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Costs and Benefits of Reducing Deforestation and Forest Degradation in Nepal

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Costs and Benefits of Reducing Deforestation and Forest Degradation in Nepal

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Foreword (MoFSC)

This study, supported by UN Environment under the UN-REDD Technical Assistance was commissioned at a time when the Government of Nepal is preparing for REDD readiness phase. By the end of 2016, Nepal will be in a position to complete its Emission Reduction Project Document. Nepal has also ratified the Paris Agreement under the United Nations Framework Convention on Climate Change and has submitted its Nationally Determined Contribution (NDC) for emission reductions. At this juncture, we are developing and customizing strategies and actions for climate mitigation measure.

Climate change is one of the greatest threats in our contemporary world, and governments around the world cannot predict what impact it will have on future economy. In this context, this study is important for the Nepali government, as it estimates and indicates the costs that will be required for reducing deforestation and forest degradation in Nepal.

The findings and cost estimates of this study for implementing REDD+ in Nepal provide some valuable insights for planning REDD+ interventions. For instance, the annual costs of reducing deforestation in Nepal is between USD 654/ha to USD 3,663/ha, and the associated opportunity cost of carbon sequestration ranges from USD 1.11 to USD 3.56 per tCO2. This figure will be useful when negotiations begin for developing a carbon purchase agreement and for estimating the financial contribution of the forestry sector to the national GDP.

I would like to thank the REDD Implementation Centre for commissioning this study and SANDEE and ICIMOD for designing and undertaking the research jointly. This study has been widely reviewed by experts working on REDD+ associated with different institutions including the Ministry of Forests and Soil Conservation, UN Environment, ICIMOD and the wider SANDEE network. I would like to extend my sincere gratitude to all the researchers, officials, experts, and reviewers who have contributed to this study.

Krishna Chandra Poudel, PhD
Secretary
Ministry of Forests and Soil Conservation

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Acronyms and Abbreviations

AAH	Annual Allowable Harvest
AGB	Above Ground Biomass
CBS	Central Bureau of Statistics
CF	Community forest
CFM	Collaborative Forest Management
C	Carbon
CFT	Cubic feet
CFUG	Community forest user group
CO_2	Carbon dioxide
CPA	Crown Projection Area
DBH	Diameter at Breast Height
DFO	District Forest Office
DFRS	Department of Forest Research and Survey
DoF	Department of Forest
ER-PIN	Emissions Reduction Program Idea Note
FGD	Focus Group Discussion
FREL	Forest Reference Emission Level
FUC	Forest Users Committee
GDP	Gross Domestic Product
GEOBIA	Geographic Object-Based Image Analysis
GoN	Government of Nepal
Ha	Hectare
ICIMOD	International Centre for Integrated Mountain Development
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
MoFSC	Ministry of Forest and Soil Conservation
NGO	Non-government organization
NPR	Nepalese Rupees
NRB	Non-Renewable Biomass
NTFP	Non timber forest products
PA	Protected areas
PF	Protected forest
REDD	Reducing emissions from deforestation and forest degradation
REDD+	Reducing emissions from deforestation and forest degradation and the role of sustainable management of forests, conservation and enhancement of forest carbon stocks
REDD-IC	REDD Implementation Center
RPP	Readiness Preparation Proposal
SANDEE	South Asian Network for Development and Environment Economics
SNA	System of National Accounts
UN	United Nations
UN-REDD	United Nations Collaborative Initiative on Reducing Emissions from Deforestation and Forest Degradation (REDD) in Developing Countries
USD	United States Dollar
t	tonne

Highlights

- The purpose of this study was to estimate the benefits and costs of reducing deforestation and forest degradation in different landscapes and management regimes in Nepal, and to provide associated opportunity costs of carbon that can be used as inputs for planning the implementation of REDD+ in Nepal.
- The annual cost of reducing deforestation in Nepal is between USD 654/ha and USD 3,663/ha, and the associated opportunity cost of carbon sequestration ranges from USD 1.11 to USD 3.56 per tCO_2.
- Certain forest management regimes, such as collaborative forest management and community forestry in the Terai, follow an intensive forest management approach that emphasizes timber production. This approach falls under the framework of scientific forest management. Regimes that follow this approach involve a far lower cost of reducing deforestation compared to other forest management regimes.
- The cost of reducing deforestation in a degraded area is less than the cost of reducing deforestation in a forest area in an average condition (both degraded and non-degraded). The cost is between USD 557/ha and USD 2,984/ha. But the opportunity cost of carbon sequestration, which is between USD 1.30/tCO_2 and USD 3.64/t CO_2, is higher in a degraded area.
- Between 2002 and 2012 the community forests of the Siwaliks and the mid-hills did not undergo degradation. The annual accumulation in the two areas was 5.5 and 4.6 tCO_2/ha respectively. The forests in the Terai, which are under community and collaborative forest management, did undergo degradation, but the introduction of scientific forest management is expected to reverse the process.
- The opportunity cost of carbon sequestration through reduction of forest degradation ranges from USD 0.72 to USD 7.09 per tCO_2.
- The findings can be used by the REDD Implementation Center (REDD-IC), government agencies and non-state actors to develop strategies for implementing REDD+ in different regions.

Executive Summary

In 2010, forests accounted for 40 percent (5.96 million ha) and other types of woodland made up 4 percent (0.65 million ha) of the land area of Nepal (DFRS 2015c). Of the total forest area, 38 percent was in the mid-hills, 32 percent in the high mountains, 23 percent in the Siwaliks, and 7 percent in the Terai. The Terai comprises the plains of Nepal and the Siwaliks are a low range of hills between the Terai and the mid-hills. The Terai and the Siwaliks have witnessed steady deforestation with the gradual conversion of forest to agricultural land and the growth of infrastructure development. In the mid-hills and high mountains, however, forest cover has been increasing since 1995 (DFRS, 2014a, 2014b, 2015a, 2015b). The annual deforestation rate is 0.44 percent (1,648 ha/yr.) in the Terai and 0.18 percent (2,537 ha/yr.) in the Siwaliks. The average carbon stock in Nepal's forests is 177 tC/ha, with the lowest amount (117 tC/ha) in the Siwaliks and the highest amount (272 tC/ha) in the mountains (DFRS, 2014a, 2015a, 2015c).

Rationale of Benefit-Cost Analysis

The government of Nepal has initiated a national REDD+ process to counter deforestation. The process seeks to highlight carbon and non-carbon benefits that forests provide to Nepali society. The rationale of REDD+ is to provide developing countries with a positive incentive to reduce deforestation and forest degradation and to stimulate conservation, sustainable use of forests and enhancement of forest carbon stocks. The incentive entails rewarding the countries for verified emission reductions or removals compared against a Forest Reference Level (FRL) or Forest Reference Emission Level (FREL) that complies with REDD+ safeguards.

Besides providing a positive incentive through results-based finance for REDD+, there is an urgent need to establish a solid domestic economic rationale for reducing deforestation and forest degradation and for rehabilitating degraded areas. This is where economic valuation of forests comes in. Accounting for other ecosystem services in addition to direct benefits can help address the failure of our economic system to accurately account for natural assets. The study will be useful in assessing the economic implications of conserving carbon through reduced deforestation and forest degradation at the landscape/watershed level.

In this context the government of Nepal requested support from the UN-REDD Programme to assess the benefits and costs of reducing deforestation and forest degradation in different landscapes and management regimes in Nepal, and to provide the opportunity costs of reducing carbon emissions that can be used as inputs for developing REDD+ policy and measure. This information can be used to assess management strategies for REDD+ programmes and their implementation in the different physiographic regions of Nepal.

Analysis

In Nepal, forests are divided into national and private forests based on ownership. National forests fall under different management regimes. The study was carried out in four types of forest management regimes:
a) community forests
b) protected areas
c) protected forests, and
d) collaboratively managed forests.

These four types of regimes cover 29 percent, 17 percent, 2 percent and 1 percent of the total forest area respectively. Except for Protected Areas, which are entirely government managed, these regimes involve local community management to varying degrees. The remaining 50 percent of the forest area comprises either private forests or other government-managed forests. The study covered three physiographic regions of Nepal – the Terai, the Siwaliks and the mid-hills. The findings were based on extensive primary surveys of 1,115 households, ground-level forest inventories, satellite image analysis, and secondary data.

Main Results

The annual benefits of reducing deforestation (retaining forest) equal the difference between the benefits derived from the forest and the cost of forest management. Benefits from the forest include direct benefits such as forest products and other ecosystem services such as hydrological services, biodiversity values, and tourism. It ranges from USD 42/ha to USD 1,131/ha across the selected regimes (Table 1, Column D). The highest values are derived from the regime with high timber harvests (collaboratively managed forests in the Terai) and the lowest from the protected area. The annual cost of reducing deforestation equals the opportunity cost of lost timber and agricultural profits. This ranges from USD 1,516/ha to 3,772/ha (Table 1, Column G). The net annual cost of reducing deforestation is the cost less the benefit (the negative of the net annual benefits of reducing deforestation), and this ranges from USD 654/ha to USD 3,663/ha (Table 1, Column H). This mainly depends on the forest management strategy and forest stock. For instance, the collaborative forest management regime, which adopts a production-oriented management approach called scientific forest management, generates the highest annual benefits and lowest cost of reducing deforestation. The cost of carbon sequestration by reducing deforestation ranges from USD 1.11 to USD 3.56 per tCO_2 (Table 1, last column). These estimates are consistent with the findings of 29 empirical studies that suggest that the cost of REDD+ is between USD 0.84 to 4.18 per tCO_2 (Boucher, 2008; Overmars et al., 2014).

Table 1: **Costs and benefits of reducing deforestation NPR/ha/year (USD/ha/year in parentheses)**

Regime	Benefits of reducing deforestation (Benefits of retaining forest)				Costs of reducing deforestation (Benefits of deforestation)			Total net benefits of reducing deforestation per ha (H= D-G)	Opp. cost of carbon (NPR/ tCO_2) (USD/ tCO_2)
	Annual direct benefits (A)	Annual other ecosystem service benefits (B)	Annual forest management cost (C)	Benefits of reducing deforestation (D= A+B-C)	Net annual flow of clear cutting (E)	Net annual benefits from agriculture (F)	Costs of reducing deforestation (G= E+F)		
CF (Mid-hills)	23,788 (243)	2,331 (23.78)	3,093 (31.56)	23,026 (235)	124,325 (1,269)	24,268 (236)	148,593 (1,516)	-125,567 (-1,281)	252 (2.57)
CF (Siwaliks)	24,962 (255)	2,331 (23.78)	2,574 (26.26)	24,719 (252)	296,445 (3,025)	11,132 (108)	307,577 (3,139)	-282,858 (-2,886)	258 (2.63)
CF (Terai)	52,830 (513)	2,450 (23.78)	848 (8.23)	54,432 (528)	145,751 (1,415)	30,494 (296)	176,245 (1,711)	-121,813 (-1,183)	186 (1.81)
Collaboratively managed forest	114,800 (1,115)	2,450 (23.78)	779 (7.56)	116,471 (1,131)	151,775 (1,473)	32,086 (312)	183,861 (1,785)	-67,390 (-654)	115 (1.11)
Protected forest	9,476 (92)	2,450 (23.78)	698 (6.78)	11,228 (109)	352,250 (3,420)	36,243 (352)	388,493 (3,772)	-377,265 (-3,663)	366 (3.56)
Protected area	-	4,831 (49.29)	734 (7.13)	4,097 (42)	204,249 (1,983)	32,086 (312)	236,335 (2,295)	-232,238 (-2,255)	230 (2.23)

Assuming that a forest with less than 40 percent crown cover is a degraded area, a sensitivity analysis shows that the net cost of reducing deforestation is lower in a degraded area than in a forest area in an average condition (both degraded and non-degraded), but the opportunity cost of carbon sequestration is higher in a degraded area than in a forest in an average condition. The annual net cost of reducing deforestation in degraded areas is between USD 557/ha and USD 2,984/ha and the cost of carbon sequestration by reducing deforestation is between USD 1.30/tCO_2 and USD 3.64/t CO_2, which is up to 33 percent higher than the cost of carbon sequestration in a forest area in an average condition. This estimate is less than half of the CO_2-equivalent cost of the biodigestion plant in Nepal, which is USD 7 per tCO_2 (Dhakal et al., 2016).

