frontiers | Frontiers in Forests and Global Change

ORIGINAL RESEARCH
published: 09 June 2022
doi: 10.3389/ffgc.2022.857145

Opportunity Costs of Forest Conservation in Nepal

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Forest biomass may vary by species composition, location, management regimes, and management interventions. To assess the variation in biomass production by management regimes, we conducted a study in three physiographic regions (mid-hills, Siwaliks and Terai) of Nepal with four different management regimes (community forest, collaborative forest, protected area, and protected forest). As community forest is the dominant forest management regime in Nepal, it was studied in all physiographic regions whereas the other two regimes were drawn only from the Terai. We interviewed a total of 1,115 forest user households, which was supplemented by high-resolution satellite image analysis and forest inventory to estimate the costs and benefits of forest management and calculate the opportunity cost of conserving forest. Our estimates suggest that the opportunity cost of conserving forest in Nepal ranged from USD 654/ha in collaborative forest to USD 3,663/ha in protected forest in 2015. The associated opportunity cost of carbon sequestration was between USD 1.11 and USD 3.56 per tCO_2. Of the forest management practices adopted, the silviculture-based intensive forest management practice had a far lower cost of forest conservation compared to the other forest management regimes. We found that such a practice is more beneficial to the forest-dependent communities as it allows them to collect the non-timber forest products that are necessary for their daily needs.

Keywords: forest conservation, opportunity cost, benefit-cost, carbon sequestration, collaborative forest, community forest, protected area, REDD+

OPEN ACCESS

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to People and Forests, a section of the journal Frontiers in Forests and Global Change

Received: *18 January 2022*
Accepted: *02 May 2022*
Published: *09 June 2022*

Citation:
Rai RK, Nepal M, Karky BS, Timalsina N, Khadayat MS and Bhattarai N (2022) Opportunity Costs of Forest Conservation in Nepal. Front. For. Glob. Change 5:857145. doi: 10.3389/ffgc.2022.857145

HIGHLIGHTS

- Compulsory participation of forest users in forest management activities increases the cost of forest management.
- Active forest management increases the direct benefits from forest products and reduces the opportunity cost of carbon conservation.
- Forests allocated for biodiversity conservation have a higher opportunity cost of carbon conservation compared to forests conserved for other objectives.
- The opportunity cost of carbon, under sustainable forest management, is less than USD 4 per tCO_2.

INTRODUCTION

Agriculture, forestry and other types of land use loom large in the global discussion on environmental policy as they are the second largest anthropogenic source of CO_2 emission after fossil fuel combustion (van der Werf et al., 2009; IPCC, 2014). This is so as reducing CO_2 emission is one of the long-term strategies to minimize global warming and resultant climate change. Reduction in emissions from deforestation and forest degradation (REDD) is expected to be an economically attractive option in such a context (Stern, 2006; Angelsen, 2008). REDD+ goes beyond reversing deforestation and forest degradation by (i) conserving forests, (ii) stimulating sustainable management of forests, and (iii) enhancing forest carbon stock (Minang and Murphy, 2010). It is therefore important to understand the associated costs and benefits of carbon sequestration, which is a byproduct of forest management.

Forests may vary by species composition, age structure, the characteristics of the geographical location they are in, and management activities. Therefore, from a utilitarian perspective, not all forests are equal, as costs and benefits of forest conservation may vary depending on their characteristics. For example, in Nepal, rural households regard private forest as the most valuable, as they have easy access to these types of forest for extracting non-timber forest products to fulfill their daily needs, followed by community-managed forest (Nepal et al., 2017). Research also shows that people's perception of the value of a particular tree species is based on how the species satisfies their economic and other needs (Selge et al., 2011; Rai and Scarborough, 2015). For example, farm households prefer broadleaved trees to conifers because the latter does not produce the fodder and fuelwood that are necessary for their livelihoods (Rai and Schmerbeck, 2018). Moreover, households believe broadleaf forest to be better for water provisioning services in comparison with pine forest (Das et al., 2019). In contrast, the construction sector prefers species that can produce timber such as conifer. Forests, thus, are an intrinsic part of rural life in developing countries although the use of forest products depends on the technological or institutional set up of a particular context (Shyamsundar et al., 2018).

