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Assessing the financial contribution and carbon emission pattern of provisioning ecosystem services in *Siwalik* forests in Nepal: Valuation from the perspectives of disaggregated users

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ABSTRACT

Provisioning Ecosystem Services (PS) from the forests contribute much to peoples' livelihoods as well as to the national economy. Previous studies have been constrained by their primary focus on biophysical quantification of PS through modelling and mapping or aggregated monetary valuation, while little attention has been paid to the issues of the distribution of financial benefits among the different forest subgroups. Using market price and substitute good price methods, this paper assesses how local users exploit financial benefits and emit carbon from the use of PS in two dominant community-based forest management systems (community forestry—CF and collaborative forestry—CFM) based on proximity (nearby vs. distant users) and socio-economic class (rich vs. poor users) in the *Siwalik* region, Nepal. Results indicated that the wealth level of the users plays a key role in the amount of financial benefits generated from the use of PS: (1) users living near forests receive the highest economic benefits compared to those living long distances from the forest area. However the distribution of benefits differs according to management modality and socioeconomic status; (2) CF users, on average, receive higher economic benefits than CFM users; and (3) compared to poor households, rich households receive higher benefits. On average, a rich household adjacent to CF receives USD 1214/year while a poor household living in the same area receives almost half of that (USD 630/year). Similarly, a poor household living far from a forest area generates USD 189/year, slightly higher than that of a rich household in the same area (USD 109/year); and (4) an average CF user emits more carbon (7.4 tCO_2/HH/year) from the consumption of PS than an average CFM user (5 tCO_2/HH/year). Finally, we discuss the reasons behind these differences and draw policy implications for developing and refining constitutions and operational plans of forest user groups.

1. Background

Forest ecosystem services (hereafter FES) play a vital role in sustaining people's livelihoods, the environment, and the economy. These services are critically important in both developed and developing nations, but are more critical for resource-poor, rural people, particularly those in developing countries where dependency on these services is higher (Christie and Rayment, 2012; Bhatta et al., 2014; Paudyal et al., 2016, 2017). Recent statistics show that FES provide approximately 20 % of the income for rural households both through cash and by meeting subsistence needs (FAO, 2018). About 75 % of poor people in developing countries are heavily dependent on FES (FAO, 2018; Acharya et al., 2019a). However, despite their significant contribution to a large number of people, the actual contributions of FES to different types of forest users have not been fully evaluated (Daw et al., 2011; Lakerveld et al., 2015).

FES valuation research has proliferated at an exponential rate. Earlier studies primarily assessed how FES contribute to generating value or benefits for people's livelihoods (Ninan and Inoue, 2013), the environment, and the economy. These studies are however constrained by a primary focus on biophysical quantification through modelling and mapping (Baral et al., 2014; Verkerk et al., 2014; Akujärvi et al., 2016; Forsius et al., 2016; Langner et al., 2017), or purely aggregated monetary valuation (Maraseni et al., 2006; Kubiszewski et al., 2013; Parthum et al., 2017; Turpie et al., 2017; Verma et al., 2017). There exists little research that demonstrates how these contributions, for example the economic benefits of FES, are distributed among different sub-groups in a community-based forest management (CBFM) system. Some studies have called for urgent action to demonstrate the financial benefits of various sub-groups while performing FES valuation research (Vihervaara et al., 2010; Daw et al., 2011; Nieto-Romero et al., 2014; Fagerholm et al., 2016; Garrido, Elbakidze, et al. 2017; Chaudhary et al., 2018).

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Some scholarly works have attempted to assess the economic contribution of FES. These studies have mostly concentrated on government-managed/public forests (de la Torre-Castro et al., 2017; Murali et al., 2017; Queiroz et al., 2017), private forests (Nordén et al., 2017), protected area systems (Cuni-Sanchez et al., 2016; Peh et al., 2016; Shoyama and Yamagata, 2016; Affek and Kowalska, 2017; Delgado-Aguilar et al., 2017; Mukul et al., 2017; Vauhkonen and Ruotsalainen, 2017), and community forests (Lakerveld et al., 2015; Paudyal et al., 2015; Bhandari et al., 2016). However, these studies have not comprehensively assessed the financial contribution of provisioning ecosystem services (PS) to different subgroups within the CBFM (Acharya et al., 2019b; Torkar and Krašovec, 2019).