The REDD Readiness Preparation Proposal has identified heavy reliance on forests for subsistence as a major driver of forest degradation. The cost of reducing forest degradation is equivalent to the quantity of forest products harvested in excess of the rate of biomass growth. Forest users of the community forests of the mid-hills and the Siwaliks as well as of the protected areas have reduced their annual consumption of forest products compared to previous years. They harvest less than the annual rate of biomass growth, resulting in net growth of forest biomass.

In the community forests of the Terai and collaboratively managed forests, the quantity of harvest exceeds the rate of biomass growth, leading to forest degradation. However, forest degradation in these areas is expected to be temporary, because once the mature trees are harvested (under the scientific forest management programme), these forest plots will be protected for natural regeneration. The value of change in annual harvest of forest products is between USD 1.34 and USD 39.15 per ha. Annual change in removed biomass stock in carbon equivalent unit is between 0.43 and 11.83 tCO_2 per ha. The cost of carbon sequestration by reducing forest degradation ranges from USD 0.72 to USD 1.19 per tCO_2.

Policy Options

This study makes the following policy recommendations for reducing deforestation and forest degradation in Nepal:

- *Expansion of the scientific forest management approach:* The rate of deforestation is higher in the Terai, where forest is dominated by mature premium-value Sal trees (*Shorea robusta*) and the forestland can be easily converted to agricultural land. This study recommends expanding the scientific forest management approach in the Terai. The approach focuses on the production of timber and fuelwood based on silvicultural prescription. It helps increase the annual benefits (timber and fuelwood) derived from forest management while reducing the benefits derived from deforestation. In this way it helps increase the supply of premium Sal timber in the market and keeps its price low, thus reducing pressure on the remaining forest.
- *Degraded forests should be prioritized for forest management and development:* As the incentive for deforestation is high in degraded forests, these areas should be prioritized for restoration to reduce further risks of deforestation.
- *Remaining government-managed forest patches in the Terai and the Siwaliks should be managed by local communities:* In view of the increasing rate of deforestation in the Terai and the Siwaliks, and the positive outcomes of community-based management, this study recommends that government-managed forests should transition into some form of community-based management regime.
- *Accounting for forest benefits in Nepal's System of National Accounts (SNA):* Forests provide economic benefits besides timber. Aside from carbon storage and potential payments for REDD+, forests provide ecosystem services such as non-timber forest products for commercial use, prevention of soil erosion, and water regulation for agriculture and other productive sectors. These are tangible economic benefits that can be accounted for directly in the System of National Accounts (SNA). Forest-derived income in other sectors such as agriculture and tourism can be included in a satellite account. This study can help pave the way towards including forest ecosystem services in Nepal's SNA.

Background

Introduction

Agriculture, forestry and other types of land use make up the second largest anthropogenic source of CO_2 emission after fossil fuel combustion (van der Werf et al., 2009; IPCC, 2014). Although forests contribute substantially in minimizing the impacts of global environmental change, their contribution to national income is insufficiently reflected in Gross Domestic Product (GDP) under the System of National Accounts (SNA). Government policy doesn't adequately capture the value of forests. This is mainly because the value of forest resources is often underestimated. For instance, official estimates show that Nepal's forestry sector contributed 3.5 percent of the GDP in 2011-12; this figure would have been closer to 10.5% had there been accounting for forest benefits derived by other sectors such as agriculture and tourism (RIC, 2015).

Reducing emissions from deforestation and forest degradation (REDD) is an economically attractive option for mitigating emissions (Stern and Treasury, 2006; Angelsen, 2008). REDD+ goes beyond tackling deforestation and forest degradation by: i) conserving forests, ii) stimulating sustainable management of forests, and iii) enhancing forest carbon stocks (Minang et al., 2010). The REDD+ mechanism seeks to encourage developing countries to reduce or remove emissions by financially rewarding these countries for results verified against a forest reference level (FRL), in compliance with the Cancun safeguards. Under this mechanism, developing countries receive economic incentives to sequester forest carbon, in keeping with performance-based management principles (Agrawal and Angelsen, 2009; Cronkleton et al., 2011).

Evidence from three pilot REDD+ implementation sites in Nepal, which primarily focus on community managed forests, indicates that the incentive-based REDD+ intervention may help improve forests by reducing forest fires, regularizing grazing and managing firewood collection (Sharma et al., 2015). The study also suggests that for Nepal's REDD+ National Strategy to be effective, REDD+ should be successfully launched in locally managed forest areas. The success of REDD+ depends on the participation of the forest user communities and local forest managers in interventions aimed at addressing deforestation and forest degradation. This will be possible only if the intervention is incentive-compatible, i.e., benefits generated from REDD+ would compensate for the costs of implementing REDD+ activities to reduce deforestation and forest degradation (Luttrell et al., 2013).

Benefits and costs associated with the depletion of forest resources should be properly valuated. This will enable policy makers to recognize the forest sector's contribution to Nepal's economy and ensure that forest managers receive appropriate payment while implementing REDD+. This study provides information about the benefits and costs of reducing deforestation and forest degradation at the landscape level, as well as an indication of such costs and benefits at the national level.

This study intends to answer the following questions:

- What are the benefits and costs of reducing deforestation and forest degradation across different regions and forest management regimes?
- What are the opportunity costs of reducing carbon emission via reduced deforestation and degradation?

The study estimated the benefits and costs of reducing deforestation and forest degradation for four different management regimes (community forests, collaboratively managed forest, protected forests, and protected areas) across three physiographic regions of Nepal (mid-hills, the Siwaliks and the Terai).[1] The findings of the study could help in identifying areas where REDD+ implementation might be feasible and improving management practices. The study will broaden the understanding of the value of forests in different landscapes and provide a basis for developing a forest/natural capital account in the future.

[1] These regions extend across the country from east to west. The Terai lies in the southern part of the country. The Siwaliks lie between the Terai and the mid-hills, and north of the mid-hills is the high mountain region.

Overview of Forest Management in Nepal

Recent data of the Department of Forest Research and Survey, Nepal, show that forests made up 5.96 million ha or 40 percent of the total land area of Nepal in 2010. Other types of woodland covered 0.65 million ha, or 4 percent of the total land area (DFRS, 2015c). Of the total forest area, 38 percent was in the mid-hills, 32 percent in the high mountains, 23 percent in the Siwaliks, and 7 percent in the Terai. The Terai is the southern belt of Nepal and the Siwaliks are a low range of hills between the Terai and the mid-hills (see Map 1). Between 1995 and 2010, the annual deforestation rate in the Terai was 0.44 percent, and in the Siwaliks it was 0.18 percent (DFRS, 2014a, 2014b). Forest cover in the mid-hills and mountains was less in 1995 (FRISP/GON 1999) than in 2010 (DFRS, 2014a, 2014b, 2015a, 2015b), indicating an increase over the fifteen-year period. However, the latest reports on these regions do not provide the rate of forest cover growth, perhaps because these numbers are not strictly comparable due to methodological differences. The average carbon stock in Nepal's forests in 2010 was 177 tC/ha, with the lowest figure in the Siwaliks at 117 tC/ha and the highest in the mountains at 272 tC/ha (DFRS, 2014a, 2015a, 2015c).

A total of nine major drivers of deforestation and forest degradation were identified in Nepal and documented in the REDD Readiness Preparation Proposal (RPP) (RIC, 2013). Among them, four are related to the utilization of forest resources: (i) high reliance on forests for subsistence use (ii) illegal harvest (iii) unsustainable harvesting practices, and (iv) overgrazing. Two drivers are related to development activities: (v) infrastructure development (vi) resettlement. The rest are: (vii) forest fire (viii) encroachment, and (ix) spread of invasive species. The Siwaliks and the Terai, in particular, may have seen some conversion of forest to agricultural land. The mid-hills and the mountains have witnessed the reverse process of fields being converted to forests, but there is no official data on this process.

Based on the ownership, forests in Nepal are divided into two categories: national forests and private forests. National forests are sub-divided into multiple management regimes: community forests (CF), collaboratively managed forests, leasehold forests, religious forests, protected forests, protected areas, and other government-managed forests. Community forests and protected areas account for nearly half of the total forest area (Table 2). Since the early 1990s, government-managed forests, which are under government ownership, have increasingly shifted to community-based forest management regimes such as community forests, collaboratively managed forests, and protected forests (DoF, 2015). This process was initiated in the mid-hills and mountains and later extended to the lower regions. Gradual conversion of government-managed forests into community-managed forests is one of the strategies proposed by the government of Nepal in its Emission Reductions Program Idea Note for the Terai Arc Landscape (GoN, 2014).

What remains unclear is the area coverage of private forests. The Master Plan for Forestry Sector of Nepal (1989) had set a target to expand private forests to cover an area of 2.39 million ha, which is around 40 percent of the total forest area. However, there is no legal obligation to register private forests, and only about 2,000 ha of private

Table 2: **Distribution of national forests in Nepal**

Regimes	Description	Percent of total forest area
Protected area (DFRS, 2015c)	Area designated for long-term biodiversity conservation including national parks, wildlife reserves, conservation areas and hunting reserves	17%
Community forest (DoF, 2014)	Part of a national forest handed over to a local user group to develop, conserve, use and manage the forest, and to sell and distribute forest products independently by fixing their prices according to the operational plan	29%
Protected forest (DoF, 2014)	Forest corridors between the protected areas, which are divided into core zones, and forests allocated for production purposes and managed by village communities	2%
Collaboratively managed forest (DoF, 2014)	Jointly managed by communities and the government, with equal sharing of benefits from the forest. Households far from the forest are also included.	1%
Leasehold forest (DoF, 2014)	A patch of degraded national forests handed over to poor households on 40-year lease with the dual objectives of forest development and poverty reduction	1%
Religious forests	Managed by temples and religious bodies	Nearly 0%

forest patches are registered in the district forest offices across the country (DoF, 2014). In fiscal year 2013/14, timber harvests from private forests amounted to 226,565 cu m (8 million cubic feet), whereas harvests from community forests amounted to 208,440 cu m (7.36 million cubic feet) (DoF, 2014). This suggests that private forests and community forests might cover equally large areas (30 percent of the total forest area), with most of remaining government-managed forests in inaccessible locations.

