franklin, S. E. (2009). *Remote sensing for biodiversity and wildlife management: synthesis and applications*. US: McGraw-Hill Professional.

Hall, A. (2012). *Forests And Climate Change : The Social Dimensions of REDD in Latin America : e-book*. Cheltenham: Edward Elgar.

Hernandez-Stefanoni, J. L., Gallardo-Cruz, J. A., Meave, J. A., & Dupuy, J. M. (2011). Combining geostatistical models and remotely sensed data to improve tropical tree richness mapping. *Ecological Indicators, 11*(5), 1046-1056. doi: 10.1016/j.ecolind.2010.11.003

Hoang, V. S., Baas, P., Keßler, P. A., Slik, J., Steege, H. T., & Raes, N. (2011). Human and environmental influences on plant diversity and composition in Ben En National Park, Vietnam. *Journal of Tropical Forest Science 23(3): 328–337 (2011).*

Hyndman, R. J., & Koehler, A. B. (2005). Another look at measures of forecast accuracy. *Department of Econometrics and Business Statistics, Monash University, VIC 3800, Australia; Department of Decision Sciences & Management Information Systems, Miami University, Oxford, Ohio 45056, USA.*

Jacquemont, F., & Caparrós, A. (2002). The Convention on Biological Diversity and the Climate Change Convention 10 Years After Rio: Towards a Synergy of the Two Regimes? *RECIEL 11 (2) 2002. ISSN 0962 8797.*

Kandel, D. L. (2004). Assessing the Effects of Different Forest Management Regimes on Forest Condition (A Case Study from Chitwan District, Nepal). *Thesis, International Institute for Geo Information Science and Earth Obseraation, Enschede, The Netherlands.* .

Karna, Y. K. (2012). Mapping above ground carbon using worldview satellite image and LIDAR data in relationship with tree diversity of forests. *ITC, Enschede, The Netherlands,.*

Karydas, C. G., Ioannis Z. Gitas, I. Z., Koutsogiannaki, E., Simantiris, N., & Silleos, G. N. (2009). EVALUATION OF SPATIAL INTERPOLATION TECHNIQUES FOR MAPPING AGRICULTURAL TOPSOIL PROPERTIES IN CRETE.

Kirby, K. R., & Potvin, C. (2007). Variation in carbon storage among tree species: Implications for the management of a small-scale carbon sink project. *Forest Ecology and Management, 246*(2-3), 208-221. doi: 10.1016/j.foreco.2007.03.072

Knox, N. M., Skidmore, A. K., Prins, H. H. T., Heitkonig, I. M. A., Slotow, R., van der Waal, C., & de Boer, W. F. (2012). Remote sensing of forage nutrients: Combining ecological and spectral absorption feature data. *Isprs Journal of Photogrammetry and Remote Sensing, 72*, 27-35. doi: 10.1016/j.isprsjprs.2012.05.013

Krishnaswamy, J., Bawa, K. S., Ganeshaiah, K. N., & Kiran, M. C. (2009). Quantifying and mapping biodiversity and ecosystem services: Utility of a multi-season NDVI based Mahalanobis distance surrogate. *Remote Sensing of Environment, 113*(4), 857-867. doi: 10.1016/j.rse.2008.12.011

Lal, R., Sivakumar, M., Faiz, S., Rahman, A., & Islam, K. (2011). *Climate change and food security in South Asia* Dordrecht: Springer.

Luyssaert, S., Schulze, E. D., Borner, A., Knohl, A., Hessenmoller, D., Law, B. E., . . . Grace, J. (2008). Old-growth forests as global carbon sinks. *Nature, 455*(7210), 213-215. doi: 10.1038/nature07276

Mace, G. M., Norris, K., & Fitter, A. H. (2012). Biodiversity and ecosystem services: a multilayered relationship. *Trends Ecol Evol, 27*(1), 19-26. doi: 10.1016/j.tree.2011.08.006

Mackey, R. L., & Currie, D. J. (2001). The diversity-disturbance relationship: Is it generally strong and peaked? *Ecology, 82*(12), 3479-3492. doi: 10.1890/0012-9658(2001)082[3479:tddrii]2.0.co;2

Mason, M. (2010). *Sample Size and Saturation in PhD Studies Using Qualitative Interviews* (Vol. 11).

MEA. (2005). Ecosystems and human weel-being: biodiversity synthesis. *World Resources Institute, Washington, DC.*

Menton, M. C. (2003). Effects of logging on non-timber forest product extraction in the Brazilian Amazon: community perceptions of change. *International Forestry Review, 5*(2), 97-105. doi: 10.1505/ifor.5.2.97.17419

Metzger, M. J., Rounsevell, M. D. A., Acosta-Michlik, L., Leemans, R., & Schrotere, D. (2006). The vulnerability of ecosystem services to land use change. *Agriculture Ecosystems & Environment, 114*(1), 69-85. doi: 10.1016/j.agee.2005.11.025

Minang, P. A., & van Noordwijk, M. (2012). Design challenges for achieving reduced emissions from deforestation and forest degradation through conservation: Leveraging multiple paradigms at the tropical forest margins. *Land Use Policy, In Press, Corrected Proof.*

Murphy, D. (2011). Safeguards and Multiple Benefits in a REDD+ Mechanism. *IISD.*

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R. E., Lehner, B., . . . Ricketts, T. H. (2008). Global mapping of ecosystem services and conservation priorities. *Proceedings of the National Academy of Sciences of the United States of America, 105*(28), 9495-9500. doi: 10.1073/pnas.0707823105

Nakakaawa, C., Aune, J., & Vedeld, P. (2010). Changes in carbon stocks and tree diversity in agro-ecosystems in south western Uganda: what role for carbon sequestration payments? *New Forests, 40*(1), 19-44. doi: 10.1007/s11056-009-9180-5

Neumann, R. P., & Hirsch, E. (2000a). Commercialisation of Non-Timber Forest Products: Review and Analysis of Research. *Center for International Forestry Research Bogor, Indonesia*.

Neumann, R. P., & Hirsch, E. (2000b). Commercialisation of Non-Timber Forest Products: Review and Analysis of Research.

Newman, M. E., McLaren, K. P., & Wilson, B. S. (2011). Use of object-oriented classification and fragmentation analysis (1985-2008) to identify important areas for conservation in Cockpit Country, Jamaica. *Environmental Monitoring and Assessment, 172*(1-4), 391-406. doi: 10.1007/s10661-010-1342-6

OCW. (2004). Cost distance and cost path analysis. *courses/civil-and-environmental-engineering/1-963-environmental-engineering-applications-of-geographic-information-systems-fall-2004/labs/lab8_1*.

Ojha, H., Persha, L., & Chhatre, A. (2009). Community Forestry in Nepal: A Policy Innovation for Local Livelihoods, IFPRI Discussion Paper 00913. *The International Food Policy Research Institute (IFPRI).*

Oliver, M. A., & Webster, R. (2008). *Geostatistics for environmental scientists*. GB: John Wiley & Sons Ltd.

Otero, M., Rubiano, J., Lema, G., & Soto, V. (2006). Using similarity analyses to scale out research findings across andear watershed basins. *Water International, 31*(3), 376-386.

Peres, C. A., & Lake, I. R. (2003). Extent of nontimber resource extraction in tropical forests: Accessibility to game vertebrates by hunters in the Amazon basin. *Conservation Biology, 17*(2), 521-535. doi: 10.1046/j.1523-1739.2003.01413.x

Pla, L. (2004). Bootstrap confidence intervals for the Shannon biodiversity index: a simulation study. *In: Journal of Agricultural, Biological, and Environmental Statistics, 9(2004)1, pp. 42-56*.

Raymond, C. M., Bryan, B. A., MacDonald, D. H., Cast, A., Strathearn, S., Grandgirard, A., & Kalivas, T. (2009). Mapping community values for natural capital and ecosystem services. *Ecological Economics, 68*(5), 1301-1315. doi: 10.1016/j.ecolecon.2008.12.006

Redford, K. H., & Richter, B. D. (1999). Conservation of biodiversity in a world of use. *Conservation Biology, 13*(6), 1246-1256. doi: 10.1046/j.1523-1739.1999.97463.x

Renaud, O., & Victoria-Feser, M. P. (2010). A robust coefficient of determination for regression. *Journal of Statistical Planning and Inference, 140*(7), 1852-1862. doi: 10.1016/j.jspi.2010.01.008

Sandbrook, C., Nelson, F., Adams, W. M., & Agrawal, A. (2010). Carbon, forests and the REDD paradox. *ORYX, 44*(3), 330-334. doi: 10.1017/s0030605310000475

SCBD. (2011). *REDD-plus and Biodiversity / Secretariat of the Convention on Biological Diversity... (CBD technical series ; no. 59)* (Vol. 59). Montreal: Secretariat of the Convention on Biological Diversity (CBD).

Schaafsma, M., Morse-Jones, S., Posen, P., Swetnam, R. D., Balmford, A., Bateman, I. J., . . . Turner, R. K. (2012). Towards transferable functions for extraction of Non-timber Forest Products: A case study on charcoal production in Tanzania. *Ecological Economics, 80*, 48-62. doi: 10.1016/j.ecolecon.2012.04.026

Scheffran, J., Brzoska, M., Brauch, H. G., Link, P. M., & Schilling, J. (2012). *Climate Change, Human Security and Violent Conflict, Challenges for Societal Stability : e-book* (Vol. 8). Berlin: Springer.

Schneiders, A., Van Daele, T., Van Landuyt, W., & Van Reeth, W. (2012). Biodiversity and ecosystem services: Complementary approaches for ecosystem management? *Ecological Indicators, 21*, 123-133. doi: 10.1016/j.ecolind.2011.06.021

Sharma, C. M., Baduni, N. P., Gairola, S., Ghildiyal, S. K., & Suyal, S. (2010). Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. *Forest Ecology and Management, 260*(12), 2170-2179. doi: 10.1016/j.foreco.2010.09.014

Shrestha, K., Shrestha, P. K., & Khanal, B. (2005). Study in Species Diversity in Chitwan District of Central Nepal. *Pro Natural Fund.*

Skidmore, A., Sillero, N., Brito, J. C., Martín-Alfageme, S., García-Meléndez, E., & Toxopeus, A. G. (2011). The significance of using satellite imagery data only in Ecological Niche Modelling of Iberian herps. *Acta Herpetologica 7(2): 221-237, 2012.*

Sluiter, R. (2009). Interpolation methods for climate data: literature review. *KNMI intern rapport ; IR 2009-04, De Bilt, 2009, PO Box 201, 3730 AE De Bi l t, Wilhelminalaan 10, De B i l t, The Netherlands.*

Smith, S. L. J. (2010). Practical Tourism Research. *CABI Tourism Texts, UK.*

Spatharis, S., Roelke, D. L., Dimitrakopoulos, P. G., & Kokkoris, G. D. (2011). Analyzing the (mis)behavior of Shannon index in eutrophication studies using field and simulated phytoplankton assemblages. *Ecological Indicators, 11*(2), 697-703. doi: 10.1016/j.ecolind.2010.09.009

Spellerberg, I. F., & Fedor, P. J. (2003). A tribute to Claude Shannon (1916-2001) and a plea for more rigorous use of species richness, species diversity and the 'Shannon-Wiener' Index. *Global Ecology and Biogeography, 12*(3), 177-179. doi: 10.1046/j.1466-822X.2003.00015.x

Swan, S., & McNally, R. (2011). High-Biodiversity REDD+: Operationalising Safeguards and Delivering Environmental Co-benefits. *SNV – The Netherlands Development Organisation.*

Swatantran, A., Dubayah, R., Roberts, D., Hofton, M., & Blair, J. B. (2011). Mapping biomass and stress in the Sierra Nevada using lidar and hyperspectral data fusion. *Remote Sensing of Environment, 115*(11), 2917-2930. doi: 10.1016/j.rse.2010.08.027

TEEB. (2010). The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB, UNEP.