Community-based forest management (CBFM) is a management model in which local people play a critical role in planning, decision-making, implementation, and benefit sharing. CBFM normally includes users living both near to and distant from forest areas and with different economic backgrounds (Rai et al., 2017; Bhattarai et al., 2018). The different groups have different needs and demands for different PS, while most studies have concentrated on aggregated values (Martín-López et al., 2012; Garrido et al., 2017a, 2017b). The users, who are the key stakeholders, resource managers and at the same time the victims of ecosystem degradation, need to understand the overall and specific use patterns of PS. Prior research has focused on carbon emissions from forest cover loss (Harris et al., 2012; Sharma et al., 2019), fuelwood consumption (Baral et al., 2019) and household emissions (Kenny and Gray, 2009; Qu et al., 2013). As differences in the use of PS among different users exist, the carbon emission patterns from the consumption of PS vary (Muhamad et al., 2014). However, no previous studies have investigated the carbon emission pattern resulting from the use of PS for different subgroups in the CBFM.

An understanding of the use patterns of different PS from forests, their financial contribution to the different users and carbon emission patterns from the consumption of PS can contribute in various ways. First, such study helps in designing appropriate policies, strategies and plans for resource use. Second, it creates a heightened awareness of the most economically important services to local people that can be helpful in improving livelihood of the forest dependent communities. Third, study findings help to refine and update constitutions and operational management plans of the CBFM units for more sustainable management of the forests. Finally, this study can contribute in refining the national accounting system of the forestry sector so that the contribution of forestry can be better visualised by the policymakers.

Using market price and substitute good price methods, this paper assesses how local users exploit financial benefits and emit carbon from the use of PS in two dominant community-based forest management systems (community forestry—CF, and collaborative forestry—CFM) based on proximity (nearby vs. distant users), socio-economic class (rich vs. poor users) in the *Siwalik* region, Nepal.

2. Methodology

2.1. Study area

This study was carried out in *Sarlahi* district, the central part of Province 2, 350 km southeast of the capital city of Nepal, Kathmandu. The district covers 125, 948 ha, of which 15.5 % is *Siwalik* and the rest is the *Bhawar* and the *Tarai* regions. The *Siwalik* region, is parallel to the Lesser Himalaya in the southern part of the Indian subcontinent (Sivakumar et al., 2010) and extends 2400 km across four countries *Pakistan, India, Nepal* and *Bhutan.* The study sites are located in part of the *Siwalik* region in the northern part of the study district. This district hosts both community and collaborative forests with nearby and distant users (Acharya et al., 2019a). The elevation of the district ranges from 60 m to 659 m (DDC, 2016) and resulting in diversity of climate, vegetation and land-use patterns (Singh, 2017; Acharya et al., 2019a). CF and CFM have been implemented in the district since the early 2000s with the support of the Biodiversity Sector Programme for *Siwalik* and Tarai (BISEP-ST), funded by the Government of The Netherlands.

We investigated two community-based forest management models, one CF and one CFM. These CBFM were *Shibeshwor* CF in the *Hariyon* municipality, and *Phuljor* CFM in the *Ishworpur* municipality covering a total area of 3130 ha of forest (CF: 711 ha, and CFM: 2419 ha) (see Fig. 1).

The CBFM group, comprising members from different socioeconomic backgrounds, some living close to the forest area and some from distant villages, are responsible for the protection, management and use of these forests. The nearby users in both the CF and CFM live in the *Siwalik* foothills. Agriculture and animal husbandry are the mainstays of their livelihoods. The distant users live within 5 km of the CF in the semi-urban (small town) area and have multiple livelihood options including commercial agriculture, services and small shops. The nearby users in both CBFM utilize many forest services such as firewood, fodder, grazing, timber, poles, agriculture implements, medicinal and aromatic plants (MAPs), and wild foods for their daily uses. The distant users in the CFM live a fair distance away from the forest (> 5–20 km) and depend on agriculture and animal husbandry for their livelihoods (GON, 2016). The distant users receive services mainly in terms of firewood, timber, sand/boulders/gravel and poles. Table 1 provides socio-demographic information (gender, age, household size, education level, ethnic, religion, income, expenditure, the status of private forest and household dependency on CBFM) for the CBFM. The reasons for selecting these two CBFMs are: (1) they comprise both nearby and distant users with different degrees of intensity of use; (2) they have a long history of community participation in forest management; and (3) the areas are endowed with rich and productive ecosystems (DPR, 2014).