Some forest species grow faster while others take a longer time for accumulating woody biomass. The slow-growing species accumulate more biomass at maturity than the fast-growing species while the fast-growing species accumulate more biomass in a shorter time-period than the former (Shimamoto et al., 2014). However, the same species may also have a different growth rate depending on location. For instance, Sal (*Shorea robusta*) grows faster in the lowlands than in the hills (Sah, 2000). In addition, the management system of the forest plays a role in manipulating the growth and structure of tree species, which would, in turn, influence the carbon sequestration capacity of the managed forest (Harmon, 2001).

Forest ownership type and the size of the forest patch are key factors that influence forest management practices (Siry et al., 2010). Forest owners assess the costs and benefits of forest management when making decisions on management practices. An important role is also played by forest policy, which affects the extent of forest management activities. For instance, the extent of the forest products harvested by community forest user groups in Nepal is set at less than the mean annual increment. In protected forests, no harvesting is permitted in the core area and users may only harvest forest products from the production zone which is outside the core area (Shrestha et al., 2014). Hence, at an individual level, households that are members of community forest user groups tend to plant more trees on their private land for fodder, firewood or timber, thereby reducing pressure on the nearby community forest (Nepal et al., 2007). Moreover, incentives for conserving forest biomass tend to increase, in addition to carbon sequestration, the adoption of cleaner cooking technologies or fuel with added health benefits to the households (Sharma et al., 2020).

This study examines the variation in the costs and benefits associated with four forest management regimes in three physiographic regions in Nepal. We surveyed 1,115 forest user households from the study areas (**Figure 1**) to collect the necessary information while obtaining additional information from other sources (Sharma et al., 2015). **Figure 2** summarizes the key information as well as the methods used in the analysis. This information is critical since understanding the opportunity cost of forest conservation would be helpful to policymakers in designing climate change mitigation policies and in assessing the net benefits from the conserved forests.

STUDY AREA

The study is carried out in three physiographic regions[1] of Nepal: the Terai, the Churia, and the middle mountains (**Figure 1**). These regions cover about 68% of the total forest area in Nepal (DFRS, 2015). The forests in these regions are managed for production of timber and non-timber forest products. The rest of the forest areas in the high mountains and high Himalaya regions are dominated by rangeland and protected areas (e.g., Chitwan National Park). Site selection was carried out in consultation with stakeholders and included based on two main pre-requisites: (i) Forest patches should have been managed under the existing forest management regimes for at least 5 years; and (ii) Forest patches should have vegetation representing the physiographic region. Previously, these areas had also been selected for a REDD+ pilot project and for the implementation of the emission reduction program in Nepal.

Forest patches were selected from four different forest management regimes in the three regions: protected forest, protected area, community forest, and collaborative forest. Of these, the national forests of Nepal enjoy either full protection status under protected areas or are managed under different community-based forest management regimes outside the protected areas. In all cases, forest management plans are

[1]These regions extend across the country from east to west. The Terai lies in the southern part of the country. The Churia lies between the Terai and the middle mountains. To the north of the middle mountains are the high mountains and the high Himal (Himalaya) region. **Figure 1** shows the entire Hindu Kush Himalaya region while the study area, which is located in Nepal, is numbered in the lower panel.