Thompson, I., Mackey, B., McNulty, S., & Mosseler, A. (2009). Forest Resilience, Biodiversity, and Climate Change. *A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43, 67 pages.*

Toxopeus, A. G. (1992). Spatial and Temporal Modeling for Sustainable Management of Tropical Rainforest: The Fuelwood Issue in the Cibodas Biosphere Reserve, West Java. *Dept. of Land Resource and Urban Sciences, ITC, Enschede, the Netherlands.*

Toxopeus, A. G., & Bakker, X. (1992). *Modelling the vulnerability of primary forest in the Cibodas biosphere reserve West Java, Indonesia : demonstration package for ILWIS 1.3, phase 2*. Enschede ; Paris: ITC ; UNESCO.

Udovicic, M., Bazdaric, K., Bilic-Zulle, L., & Petrovecki, M. (2007). What we need to know when calculating the coefficient of correlation? *Biochemia Medica, 17*(1), 10-15.

UN-REDD. (2009). Multiple Benefits – Issues and Options for REDD. *UN-REDD Programme*.

UN Global Compact and IUCN. (2012). A framework for corporate action on biodiversity and ecosystem services. *2012 International Union for Conservation of Nature and Natural Resources, UN Global Compact*.

UNEP. (2011). UNEP - Climate Change REDD+ from http://www.unep.org/climatechange/reddplus

UNEP, F. I. (2008). Biodiversity and Ecosystem Services : bloom or bust report. *UNEP FI Biodiversity & Ecosystem Services Work Stream (BESW).*

Utset, A., Lopez, T., & Diaz, M. (2000). A comparison of soil maps, kriging and a combined method for spatially predicting bulk density and field capacity of ferralsols in the Havana-Matanzas Plain. *Geoderma, 96*(3), 199-213. doi: 10.1016/s0016-7061(99)00055-5

Verburg, P. H., Overmars, K. P., & Witte, N. (2004). Accessibility and land-use patterns at the forest fringe in the northeastern part of the Philippines. *Geographical Journal, 170*, 238-255. doi: 10.1111/j.0016-7398.2004.00123.x

Wang, W. F., Lei, X. D., Ma, Z. H., Kneeshaw, D. D., & Peng, C. H. (2011). Positive Relationship between Aboveground Carbon Stocks and Structural Diversity in Spruce-Dominated Forest Stands in New Brunswick, Canada. *Forest Science, 57*(6), 506-515.

Widayati, A., Jones, S., & Carlisle, B. (2010). Accessibility Factors and Conservation Forest Designation Affecting Rattan Cane Harvesting in Lambusango Forest, Buton, Indonesia. *Human Ecology, 38*(6), 731-746. doi: 10.1007/s10745-010-9358-7

Williams, P. (2000). Some properties of parity scores used in site quality assessment. *Biogeography and Conservation Lab, The Natural History Museum, London SW7 5BD, UK.*

Williams, P., Gibbons, D., Margules, C., Rebelo, A., Humphries, C., & Pressey, R. (1996). A comparison of richness hotspots, rarity hotspots, and complementary areas for conserving diversity of British birds. *Conservation Biology, 10*(1), 155-174. doi: 10.1046/j.1523-1739.1996.10010155.x

Willms, W. D., Dormaar, J. F., Adams, B. W., & Douwes, H. E. (2002). Response of the mixed prairie to protection from grazing. *Journal of Range Management, 55*(3), 210-216. doi: 10.2307/4003125

WRI. (2012). The REDD+ Decision in Cancun | World Resources Institute, from http://www.wri.org/stories/2010/12/redd-decision-cancun

Yamamoto, J. K. (2000). An alternative measure of the reliability of ordinary kriging estimates. *Mathematical Geology, 32*(4), 489-509. doi: 10.1023/a:1007577916868

Yue, T. X., Ji, Y. L., Zheng, Q. L., Si, Q. C., Sheng, N. M., Yong, Z. T., & Ge, F. (2005). Considerable effects of diversity indices and spatial scales on conclusions relating to ecological diversity. *Ecological Modelling, 188*(2-4), 418-431. doi: 10.1016/j.ecolmodel.2004.12.019

APPENDICES

Appendix 1: Questionnaire

			Watershed	Kayerkhola	
			CF name		
			Village name		
			Name of Collector		
			GPS coordinates of the house		
Name of respondent:		**Age:**	**Sex:**	**Education Level**	**Occupation:**

No.	**Questions**
1	Please list the name of the NTFPs you collect from the forest (respective CF).
2	For what purpose do you use these NTFPs?
3	How far do you walk/travel to collect these products?
4	Where (what particular place) do you collect these particular NTFPs?
5	Why do you specifically go there to collect this/these particular NTFPs? *(Is it b/se of proximity to your locality or since it is found only there, or what?)*

Appendix 2: List of NTFPs identified in the study area

S.N.	Local Name	English Name	Scientific Name	Use
1	Allo	Himalayan nettle	Girardinia diversifolia	medicine
2	Amala	Emblic myrobalan	Phyllanthus emblica	medicine
3	Argeli	Nepalese paper bush	Edgeworthia gardneri	medicine
4	Asaree	crape myrtle	Lagerstroemia parviflora	fruit/food
5	Bajuri	Asian meadow-rue	Thalictrum foliolosum	medicine
6	Ban Lasun	Himalaya Onion, Jimbur	Allium wallichii	medicine
7	Barra	Bastard myriobilion	Terminalia belerica	medicine
8	Bel	Bael fruit, wood apple	Aegle marmelos	medicine
9	Bhakur	Wild Yam, Deltiod Yam	Dioscorea deltoids	fruit/food
12	Bhorla	Camel's foot climber	Bauhinia vahlii	medicine
13	Bojho	Sweetflag, Calamus	Acorus calamus	medicine
14	Chau	Mushroom	Pleurotus sps.	food
15	Chuiri	Nepali butter fruit	Bassia butyracea	medicine
16	Dalchini	Cinnamon	Cinnamomum zeylanicum	medicine
17	Dhobeni Jara		Mussaenda macrophylla	medicine
18	Dumarai			medicine
19	Dumbiri	Cluster fig	Ficus racemosa L. Moraceae	fruit/food
20	Fodder			Animal feed
21	Gitta	Air potato	Dioscorea bulbifera	fruit/food
22	Ghurjho	Tinospora	Tinospora sinensis	medicine
23	Ginderi		Premna integrifolia	medicine
24	Harchu		Viscum articulatum	medicine
25	Harra	Yellow/black chebulic myriobilion	Terminalia chebula	medicine
26	Jamuni	Black plum	Eugenia formosa Wall. Myrtaceae.	medicine
27	Kaulo		Persea odoratissima	Incense
28	Khirro	Tallow Tree	Sapium insigne	medicine
29	Kurilo	Wild asparagus	Asparagus racemosu	medicine
30	Kusmuro			medicine
31	Kusum	Lac tree	SchlUIchera oleosa	fruit/food
32	Moha	Honey	Apies nepalensis	medicine
33	Pipla	Long piper	Piper longum	medicine
34	Quinete			medicine
35	Seto Jara		Maianthemum fuscum	medicine
36	Sikari		Maianthemum purpureum	medicine
37	Sinkauli		Cinnamomum tamala	spices
38	Sunpati	Fragrant rhododendron	Rhododendron anthopogan	medicine
39	Tejpat	Cinnamon	Cinnamomum tamala	medicine
40	Timur	Prickly ash, Nepal Pepper	Zanthoxylum armatum	medicine
41	Twari	Devil's cotton	Abroma angusta	An. feed / med.

Appendix 3: List of NTFP Places identified in three CF in Kayerkhola watershed

Place No	Place Name	Coordinates	
		X	Y
Dev1	Ajingaredada	84.59658889	27.69579722
Dev2	Amaladada	84.59121389	27.70070556
Dev3	Bhanjang	84.59955833	27.71108889
Dev4	Champati	84.59689722	27.7119
Dev5	Changagaira	84.60086389	27.70373611
Dev6	Chipani Dada	84.59478889	27.70684722
Dev9	Jogeni	84.5973	27.70312222
Dev10	Kabuliate	84.59251667	27.69876667
Dev11	Kaldunga	84.60188056	27.69789167
Dev12	Kalikhola	84.58953889	27.70769444
Dev15	Lamudada	84.59036389	27.70500833
Dev17	Orthurgugeada	84.59458889	27.701275
Dev18	Ratudada	84.59231389	27.71129444
Dev19	Sanodada	84.59549167	27.70973056
Dev21	Thulodada	84.59015	27.70677778
Dev22	Tirtire	84.59203889	27.70215556
Jana1	Bangnasegaira	84.6004	27.71456667
Jana2	Bhojdada	84.59999722	27.71352778
Jana3	Gorbangdada	84.59914167	27.71423889
Jana4	Histrydygaira	84.59879722	27.71988611
Jana5	Jaisedada	84.60133611	27.71429167
Jana6	Jandadagaira	84.60702222	27.71705
Jana7	Joghera	84.60293611	27.71330278
Jana8	Lokhanthapa/dada	84.60048889	27.71219444
Jana10	Nakedada	84.60061944	27.71840833
Jana11	Odanepani	84.60151389	27.71750278
Jana12	Salmoripakha	84.60453611	27.71608611
Jana13	Sisnegaira	84.59931944	27.71905556
Jana14	Suparidada	84.60198056	27.71240833
Nib1	Bhalumani	84.62441944	27.70375833
Nib2	Biraltar	84.60641111	27.71365
Nib3	Bougadada	84.61792222	27.69691944
Nib4	Chartali	84.62127222	27.69948333
Nib6	Dalantar/gaira	84.61082222	27.71475556
Nib7	Dhanedada	84.61084722	27.71293333
Nib8	Hartakola	84.62186111	27.70300278
Nib9	Hiramanidada	84.61896389	27.70037222
Nib10	Kasbangdada	84.61620833	27.70941111
Nib11	Kosaradada	84.62344722	27.70388889
Nib12	Kraktibang	84.61589444	27.69696944

Place No	Place Name	Coordinates	
		X	Y
Nib13	Lonttondada	84.60126111	27.70746111
Nib14	Metrang	84.61475833	27.71022778
Nib15	Moinaghanidada	84.62401944	27.69484444
Nib16	Phurkesal	84.61511667	27.70171111
Nib17	Sailimaili	84.6081	27.70691111
Nib18	Sanomoibang	84.62219722	27.70178611
Nib19	Tarbari	84.613525	27.70403889

Appendix 4: Spatial Spearman's correlation statistics results

Spatial Spearman's correlation statistics of NTFP richness and NTFP uniqueness maps

Layer is NTFP richness
Layer 2 is NTFP uniqueness

Layer	MIN	MAX	MEAN	STD
1	4.2345	13.9484	9.1657	2.5196
2	0.4379	2.9299	1.3505	0.4644
COVARIANCE MATRIX				
Layer	1	2		
1	3.55318	0.43363		
2	0.43363	0.12070		
CORRELATION MATRIX				
Layer	1	2		
1	1.00000	0.66215		
2	0.66215	1.00000		

Spatial Spearman's correlation statistics of tree species diversity & NTFP Richness Maps

Layer is Tree species diversity
Layer 2 is NTFP richness

Layer	MIN	MAX	MEAN	STD
1	1.0000	9.0000	5.9664	2.3792
2	1.0000	9.0000	4.9280	2.4832
COVARIANCE MATRIX				
Layer	1	2		
1	0.84711	-0.63414		
2	-0.63414	3.45727		
CORRELATION MATRIX				
Layer	1	2		
1	1.00000	-0.37055		
2	-0.37055	1.00000		