The study gathered primary data from four forest management regimes: community forests, collaboratively managed forest, protected forests, and protected areas. Together, these four types of forests account for almost half of the total forest area (Table 2). The remaining half of the forest area comprises government-managed forests or private forests. As government-managed forests are still transitioning into community-based forest management regimes, the share of government-managed forests (other than protected areas) is expected to be small in the future.

Methodology

The study followed a participatory approach to ensure that the research design was appropriate and that the findings would help address the government's policy needs. As a first step, extensive consultations were carried out with central government officials to identify information gaps on the drivers of deforestation and forest degradation, and the benefits and costs of implementing REDD+ (see Annex 1). This was followed by discussions with district-level forest officials and non-government organizations (NGOs), and focus group discussions (FGDs) with local forest user communities.

The second step involved a series of household surveys and carbon measurements. The pilot survey obtained feedback on survey instruments, particularly questionnaire structure and content, from local communities. This was followed by a household survey to collect information on the use of forest and forest products, discussions with community leaders and local officials to understand management issues, and carbon measurements to document evidence of forest carbon changes. Secondary evidence and data from other studies were used to support analyses in different study areas.

Analytical Framework

The benefits and costs of reducing deforestation and forest degradation were estimated separately for different types of forest management regimes. Historical data and recent forest resource assessments suggest that the rate of afforestation or reforestation exceeds deforestation in the mid-hills between 1991 and 2010; the opposite is true for the Terai and the Siwaliks (FRISP/GON, 1999; DFRS, 2014a, 2014b ; DFRS, 2015b). However, the positive trend of forest growth in the mid-hills may reverse in the future when infrastructure development, particularly road construction and hydropower development, is accelerated in the region. This may contribute to deforestation. We therefore estimated the cost of reducing deforestation for the Terai, the Siwaliks and the mid-hills. Benefits and costs of reducing forest degradation were not estimated for the protected area regime, as these are strictly protected. Cost-benefit analysis was conducted assuming that conversion of forests into agricultural land will continue for an indefinite period of time. Therefore, estimated values of costs and benefits are presented in annual cash flow in perpetuity.

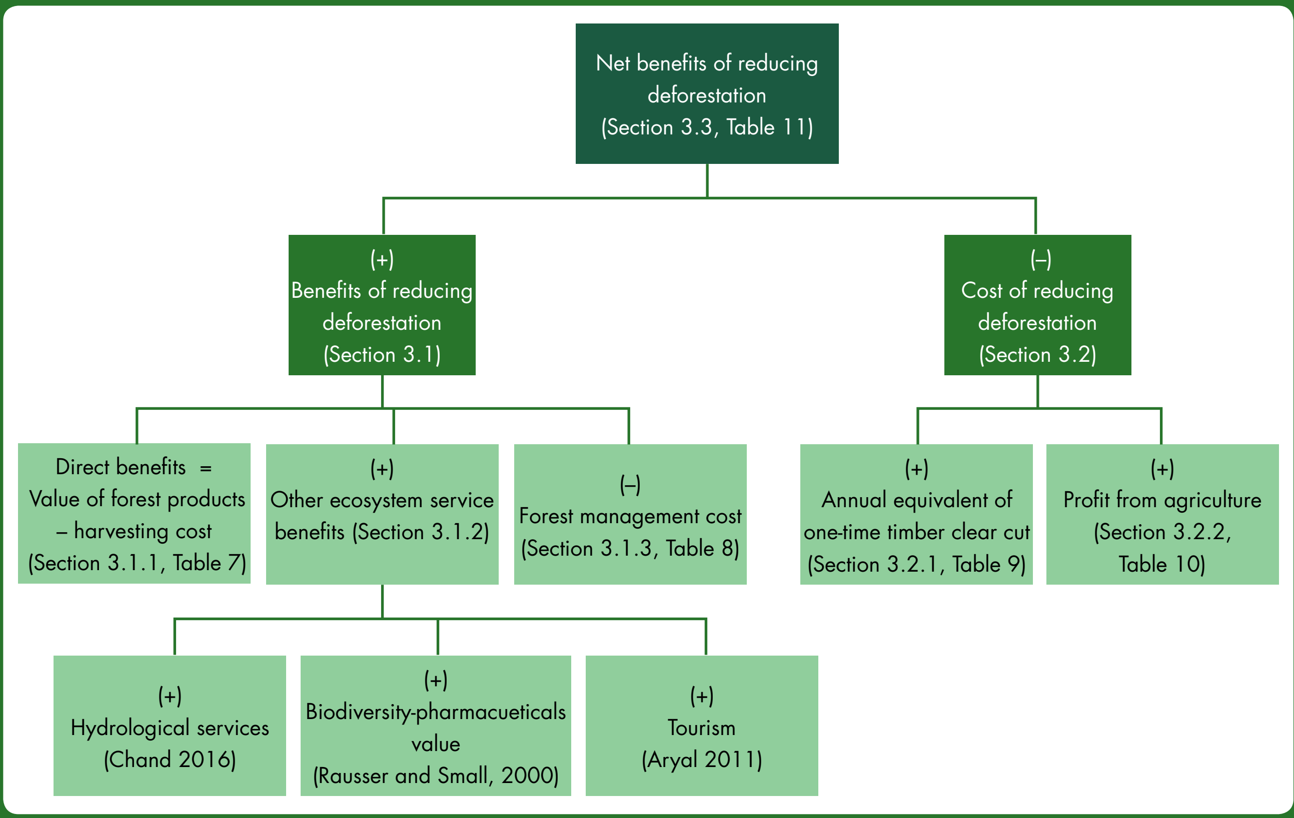
Benefits and costs of reducing deforestation

The analytical framework for assessing the benefits and costs of reducing deforestation is depicted in Figure 1. All amounts are in Nepali rupees (NPR) but are also converted to United States dollar (USD) per hectare per year. The net benefit of reducing deforestation is the benefit of reducing deforestation minus the cost of reducing deforestation. The benefit of reducing deforestation is the sum of direct benefits and other ecosystem services from the forest minus the cost of managing the forest. When deforestation occurs, it provides a one-time benefit from clearing the forest (timber and fuelwood), and the land freed up can be used for agriculture in perpetuity. Foregoing these benefits is the cost of reducing deforestation.

When a forest is retained, it regularly provides both direct benefits and other ecosystem services. Direct benefit is the value of forest products harvested minus the harvesting costs, and other ecosystem services include water regulation, recreation and biodiversity. It is important to note that various ecosystem services have not been included in this study due to lack of data. To measure the net benefit of reducing deforestation, the cost of managing forests should be subtracted from the sum of direct benefits and other ecosystem services.

The study did not include the value of carbon stocks stored in the forests. However, while calculating the net benefit (benefits minus costs) of reducing deforestation in Table 11, it was noted that these are negative in all cases. That is, reducing deforestation has a net cost per ha. If we divide this cost by the carbon stock per ha, we can obtain the opportunity cost of saving a tonne of CO_2.

Figure 1: **Analytical framework of estimating benefits and costs of reducing deforestation**



When a forest is cleared, profits obtained from the timber and fuelwood can be invested in XX that bring annual returns. This is the annual equivalent flow of benefits from the one-time harvest of timber and fuelwood. Here, an 8 percent discount rate is used to estimate the annual flow; as this is the annual rate of return that the Central Bank of Nepal offers on the National Savings Certificate, one of its long-term investment schemes.

This study assumes that the deforested land will be cultivated, as this is the most common alternative use. The annual flow of net benefits from agriculture is expressed as:

$$Ben_{agr} = \sum(Value_{cereals} - Cost_{production}) \quad (1)$$

where, $Value_{cereals}$ is the value of the total production of cereals. This is estimated as a product of the total quantity produced per ha and market price. $Cost_{production}$ is the cost of producing cereals. This study considers major cereal crops cultivated in the study areas, excluding some pocket areas where people grow high-value vegetables. Forestlands that have been encroached on are mostly away from the major urban centres and used for illegal settlement and subsistence farming. These lands are usually cultivated during three cropping seasons (paddy, maize and wheat), which suggests that the converted forestlands become irrigated lands during these seasons.

Benefits and costs of reducing forest degradation

The benefits and costs of forest degradation was estimated based on the idea that a reduction in the harvesting of timber and firewood will reduce direct benefits to local users but increase biomass accumulation. The cost of reducing forest degradation is defined as the change in annual benefits from forest products relative to the baseline scenario. If the harvest of forest products is greater than the natural increment of forest biomass, then the amount by which the harvest exceeds the natural increment is defined as non-renewable biomass (NRB) (Johnson et al., 2010).

Net benefit of reducing forest degradation in carbon equivalent unit can be expressed as:

$$\textit{Net benefit of reducing forest degradation/ha} = \frac{\Delta \text{ in annual benefits from forest products relative to the baseline scenario/ha}}{\text{NRB } (tCO_2/ha)} \quad (2)$$

Data

Study area

The study sites were selected to capture variations in possible costs of REDD+ implementation in three physiographic regions namely, the Terai, the Siwaliks and the mid-hills. These regions cover about 68 percent of the total forest area in Nepal (Table 3). The sites were identified based on intensive consultations with the stakeholders including the Department of Forest, district forest offices, the National Planning Commission, and forest users. The two main selection criteria were: 1) Forest patches are managed under the existing forest management regimes for at least five years; and 2) Forest patches have vegetation representing the physiographic region. The selected areas represent different forest management regimes, such as community forests, collaboratively managed forests, protected forests and protected areas. The study did not cover the northernmost region (mountain region) because vegetation growth rate and population pressure in this zone is substantially lower.

In this study, community forest user groups (CFUGs) of Ludikhola sub-watershed in Gorkha district represent the mid-hills. The CFUGs in this region harvest forest products such as timber, firewood, fodder, and leaf-litter according to annual allowable harvest quantity prescribed in their operational plan. The CFUGs sampled from Kayarkhola sub-watershed of Chitwan district represent around 3,000 CFUGs in the Siwaliks region, which was declared an Environmental Conservation Zone by the government of Nepal in June 2014. The CFUGs in this region can only harvest enough for household consumption and mostly dead, dying and diseased trees.

In the Terai region, the Department of Forest has adopted (timber and non-timber) a production-oriented forest management approach called scientific forest management. Under this scheme, large patches of forests in the Terai region are being managed under the Collaborative Forest Management (CFM) modality. The idea behind this approach is to halt illegal felling of mature trees by involving local users in managing the forest, and harvesting timber from the old growth Sal (*Shorea robusta*) forest. This can help prevent the loss of premium Sal timber from natural decay of old trees and allow regeneration of natural forest in the harvested areas. Unlike CFUGs, the collaborative forest management modality also involves distant users and shares 50 percent of benefits (harvested timber and fuelwood) with the government. By contrast, in the community forest model, all benefits from forest products go to the CFUG fund. In collaboratively managed forests, users are allowed to collect non-timber forest products (NTFP) in a sustainable manner. However, the allowable quantity of NTFP and access varies from site to site. Table 3 provides summarized information on the sampled sites.