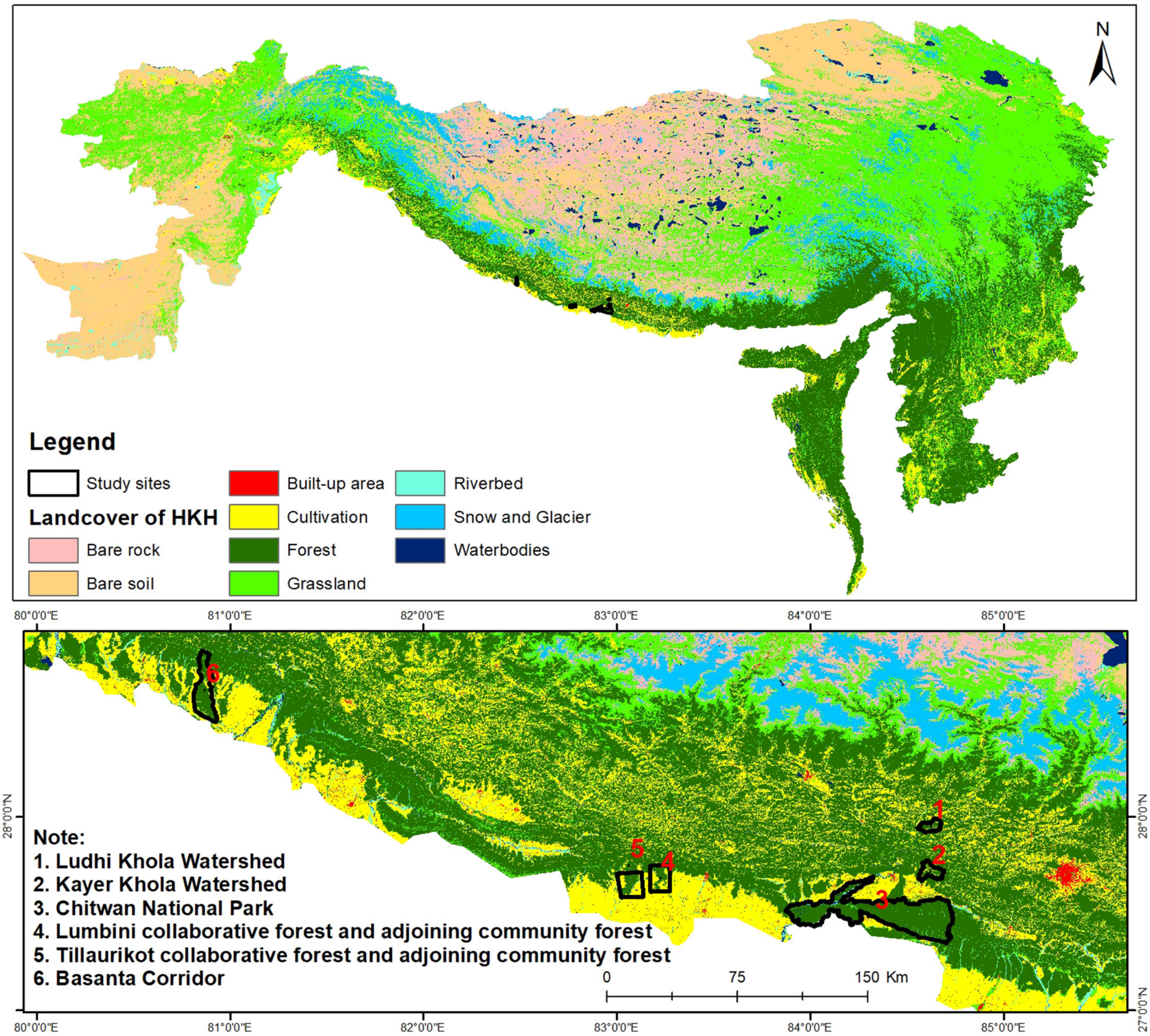

FIGURE 1 | Map of the study sites.

developed and used as a guide for managing the forests (Nepal, 2002; Heinen and Shrestha, 2006)[2]. Among the different models for forest management in Nepal, Community Forest (CF) is the dominant forest management strategy, where community forest user groups enjoy autonomous status and determine the management, utilization and distribution of forest products and benefits based on rules and guidelines set by the government (Acharya, 2002). Collaborative Forest Management (CFM), on the other hand, is a joint management of forests between the government and communities. Under this type of management, large forest patches are managed through the involvement of both local and distant users (Rai et al., 2017). Forest patches that are classified as "fully protected" function as corridors between two protected areas for the movement of protected wild animals while areas outside these core zones are allocated for production (Shrestha et al., 2014). Only the Terai region includes all the forest management regimes selected for the study while community forest (CF) is the only management regime found across the three physiographic regions selected.

MATERIALS AND METHODS

Data Collection

For this study, we used two different data sets on forest resources, forest products harvest, and contribution to forest management. We conducted a primary survey covering 1,115 households to collect the data on forest products harvested and contribution to forest management by households. Households were selected using a systematic sampling method. The questionnaire focused on the benefits (through forest product extraction and use) received from and the contribution of users toward forest management. The study used a similar data set generated by

[2]Management plans for the protected areas in Nepal can be found at https://dnpwc.gov.np/en/publication-detail/6/ (accessed April 3, 2022).