Layer	MIN	MAX	MEAN	STD
1	243.00	5212.00	2640.92	920.13
2	0.44	1.73	1.22	0.25
COVARIANCE MATRIX				
Layer	1	2		
1	245201.89	-0.18		
2	-0.18	0.03		
CORRELATION MATRIX				
Layer	1	2		
1	1.000	-0.002		
2	-0.002	1.000		

Spatial Spearman's correlation statistics of carbon and tree species diversity maps

Layer 1 is tree species diversity
Layer 2 is carbon stock

Layer	MIN	MAX	MEAN	STD
1	4.24	13.95	9.17	2.52
2	243.00	5212.00	2640.92	920.13
COVARIANCE MATRIX				
Layer	1	2		
1	3.55318	-27.19544		
2	-27.19544	301989.32135		
CORRELATION MATRIX				
Layer	1	2		
1	1.000	-0.026		
2	-0.026	1.000		

Spatial Spearman's correlation statistics of NTFP richness and carbon

Layer 1 is NTFP richness
Layer 2 is carbon stock

Appendix 5: Cross validation reports and LOOCV statistics results

A- Cross validation report summary for 6 interpolation methods and LOOCV statistics for best two methods

	Cross Validation Report				
Type of interpolation	**Average error**	**StdError**	**Stdd_Error**	**RMSE**	**%RMSE**
Ordinary Kriging	0.041994341	0.999779826	0.030716524	0.128869327	10.06701003
Empirical Bayesian Kriging	0.079130439	1.119320172	0.07039532	0.131786468	10.29489116
Kernel Smoothning	0.346454806	1.08473346	0.367262038		
IDW	0.440309982				
Local Polynomial Interpolation	0.754347952	0.754347952			
Spline	-2.532669388				
Leave one out cross validation statistics					
	RMSE	**% RMSE**	**ME**	**MAE**	**%MAE**
Ordinary Kriging	0.567510714	109.6858602	0.010535674	0.567510714	109.6858602
Empirical Bayesian Kriging	0.97556126	187.2129021	0.01270532	0.894264488	171.611827

B – Ordinary Kriging (for NTFP uniqueness map)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1							Ordinary Kriging - NTFP Uniqueness						
2	No.	Measured	Predicted	Error	StdError	Stdd_Error	NormValue	Source_ID	Included	(Predicted -Measured)	(Predicted -Measured)^2	(Predicted -Measured)^2/n	√(Predicted -Measured)2/n
3	1	0.72000000000	0.96567713288	0.24567713288	1.17354113377	0.20934684419	-0.05335781486	0	Yes	0.24567713288	0.060357254	0.001284197	0.035835693
4	2	0.09090900000	0.63379250142	0.54288350142	0.97992541810	0.55400491853	0.21497445346	1	Yes	0.54288350142	0.294722496	0.006270691	0.079187697
5	3	2.45000000000	1.61523029887	-0.83476970113	0.93107584289	-0.89656466496	-0.83404553355	2	Yes	-0.83476970113	0.696840454	0.014826393	0.121763675
6	4	0.90000000000	1.47719792435	0.57719792435	0.97063403144	0.59466071212	0.26990409264	3	Yes	0.57719792435	0.333157444	0.007088456	0.08419297
7	5	3.56044000000	2.16789013207	-1.39254986793	1.06721630415	-1.30484313491	-1.19000975780	4	Yes	-1.39254986793	1.939195135	0.041259471	0.203124275
8	6	0.59259300000	1.54999033258	0.95739733258	1.02222533562	0.93658149453	0.83404553355	5	Yes	0.95739733258	0.916609652	0.019502333	0.139650754
9	7	4.79207900000	1.31038258906	-3.48169641094	1.02823111287	-3.38610295620	-2.30303994872	6	Yes	-3.48169641094	12.1222099	0.25791936	0.507857617
10	8	0.64000000000	0.55249594204	-0.08750405796	1.02492730787	-0.08537586743	-0.32566101565	7	Yes	-0.08750405796	0.00765696	0.000162914	0.012763779
11	9	0.50000000000	1.98465170544	1.48465170544	1.19832141528	1.23894281327	1.44329932786	8	Yes	1.48465170544	2.204190686	0.046897674	0.216558708
36	34	1.25217400000	0.57457744843	-0.67759655157	0.98242484804	-0.68971845828	-0.56148334760	33	Yes	-0.67759655157	0.459137087	0.009768874	0.098837615
37	35	0.19047600000	1.09334359791	0.90286759791	1.02011404759	0.88506535131	0.62508558025	34	Yes	0.90286759791	0.815169899	0.01734404	0.131696774
38	36	1.05263200000	1.49132169426	0.43868969426	0.94185631564	0.46577135703	0.16068635891	35	Yes	0.43868969426	0.192448648	0.004094652	0.063989469
39	37	2.09032300000	1.33965721895	-0.75066578105	0.98034415266	-0.76571658943	-0.69132439673	36	Yes	-0.75066578105	0.563499115	0.011989343	0.109495858
40	38	2.45398800000	0.97336025695	-1.48062774305	1.05130514165	-1.40837106600	-1.30618585223	37	Yes	-1.48062774305	2.192258513	0.046643798	0.215971753
41	39	2.01242200000	0.90816292852	-1.10425907148	0.96310402588	-1.14656261609	-0.99620830835	38	Yes	-1.10425907148	1.219388097	0.025944428	0.16107274
42	40	0.26470600000	1.70868222750	1.44397622750	1.04988428052	1.37536703263	1.61466631379	39	Yes	1.44397622750	2.085067346	0.044363135	0.21062558
43	41	1.53125000000	2.48952466758	0.95827466758	1.05857196054	0.90525226749	0.76074646635	40	Yes	0.95827466758	0.918290339	0.019538092	0.139778726
44	42	0.79032300000	1.66436866561	0.87404566561	1.02683487191	0.85120372274	0.44050076627	41	Yes	0.87404566561	0.763955826	0.016254379	0.127492664
45	43	0.50000000000	1.39185392577	0.89185392577	1.26581151331	0.70457087520	0.32566101565	42	Yes	0.89185392577	0.795403425	0.016923477	0.130090265
46	44	0.69444400000	1.60809523918	0.91365123919	1.03751610763	0.88061402851	0.56148334760	43	Yes	0.91365123918	0.834758587	0.017760821	0.13326973
47	45	0.52941200000	1.39172553173	0.86231353173	1.16245618265	0.74180304135	0.38244994656	44	Yes	0.86231353173	0.743584627	0.01582095	0.125781356
48	46	1.32967000000	1.38348469407	0.05381469407	0.93284978515	0.05768848846	-0.21497445346	45	Yes	0.05381469407	0.002896021	6.16175E-05	0.00784968
49	47	2.09032300000	1.16231790953	-0.92800509047	1.07648771640	-0.86206751487	-0.76074646635	46	Yes	-0.92800509047	0.861193448	0.018323265	0.135363455
50	**Sum**	**60.16541500000**	**62.13914903199**										
51			**Averages**	**0.04199434111**	**0.99977982635**	**0.03071652400**	**0.00000000000**					**RMSE**	**0.128869327**
52												**% RMSE**	**10.06701003**
53		row 12 to 35 hidden for display purpose											
54													

C – EBK (for NTFP uniqueness map)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1								EBK Cross Validation Results - NTFP Uniqueness					
2	No.	Measured	Predicted	Error	StdError	Stdd_Error	NormValue	Source_ID	Included	(Predicted -Measured)	(Predicted -Measured)^2	(Predicted -Measured)^2/n	√(Predicted -Measured)2/n
3	1	0.72000000000	1.21468647875	0.49468647875	1.12380851039	0.44018751787	0.16068635891	0	Yes	0.49468647875	0.244714712	0.005206696	0.072157439
4	2	0.09090900000	0.55773997088	0.46683097088	1.11846993483	0.41738356691	0.10686808981	1	Yes	0.46683097088	0.217931155	0.004636833	0.068094296
5	3	2.45000000000	1.80618866977	-0.64381133023	1.11800501899	-0.57585728087	-0.62508558025	2	Yes	-0.64381133023	0.414493029	0.008819001	0.093909534
6	4	0.90000000000	1.73145349623	0.83145349623	1.11946768987	0.74272219177	0.56148334760	3	Yes	0.83145349623	0.691314916	0.014708828	0.121279957
7	5	3.56044000000	1.51227040165	-2.04816959835	1.12147935451	-1.82631056927	-1.61466631379	4	Yes	-2.04816959835	4.194998704	0.089255292	0.298756241
8	6	0.59259300000	1.59866113722	1.00606813722	1.11993099138	0.89833047301	0.83404553355	5	Yes	1.00606813722	1.012173097	0.021535598	0.14675012
9	7	4.79207900000	1.24790284446	-3.54417615554	1.11977602024	-3.16507595403	-2.30303994872	6	Yes	-3.54417615554	12.56118462	0.267259247	0.516971225
10	8	0.64000000000	1.20826382155	0.56826382155	1.12108238360	0.50688854795	0.26990409264	7	Yes	0.56826382155	0.322923771	0.006870719	0.082889797
11	9	0.50000000000	1.97032471694	1.47032471694	1.12540211467	1.30648831896	1.85336692201	8	Yes	1.47032471694	2.161854773	0.04599691	0.214468902
36	34	1.25217400000	0.74130100075	-0.51087299925	1.11872223606	-0.45665758915	-0.50007642153	33	Yes	-0.51087299925	0.260991221	0.005553005	0.074518486
37	35	0.19047600000	1.14759917853	0.95712317854	1.11925368948	0.85514409068	0.69132439673	34	Yes	0.95712317853	0.916084779	0.019491166	0.139610764
38	36	1.05263200000	1.51320446253	0.46057246253	1.11707768179	0.41230119448	0.05335781486	35	Yes	0.46057246253	0.212126993	0.00451334	0.067181398
39	37	2.09032300000	1.36668614098	-0.72363685902	1.11867009163	-0.64687244652	-0.76074646635	36	Yes	-0.72363685902	0.523650304	0.011141496	0.105553284
40	38	2.45398800000	1.00191889762	-1.45206910238	1.12106293727	-1.29526100105	-1.30618585223	37	Yes	-1.45206910238	2.108504678	0.044861802	0.211806047
41	39	2.01242200000	1.30729038806	-0.70513161194	1.11848470174	-0.63043473982	-0.69132439673	38	Yes	-0.70513161194	0.49721059	0.010578949	0.102854017
42	40	0.26470600000	1.72707932094	1.46237332094	1.12103406551	1.30448606865	1.61466631379	39	Yes	1.46237332094	2.13853573	0.04550076	0.213309072
43	41	1.53125000000	3.17023791277	1.63898791277	1.12073089829	1.46242770256	2.30303994872	40	Yes	1.63898791277	2.686281378	0.057154923	0.239070958
44	42	0.79032300000	1.31847034303	0.52814734303	1.12092046524	0.47117289710	0.21497445346	41	Yes	0.52814734303	0.278939616	0.005934885	0.077038208
45	43	0.50000000000	1.48769080054	0.98769080054	1.12642959537	0.87683314128	0.76074646635	42	Yes	0.98769080054	0.975533117	0.020756024	0.14406951
46	44	0.69444400000	1.64234005257	0.94789605257	1.12078866427	0.84574022096	0.62508558025	43	Yes	0.94789605257	0.898506926	0.019117169	0.13826485
47	45	0.52941200000	1.10377550709	0.57436350709	1.12322344513	0.51135284754	0.32566101565	44	Yes	0.57436350709	0.329893438	0.007019009	0.083779528
48	46	1.32967000000	1.45708045861	0.12741045861	1.11691052344	0.11407400677	-0.16068635891	45	Yes	0.12741045861	0.016233425	0.000345392	0.018584725
49	47	2.09032300000	1.30529126007	-0.78503173993	1.12093418804	-0.70033704771	-0.83404553355	46	Yes	-0.78503173993	0.616274833	0.01311223	0.114508648
50	Sum	60.165415	63.88455										
51			Averages	0.07913043934	1.11932017162	0.07039531965	0.00000000000					RMSE	0.131786468
52												% RMSE	10.29489116
53		sheet row 12 to 35 hidden for display purpose											