In 2011 the government of Nepal categorized some forest patches with high conservation value as Protected Forests (PF). Core zones of such forests are protected exclusively for wildlife and biodiversity conservation, and the area between the core zone and the village is allotted for production purposes (Shrestha et al., 2014).

Certain areas are declared protected areas (PAs) for long-term conservation of biodiversity and related cultural values. PAs include national parks, wildlife reserves and conservation areas, which are guarded by forest guards. Local people are not allowed to collect forest products from PAs, except in conservation areas.

Map 1 shows the geographic locations of the six study sites. The selected forest management regimes may correspond to different REDD+ activities. For instance, all forest management regimes of the Terai and the Siwaliks share similar goals as REDD+ (i.e., reducing deforestation or forest degradation, conservation, sustainable management of forests, or enhancement of forest carbon stock). The CFUGs from the mid-hills and the Terai may fall under the sustainable forest management category. The CFUGs in the Siwaliks carry out activities for the conservation of forest carbon stocks. The collaborative forest management modality in the Terai is aimed at sustainable forest management and enhancement of forest carbon stocks. This is because collaborative forest management is intended to harvest mature trees and bring about natural regeneration of degraded and deforested areas. Table 4 provides the forest area under different management regimes and the number of households dependent on the resources of these forests.

Table 3: **Description of study sites**

Regimes	Forest management	Location	Scope of REDD+ activity
Community forest	• Harvest according to annual allowable cut • Focus on timber, fuelwood and fodder production	Ludikhola Sub-watershed, Gorkha District (Mid-hills)	Sustainable management of forests
Community forest	• Harvest only for household needs • Mostly remove dead, dying and diseased trees	Kayarkhola Sub-watershed, Chitwan (Siwaliks)	Conservation of forest carbon stocks, reducing deforestation and forest degradation
Community forest	• Follow the scientific forest management approach focusing on timber production • Carry out plot-based felling, retaining mother trees for regeneration	Prithvi, Lalmatiya, Nava Jagrit, Trishuli and Sagarahawa CFUGs, Kapilvastu (Terai)	Sustainable management of forests, reducing deforestation and forest degradation
Collaboratively managed forest	• Follow the scientific forest management approach, focusing on timber production • Carry out plot-based felling, retaining mother trees for regeneration • Include distant users, share benefits between communities and the government, and manage jointly.	Lumbini CFM Rupandehi, and Tilaurakiot, CFM Kapilvastu (Terai)	Sustainable management of forests, enhancement of forest carbon stocks, reducing deforestation and forest degradation
Protected forest	• Harvest only in peripheral area according to annual allowable harvest • Core area is conserved as a wildlife corridor	Basanta Corridor, Kailali (Terai)	Sustainable management of forests, conservation of forest carbon stocks, reducing deforestation and forest degradation
Protected area	• Protected for biodiversity conservation	Chitwan National Park, Chitwan	Conservation of forest carbon stocks

Map 1: **Map of Nepal with study areas**

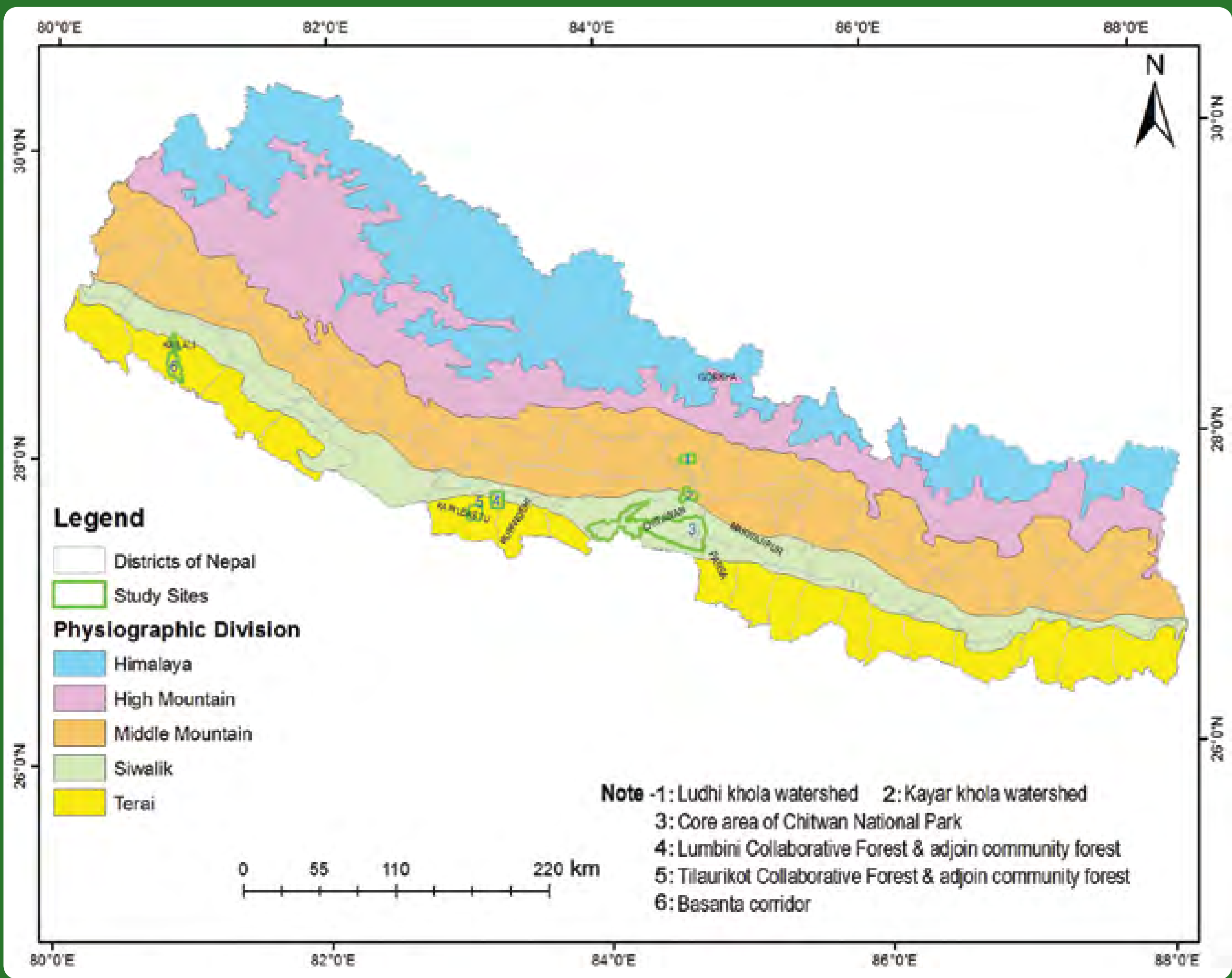


Table 4: **Description of sub-watershed and forest patches**

Regime	Location	Forest area (ha)	No. of households managing forest	No. of households sampled
Community forest (Mid-hills)	Gorkha	4,869 (1,888)	4,110	105
Community forest (Siwaliks)	Chitwan	5,892 (2,381)	4,146	105
Community forest (Terai)	Kapilvastu	653.7	1,235	247
Collaboratively managed forest	Kapilvastu, Rupandehi	3,835	48,556	355
Protected forest	Kailali	68,837	24,842	303
Protected area	Chitwan	93,200	–	–

Note: Numbers in parentheses indicate the areas of the community forest in Ludikhola Watershed of Gorkha District and Kayarkhola Watershed of Chitwan District.

Sampling

Two types of data were collected for this study. The first type was socioeconomic information, which is related to forest products collection, agricultural activities and the contribution of households in forest management and protection. Secondary information on the change in forest product harvest, quantity of timber harvest, and forest management and other costs were collected from the official records of forest user groups. The second type of data is related to forest carbon.

Socioeconomic survey

The study team carried out several consultation meetings and focus group discussions (see Annex 1). The main objectives of the focus group discussions were to identify the study sites and to understand the underlying issues in different forest management regimes. The study team revisited REDD pilot sites where ICIMOD implemented field-based experiments in 2010-2013. The goal of these experiments was to understand the implications of REDD+ interventions for the biophysical condition of the forests and the impacts of the interventions on household welfare (Sharma et al, 2015). The team also consulted district forest officers and officials of NGOs working in the districts. The findings of the focus group discussions and local-level consultations were shared with central level stakeholders, staff of the REDD Implementation Center, and researchers during a workshop. The consultations mainly focused on identifying the study area, and forest management issues related to the design of the household survey questionnaire.

A draft questionnaire was prepared based on the focus group discussions and consultations and the suggestions from the UN Environment team. The draft questionnaire was pre-tested in Kapilvastu in June 2015. Based on the feedback of 20 pre-test interviewees, the questionnaire was revised and finalized.

After finalizing the questionnaire, a total of 1,115 households were interviewed to understand their behaviour with regard to forest products collection and their contribution to forest management. To increase the coverage of the study, the household survey data from this study was combined with another set of data from the mid-hills and the Siwaliks, which was collected for another project by SANDEE and ICIMOD (Sharma et al., 2015). Details of the sampled households are reported in Table 5. While combining data sets from the two periods, all nominal variables using USD exchange rates[2] were adjusted.

Households were selected using a systematic sampling strategy. For collaborative forest users and community forest users of the Terai, households were stratified based on their distance from the forest. In collaboratively managed forests, households more than 5 km from the forest boundary are called distant users. Half of the households were interviewed from the first stratum (less than 5 km) and the rest from villages more than 5 km away from the forest. In community forests (Terai), two strata were formed: (i) villages within 1 km from the forest and (ii) villages more than 1 km from the forest. In protected forests, villages were divided into three strata: (i) foothills of the Siwaliks (sloped area) (ii) north of the highway (plains), and (iii) south of the highway. This is because according to forestry officials and forest users, forest users of the second stratum are more active than the third, and forests in the foothills of the Siwaliks (sloped area) are different from forests in the other two strata.

[2] 1 USD = NPR 98 in 2013, and 1 USD = NPR 103 in September 2015.

Table 5: **Sample characteristics**

	Community forest (Mid-hills)	Community forest (Siwaliks)	Community forest (Terai)	Collaboratively managed forest	Protected forest
Female	32 (32%)	12 (12%)	73 (30%)	55 (15%)	128 (42%)
Household head	86 (82%)	95 (90%)	188 (76%)	305 (86%)	248 (82%)
Age (years)	53.4 (12.3)	46.3 (12.8)	45.1 (14.0)	46.10 (13.3)	38.3 (13.2)
Family size	4.29 (1.75)	5.52 (1.98)	7.30 (3.43)	7.62 (3.25)	6.64 (3.09)
Education (years)	3.61 (3.99)	4.09 (4.14)	3.91 (4.14)	3.99 (4.40)	3.99 (4.07)
Irrigated land (ha)	0.20 (0.24)	0.39 (0.46)	0.10 (0.20)	0.13 (0.23)	0.54 (0.55)
Non-irrigated land (ha)	0.33 (0.34)	0.27 (0.43)	0.12 (0.16)	0.26 (0.32)	0.05 (0.15)
Households having agriculture as main occupation	37 (35%)	54 (51%)	158 (64%)	290 (82%)	302 (99%)

Note: Numbers in parentheses that are not followed by % represent standard deviation.