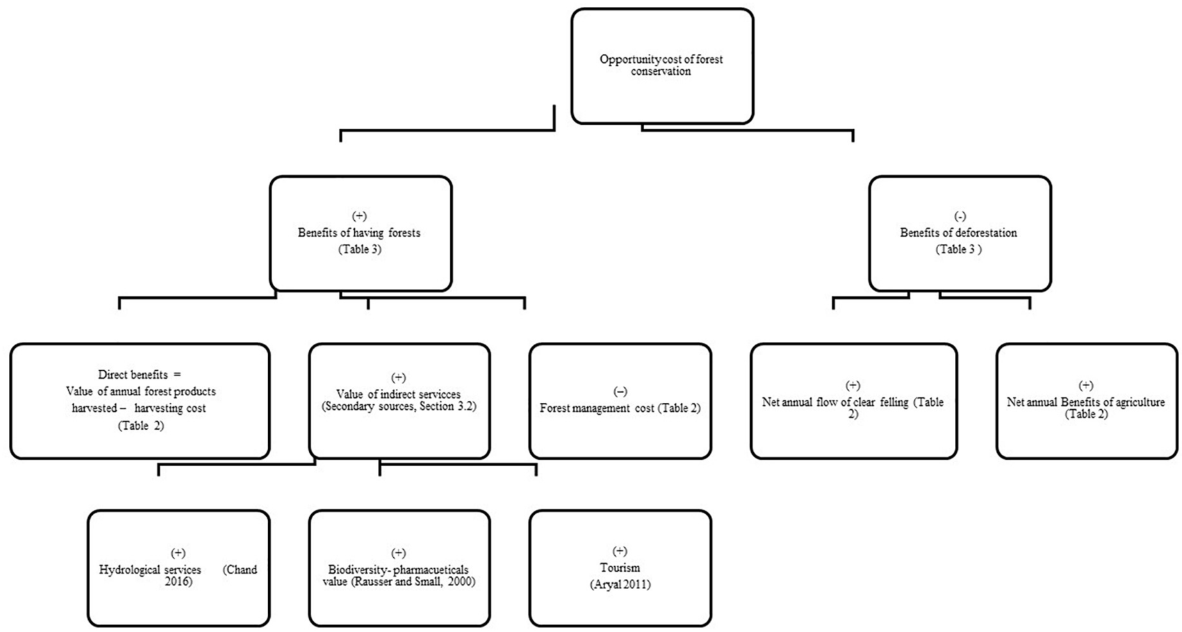

FIGURE 2 | Analytical framework of estimating benefits and costs of reducing deforestation.

another project from the middle hills and the Churia to increase the coverage of the study (Sharma et al., 2015, 2017, 2020). The data were used to calculate the value of forest products harvested, harvesting cost, and forest management cost. All nominal variables were converted to USD for comparison purposes using the 2015 exchange rate.[3]

We carried out the forest inventory in the selected forest sites using a random sampling technique. The diameter and height of all trees with a diameter at breast height greater than or equal to 5 cm were measured inside the 600 circular sampling plots of 500 m^2. Based on the forest inventory data, we carried out carbon stock estimations for two different periods using high-resolution satellite images.[4]

Data Analysis

Opportunity Cost of Forest Conservation

In this study, the opportunity cost of forest conservation refers to the net benefit from deforestation, which is calculated by deducting the benefit of having a forest from the benefits of deforestation (**Figure 2**). The locally captured benefits of deforestation are derived by adding up the net annual flow of benefits from clear-cutting and the net benefits from agriculture in the freed-up land. Clear-cutting provides one-time net benefits from forest products (value of timber and fuelwood minus the clear-cutting cost). The net value of the forest products was discounted at 8% to estimate the annual flow (NRB, 2016). The discount rate was based on the interest rate offered by the Agricultural Development Bank, which offers different financial instruments to rural people, for short-term personal fixed deposit. The net benefit from agriculture was estimated by subtracting the annual cost of cultivating, growing, and harvesting the major cereal crops from crop revenue in the study area. This also includes the one-time land preparation cost after removing the tree stumps.

The benefit of having a forest is derived by adding up the direct benefits and indirect services minus the cost of forest management. Direct benefits are estimated as the difference between the value of the annual forest products harvested (timber, fuelwood, and fodder) and the annual harvesting and administrative cost of the forest user groups. The value of forest products that are sold in the market is based on market prices whereas the value of products consumed by forest users is based on the opportunity cost of time to collect the forest products, which is estimated based on the local wage rate.[5] The indirect benefits from forests included in the study were hydrological services, biodiversity option value, and recreational benefits from tourism. These are the major indirect benefits that people in the Himalaya regions expect from the forests (Shrestha et al., 2014; Sharma et al., 2017; Das et al., 2019). While there may be other benefits, we do not have case studies to extract the relevant information.