D – Kernel smoothening (for NTFP uniqueness map)

	A	B	C	D	E	F	G	H	I
1				Kernel Smoothning - NTFP uniqueness					
2	**Measured**	**Weight**	**Predicted**	**Error**	**StdError**	**Stdd_Error**	**NormValue**	**Source_ID**	**Included**
3	0.72000000000	1.00000000000	0.59155193847	-0.12844806153	1.28495090016	-0.09996340056	-0.32566101565	0	Yes
4	0.09090900000	1.00000000000	0.33693344971	0.24602444971	1.23615496321	0.19902395495	-0.21497445346	1	Yes
5	2.45000000000	1.00000000000	1.90828214594	-0.54171785406	0.98217837984	-0.55154732092	-0.62508558025	2	Yes
6	0.90000000000	1.00000000000	1.76285788705	0.86285788705	0.99623854692	0.86611574078	0.16068635891	3	Yes
7	3.56044000000	1.00000000000	3.24213654572	-0.31830345428	1.00403693895	-0.31702364916	-0.44050076627	4	Yes
8	0.59259300000	1.00000000000	2.71610709182	2.12351409182	0.97918086448	2.16866379731	1.85336692201	5	Yes
9	4.79207900000	1.00000000000	2.35543250168	-2.43664649832	1.03983405587	-2.34330322667	-2.30303994872	6	Yes
10	0.64000000000	1.00000000000	-0.28809244883	-0.92809244883	1.50461149691	-0.61683195346	-0.76074646635	7	Yes
11	0.50000000000	1.00000000000	2.06267300717	1.56267300717	1.10814063624	1.41017570881	1.08799854348	8	Yes
12	3.12195100000	1.00000000000	1.17916757139	-1.94278342861	1.12910320703	-1.72064291068	-1.85336692201	9	Yes
37	0.19047600000	1.00000000000	1.16051229872	0.97003629872	1.11103387746	0.87309335782	0.21497445346	34	Yes
38	1.05263200000	1.00000000000	1.81370643782	0.76107443782	1.01022630723	0.75337024226	0.00000000000	35	Yes
39	2.09032300000	1.00000000000	1.37179264302	-0.71853035698	0.99484531571	-0.72225334496	-0.83404553355	36	Yes
40	2.45398800000	1.00000000000	0.90295178299	-1.55103621701	1.32340302590	-1.17200594729	-1.44329932786	37	Yes
41	2.01242200000	1.00000000000	0.66547157477	-1.34695042523	1.23553623507	-1.09017476542	-1.30618585223	38	Yes
42	0.26470600000	1.00000000000	1.93605019784	1.67134419784	1.10186562898	1.51683123048	1.30618585223	39	Yes
43	1.53125000000	1.00000000000	3.04612505792	1.51487505792	0.97404910784	1.55523478819	1.44329932786	40	Yes
44	0.79032300000	1.00000000000	2.32947065226	1.53914765226	1.07489381473	1.43190669736	1.19000975780	41	Yes
45	0.50000000000	1.00000000000	1.71975644406	1.21975644406	1.11911726075	1.08992729077	0.44050076627	42	Yes
46	0.69444400000	1.00000000000	2.00851185947	1.31406785947	1.01618516864	1.29313819963	0.83404553355	43	Yes
47	0.52941200000	1.00000000000	1.73150612811	1.20209412811	1.02314000821	1.17490677567	0.50007642153	44	Yes
48	1.32967000000	1.00000000000	1.62824628216	0.29857628216	0.99542316725	0.29994909901	-0.16068635891	45	Yes
49	2.09032300000	1.00000000000	0.99816311466	-1.09215988534	1.21684797317	-0.89753190984	-1.08799854348	46	Yes
50									
51			**Averages**	**0.34645480618**	**1.08473346018**	**0.36726203830**	**0.00000000000**		
52									
53	**sheet row 13 to 36 hidden for display purpose**								
54									

E – IDW (for NTFP uniqueness map)

	A	B	C	D	E	F
1			IDW - NTFP uniqueness			
2	**Measured**	**Weight**	**Predicted**	**Error**	**Source_ID**	**Included**
3	0.72000000000	0.72000000000	2.36934232188	1.64934232188	0	Yes
4	0.09090900000	0.09090900000	0.48590272176	0.39499372176	1	Yes
5	2.45000000000	2.45000000000	2.71104242239	0.26104242239	2	Yes
6	0.90000000000	0.90000000000	2.24165811125	1.34165811125	3	Yes
7	3.56044000000	3.56044000000	4.06162690212	0.50118690212	4	Yes
8	0.59259300000	0.59259300000	2.70009158520	2.10749858520	5	Yes
9	4.79207900000	4.79207900000	3.17616609989	-1.61591290011	6	Yes
10	0.64000000000	0.64000000000	0.87319195906	0.23319195906	7	Yes
11	0.50000000000	0.50000000000	3.54498158774	3.04498158774	8	Yes
35	1.67320300000	1.67320300000	1.77863872609	0.10543572609	32	Yes
36	1.25217400000	1.25217400000	0.25417803622	-0.99799596378	33	Yes
37	0.19047600000	0.19047600000	1.25105339909	1.06057739909	34	Yes
38	1.05263200000	1.05263200000	1.46134347082	0.40871147082	35	Yes
39	2.09032300000	2.09032300000	1.64288975332	-0.44743324668	36	Yes
40	2.45398800000	2.45398800000	0.79598523612	-1.65800276388	37	Yes
41	2.01242200000	2.01242200000	0.54203773897	-1.47038426103	38	Yes
42	0.26470600000	0.26470600000	2.06965574239	1.80494974239	39	Yes
43	1.53125000000	1.53125000000	3.19031501177	1.65906501177	40	Yes
44	0.79032300000	0.79032300000	2.45168939160	1.66136639160	41	Yes
45	0.50000000000	0.50000000000	1.78398049810	1.28398049810	42	Yes
46	0.69444400000	0.69444400000	2.07260495433	1.37816095433	43	Yes
47	0.52941200000	0.52941200000	1.66595775385	1.13654575385	44	Yes
48	1.32967000000	1.32967000000	1.14824925231	-0.18142074769	45	Yes
49	2.09032300000	2.09032300000	0.86937023097	-1.22095276903	46	Yes
50						
51			**Average**	**0.44030998175**		
52						
53	**sheet row 12 to 34 hidden for display purpose**					
54						

F – LPI (for NTFP uniqueness map)

	A	B	C	D	E	F
1	Local Polynomial Interpolation = NTFP Uniqueness					
2	**Measured**	**Weight**	**Predicted**	**Error**	**Source_ID**	**Included**
3	0.72000000000	0.72000000000	3.42042105639	2.70042105639	0	Yes
4	0.09090900000	0.09090900000	2.88211852091	2.79120952091	1	Yes
5	2.45000000000	2.45000000000	2.12250308999	-0.32749691001	2	Yes
6	0.90000000000	0.90000000000	2.19301163226	1.29301163226	3	Yes
7	3.56044000000	3.56044000000	2.57442906257	-0.98601093743	4	Yes
8	0.59259300000	0.59259300000	2.67490246631	2.08230946631	5	Yes
9	4.79207900000	4.79207900000	2.04345879817	-2.74862020183	6	Yes
35	1.67320300000	1.67320300000	1.70804278345	0.03483978345	32	Yes
36	1.25217400000	1.25217400000	1.46816698849	0.21599298850	33	Yes
37	0.19047600000	0.19047600000	1.46387289642	1.27339689642	34	Yes
38	1.05263200000	1.05263200000	1.61095102548	0.55831902548	35	Yes
39	2.09032300000	2.09032300000	1.73032185816	-0.36000114184	36	Yes
40	2.45398800000	2.45398800000	1.22940922137	-1.22457877863	37	Yes
41	2.01242200000	2.01242200000	1.25374699099	-0.75867500901	38	Yes
42	0.26470600000	0.26470600000	2.14139193557	1.87668593557	39	Yes
43	1.53125000000	1.53125000000	2.45009724975	0.91884724975	40	Yes
44	0.79032300000	0.79032300000	1.58888282117	0.79855982117	41	Yes
45	0.50000000000	0.50000000000	1.83933321648	1.33933321648	42	Yes
46	0.69444400000	0.69444400000	1.99600148310	1.30155748310	43	Yes
47	0.52941200000	0.52941200000	2.07350453201	1.54409253201	44	Yes
48	1.32967000000	1.32967000000	1.61477948573	0.28510948573	45	Yes
49	2.09032300000	2.09032300000	1.89628657138	-0.19403642862	46	Yes
50						
51			**Average**	**0.75434795220**		
52						
53	**row 10 to 34 hidden for display purpose**					
54						

G – Spline (for NTFP uniqueness map)