In each stratum, the first household was selected randomly from the given community and the rest at pre-defined intervals. The intervals were selected based on the sample size and population. Household heads of either gender were interviewed from sampled households. The response rate was 100 percent, as all sampled households agreed to participate in the interview. This was possible because the local forest user groups were involved in planning and focus group discussions, where local community leaders extended their support for conducting household survey. Table 5 reports individual and household characteristics of sample households. Majority of households in all forest regimes have agriculture as their main source of income.

Forest carbon

Carbon stocks were calculated using data from a ground-level forest inventory. The inventory for two of the study areas (CF-mid-hills and CF-Siwaliks) was prepared by Sharma et al in 2012, and the inventory for the other four study areas by the study team in 2015. This study refers to 2012 and 2015 as the end years for the respective study areas. High-resolution satellite images[3] were used to derive crown cover in these areas and a regression model was fitted for each area with crown cover as the predictor and carbon stock as the dependent variable. Satellite images for a base year (either 2002 or 2003 depending on the availability of images) for each area were then used to predict carbon stocks in the base year using the fitted regression model. The estimated carbon stocks are shown in Annex 3.

The forest inventory data were collected using a random sampling technique. The diameter at breast height (DBH) at 1.3 metre and the height of all trees with DBH greater than or equal to 5 cm in a circular plot (500 m^2) were measured. A diameter tape, linear tape and clinometers, or vertex-IV/transponder were used to measure tree diameter and height.

Forest carbon was estimated in the following three steps:

Biomass of field plots

Above-ground tree biomass (AGB) of each plot was calculated by summing up the biomass of individual trees on that plot. Tree biomass was estimated using the following formula proposed for moist area (Chave et al., 2005):

$$AGB = 0.0509 \times pD^2H \qquad (3)$$

Where,

p refers to specific gravity (wood density in kg/m^3) and the value was assigned as suggested by Forest Inventory Guideline, 2011.

D refers to diameter of tree at breast height in cm

H refers to height of the tree in m.

[3] High-resolution satellite images of IKONOS-2, Quick Bird, GeoEye-1 and Pleiades were used depending on their availability.

Below-ground (tree root) carbon was estimated assuming that it equals 15 percent of the above-ground carbon (MacDicken, 1997). The biomass per ha in each of the six study areas was calculated for the end years (2012 and 2015, depending on the study area). Multiplying by 0.47 yields carbon stock in tC/ha. This is reported in Table 6 (and Column D in Annex 3). The carbon stock ranges from a low of 136 tC/ha in the mid-hills CFs to a high of 299 tC/ha in the Siwaliks CFs. By comparison, government data for 2010 show carbon stocks of 138 tC/ha in the mid-hills, 117 tC/ha in the Siwaliks and 123 tC/ha in the Terai (DFRS, 2014a, 2014b, 2015b). Three forest management regimes including CF-Siwaliks, protected forest, and protected area, which are meant for biodiversity conservation, have fast-growing stocks.

Tree crown delineation

The geographic object-based image analysis (GEOBIA) was used for detecting and delineating tree crowns based on high-resolution satellite imagery. The scale-10, shape-0.7, and compactness-0.3 were used in segmenting high resolution satellite images. The image segmentation parameters were chosen using estimations from the scale parameter (ESP) tool (Drăguţ et al., 2010).

Tree crown detection and delineation using high resolution is a cost-effective, efficient, accurate and reliable method (Zhen et al., 2016). In addition, use of images with pixels significantly smaller than the tree canopy size was found to be effective for tree crown delineation (Pouliot et al., 2002; Gomes and Maillard, 2016). The analysis also used the results of a previous study by ICIMOD; therefore, the same methodology was used to ensure consistency (Gilani et al., 2015).

Model development

A linear regression relationship between field plots' biomass in 1 ha grid and crown projection area (CPA) were developed. The model was calibrated and validated using field-based data and crown-based data. Crown-based data is the same as tree crown data acquired from the high-resolution image but verification was done from field canopy measurement of selected plots. After obtaining satisfactory significant correlation coefficient, biomass in tC/ha for each of the six study areas for the base years was calculated. This is reported in Column A of Annex 3. (The details of the estimated regression models are given in Annex 2.)

The annual increase in biomass (AGB) productivity was estimated for each study area by subtracting the biomass in the base year from the biomass in the end year and dividing the result by the number of years in between. Soil carbon accumulates slowly, and as our data covers a short duration of 10–12 years (2002/2003 to 2012/2015), the study did not account for the change in soil carbon (Vesterdal et al., 2002)2002. Carbon stock has increased in all forest management regimes over the study period (Table 6). Forest patches selected for this study are under the control of local communities and their role in reducing deforestation and forest degradation has been acknowledged (GoN, 2014).

The community forests of the mid-hills and the Siwaliks have higher rates of annual carbon increment compared to other forest management regimes. Site-specific studies have found that forest resources have improved in the mid-hills (Niraula et al., 2013). In the Siwaliks region, forest carbon has increased since the government imposed restrictions whereby CFUGs can harvest forest resources only for household requirements. Another reason for the

Table 6: **Average growing stock, and average stock and annual change of above-ground carbon**

Regime	Volume (m^3/ha)		Carbon (tC/ha)	Average annual change
	Sal (*Shorea robusta*)	Other species		(tC/ha/year)
CF (Mid-hills)	19	13	136	1.96
CF (Siwaliks)	56	37	299	1.84
CF (Terai)	35	11	178	0.18
Collaborative forest	39	12	160	0.01
Protected forest	51	31	281	0.35
Protected area	40	20	275	0.15

Note: See Annex 3 for details.

high annual growth rates in the mid-hills and the Siwaliks could be that these areas are still recovering from severe degradation that occurred more than two decades ago.

Community and collaboratively managed forests of the Terai have lower above-ground carbon stock compared to the other regimes in the Terai. In addition, these forests have been under the scientific forest management programme since 2010. Each year there is intensive timber felling in particular areas of these forests, and the clear-cut areas are protected to allow regeneration of the natural forest. In the short run, selective logging areas usually have low carbon storage (Asner et al., 2005). In the case of protected forest, which is designed for both resource utilization and conservation, forest carbon stock is highest and also grows faster compared to other forest regimes (community forest and collaboratively managed forest) in the Terai region.

In the case of protected area, grassland and other open areas have been converted into forestland. This could be due to vegetation succession and a small increment in forest carbon.

Benefits and Costs of Reducing Deforestation

Benefits of Reducing Deforestation

Direct benefits (forest products)

Forest users regularly receive direct benefits from the forest. Direct benefits include forest products such as timber, fuelwood, grass, leaf-litter and other non-timber forest products (see Annex 4 for details). The value of harvested forest products ranges from USD 152/ha to USD 1,942/ha (Table 7). The value of annual forest products is lowest in protected forests, where large areas are demarcated for biodiversity conservation and harvesting of forest products is restricted. The value of annual forest products is highest in collaboratively managed forests, which have adopted a production-oriented approach called scientific forest management. The net annual direct benefits from forests ranges from USD 92/ha and USD 513/ha.

Other ecosystem service benefits

Three types of other ecosystem service benefits were considered for this study: (i) hydrological services (ii) biodiversity, and (iii) tourism. Our choices were based on the availability of relevant information. In the context of this study, the total value of other ecosystem service benefits is the sum of the values of these three services. Among the selected forest management regimes, only protected areas offer tourism value. However, tourism may imply there is limited harvest of forest products, and therefore, the net benefits may be equal to that of the other regimes. As the values of other ecosystem service benefits included in this study do not account for all types of ecosystem services, this estimation should be regarded as a lower bound.

The value of hydrological services was estimated using the change in annual water flow due to the change from forest cover to agricultural land or bare soil. The change in water flow is based on the only available study for Nepal, Chand (2016), who studied trade-offs and synergies between ecosystem services in the Kayarkhola watershed in Chitwan district using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) hydrological model. The conversion of a hectare of forest into agricultural land or bare soil increases water flow by 12 cubic metres per year; this means that the hydrological service benefit associated with reduced deforestation is in the negative (Chand, 2016). The price of water, which is from RIC (2015), is NPR 24 (USD 0.23) per cubic metre. Thus the value of hydrological services derived from reducing deforestation is NPR –286 (USD –2.78) per ha per year.

The value of biodiversity derived from bioprospecting for pharmaceutical products is taken from Rausser and Small (2000). They estimate the option value of genetic resources in the eastern Himalayas to be USD 332 per ha (Rausser and Small, 2000). The annual flow in perpetuity at 8 percent discount rate is USD 26.56 per ha.

Table 7: **Costs and benefits of annual forest products harvest NPR/ha (USD/ha in parentheses)**

Regime	Annual biomass harvested tC/ha (A)	Value of Annual forest products harvested (B)		Annual costs of harvesting forest products (C)		Net annual direct benefits (forest products harvest) (D= B-C)	
CF (Mid-hills)	0.45	40,043	(409)	16,255	(166)	23,788	(243)
CF (Siwaliks)	0.59	58,783	(600)	33,821	(345)	24,962	(255)
CF (Terai)	1.68	87,567	(850)	34,737	(337)	52,830	(513)
Collaborative forest	3.23	200,010	(1,942)	85,210	(827)	114,800	(1,115)
Protected forest	0.23	15,705	(152)	6,229	(60)	9,476	(92)

Note: This estimation is based on Annex 4. Local market rate was used to estimate the value of forest products and cost of harvesting is based on time spent by forest users to collect per unit forest products.

The recreational value of forest ecosystem was estimated based on the study by Aryal (2011). This study used the travel cost method and estimated the annual recreational value of the Chitwan National Park to be NPR 233 million (USD 2.37 million) per year. This yields an annual recreational value of USD 25.51 per ha for the protected area.

Based on these three estimates, the estimated annual value of other ecosystem service benefits is USD 49.29 per ha for the protected area and USD 23.78 per ha for the other forest management regimes. However, in the absence of green national accounting system, it is not easy to estimate other ecosystem service benefits, and it is even more difficult to assign values in per hectare terms.

Forest management costs

As described in Figure 1, forest managers have to manage their forests regularly. This imposes costs on forest managers. These costs should be subtracted to estimate the net benefits from the forest. Forest management entails two types of regular costs: (i) Costs of forest management activities (ii) administrative costs. The first type of cost is related to activities such as thinning, pruning, cleaning, firefighting, fire line construction, plantation, and patrolling. Administrative cost is associated with activities that facilitate the forest management process, such as meetings, user assemblies and visits to forest offices.

Households contribute time or cash for forest management activities for community-managed forests. Usually, they pay an annual fee, and the amount varies across forest user groups. Labour contribution is converted into a monetary value using the average self-reported daily wage rate.

For protected areas, the study uses the government's average annual cost of protecting Chitwan National Park over the study period, which is NPR 42 million (USD 0.41 million).

The total annual cost of forest management ranges from USD 6.78/ha to USD 31.56/ha (Table 8). The average annual cost of forest management is lowest in protected forests. This is not surprising because forest management activities are confined to the area designated for forest products harvest and there are no activities in the core zone demarcated for biodiversity conservation. In the community forests of the Siwaliks and the mid-hills, forest users participate equally in every activity, resulting in lower marginal productivity of labour and higher costs of forest management. On the other hand, voluntary contribution for forest management is not common among forest users in the Terai region, and as a result the forest management cost is expected to be low.