2.2. Valuation of ecosystem services

2.2.1. Prioritisation of provisioning ecosystem services (PS)

In general, *Siwalik* forests provide firewood, timber, grass, fodder, bedding material, medicinal plants, sand/stone/boulders, and grazing services (PCTMCDB, 2017). Through a rigorous consultation process involving eight different focus group discussions (FGD) which considered each subgroup (modality: CF/CFM, economic class: rich/poor, spatial distance: nearby/distant), a total of 16 PS were identi-

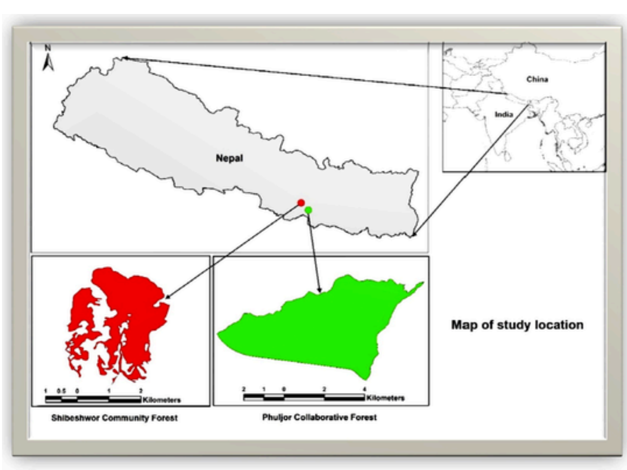

Fig. 1. Map of Siwalik region and study sites (*Shibeshwor* Community Forest left) and *Phuljor* Collaborative Forest (right) in Nepal.

Table 1
Sociodemographic information for the respondents.

Demographic features	CF Nearby		CF Distant		CFM Nearby		CFM Distant	
	Rich (n = 32)	Poor (n = 31)	Rich (n = 31)	Poor (n = 31)	Rich (n = 32)	Poor (n = 31)	Rich (n = 33)	Poor (n = 32)
Gender (Number)	F = 20 M = 12	F = 20 M = 11	F = 6 M = 25	F = 10 M = 21	F = 10 M = 22	F = 11 M = 20	F = 5 M = 28	F = 6 M = 26
Median age of the respondents range (years)	41 (19–75)	40 (18–80)	48 (24–79)	48.50 (21–74)	39 (22–68)	45 (20–75)	51 (20–84)	45 (25–77)
Average family size and standard error of mean	6.10 (0.46)	5.33 (0.37)	6.3 (0.5)	5.67 (0.41)	6.27 (0.40)	5.83 (0.53)	6.10 (0.46)	7.43 (0.55)
Education	I = 6 P = 6 S = 16 T = 4	I = 9 P = 12 S = 8 T = 2	I = 1 P = 4 S = 15 T = 11	I = 13 P = 5 S = 12 T = 1	I = 6 P = 9 S = 15 T = 2	I = 7 P = 12 S = 12 T = 0	I = 10 P = 5 S = 17 T = 1	I = 18 P = 7 S = 6 T = 1
Ethnic composition (Number)	UC = 4 LC = 28	UC = 2 LC = 29	UC = 24 LC = 7	UC = 8 LC = 23	UC = 14 LC = 18	UC = 7 LC = 24	UC = 28 LC = 5	UC = 17 LC = 15
Religion of Respondents	H = 24 B = 6	H = 24 B = 7	H = 31	H = 28 M = 3	H = 23 B = 7 M = 2	H = 21 B = 9 M = 1	H = 33	H = 32
Average Income/HHs (USD) (Standard Dev.)	3532 (±2172)	1395 (±794)	6515 (±3767)	1421 (±935)	4933 (±2520)	1463 (±708)	3684 (±1785)	1671 (±985)
Expenditure/HHs (USD)	2026	1091	6161	1302	2672	1319	2321	1470
% of private forests owners	66	50	40	37	28	16	64	41
%of dependency on CBFMs	56	46.28	6%	14	65	68	6	11