Spline - NTFP Uniqueness

	No.	Place	X	Y	EI	No.	Measured	Predicted		(Predicted -Measured)	(Predicted -Measured)^2	(Predicted -Measured)^2/n	$\sqrt{(\text{Predicted -Measured})^2/n}$	% RMSE
3	1	Ajingaredada	84.59658889	27.69579722	0.72	1	0.72	-0.161609	-0.881609	-0.881609	0.777234429	0.777234429	0.881609	122.4456944
4	2	Amaladada	84.59121389	27.70070556	0.090909091	2	0.090909091	0.674686	0.583776909	0.583776909	0.34079548	0.34079548	0.583776909	642.1546
5	3	Bhanjang	84.59955833	27.71108889	2.45	3	2.45	3.51961	1.06961	1.06961	1.144065552	1.144065552	1.06961	43.65755102
6	4	Champati	84.59689722	27.7119	0.9	4	0.9	2.563152	1.663152	1.663152	2.766074575	2.766074575	1.663152	184.7946667
7	5	Changagaira	84.60086389	27.70373611	3.56043956	5	3.56043956	3.466985	-0.09345456	-0.09345456	0.008733755	0.008733755	0.09345456	2.624804012
8	6	Chipani Dada	84.59478889	27.70684722	0.592592593	6	0.592592593	0.645328	0.052735407	0.052735407	0.002781023	0.002781023	0.052735407	8.8991
9	7	Jogeni	84.5973	27.70312222	4.792079208	7	4.792079208	0.953027	-3.839052208	-3.839052208	14.73832186	14.73832186	3.839052208	80.1124531
10	8	Kaldunga	84.59251667	27.69876667	0.64	8	0.64	-0.503788	-1.143788	-1.143788	1.308250989	1.308250989	1.143788	178.716875
11	9	Kalikhola	84.60188056	27.69789167	0.5	9	0.5	1.637488	1.137488	1.137488	1.29387895	1.29387895	1.137488	227.4976
12	10	Kobulete	84.58953889	27.70769444	3.12195122	10	3.12195122	out						
13	34	Dalantar/gaira	84.60939444	27.71363889	1.252173913	34	1.252173913	0.271831	-0.980342913	-0.980342913	0.961072227	0.961072227	0.980342913	78.29127431
14	35	Dhanedada	84.61084722	27.71293333	0.19047619	35	0.19047619	1.080167	0.88969081	0.88969081	0.791549737	0.791549737	0.88969081	467.087675
15	36	Hardakola	84.62186111	27.70300278	1.052631579	36	1.052631579	2.527014	1.474382421	1.474382421	2.173803524	2.173803524	1.474382421	140.06633
16	37	Hiramanidada	84.61896389	27.70037222	2.090322581	37	2.090322581	0.54889	-1.541432581	-1.541432581	2.376014401	2.376014401	1.541432581	73.74137346
17	38	Kasbangdada	84.61620833	27.70941111	2.45398773	38	2.45398773	1.142496	-1.31149173	-1.31149173	1.720010558	1.720010558	1.31149173	53.443288
18	39	Kosaradada	84.62344722	27.70388889	2.01242236	39	2.01242236	0.521959	-1.49046336	-1.49046336	2.221481028	2.221481028	1.49046336	74.06314846
19	40	Kraktibang	84.61589444	27.69696944	0.264705882	40	0.264705882	1.301074	1.036368118	1.036368118	1.074058875	1.074058875	1.036368118	391.5168444
20	41	Lonttondada	84.60126111	27.70746111	1.53125	41	1.53125	3.322576	1.791326	1.791326	3.208848838	3.208848838	1.791326	116.9845551
21	42	Metrang	84.61475833	27.71022778	0.790322581	42	0.790322581	1.666956	0.876633419	0.876633419	0.768486152	0.768486152	0.876633419	110.9209633
22	43	Moinaghanidada	84.62401944	27.69484444	0.5	43	0.5	out						
23	44	Phurkesal	84.61511667	27.70171111	0.694444444	44	0.694444444	1.916338	1.221893556	1.221893556	1.493023861	1.493023861	1.221893556	175.952672
24	45	Sailimaili	84.6081	27.70691111	0.529411765	45	0.529411765	0.244769	-0.284642765	-0.284642765	0.081021503	0.081021503	0.284642765	53.76585556
25	46	Sanomoibang	84.62219722	27.70178611	1.32967033	46	1.32967033	0.055039	-1.27463133	-1.27463133	1.624685027	1.624685027	1.27463133	95.86070331
26	47	Tarbari	84.613525	27.70403889	2.090322581	47	2.090322581	0.601505	-1.488817581	-1.488817581	2.216577788	2.216577788	1.488817581	71.22429784
27														
28						Sun	**34.1501**	**27.995**	**-2.5326694**					
29												RMSE	**1.18758103**	**154.2646511**
30		sheet row 12 to 34 hidden for display purpose												
31														

H – LOOCV – EBK - (for NTFP uniqueness map)

Leave one out Cross validation result - NTFP Uniqueness - EBK

	A	B	C	D	E	G	H	I
2	No.	Place	X	Y	EI	No.	Measured	Predicted
3	1	Ajingaredada	84.59658889	27.69579722	0.72	1	0.72	1.252574
4	2	Amaladada	84.59121389	27.70070556	0.090909091	2	0.090909091	1.429007
5	3	Bhanjang	84.59955833	27.71108889	2.45	3	2.45	1.368073
6	4	Champati	84.59689722	27.7119	0.9	4	0.9	1.37535
7	5	Changagaira	84.60086389	27.70373611	3.56043956	5	3.56043956	1.356171
8	6	Chipani Dada	84.59478889	27.70684722	0.592592593	6	0.592592593	1.562222
9	7	Jogeni	84.5973	27.70312222	4.792079208	7	4.792079208	1.112676
10	8	Kaldunga	84.59251667	27.69876667	0.64	8	0.64	1.38774
11	9	Kalikhola	84.60188056	27.69789167	0.5	9	0.5	1.310983
12	10	Kobulete	84.58953889	27.70769444	3.12195122	10	3.12195122	out
13	11	Lamudada	84.59036389	27.70500833	0.346153846	11	0.346153846	1.229878
14	35	Dhanedada	84.61084722	27.71293333	0.19047619	35	0.19047619	1.394937
15	36	Hardakola	84.62186111	27.70300278	1.052631579	36	1.052631579	1.372055
16	37	Hiramanidada	84.61896389	27.70037222	2.090322581	37	2.090322581	1.327944
17	38	Kasbangdada	84.61620833	27.70941111	2.45398773	38	2.45398773	1.130017
18	39	Kosaradada	84.62344722	27.70388889	2.01242236	39	2.01242236	1.322434
19	40	Kraktibang	84.61589444	27.69696944	0.264705882	40	0.264705882	1.409794
20	41	Lonttondada	84.60126111	27.70746111	1.53125	41	1.53125	1.710729
21	42	Metrang	84.61475833	27.71022778	0.790322581	42	0.790322581	1.164497
22	43	Moinaghanidada	84.62401944	27.69484444	0.5	43	0.5	out
23	44	Phurkesal	84.61511667	27.70171111	0.694444444	44	0.694444444	1.40629
24	45	Sailimaili	84.6081	27.70691111	0.529411765	45	0.529411765	1.655543
25	46	Sanomoibang	84.62219722	27.70178611	1.32967033	46	1.32967033	1.394607
26	47	Tarbari	84.613525	27.70403889	2.090322581	47	2.090322581	1.253549
27								
28						**Sum**	**33.2441**	
29								
30		**sheet row 12 to 34 hidden for display purpose**						
31								

	K	L	M	N	P	Q	R	S
2	(Predicted -Measured)	$(Predicted - Measured)^2$	$(Predicted - Measured)^2/n$	$\sqrt{(Predicted - Measured)^2/n}$	% RMSE	ME	MAE	%MAE
3	0.532574	0.283635065	0.283635065	0.532574	73.96861111	0.532574	0.532574	73.968611
4	1.338097909	1.790506014	1.790506014	1.338097909	1471.9077	1.338097909	1.3380979	1471.9077
5	-1.081927	1.170566033	1.170566033	1.081927	44.16028571	-1.081927	1.081927	44.160286
6	0.47535	0.225957623	0.225957623	0.47535	52.81666667	0.47535	0.47535	52.816667
7	-2.20426856	4.858799887	4.858799887	2.20426856	61.91001204	-2.20426856	2.2042686	61.910012
8	0.969629407	0.940181188	0.940181188	0.969629407	163.6249625	0.969629407	0.9696294	163.62496
9	-3.679403208	13.53800797	13.53800797	3.679403208	76.78093471	-3.679403208	3.6794032	76.780935
10	0.74774	0.559115108	0.559115108	0.74774	116.834375	0.74774	0.74774	116.83438
11	0.810983	0.657693426	0.657693426	0.810983	162.1966	0.810983	0.810983	162.1966
12						0	0	0
13	0.883724154	0.78096838	0.78096838	0.883724154	255.2980889	0.883724154	0.8837242	255.29809
14	1.20446081	1.450725842	1.450725842	1.20446081	632.341925	1.20446081	1.2044608	632.34193
15	0.319423421	0.102031322	0.102031322	0.319423421	30.345225	0.319423421	0.3194234	30.345225
16	-0.762378581	0.5812211	0.5812211	0.762378581	36.47181481	-0.762378581	0.7623786	36.471815
17	-1.32397073	1.752898494	1.752898494	1.32397073	53.95180725	-1.32397073	1.3239707	53.951807
18	-0.68998836	0.476083937	0.476083937	0.68998836	34.28645864	-0.68998836	0.6899884	34.286459
19	1.145088118	1.311226797	1.311226797	1.145088118	432.5888444	1.145088118	1.1450881	432.58884
20	0.179479	0.032212711	0.032212711	0.179479	11.72107755	0.179479	0.179479	11.721078
21	0.374174419	0.140006496	0.140006496	0.374174419	47.34451837	0.374174419	0.3741744	47.344518
22						0	0	0
23	0.711845556	0.506724095	0.506724095	0.711845556	102.50576	0.711845556	0.7118456	102.50576
24	1.126131235	1.268171559	1.268171559	1.126131235	212.7136778	1.126131235	1.1261312	212.71368
25	0.06493667	0.004216771	0.004216771	0.06493667	4.883666942	0.06493667	0.0649367	4.8836669
26	-0.836773581	0.700190025	0.700190025	0.836773581	40.03083488	-0.836773581	0.8367736	40.030835
27								
28	0.013860349							
29			**RMSE**	**0.97556126**	**187.2129021**	**0.01270532**	**0.8943**	**171.61**
30			**% RMSE**	**187.2129021**				
31								

I – LOOCV – Kriging (for NTFP uniqueness map)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1							Leave one out cross validation - NTFP Uniqueness - Kriging										
2												RMSE					
3	No.	Place	X	Y	EI	LOO No.	Measured (Observed)	Predicted	(Predicted -Measured)	(Predicted -Measured)^2	(Predicted -Measured)^2/n	$\sqrt{(\text{Predicted -Measured})^2/n}$		%RMSE	ME	MAE	%MAE
4	1	Ajingaredada	84.59658889	27.69579722	0.72	1	0.72	0.874865	0.154865	0.023983168	0.023983168	0.154865		21.50902778	0.154865	0.154865	21.50903
5	2	Amaladada	84.59121389	27.70070556	0.090909091	2	0.090909091	0.404331	0.313421909	0.098233293	0.098233293	0.313421909		344.7641	0.313422	0.31342191	344.7641
6	3	Bhanjang	84.59955833	27.71108889	2.45	3	2.45	1.802987	-0.647013	0.418625822	0.418625822	0.647013		26.40869388	-0.64701	0.647013	26.40869
7	4	Champati	84.59689722	27.7119	0.9	4	0.9	1.29311	0.39311	0.154535472	0.154535472	0.39311		43.67888889	0.39311	0.39311	43.67889
8	5	Changagaira	84.60086389	27.70373611	3.56043956	5	3.56043956	2.795219	-0.76522056	0.585562506	0.585562506	0.76522056		21.49230586	-0.76522	0.76522056	21.49231
9	6	Chipani Dada	84.59478889	27.70684722	0.592592593	6	0.592592593	0.928501	0.335908407	0.112834458	0.112834458	0.335908407		56.68454375	0.335908	0.33590841	56.68454
10	7	Jogeni	84.5973	27.70312222	4.792079208	7	4.792079208	2.691019	-2.101060208	4.414453997	4.414453997	2.101060208		43.84443822	-2.10106	2.10106021	43.84444
11	8	Kaldunga	84.59251667	27.69876667	0.64	8	0.64	0.553686	-0.086314	0.007450107	0.007450107	0.086314		13.4865625	-0.08631	0.086314	13.48656
12	9	Kalikhola	84.60188056	27.69789167	0.5	9	0.5	1.170067	0.670067	0.448989784	0.448989784	0.670067		134.0134	0.670067	0.670067	134.0134
13	10	Lamudada	84.59036389	27.70500833	0.346153846	10	0.346153846	0.706285	0.360131154	0.129694448	0.129694448	0.360131154		104.0378889	0.360131	0.36013115	104.0379
14	11	Orthurgugedada	84.59458889	27.701275	0.090909091	11	0.090909091	1.192019	1.101109909	1.212443032	1.212443032	1.101109909		1211.2209	1.10111	1.10110991	1211.221
35	32	Dhanedada	84.61084722	27.71293333	0.19047619	32	0.19047619	0.8356	0.64512381	0.41618473	0.41618473	0.64512381		338.69	0.645124	0.64512381	338.69
36	33	Hardakola	84.62186111	27.70300278	1.052631579	33	1.052631579	1.549331	0.496699421	0.246710315	0.246710315	0.496699421		47.186445	0.496699	0.49669942	47.18645
37	34	Hiramanidada	84.61896389	27.70037222	2.090322581	34	2.090322581	1.558783	-0.531539581	0.282534326	0.282534326	0.531539581		25.42859105	-0.53154	0.53153958	25.42859
38	35	Kasbangdada	84.61620833	27.70941111	2.45398773	35	2.45398773	1.600471	-0.85351673	0.728490808	0.728490808	0.85351673		34.78080675	-0.85352	0.85351673	34.78081
39	36	Kosaradada	84.62344722	27.70388889	2.01242236	36	2.01242236	1.550446	-0.46197636	0.213422157	0.213422157	0.46197636		22.95623272	-0.46198	0.46197636	22.95623
40	37	Kraktibang	84.61589444	27.69696944	0.264705882	37	0.264705882	1.149622	0.884916118	0.783076535	0.783076535	0.884916118		334.3016444	0.884916	0.88491612	334.3016
41	38	Lonttondada	84.60126111	27.70746111	1.53125	38	1.53125	2.110636	0.579386	0.335688137	0.335688137	0.579386		37.83745306	0.579386	0.579386	37.83745
42	39	Metrang	84.61475833	27.71022778	0.790322581	39	0.790322581	1.352994	0.562671419	0.316599126	0.316599126	0.562671419		71.19515918	0.562671	0.56267142	71.19516
43	40	Phurkesal	84.61511667	27.70171111	0.694444444	40	0.694444444	1.257849	0.563404556	0.317424693	0.317424693	0.563404556		81.130256	0.563405	0.56340456	81.13026
44	41	Sailimaili	84.6081	27.70691111	0.529411765	41	0.529411765	0.932098	0.402686235	0.162156204	0.162156204	0.402686235		76.06295556	0.402686	0.40268624	76.06296
45	42	Sanomoibang	84.62219722	27.70178611	1.32967033	42	1.32967033	1.517655	0.18798467	0.035338236	0.035338236	0.18798467		14.13769008	0.187985	0.18798467	14.13769
46	43	Tarbari	84.613525	27.70403889	2.090322581	43	2.090322581	1.558955	-0.531367581	0.282351506	0.282351506	0.531367581		25.42036265	-0.53137	0.53136758	25.42036
47						**SUM**	**55.28050001**	**55.734**	**0.010535674**	**0.458406664**	**0.458406664**	**0.567510714**		**109.6858602**	**0.011**	**0.56751**	**109.7**
48																	
49												**RMSE**	**0.568**				
50		**row 10 to 34 hidden for display purpose**										**% RMSE**	**109.7**				
51												**ME**	**0.011**				
52												**MAE**	**0.568**				
53												**%MAE**	**109.7**				