Table 8: **Annual costs of forest management in NPR/ha (USD/ha)**

Regime	Forest management activities (A)		Administrative costs (B)		Total forest management cost (C= A+B)	
CF (Mid-hills)	1,713	(17.48)	1,380	(14.08)	3,093	(31.56)
CF (Siwaliks)	1,543	(15.74)	1,031	(10.52)	2,574	(26.26)
CF (Terai)	544	(5.27)	304	(2.95)	848	(8.23)
Collaboratively managed forest	502	(4.87)	277	(2.69)	779	(7.56)
Protected forest	323	(3.14)	375	(3.65)	698	(6.78)
Protected area	–		–		734	(7.13)

Note: All figures except for protected area are from Annex 5. The figure for protected area is from government records. Only the total cost is provided, as a breakdown of the protected area budget (into management and administrative costs) is not available.

Cost of Reducing Deforestation

Annual equivalent of one-time timber clear cutting

Forest managers receive one-time forest products from clear cutting the forest. The net value of one-time forest products is the difference between the value of products (timber and fuelwood) and their harvesting cost. The expected value of forest products obtained after clear cutting ranges from USD 18,822/ha to USD 55,921/ha, and the expected cost of clear cutting is between USD 2,964 /ha and USD 18,109/ha (Table 9). The expected value of forest products and cost of clear cutting are directly related to the growing stock of forest reported in Table 6. The

Table 9: **Expected value and harvesting cost of forest products from clear cut NPR/ha (USD/ha)**

Regime	Value of Forest products		Cost of clear cutting		Net annual flow of clear cutting (E=B–D)
	Expected value of forest stock (A)	Annual flow of the expected benefits of forest stock (B)	Expected harvesting cost (C)	Annual flow of the expected harvesting cost (D)	
CF (Mid-hills)	1,844,570 (18,822)	147,566 (1,506)	290,514 (2,964)	23,241 (237)	124,325 (1,269)
CF (Siwaliks)	5,480,270 (55,921)	438,422 (4,474)	1,774,713 (18,109)	141,977 (1,449)	296,445 (3,025)
CF (Terai)	2,379,453 (23,101)	190,356 (1,848)	1,181,061 (11,467)	94,485 (917)	145,751 (1,415)
Collaborative forest	3,266,893 (31,717)	261,351 (2,537)	1,369,708 (13,298)	109,577 (1,064)	151,775 (1,473)
Protected forest	4,911,277 (47,682)	392,902 (3,815)	508,151 (4,934)	40,652 (395)	352,250 (3,420)
Protected area	3,707,376 (35,994)	296,590 (2,880)	1,154,269 (11,099)	92,342 (888)	204,249 (1,983)

Note: Values reported in column B and D are annual flow equivalent (at 8% interest rate) of column A and C respectively. Clear-felling costs and expected value are estimated based on harvesting cost and forest products value reported in Annex 4.

annualized perpetual flow of the expected value of forest stock and the cost of clear cutting is estimated using an 8 percent discount rate. The net annual flow of clear cutting is between USD 1,269 and USD 3,420 per ha.

Profit from agriculture

Deforestation is occurring in the Terai and the Siwaliks region (DFRS, 2015c). The government of Nepal has identified encroachment of forests for subsistence farming as one of the major drivers of deforestation (MoFSC, 2010). This study estimates the costs of reducing deforestation considering that forest patches will permanently be converted into agricultural land for subsistence farming. Paddy, wheat and maize are the three major crops grown by Nepal's marginal farmers during the three growing seasons. The total annual benefit from agriculture is the sum of the benefits of these three crops. Table 10 provides the estimated net profits from cereal crops when forest patches are converted to agricultural lands. These figures are consistent with the estimates reported in a previous study (Bhandari et al., 2015).

Net profit from cereals (Ben_{agr}) is higher in the Terai than in the other two regions because agricultural land in the Terai is highly productive. Net profit from agriculture in the mid-hills is higher than the net profit in the Siwaliks, where the production cost is higher (Annex 6). As the study did not cover the households around the protected area, it used the estimates for collaboratively managed forests. Both protected and collaboratively managed forests selected for the study are in the Terai region. Collaboratively managed forests in the Terai offer a moderate amount of benefits.

Table 10: **Net annual benefits from agriculture NPR/ha (USD/Ha)**

Cereals	CF- mid-hills		CF-Siwaliks		CF-Terai		Collaboratively managed forest		Protected forest	
Paddy (A)	8,016	(77.83)	2,337	(22.69)	28,392	(275.65)	28,569	(277.36)	3,374	(32.76)
Maize (B)	3,854	(37.42)	5,386	(52.29)	798	(7.75)	2,698	(26.19)	4,396	(42.68)
Wheat (C)	12,398	(120.37)	3,409	(33.10)	1,304	(12.66)	819	(7.95)	28,473	(276.44)
Annual net benefits	24,268	(236)	11,132	(108)	30,494	(296)	32,086	(312)	36,243	(352)

Note: Nepal has three growing seasons in a year. The most widely cultivated crops are maize, paddy and wheat. Therefore, annual net benefits from agriculture equal the sum of the net benefits from these three crops. See Annex 6 for details.

Net Benefits of Reducing Deforestation

The benefit of reducing deforestation or retaining the forest is the sum of direct and other ecosystem service benefits minus the annual cost of forest management, as reported in Column A of Table 11(see Annex 7 for details). The results indicate that the net annual benefits of reducing deforestation ranges from USD 17 /ha to USD 1,131/ ha. The protected area, managed exclusively for biodiversity conservation, has the lowest return of USD 17/ha/ year. The annual benefit of retaining the forest is highest (USD 1,131/ha) in the collaborative forest management regime, which focuses on timber production in keeping with the scientific management. It should be noted that the net benefits of reducing deforestation presented here represent conservative estimates, because the study only encompasses a limited number of forest ecosystem services.

The cost of reducing deforestation is the sum of the annual flow equivalent of a one-time clear cutting of the forest and the annualized flow perpetual net benefits from agriculture. This is computed in Annex 8 and reported in Column B of Table 11. The annual cost of reducing deforestation ranges from USD 1,516/ha to USD 3,772/ha. Annex 8 shows that clear cutting accounts for the bulk of the benefits from deforestation. It ranges from 83 to 96 percent of the total cost of reducing deforestation.

The net annual cost of reducing deforestation (negative of the net benefit in Column C, Table 11) ranges from USD 654 to USD 3,663 per ha depending on the forest management regime. These results are consistent with estimates derived from undisturbed forests in Indonesia. Carbon stock in these undisturbed forests amounts to 300 tC/ha and the opportunity cost of deforestation ranges from USD 1,817 to USD 3,787 per ha or USD 1.65 to USD 3.44 per tCO_2 (Olsen and Bishop, 2009).

Dividing the net cost of deforestation by the carbon stock per ha, we get the annual opportunity cost of deforestation, which ranges from USD 1.11 to USD 3.56 per tCO_2. These estimates are consistent with the range found in a review of 29 empirical studies, which placed the cost of REDD+ between USD 0.84 and 4.18 per tCO_2 (Boucher, 2008; Overmars et al., 2014).

The results indicate that the cost of reducing deforestation heavily depends on the annual benefits obtained from the forest given the high potential opportunity cost (foregone benefit from alternative land use). It costs more to reduce deforestation in forest management regimes that are primarily conservation-oriented and do not offer substantial annual benefits from timber harvest. The benefit from deforestation is lowest in production oriented regimes such as collaborative forest management.

The cost of reducing deforestation is lowest in collaboratively managed forests and community forests of the Terai, and highest in the protected forest regime, followed by the CF-Siwaliks. This is mainly because the collaboratively managed forests and community forests in the Terai offer high annual direct benefits (forest products) and have slow-growing stock due to regular thinning/harvesting. In forest management regimes with dual objectives of biodiversity conservation and forest product collection, the cost of reducing deforestation is high because of the smaller-scale harvest of forest products and the fast-growing stock.

Table 11: **Annual benefits and costs of reducing deforestation in NPR per ha (USD in parentheses)**

Regimes	Benefits of reducing deforestation (A)		Costs of reducing deforestation (B)		Net benefits of reducing deforestation (C= A-B)		Forest carbon stock (tCO_2/ha) (D)	Opportunity cost of carbon per tCO_2 (E=C/D)	
CF-Mid-hills	23,026	(235)	148,593	(1,516)	−125,567	(1,281)	498	252	(2.57)
CF-Siwaliks	24,719	(252)	307,577	(3,139)	−282,858	(2,886)	1,097	258	(2.63)
CF-Terai	54,432	(528)	176,245	(1,711)	−121,813	(1,183)	653	186	(1.81)
Collaboratively managed forest	116,471	(1,131)	183,861	(1,785)	−67,390	(654)	586	115	(1.11)
Protected forest	11,228	(109)	388,493	(3,772)	−377,265	(3,663)	1,030	366	(3.56)
Protected area	4,097	(42)	236,335	(2,295)	−232,238	(2,255)	1,010	230	(2.23)

Note: The opportunity cost of carbon (column E) is calculated with the assumption that soil organic carbon in community forest and in agricultural land is not significantly different, and that the biomass of grass and herbs is equal to the biomass of cereal crops (Gami et al., 2009; DFRS, 2014b; Bajracharya et al., 2015).

Sensitivity Analysis

Two scenarios were developed to further analyse the opportunity cost of reducing forest degradation (Table 12). In the first scenario (Scenario 1), the benefits and costs of deforestation were estimated using a lower discount rate (see

Annex 9 for details). A 5 percent discount rate was used as the social discount rate is lower than the market discount rate (Dasgupta and Pearce, 1972). Net annual equivalent flow associated with clear cutting was estimated using a 5 percent discount rate.

In Scenario 2, the costs and benefits in a degraded forest were estimated using an 8 percent discount rate (see Annex 10 for details). This scenario was based on two premises. The first premise was that deforestation occurs mostly in degraded areas. Here, degraded forest is defined as a sparse forest area having less than 40 percent crown cover (Acharya and Dangi, 2009). Annual harvest of forest products, the value of clear cutting, and forest management costs are estimated using the same ratio of forest carbon stock between the forest area in an average condition and the sparse forest area, but net benefits from agriculture remain the same. Second, this scenario may help address the issue behind sample forest patches within a given physiographic region have faster growing stock compared to the rest of the region, as stated in the national forest inventory report (DFRS, 2015c).

At a 5 percent discount rate, the annual net benefits of deforestation range between USD 112 and USD 2,390 per ha. In carbon equivalent unit, the opportunity cost of carbon is between USD 0.19 and USD 2.32 per tCO_2. Analysis that uses a lower discount rate indicates that the opportunity cost of reducing deforestation decreases significantly with the increasing net value of annual forest products harvest. For instance, protected forests have the lowest net value of annual harvest and the opportunity cost decreases by 35 percent. On the contrary, collaboratively managed forests have the highest net value of annual forest products harvest (13 times higher than that of protected forests) and the opportunity cost decreases by 84 percent.