We used hydrological services (stream flow), biodiversity option values, and tourism-related recreational values to account for the indirect services that the forest ecosystem under consideration provides to the local people and those beyond.

[3] 1 USD = NPR 98 in 2013 and 1 USD = NPR 103 in September 2015. NPR (Nepali Rupees) is the Nepali currency.

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

[5] In the areas where households collect and consume forest products, a local market for these products rarely exists. Therefore, we used the local wage rate to calculate the opportunity cost of time to collect forest products.

The choice of the services included in the study were based on available case studies from comparable landscapes, suggesting that our estimates provide the lower bound of the value of indirect services that the forest ecosystem provides. The values of these indirect services were derived from the available studies using the benefit transfer approach as discussed below.

Forests have negative hydrological impacts in certain conditions. Dense forest causes the loss of local water through evapotranspiration (Calder, 2002; Farley et al., 2005). A case study in Nepal has found that the conversion of forest into agricultural land or bare soil increases the stream flow by 12 cubic meter per ha annually (Chand, 2016), suggesting that forest conversion may even increase dry season flow. The imputed price of per cubic meter of water was NPR 24 (USD 0.23) in 2015 (RIC, 2015), which is used in our study for calculating the value of water. Using these two estimates, the value of hydrological services from forest conservation was calculated to be NPR 286 (USD 2.78) per ha annually[6]. The value of biodiversity was estimated as the option value of genetic resources in the eastern Himalaya, which is USD 332 per ha. At the given discount rate, the annual flow in perpetuity is USD 26.56 per ha (Rausser and Small, 2000). The biodiversity option value is considered as an indicator of change in the status of nature's contribution to people (Faith, 2021).

The recreational value of the forest ecosystem of the Chitwan National Park is NPR 233 million (USD 2.37 million) per year (Aryal, 2011). This results in USD 25.51 per ha of annual recreational value for the protected areas. Combining all these estimates, the annual value of indirect benefits is roughly estimated at USD 49.29 per ha for the protected areas and USD 23.78 per ha for the other regimes. These estimates are clearly the lower bounds as we do not have information on other potential benefits. It is to be noted that these estimated values are not limited to the stipulated local boundaries as some services such as hydrological services, recreational services, and the option value cross local boundaries depending on where these forest patches are available. We estimated the recreational value from only the protected areas as community managed forests are not designed to generate recreational benefits.

Opportunity Cost of Forest Carbon

The opportunity cost of forest carbon in all forest management regimes and physiographic regions was estimated using the five forest carbon pools, i.e., aboveground, belowground, deadwood, litter, and soils. A comparison of the change in carbon stock between forests and agriculture allowed us to assume that there is no difference in litter and soil biomass between forests and land under agriculture. As agriculture too enables green coverage, soil carbon may not be different in these two land use types in the short term. Therefore, the estimated change in forest carbon stock due to deforestation is the sum of aboveground, belowground, and deadwood carbon pools. The opportunity cost of forest carbon is defined as the ratio between a change in net benefits from deforestation and difference in forest carbon stock between forest and alternative land use such as agriculture.

In order to estimate the forest carbon biomass, we developed a model to establish a relationship between the field plots' biomass (1 ha grid) and crown projection area. We then used the data from the forest inventory and crown-based data to calibrate and validate the model. Crown-based data were acquired from a high-resolution image as tree crown data, which was verified from field data. We estimated carbon stocks for the base year for each area based on the availability of satellite images (2002 or 2003) using the fitted regression model. While the data set for two of the study areas (CF-middle hills and CF-Churia) had been collected for another study in 2012 (Sharma et al., 2015, 2017), the inventory for the other four study areas was prepared by the study team in 2015. The present study refers to 2012 and 2015 as the end years for the respective study areas but all monetary values have been converted to 2015 constant price. The annual increase in biomass 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 difference by the number of years in between.

[6]We note that forests may also help prevent soil erosion when they control water flow and improve agricultural stream productivity but we do not have such information for further analysis. We have used the per unit price of drinking water from a government source (RIC, 2015). Since most of the areas where we collected data experience a shortage of water during the dry season, we deem this price reasonable for accounting proposes.

RESULTS

Forest Biomass and Carbon Stock

Sal (*Shorea robusta)* is the major species in all the selected forests (**Table 1**). A comparison of the growing stock between the selected study areas indicates that forests that are protection-oriented such as community forest (Churia), which is under the Churia Conservation Program, and forests designated as wildlife corridors (protected forest) and for wildlife conservation (protected area) have the highest woody biomass and carbon stocks.