J – LOOCV – Kriging (Tree species diversity)

	H	I	J	K	L	M	N	O	P	Q	R	S	T
1						Leave one out cross validation - Tree species diversity - Kriging							
2	Measured(Observed)	Predicted		(Predicted -Measured)	(Predicted -Measured)^2	(Predicted -Measured)^2/n	$\sqrt{(\text{Predicted -Measured})^2/n}$		%RMSE		ME	MAE	%MAE
3	0.859967281	0.951165		-0.091197719	0.008317024	0.008317024	0.091197719		10.60478939		0.091197719	0.0911977	10.60478939
4	0.815920577	1.01535		-0.199429423	0.039772095	0.039772095	0.199429423		24.44225933		0.199429423	0.1994294	24.44225933
5	0.544283733	1.037987		-0.493703267	0.243742916	0.243742916	0.493703267		90.70696718		0.493703267	0.4937033	90.70696718
6	0.655975732	0.948088		-0.292112268	0.085329577	0.085329577	0.292112268		44.53095645		0.292112268	0.2921123	44.53095645
7	0.598269589	0.95345		-0.355180411	0.126153125	0.126153125	0.355180411		59.36795354		0.355180411	0.3551804	59.36795354
8	1.524707393	1.033992		0.490715393	0.240801597	0.240801597	0.490715393		32.18423386		-0.490715393	0.4907154	32.18423386
9	1.096575434	1.026517		0.070058434	0.004908184	0.004908184	0.070058434		6.388838567		-0.070058434	0.0700584	6.388838567
10	1.156987644	1.021483		0.135504644	0.018361509	0.018361509	0.135504644		11.71184887		-0.135504644	0.1355046	11.71184887
11	0.214559155	1.184164		-0.969604845	0.940133555	0.940133555	0.969604845		451.9056034		0.969604845	0.9696048	451.9056034
95	1.418484	out											
96	1.277034	0.96604		0.310994	0.096717268	0.096717268	0.310994		24.35283634		-0.310994	0.310994	24.35283634
97	1.05492	1.365314		-0.310394	0.096344435	0.096344435	0.310394		29.42346339		0.310394	0.310394	29.42346339
98	1.517152	1.338782		0.17837	0.031815857	0.031815857	0.17837		11.75689713		-0.17837	0.17837	11.75689713
99	0.988154	1.618664		-0.63051	0.39754286	0.39754286	0.63051		63.80685602		0.63051	0.63051	63.80685602
100	2.02623	1.143499		0.882731	0.779214018	0.779214018	0.882731		43.5651925		-0.882731	0.882731	43.5651925
101	1.286873	1.281901		0.004972	2.47208E-05	2.47208E-05	0.004972		0.386362912		-0.004972	0.004972	0.386362912
102	0.271189	1.217301		-0.946112	0.895127917	0.895127917	0.946112		348.8755075		0.946112	0.946112	348.8755075
103	1.390438	1.255399		0.135039	0.018235532	0.018235532	0.135039		9.711975651		-0.135039	0.135039	9.711975651
104	2.083766	0.892523		1.191243	1.419059885	1.419059885	1.191243		57.16779139		-1.191243	1.191243	57.16779139
105	2.101244	1.307598		0.793646	0.629873973	0.629873973	0.793646		37.77029226		-0.793646	0.793646	37.77029226
106	1.420572	1.343129		0.077443	0.005997418	0.005997418	0.077443		5.451536423		-0.077443	0.077443	5.451536423
107	2.245035	1.275472		0.969563	0.940052411	0.940052411	0.969563		43.18698818		-0.969563	0.969563	43.18698818
108	1.386294	1.548836		-0.162542	0.026419902	0.026419902	0.162542		11.72492992		0.162542	0.162542	11.72492992
109													
110	120.080818	115.855731		0.014124716		RMSE	0.468195763	%RMSE	47.48023		-0.01412472	0.4682	47.4802
111								ME	-0.01412				
112	sheet row 12 to 94 hidden for display purpose							MAE	0.468196				
113								%MAE	47.48023				
114													

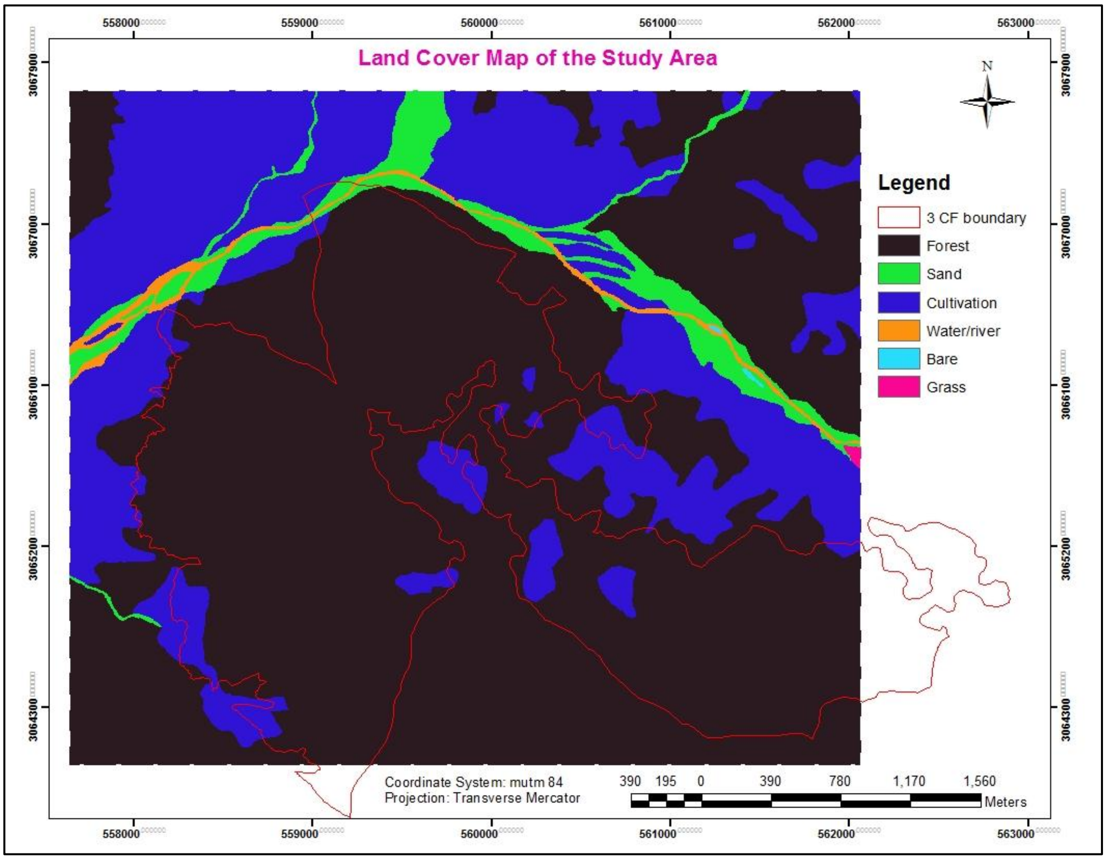
K – LOOCV – Kriging (NTFP richness)