In a degraded forest, the opportunity cost of reducing deforestation is high compared to a dense forest with a canopy cover of more than 40 percent. In general, degraded forest patches have low carbon stock and the opportunity cost of reducing carbon emission is likely to be higher (Olsen and Bishop, 2009). The opportunity cost of deforestation increases at a higher rate in degraded forests than in forest areas in an average condition. For instance, degraded forest patches of CF (mid-hills) and CF (Siwaliks) have 40 percent and 95 percent biomass of the forest area in an average condition per ha respectively. The opportunity cost of reducing deforestation in CF (mid-hills) increases by one fourth and by less than one percent in CF (Siwaliks).

Table 12: **Benefits and costs of deforestation in different scenarios**

Regimes	Scenario 1–5% discount rate				Scenario 2–Degraded forest (8% discount rate)				
	Annual costs of reducing deforestation (A)	Annual benefits of reducing deforestation (B)	Net annual benefits of reducing deforestation (C=B–A)	Opportunity cost (per tCO_2) D (= C/D of Table 11)	Carbon stock (tCO_2/ha) (E)	Annual costs of reducing deforestation (F)	Annual benefits of reducing deforestation (G)	Net annual benefits of reducing deforestation (H=G–F)	Opportunity cost (per tCO_2) (I= H/E)
CF-Mid-hills	101,971 (1,041)	22,050 (225)	-79,921 (-816)	160 (1.63)	194	72,707 (742)	8,506 (87)	-64,201 (-655)	331 (3.38)
CF-Siwaliks	196,410 (2,004)	23,743 (242)	-172,667 (-1,762)	157 (1.60)	1,050	294,706 (3,007)	23,635 (241)	-271,071 (-2,766)	258 (2.64)
CF-Terai	121,588 (1,180)	53,406 (518)	-68,182 (-662)	104 (1.01)	547	152,447 (1,480)	45,806 (445)	-106,641 (-1,035)	195 (1.89)
Collaboratively managed forest	126,945 (1,232)	115,445 (1,121)	-11,500 (-112)	20 (0.19)	427	142,646 (1,385)	85,297 (828)	-57,349 (-557)	134 (1.30)
Protected forest	256,399 (2,489)	10,202 (99)	-246,197 (-2,390)	239 (2.32)	820	316,653 (3,074)	9,295 (90)	-307,358 (-2,984)	375 (3.64)
Protected area	159,741 (1,551)	3,121 (30)	-157,620 (-1,521)	155 (1.5)	–	–	–	–	–

Note: For detailed analyses of Scenario 1 and 2, see Annexes 9 and 10 respectively.

Benefits and Costs of Reducing Forest Degradation

Heavy reliance on forests for subsistence is a major driver of forest degradation in Nepal (RIC, 2013). Benefits of reducing degradation comprise positive change in carbon stock or negative non-renewable biomass (NRB) in tCO_2/ha (the difference between harvested biomass and annual increment), and costs comprise the change in the value of harvested forest products. In two forest management regimes (CF-Terai and collaboratively managed forest), harvest of forest products exceeds the natural biomass increment or positive NRB. This means forests in these two regimes underwent degradation during the study period. In other regimes, harvest is less than annual increment or negative NRB, which indicates an absence of forest degradation during the study period. However, forest degradation in CF-Terai and collaboratively managed forests is expected to be reversed after the implementation of scientific forest management. Net value of annual forest products harvest increases with positive NRB and vice-versa. The correlation between NRB and the c hange in net value of annual forest products harvest suggests that harvesting less forest products or increasing the supply of forest products through enhanced productivity of forests can reduce forest degradation.

NRB, whether positive or negative, is between 0.43 and 11.83 tCO_2 per ha, and the change in net value of annual direct benefits is between USD 1.34 and USD 39.15 per ha. Community forests of the Siwaliks and the mid-hills, and protected forests have not undergone degradation. Annual increment of carbon ranges from 0.43 to 5.54 tCO_2/ha in these forests. These estimates corroborate previous findings that show mean annual increment in Nepal's forests is between 2.5–7.6 cubic metre per ha (Puri et al., 2013). The opportunity cost of reducing forest degradation in carbon equivalent unit ranges from USD 0.72 to USD 1.19 per tCO_2 (Table 13). These figures represent the lower end of the previously estimated range, which suggested that the break-even price of carbon sequestration from forest enhancement in Nepal's community forests, i.e., between USD 0.55 tCO_2 and USD 17.44/ tCO_2 (Karky and Skutsch, 2009).

Table 13: **Annual costs and benefits of reducing forest degradation in NPR (USD in parentheses)**

Regimes	Harvest biomass in tCO_2/ha (A)	Annual increment (tCO_2/ha) (B)	NRB in tCO_2/ha (C=A – B)	Cost of reducing forest degradation (Change in net value of annual forest products harvest per ha) (D)		Opportunity cost of reducing forest degradation (per tCO_2) (E= D/C)	
CF-Mid-hills	1.64	7.17	-5.54	-3,847	(39.15)	695	(7.09)
CF-Siwaliks	2.17	6.75	-4.58	-716	(7.30)	156	(1.59)
CF-Terai	6.19	0.67	5.51	676	(6.56)	123	(1.19)
Collaboratively managed forest	11.87	0.04	11.83	876	(8.50)	74	(0.72)
Protected forest	0.83	1.27	-0.43	-138	(1.34)	319	(3.09)

Note: NRB is the difference between column A and average annual change in carbon estimated based on the average annual above-ground carbon in Table 6.

Conclusion and Policy Recommendations

Conclusion

This study will be useful in developing effective policies and measures for REDD+ implementation and revising forest management strategies in Nepal. First, it provides valuable information about the minimum cost that forest users/forest managers may incur while conserving forests under different management regimes. The estimated annual costs of reducing deforestation range from USD 112/ha to USD 3,663/ha depending on the forest management regime and discount rate. The annual cost of conserving carbon by reducing deforestation is between USD 0.19/tCO_2 and USD 3.56/tCO_2, and by reducing forest degradation is between USD 0.72 and USD 1.19 per tCO_2. These estimates indicate that REDD+ is a cheaper option compared to other strategies for reducing carbon emission such as biogas. The estimated cost of carbon sequestration using a bio-digestion plant in Nepal is USD 7.00/tCO_2 (Dhakal et al., 2016). The growing stock in forests and annual direct benefits from forests are key determinants of the costs and benefits of reducing deforestation, with profits from agriculture playing a much smaller role.

The estimated cost of reducing the annual deforestation rate of 2,537 ha in the Siwaliks (in 1995-2010) to zero is between USD 1.75 million and USD 2.88 million depending on the discount rate only. In the case of Terai, the estimated annual costs of reducing deforestation from 1,684 ha/year to zero ranges from USD 0.14 million to 2.71 million depending on the forest management regimes and discount rate. These estimates are based on the average carbon stock in these regions i.e. 116.94 tC/ha (429.17t CO_2/ha) in Siwaliks and 123.14 tC/ha (429.17 t CO_2/ha) in the Terai (DFRS, 2014a, b).

This study also indicates that the scientific forest management approach, which emphasizes timber production, can enhance both forest benefits and forest carbon stock. The opportunity cost of reducing deforestation and degradation is low in these two regimes. This management approach disincentivizes agents from converting forestland into agriculture or degrading the forest.

Reducing forest users' dependency on forest products by providing alternatives such as biogas (Somanathan and Bluffstone, 2015) or increasing the supply of forest products through an appropriate forest management strategy may help reduce the rate of forest degradation. In the context of the Siwaliks region, this study suggests that the benefits missed by the community due to the declaration of conservation zone can be compensated for by providing them REDD+ payments for enhanced biomass (in terms of carbon).

The sensitivity analyses indicate that two factors have an important role in determining the opportunity costs of reducing deforestation besides discount rate. The first is the value of annual forest products harvest, which relies on the forest management approach. The higher the net value of annual forest products harvest, the lower the opportunity cost of reducing deforestation. The second factor is the condition of the forest. Sparse forests have a higher opportunity cost of reducing deforestation than dense forests in carbon equivalent terms.

The study could be enriched by extending the analysis to different types of forests (selected based on species), particularly in the mid-hills and high mountains. In addition, assessing the costs and benefits of individual drivers of forest degradation, including fire and invasive species, could prove useful in designing forest management activities.

Suggested Policy Options

Based on the analysis, this study suggests the following policy options:

- *Expansion of the scientific forest management approach:* The rate of deforestation is higher in the Terai, where forest is dominated by mature premium-value Sal trees (*Shorea robusta*) and the forestland can be easily converted to agricultural land. This study recommends expanding the scientific forest management approach, which focuses on timber and fuelwood production based on silvicultural prescription, in Terai forests. The scientific forest management approach increases annual benefits (timber and fuelwood) from forest management and reduces the benefits to be obtained from deforestation. Moreover, this forest management approach helps to increase the supply of premium Sal timber in the market. This contributes in keeping the market price of Sal timber low, and as a result less pressure will be exerted on the remaining forest.

- *Degraded forest should be given priority for forest management and development:* As the incentive for deforestation is high in degraded forests, priority should be placed on restoring these areas to reduce further risks of deforestation.
- *Remaining government managed forest patches in the Terai and the Siwaliks should be managed by local communities:* In view of the increasing rate of deforestation in the Terai and the Siwaliks, and the positive outcomes of community-based management, this study recommends that government-managed forests should transition into some form of community-based management regime.
- *Accounting for forest benefits in Nepal's System of National Accounts:* Forests provide economic benefits besides timber. Aside from carbon storage and potential payments for REDD+, forests provide ecosystem services such as non-timber forest products for commercial use, prevention of soil erosion, and water regulation for agriculture and other productive sectors. These are tangible economic benefits that can be accounted for directly in the System of National Accounts (SNA). Forest-derived income in other sectors such as agriculture and tourism can be included in a satellite account. This study can help pave the way towards including forest ecosystem services in Nepal's SNA.