Community forests in the Middle hills and Churia have the highest growth rate of forest carbon. This may be due to the fact that these regions are recovering from severe degradation in the past. In contrast, the lowest annual change is recorded in collaborative forest, which has adopted an intensive forest management approach focusing on timber production since 2010. In the short run, such felling areas usually have low carbon storage after the timber is harvested (Asner et al., 2005).

Costs and Benefits of Deforestation and Forest Management

Table 2 reports the costs and benefits associated with forest management activities and deforestation in the study area. It shows that the value of annual forest products harvested was between USD 152 and USD 1,942 per ha. The collaborative forest, which adopts intensive forest management and permits timber harvest at commercial scale, had the highest benefits from forest products whereas community forests (middle hills), which require compulsory participation of forest users in all forest management activities, had the highest forest management cost.

The Table also indicates that forest management regimes which require compulsory participation of all users in forest

TABLE 1 | Forest growing stock and carbon stock.

Regime	Physiographic region	Volume (m^3/ha)		Carbon (tCO_2/ha)	Average annual change (tCO_2/ha/year)
		Sal (*Shorea robusta*)	Other species		
CF	Middle hills	19	13	499	7.19
CF	Churia	56	37	1,097	6.75
CF	Terai	35	11	653	0.66
Collaborative	Terai	39	12	587	0.04
Protected forest	Terai	51	31	1,031	1.28
Protected area	Terai	40	20	1,009	0.55

Source: Field survey, 2012 and 2015. CF, community forest.

TABLE 2 | Costs and benefits of forest management activities per ha in NPR (USD in parentheses).

Regime	Benefits of forest management				Benefits of deforestation	
	Direct benefits			Total forest management cost	Net annual flow of clear felling	Net benefits of agriculture
	Value of annual forest products harvested (a)	Annual cost of harvesting forest products (b)	Net annual direct benefits (forest products harvested) (c = a-b)			
CF (Middle hills)	40,043 (409)	16,255 (166)	23,788 (243)	3,093 (31.56)	124,325 (1,269)	24,268 (236)
CF (Siwaliks)	58,783 (600)	33,821 (345)	24,962 (255)	2,574 (26.26)	296,445 (3,025)	11,132 (108)
CF (Terai)	87,567 (850)	34,737 (337)	52,830 (513)	848 (8.23)	145,751 (1,415)	30,494 (296)
Collaborative forest	200,010 (1,942)	85,210 (827)	114,800 (1,115)	779 (7.56)	151,775 (1,473)	32,086 (312)
Protected forest	15,705 (152)	6,229 (60)	9,476 (92)	698 (6.78)	352,250 (3,420)	36,243 (352)
Protected area	–	–	–	734 (7.13)	204,249 (1,983)	

Source: Field survey, 2012 and 2015 (monetary values are converted to 2015 constant price).

TABLE 3 | Annual benefits and costs of reducing deforestation in NPR per ha (USD in parentheses).

Regimes	Benefits of having forest (A)	Benefits of deforestation (B)	Opportunity cost of forest conservation (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)

Source: Field survey, 2012 and 2015 (monetary values are converted to 2015 constant price).

management activities are far more expensive as the contributed time under compulsory participation is not used productively given that they lack an incentive mechanism for participation compared to forest management regimes that use hired labor for forest management activities. In community forests (Middle hills and Siwaliks), all forest users are required to participate in forest management activities failing which they have to pay a non-compliance penalty. In the Terai, on the other hand, forest management activities usually rely on hired labor (Rai et al., 2017). The conversion of a forest into other land use types yields a one-time benefit in the form of forest products, such as timber and firewood. The expected value of forest products after clear-cutting ranges from USD 18,822 to USD 55,921 per ha while the expected cost of clear-cutting falls between USD 2,964 and USD 18,109 per ha. The net annual flow of clear cutting, at 8 percent discount rate, is between USD 1,269 and USD 3,420 per ha.

Based on the limited information we have on the estimated benefits of forest conservation, protected areas, managed exclusively for biodiversity conservation, has the lowest return at USD 42/ha/year (**Table 3**) while collaborative forest, which focuses on timber production, generates the highest benefits at USD 1,131/ha benefits.