1	Leave one out cross validation - NTFP Richness - Kriging														
2	PlaceNo	PlaceName	X	Y	Richness	Measured (Observed)	Predicted	(Predicted -Measured)	$(\text{Predicted -Measured})^2$	$(\text{Predicted -Measured})^2/n$	$\sqrt{(\text{Predicted -Measured})^2/n}$	%RMSE	ME	MAE	%MAE
3	Dev1	Ajingaredada	84.59658889	27.69579722	6	6	8.5872	2.5872	6.69360384	6.69360384	2.5872	43.12	2.5872	2.5872	43.12
4	Dev2	Amaladada	84.59121389	27.70070556	1	1	7.531755	6.531755	42.66382338	42.66382338	6.531755	653.1755	6.531755	6.531755	653.1755
5	Dev3	Bhanjang	84.59955833	27.71108889	14	14	10.016382	-3.983618	15.86921237	15.86921237	3.983618	28.45441429	-3.983618	3.983618	28.45441429
6	Dev4	Champati	84.59689722	27.7119	6	6	9.455276	3.455276	11.93893224	11.93893224	3.455276	57.58793333	3.455276	3.455276	57.58793333
7	Dev5	Changagaira	84.60086389	27.70373611	18	18	8.717941	-9.282059	86.15661928	86.15661928	9.282059	51.56699444	-9.282059	9.282059	51.56699444
8	Dev6	Chipani Dada	84.59478889	27.70684722	4	4	7.928437	3.928437	15.43261726	15.43261726	3.928437	98.210925	3.928437	3.928437	98.210925
9	Dev9	Jogeni	84.5973	27.70312222	22	22	7.17283	-14.82717	219.8449702	219.8449702	14.82717	67.39622727	-14.82717	14.82717	67.39622727
10	Dev10	Kabuliate	84.59251667	27.69876667	16	16	3.724116	-12.275884	150.697328	150.697328	12.275884	76.724275	-12.275884	12.275884	76.724275
11	Dev11	Kaldunga	84.60188056	27.69789167	4	4	11.244545	7.244545	52.48343226	52.48343226	7.244545	181.113625	7.244545	7.244545	181.113625
35	Nib4	Chartali	84.62127222	27.69948333	16	16	11.242643	-4.757357	22.63244563	22.63244563	4.757357	29.73348125	-4.757357	4.757357	29.73348125
36	Nib6	Dalantar/gaira	84.61082222	27.71475556	12	12	5.154675	-6.845325	46.85847436	46.85847436	6.845325	57.044375	-6.845325	6.845325	57.044375
37	Nib7	Dhanedada	84.61084722	27.71293333	2	2	9.672704	7.672704	58.87038667	58.87038667	7.672704	383.6352	7.672704	7.672704	383.6352
38	Nib8	Hartakola	84.62186111	27.70300278	10	10	12.123584	2.123584	4.509609005	4.509609005	2.123584	21.23584	2.123584	2.123584	21.23584
39	Nib9	Hiramanidada	84.61896389	27.70037222	18	18	11.583995	-6.416005	41.16512016	41.16512016	6.416005	35.64447222	-6.416005	6.416005	35.64447222
40	Nib10	Kasbangdada	84.61620833	27.70941111	20	20	9.096835	-10.903165	118.879007	118.879007	10.903165	54.515825	-10.903165	10.903165	54.515825
41	Nib11	Kosaradada	84.62344722	27.70388889	18	18	10.997319	-7.002681	49.03754119	49.03754119	7.002681	38.90378333	-7.002681	7.002681	38.90378333
42	Nib12	Kraktibang	84.61589444	27.69696944	3	3	12.339678	9.339678	87.22958514	87.22958514	9.339678	311.3226	9.339678	9.339678	311.3226
43	Nib13	Lonttondada	84.60126111	27.70746111	14	14	13.125552	-0.874448	0.764659305	0.764659305	0.874448	6.246057143	-0.874448	0.874448	6.246057143
44	Nib14	Metrang	84.61475833	27.71022778	7	7	13.255174	6.255174	39.12720177	39.12720177	6.255174	89.35962857	6.255174	6.255174	89.35962857
45	Nib15	Moinaghanidada	84.62401944	27.69484444	4	4	out								0
46	Nib16	Phurkesal	84.61511667	27.70171111	5	5	13.807141	8.807141	77.56573259	77.56573259	8.807141	176.14282	8.807141	8.807141	176.14282
47	Nib17	Sailimaili	84.6081	27.70691111	3	3	11.454838	8.454838	71.48428561	71.48428561	8.454838	281.8279333	8.454838	8.454838	281.8279333
48	Nib18	Sanomoibang	84.62219722	27.70178611	11	11	11.884418	0.884418	0.782195199	0.782195199	0.884418	8.040163636	0.884418	0.884418	8.040163636
49	Nib19	Tarbari	84.613525	27.70403889	18	18	10.153291	-7.846709	61.57084213	61.57084213	7.846709	43.59282778	-7.846709	7.846709	
50															
51										**RMSE**	**5.741778953**	**134.9333**	**-0.150482**	**5.741779**	**125.1856748**
52		row 12 to 34 hidden for display purpose								**%RMSE**	**134.9333458**				
53										**ME**	**-0.150481977**				
54										**MAE**	**5.741778953**				
55										**%MAE**	**125.1856748**				
56															

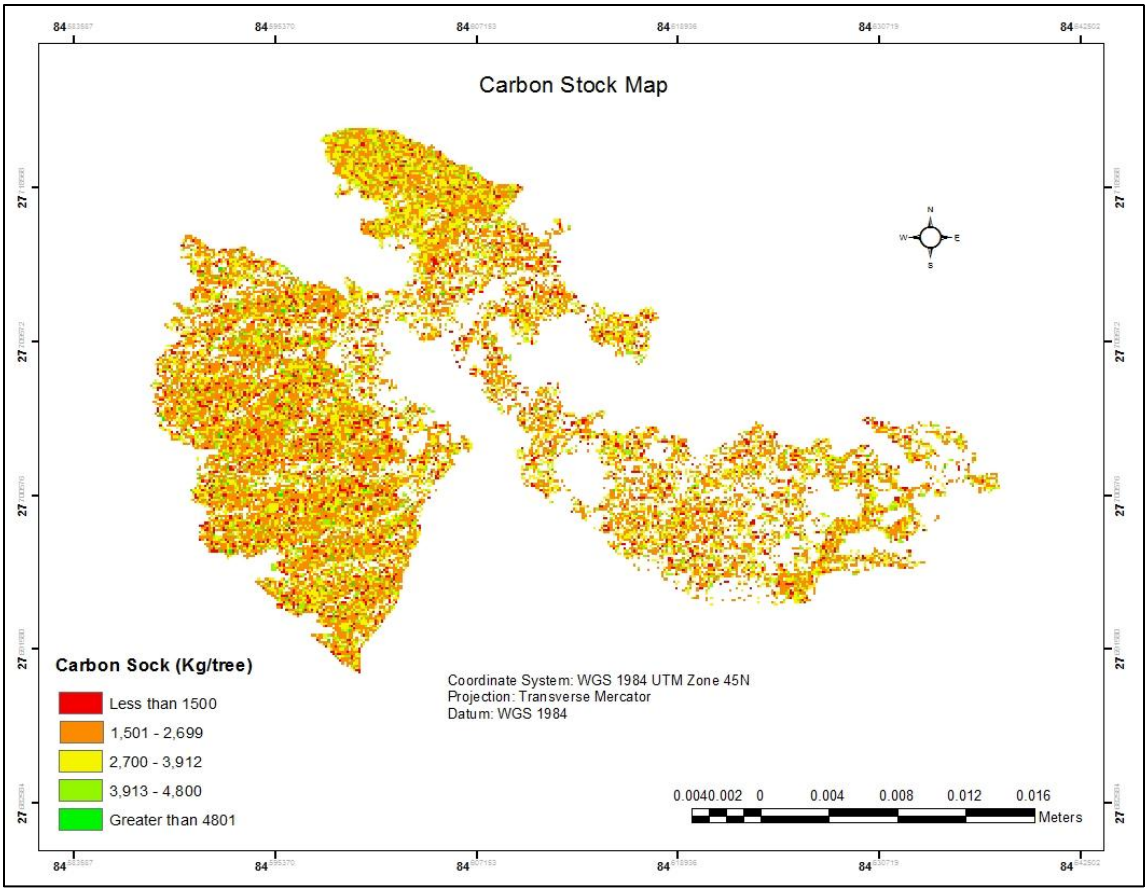
Appendix 6: List of tree species in the study area

No.	Local Name	Scientific Name
1	Kyamunaa	*Cleistocalyx operculatus*
2	Asare	Mussaenda frondosa
3	Asna	Terminalia tomentosa
4	Badkaule	Caseria graveolens
5	Barro	Terminalia belerica
6	Bhalayo	Semicarpous anacardium
7	Bhalukath	Sida rhombifolia
8	Botdhairo	Lagerstromia parviflora
9	Chilaune	Schima wallichii
10	Dumari	Ficus benjamina
11	Dumari	Ficus benjamina
12	Gulay	Elaeagnus latifolia
13	Hara	Terminalia chebula
14	Harchul	Vernacular name
15	Horra	Terminalia chebula
16	Jamun	Syzygium cumini
17	Kaya	Vernacular name
18	Khira	Holarrhena pubescens
19	*Kodam*	Vernacular name
20	Kummi	Careya arborea
21	Kyamuna	Syzygium serasoides
22	Lakigord	Vernacular name
23	Laticat	Cornus oblonga
24	Mancade	Vernacular name
25	Omula	Phyllanthus emblica
26	Ora	Vernacular name
27	Saj	Terminalia alata
28	Sal	Shorea robusta
29	Sandan	OugUInia oojUInensis
30	Sekera	Vernacular name
31	seto siris	Albezia procera
32	Sindure	Mallotus phillippensis
33	Singine	Quercus pachyphylla
34	Tatare	Dillenia pentagyna
35	Tiyiri	Vernacular name
36	Totele	Oroxylon indicum

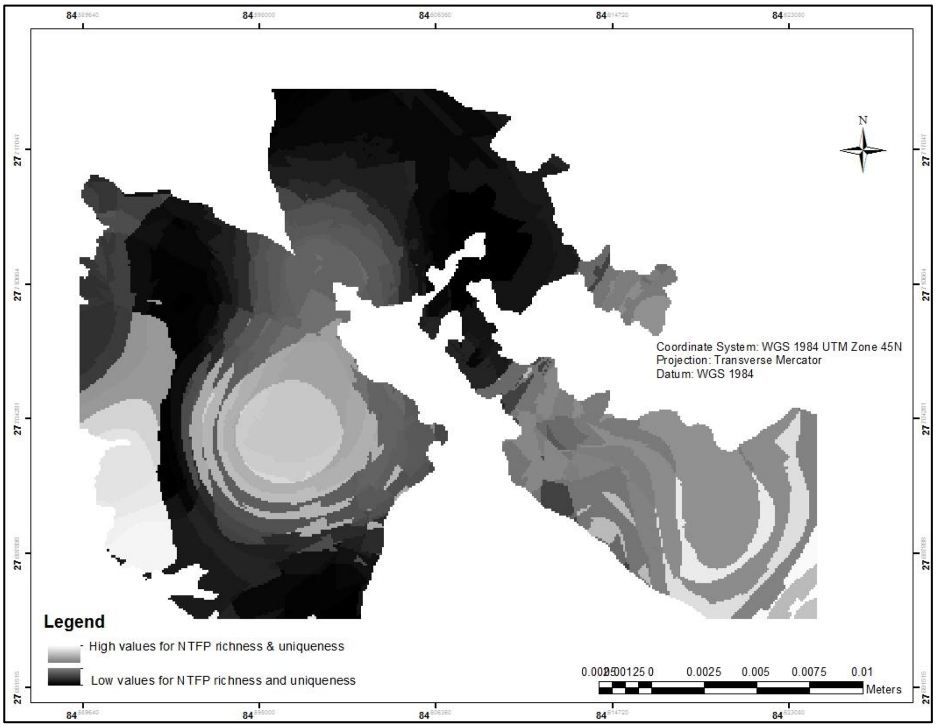
Appendix 7: Land cover map of the study area



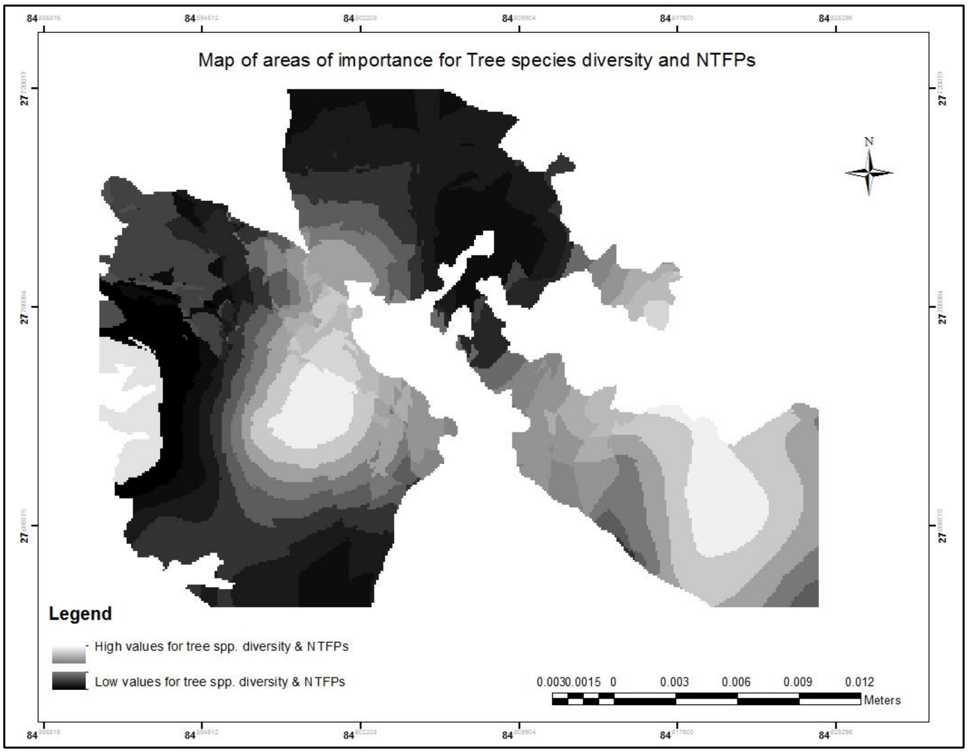
Appendix 8: Carbon stock map of the study area