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Annex 1: Description of meetings and consultations

Activities	Date	Description
Central level meeting	24 November 2014	A half-day meeting with central level government officials from the Central Bureau of Statistics and REDD Implementation Center
Gorkha district	14 and 15 December 2014	Two focus group discussions with forest users, consultation with the District Forest Officer and Local Development Officer, Gorkha
Chitwan district	5-6 January 2015	Three focus group discussions with forest users, consultation with the District Forest Officer, Chitwan
Rupandehi and Kapilvastu districts	2-4 February 2015	Four focus group discussions with forest users, consultation with the District Forest Officer (Rupandehi), Senior Forest Officer (Kapilvastu), Assistant Forest Officers (Rupandehi and Kapilvastu), Multi-stakeholder Forestry Programme – Cluster Coordinator (Rupandehi)
REDD Implementation Center	6 February 2015	Staff of REDD Implementation Center – Chief, two Forest Officers, and two Assistant Forest Officers provided feedback on preliminary findings of field visit and research design
Dhulikhel Mountain Resort	9 February 2015	Researchers from IDRC Canada, Bangladesh, India, Nepal, Pakistan and Sri Lanka provided feedback on research design.
National Planning Commission	27 February 2015	Sharing of research design with Purushottam Ghimire, Joint-Secretary, National Planning Commission
Godavari	31 August 2015	Half-day workshop for sharing of research design with stakeholders including UN Environment, REDD+ IC, and forestry donors and forestry professionals in Nepal
Dhulikhel	7 April 2016	Half-day workshop to get experts' feedback on preliminary findings

Annex 2: Model for CPA estimations, their R^2 and R^2 of validation of segmented image

Regime	Model for CPA	R^2 CPA Model	R^2 of validation of segmented image
CF (Mid-hills)	y= 0.0441x-18.226	0.77	0.87
CF (Siwaliks)	y= 0.0543x-62.078	0.76	0.85
CF (Terai)	y = 0.0414x - 119.01	0.64	0.85
Collaborative forest	y = 0.0685x +25.898	0.64	0.87
Protected Forest	y = 0.1149x - 465.75	0.66	0.70
Protected area	y = 0.0296x + 171.47	0.65	0.77

Annex 3: Forest carbon stock and change carbon stock in forest management regimes

Regime	Base year (tC/ha)	End year (tC/ha)			Annual change in carbon (tC/ha)			Remarks (base year and end year)	Sparse forest above-ground carbon (tC/ha)
	Above-ground carbon (A)	Above-ground carbon (B)	Below ground (C)	Tree component (D= B+C)	Above ground (E)	Below ground (F)	Tree component (G= E+F)		
Community forest (Mid-hills)	101.00	118.00	17.70	135.70	1.70	0.26	1.96	2002 and 2012	45.98
Community forest (Siwaliks)	244.00	260.00	39.00	299.00	1.60	0.24	1.84	2002 and 2012	248.71
Community forest (Terai)	153.21	154.80	23.22	178.02	0.16	0.02	0.18	2002/2003 and 2013/2015	129.69
Collaboratively managed forest	138.75	138.87	20.83	159.70	0.01	0.00	0.01	2002/2003 and 2013/2015	101.25
Protected forest	240.00	244.00	36.60	280.60	0.30	0.05	0.35	2002 and 2015	194.24
Protected area	237.77	239.40	35.91	275.31	0.13	0.02	0.15	2020002 and 2015	-

Note: Below-ground carbon is 15% of the above-ground carbon. Above-ground carbon was calculated using the Equation 3.

Annex 4: Annual forest products harvested per household

Forest products	CF (Mid-hills)			CF (Siwaliks)			CF (Terai)			Collaborative forest management			Protected forest		
	Base year (2011)	End year (2013)	Harvest cost per unit (NPR)	Base year (2011)	End year (2013)	Harvest cost per unit (NPR)	Base year (2010)	End year (2015)	Harvest cost per unit (NPR)	Base year (2010)	End year (2015)	Harvest cost per unit (NPR)	Base year (2010)	End year (2015)	Harvest cost per unit (NPR)
Fuelwood (Bhari)	9.69	9.53	169	24.82	23.74	155	84.02	62.59	192	64.91	56.73	195	53.65	49.69	92
Fodder (Bhari)	61.60	43.96	55	102.51	125.82	89	9.97	12.09	127	21.20	23.89	150	99.64	91.00	106
Leaf litter (Sack)	3.77	7.60	41	24.34	39.61	53	-	-	-	-	-	-	0.00	0.00	0.00
Timber (cu ft.)	9.66	6.83	327	6.87	2.91	787	0.76	4.76	1050	0.94	2.09	1125	1.10	2.65	230
Thakra (number)	0.00	0.00	0.00	-	-	-	0.12	0.10	105.	-	-	-	6.22	9.07	81
Thatch (Bhari)	-	-	-	-	-	-	-	-	-	-	-	-	6.28	7.85	186
Saccharum (Bhari)	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.21	92

Note: 'Bhari' is load carried on the head and is equivalent to 25kg, and 'Thakra' is a wooden support for climbing vegetables. Harvest cost is calculated as the time spent to collect one unit of forest product times the average self-reported wage rate, which varies across the region. The quantity is annual forest product harvest, which is average of the base year and end year. The market price of Sal (Shorea robusta) log is NPR 3,000/cu ft. and of other species is NPR 1500/cu ft. Fuelwood market price is NPR 300/Bhari in the Mid-hills and the Siwaliks, and NPR 500/Bhari in the Terai.

Annex 5: Average annual contribution of forest users to forest management (sd in parentheses)

Activities	CF-Mid-hills		CF-Siwaliks		CF- Terai		Collaborative forest		Protected forest	
Patrolling (days)	0.49	(1.59)	1.28	(3.25)	0.43	(2.67)	0.11	(0.91)	2.25	(5.45)
Thinning-pruning (days)	2.55	(2.87)	0.66	(1.29)	0.05	(0.26)	0.006	(0.15)	0.30	(0.59)
Alien plant control (days)	-		-		-		-		0.02	(0.18)
Plantation (days)	-		-		0.29	(0.54)	0.003	(0.06)	0.51	(1.32)
Plant management (days)	-		-		0.12	(0.45)	-		0.03	(0.25)
Cleaning (days)	0.04	(0.25)	0.03	(0.18)						
Regular meeting (days)	1.24	(2.19)	0.99	(1.68)	0.29	(0.18)	0.06	(1.32)	3.12	(2.34)
Annual general meeting (days)	0.52	(0.38)	0.52	(0.34)	0.21	(0.38)	0.005	(0.13)	0.49	(0.50)
Forest office visit (days)	0.35	(3.21)	0.10	(0.56)	-		-		0.03	(0.19)
Average wage rate (NPR/day)	280.00		392.25		323.38		332.36		286.8	
Number of sample households	105		105		247		355		303	

Annex 6: Costs and benefits of cultivating major cereal crops

Cereals	CF-Siwaliks			CF-Terai			Collaboratively managed forest			Protected forest		
	Production (Quintal)	Price (NPR/ quintal)	Production cost (NPR/ Quintal)	Production (Quintal)	Price (NPR/ quintal)	Production cost (NPR/ quintal)	Production (Quintal)	Price (NPR/ quintal)	Production cost (NPR/ quintal)	Production (Quintal)	Price (NPR/ quintal)	Production cost (NPR/ quintal)
Paddy	33.1 (15.44)	3,000	96,963	37.12 (9.32)	2,075	44,482	39.34 (15.67)	2,075	44,762	24.85 (11.24)	1,900	43,841
Maize	39.89 (10.73)	2,000	74,394	20.45 (6.40)	2,400	60,282	34.01 (12.89)	2,400	66,926	15.97 (7.09)	2,100	53,835
Wheat	15.67 (16.79)	3,000	43,601	22.42 (6.03)	2,260	53,885	20.70 (10.19)	2,260	77,263	25.73 (7.69)	2,400	33,279

Note: These estimations are based on household surveys. Net profit for the mid-hills was derived from Bhandari et al. (2015), as primary data on household-level input and output is not available for this region.

Annex 7: Net annual benefits of reducing deforestation NPR/ha (USD/ha)

Regime	Net annual direct benefits (A)		Other ecosystem service benefits (B)		Annual forest management cost (C)		Net annual benefits of retaining forest (D= A+B-C)	
CF (Mid-hills)	23,788	(243)	2,331	(23.78)	3,093	(31.56)	23,026	(235)
CF (Siwaliks)	24,962	(255)	2,331	(23.78)	2,574	(26.26)	24,719	(252)
CF (Terai)	52,830	(513)	2,450	(23.78)	848	(8.23)	54,432	(528)
Collaboratively managed forest	114,800	(1,115)	2,450	(23.78)	779	(7.56)	116,471	(1,131)
Protected forest	9,476	(92)	2,450	(23.78)	698	(6.78)	11,228	(109)
Protected area	-		4,831	(49.29)	734	(7.13)	4,097	(42)

Annex 8: Costs of reducing deforestation NPR/ha (USD/ha)

Regime	Net annual flow of clear cutting		Net annual benefits from agriculture		Benefits of reducing deforestation	
CF (Mid-hills)	124,325	(1,269)	24,268	(236)	148,593	(1,516)
CF (Siwaliks)	296,445	(3,025)	11,132	(108)	307,577	(3,139)
CF (Terai)	145,751	(1,415)	30,494	(296)	176,245	(1,711)
Collaboratively managed forest	151,775	(1,473)	32,086	(312)	183,861	(1,785)
Protected forest	352,250	(3,420)	36,243	(352)	388,493	(3,772)
Protected area	204,249	(1,983)	32,086	(312)	236,335	(2,295)

Annex 9: Annual costs and benefits of reducing deforestation at 5% discount rate (NPR/ha)

Regime	Clear-cut cost		Clear-cut benefits		Annual agricultural benefits (E)	Annual direct benefits (F)	Annual harvest cost (G)	Forest management cost (H)	Other ecosystem service benefits (I)	Carbon stocks (tCO_2/ha) (J)	Costs of reducing deforestation (K=D-B+E)	Benefits of reducing deforestation (L=F-G-H+I)	Net benefit of reducing deforestation (M=K-L)
	Total harvest (A)	Annual flow (B)	Total benefits (C)	Annual flow (D)									
CF (Mid-hills)	290,514	14,526	1,844,570	92,229	24,268	40,043	16,255	3,093	1,355	498	101,971	22,050	79,921
CF (Siwaliks)	1,774,713	88,736	5,480,270	274,013	11,132	58,783	33,821	2,574	1,355	1,097	196,410	23,743	172,667
CF (Terai)	1,181,061	59,053	3,002,943	150,147	30,494	87,567	34,737	848	1,424	653	121,588	53,406	68,182
Collaboratively managed forest	1,369,708	68,485	3,266,893	163,345	32,086	200,010	85,210	779	1,424	586	126,945	115,445	11,500
Protected forest	508,151	25,408	4,911,277	245,564	36,243	15,705	6,229	698	1,424	1,030	256,399	10,202	246,197
Protected area	1,154,269	57,713	3,707,376	185,369	32,086	25,750		734	3,855	1,010	159,741	3,121	156,620

Annex 10: Annual costs and benefits of reducing deforestation of degraded area at 8% discount rate (NPR/ha)

Regime	Clear-cut cost		Clear-cut benefits		Annual agricultural benefits (E)	Annual direct benefits (F)	Annual harvest cost (G)	Forest manage-ment cost (H)	Other ecosystem service benefits (I)	Carbon stocks (tCO²/ha) (J)	Costs of reducing deforestation (K=D-B+E)	Benefits of reducing deforestation (L=F-G-H+I)	Net benefit of reducing deforestation (M=K-L)
	Total harvest (A)	Annual flow (B)	Total benefits (C)	Annual flow (D)									
CF (Mid-hills)	113,190	9,055	718,679	57,494	24,268	15,602	6,333	3,093	2,331	194	72,707	8,506	-64,201
CF (Siwaliks)	1,697,660	135,813	5,242,332	419,387	11,132	56,231	32,353	2,574	2,331	1,050	294,706	23,635	-271,071
CF (Terai)	988,224	79,058	2,512,641	201,011	30,494	73,270	29,065	848	2,450	547	152,447	45,806	-106,641
Collaboratively managed forest	997,765	79,821	2,379,770	190,382	32,086	145,697	62,071	779	2,450	427	142,646	85,297	-57,349
Protected forest	404,515	32,361	3,909,639	312,771	36,243	12,502	4,959	698	2,450	820	316,653	9,295	-307,358

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