In contrast, the highest estimated benefits from deforestation come from protected forest as these forests have more biomass per ha. It has to be noted that the net benefits of reducing deforestation presented here represent conservative estimates as the study covered only a limited number of forest ecosystem services due to lack of relevant case studies. This means it underestimates the value of benefits of having forests.

The opportunity cost of forest conservation ranges from USD 654 to USD 3,663 per ha per year depending on the forest management regime in place. These estimates are consistent with the estimates derived from undisturbed forests in Indonesia where the carbon stock is 1,101 tCO_2/ha and the opportunity cost of deforestation ranges from USD 1,817 to USD 3,787 per ha or from USD 1.65 to USD 3.44 per tCO_2 (Olsen and Bishop, 2009).

The opportunity cost of carbon sequestration is the ratio between the opportunity cost of forest conservation per ha and the difference in forest carbon stock between forest and alternative land use (agriculture) per ha, 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). In addition, these estimates indicate that mitigation through forest conservation is a cheaper option compared to other strategies such as biogas. For example, the estimated cost of carbon sequestration using a biogas plant in Nepal is USD 7.00/tCO_2 (Dhakal et al., 2016).

The opportunity cost of forest conservation depends heavily on the annual benefits obtained from the forest given the high foregone benefits from alternative land uses. The cost of reducing deforestation is high in forest management regimes that are primarily conservation-oriented and do not offer substantial annual benefits from timber harvesting. The benefit from deforestation is lowest in production-oriented regimes such as collaborative forest management.

The results of the study show that the cost of reducing deforestation is the lowest in collaboratively managed and community forests of the Terai while it is the highest in protected forest regimes in the Terai region. This is mainly because the former offers high annual direct benefits (from forest products) and low management costs as they use hired labor. In protected forests, on the other hand, which have the dual objectives of biodiversity conservation and forest product collection, the cost of reducing deforestation is high because harvesting of forest products happens on a smaller scale than in the former.

CONCLUSION

This study generates valuable information on the opportunity cost of conserving forests by avoiding deforestation, which is estimated to be between USD 1.11/tCO_2 and USD 3.56/tCO_2. This shows forest conservation is a cost-effective climate change mitigation strategy compared to biogas digesters that help capture methane and reduce the use of firewood for cooking. Our study suggests that the opportunity cost of forest conservation depends on the growing stock in forests and annual direct benefits from forests. The findings point to an intensive forest management approach, which emphasizes timber production as a useful strategy to improve both non-carbon benefits from forests as well as forest carbon stock. This is because higher benefits from forest management disincentivize agents from depleting forest resources.

The study also indicates that compulsory participation of forest users in forest management increases the cost as this violates the basic economic principle of incentive compatibility. In the absence of incentive mechanisms, users are less likely to use the time spent in such activities productively. Therefore, a proper resource allocation plan is needed to make community forestry programs more efficient. Although the estimated benefits from forest management regimes focusing on biodiversity conservation are low, the inclusion of indirect benefits may increase the estimated benefits from such regimes. For that, it is essential to have detailed estimates of the value of forest ecosystem services from the different forest management regimes. The spatial trade-offs between different forest management regimes that our study provides can help policymakers to achieve sustainable forest management.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study team adopted the highest ethical standards for the study including field work, focused group discussions, and data collection.

AUTHOR CONTRIBUTIONS

RR, MN, and BK designed the study, acquired the funding, and developed the survey instrument. RR, NT, MK, and NB conducted the field work. NT analyzed the satellite data. RR and MN developed the methodology for data analysis. RR analyzed the data and prepared the first draft of the manuscript. MN edited and revised the manuscript. All authors read and approved the manuscript.

FUNDING

This study was supported by the UN Environment Program under the UN-REDD Technical Assistance Program to the Government of Nepal. MN received funding from the International Development Research Centre (IDRC) for examining the economics of forest restoration (grant #109748-001).

ACKNOWLEDGMENTS

We thank Mohan Prasad Poudel, Sagar Kumar Rimal, and Narendra Chand from the Ministry of Forest and Soil Conservation; Anukram Adhikary from Forest Action Nepal; Thomas Enters, Keiko Nomura, and Ivo Mulder from the UN Environment Program; and E. Somanathan from Indian Statistical Institute, for their comments and feedback on the earlier version of the manuscript. The International Centre for Integrated Mountain Development (ICIMOD), to which some of the authors are affiliated, acknowledges with gratitude the support of the Governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Sweden, and Switzerland.

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