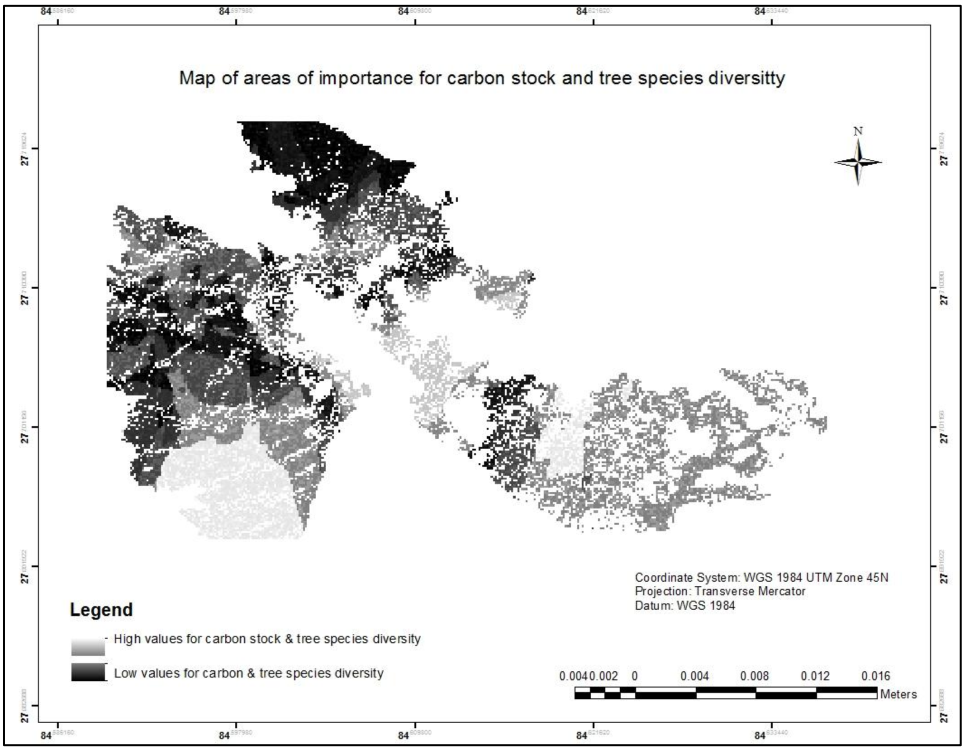
Appendix 9: Maps of areas of importance



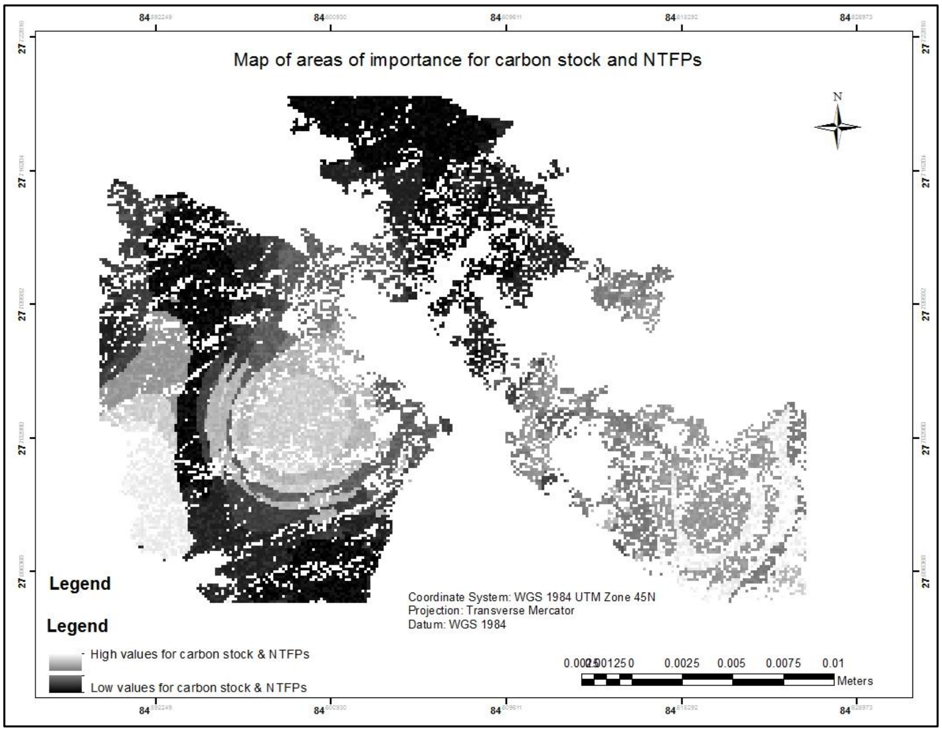
A) Map of area of importance for NTFP richness and NTFP uniqueness



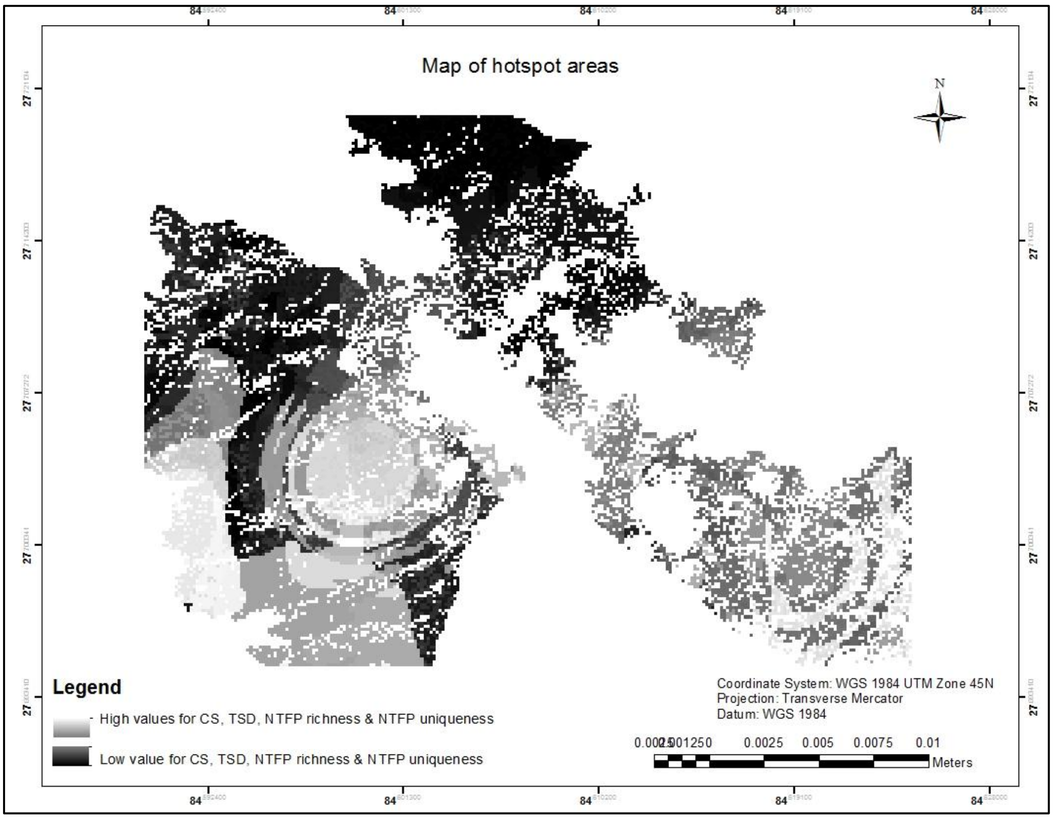
B) Map of area of importance for tree species diversity and NTFPs



C) Map of areas of importance for carbon stock and tree species diversity



D) Map of areas of importance for carbon stock and NTFPs



E) Map of hotspot areas based on carbon, tree species diversity and NTFPs

Appendix 10: The excel data sheet with which the UI was derived

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	NTFPs	Chipani Dada	Champati	Thulodada	Bhanjang	Changagaira	Jogeni	Kobulete	Ratudada	Ajingaredada	Kaldunga	Sanodada	Lamudada	Orthurgugeda	Amaladada	Tirtire	Kalikhola	Sum/Total (Pe	Sum/Total (Pr		No. of Places/
2	Asaree						1											1	1		0.04545455
3	Bhakur															1		1	1		0.50000000
4	Dhobeni Jara					1												1	1		0.05555556
5	Twari						1											1	1		0.04545455
6	Jamuni					1												1	1		0.05555556
7	Kusum						2											2	1		0.04545455
8	Quinete					1		1										2	2		0.05882353
9	Fodder					1												1	1		0.05555556
10	Timur		1				1	1										3	3		0.06818182
11	Ghitta/Rhitta				2		6	4										12	3		0.05769231
12	Bel				7	4	2	6	2									21	5		0.06410256
13	Bojho			2	1	2		1										6	4		0.05128205
14	Kaulo		1	1	1	1	5											9	5		0.07352941
15	Pipla	1			1		2		1		1							6	5		0.09615385
16	Argeli	1		4		2	5	4		2			2					20	7		0.09090909
17	Chuiri	1	3	1	2	2	7	2										18	7		0.07954545
18	Kurilo	1	2			3	2	9	1	2		1						21	8		0.09638554
19	Barra			1	2	3	10	2	1	1		2						22	8		0.08421053
20	Chau		1	2	1	3	5	3										15	6		0.07142857
21	Amala		1		1	4	8	2	1	2	1		1	2	1			24	11		0.11111111
22	Harra				3	2	10	3	1			2	1			1		23	8		0.09302326
23	Moha			1	2	2	9		2	1	1							18	7		0.12068966
24	Ban Lasun			1	1	1	3	1		1								8	6		0.07142857
25	Allo/Sisnu				1		4		1									6	3		0.06818182
26	Harchu					1	1											2	2		0.05000000
27	Dalchini				1	1												2	2		0.06250000
28	Tejpat							4			1							5	2		0.10000000
29	Dumarai						3											3	1		0.04545455
30	Kusmuro						1										1	1	2		0.08695652
31	Sikari						1											1	1		0.04545455
32	Sunpati							1										1	1		0.06250000
33	Dumbiri							1										1	1		0.06250000
34	No. Of People	4	9	13	26	35	89	45	10	9	4	5	4	2	1	2	1				
35	No. Of NTFPs (n)	4	6	8	14	18	22	16	8	6	4	3	3	1	1	2	1				
36																					
37	No of Products/No of Places	0.148148148	0.15	0.16	0.175	0.197802198	0.21782178	0.195121951	0.145454545	0.12	0.16	0.13	0.115384615	0.090909091	0.090909091	0.222222222	0.5				
38	(No of Products/No of Places)*n	0.592592593	0.9	1.28	2.45	3.56043956	4.79207921	3.12195122	1.163636364	0.72	0.64	0.38	0.346153846	0.090909091	0.090909091	0.444444444	0.5				
39																					