Data in parenthesis are standard deviation; Gender: M: Male, F: Female; Education level: I = Illiterate, P = Primary/lower secondary, S = High school educated, T = College & above; Ethnic composition: Upper Caste: Bahun/Kshetri/Dashanami/Madeshi, Lower caste: Janajati, Janajati/Madhesi, and Dalit; Religion: H = Hindu, B = Buddhists, M = Muslim.
Incomes are derived from agriculture, horticulture, livestock, daily wages, foreign employment, different types of salaries, small businesses, fisheries, NTFP/medicinal plants, and firewood collection.
1 USD = NPR 110.52.
Expenditure includes foodstuff, clothing, education, health, agriculture, purchasing land, livestock, paying interest.

fied (Acharya et al., 2019a). Their priorities differed according to management modality, spatial distance and economic class. However, four provisioning ecosystem services genetic resources, wild animals, thatching materials, and medicinal and aromatic plants (MAPs) were least important for all groups. This was verified through FGD and CBFM records, and therefore, these were not further considered in this study. Overall, the top ranking 11 PS for all sub-groups were firewood, fodder, timber, poles, grasses, grazing, sand, boulders and gravel, non-timber forest products (NTFPs) other than MAPs, and wild foods (see Acharya et al. (2019a) for details on the prioritisation of all PS).

2.2.2. Valuation of provisioning ecosystem services (PS)

Many researchers have estimated PS using the revealed price (RP) approach (Sumarga et al., 2015; Baral et al., 2016; Verma et al., 2017). The revealed price (RP) method estimates low value compared to actual market value if there is any policy distortion (Pagiola et al., 2004; Rasul et al., 2011). For example, the *Sal* timber (*Shorea robusta*) royalty to the CF users is fixed at USD 0.2 – 0.55/cft (Poor: USD 0.2/cft, rich: USD 0.55/cft), while *Sal* timber sells for USD 31.7–40.7/cft in the nearby market. Considering a similar market distortion situation in the study sites, we employed market prices and substitute goods prices for the various categories of prioritised PS, as detailed in Table 2.

Sampling techniques and data collection: A pilot survey was conducted with 20 randomly selected households in four villages drawn from nearby and distant users in both CBFM to determine a proportion (*p*) of householders who benefit from PS. The sample size was estimated, following Eq. 1 as suggested by (Köhl et al., 2006);

$$n = \left[\frac{1}{e^2}\left(p\,(1-p)\,U^2 1 - \frac{\alpha}{2}\right)\right] \tag{1}$$

where n is the estimated sample size, U is the value of normal random variable (1.96 for α = 0.05) and e, the allowable margin of error from this survey, held to be 5%. According to the formula developed by Köhl et al. (2006), 240 households (p = 80 %) were required for survey. Households in both CBFM are relatively homogenous in-terms of their demographic and socio-economic features. Being users of CBFM, all households are governed by the same Forest Act and Forest Regulations. Therefore, their forest use rights are more or less similar. In addition, we categorised the whole population into eight homogenous strata based on management modality (CF/CFM), economic class (rich/poor) and spatial distance (nearby/distant[1]) from the forests (Acharya et al., 2019a). Therefore, we argue that our sample size (253 households) truly represents the population.

The field data for the study were collected from July to October 2018. A 45-minute face-to-face interview with each household head was conducted in their house. The household questionnaire consisted of three sections. The first section focuses on general information of the household. The second section elicits about the basic household information such as gender, age, caste, religion, ethnicity, livestock, education, occupation, income and expenditure of the respondents while the third section records about quantity of PS used and sold and their market prices.

One-year data could be influenced by some local factors (such as flood, drought, earthquake) and therefore the distribution could be skewed. Therefore, we collected data for three years of use patterns of PS and then averaged these to provide more reliable use patterns of PS. Household data were independently verified with the executive mem-

[1] **Nearby/distant:** In collaborative forest management (CFM): Users living within 5 km from forests are considered nearby and beyond 5 km as distant users; in CF users living 3 km from forests are considered distant users. **Rich/Poor:** CBFM classifies users into four categories (Well-off, Medium, Poor and Very -poor). This study considers the first two as Rich and the other two as Poor.

Table 2
Methods used to estimate values of provisioning ecosystem services.

Category	Valuation method	Valuation procedure
Firewood	Market price	Average firewood quantity and benefits obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of firewood
Grazing	Market price	Average livestock unit raised by sample user households from CBFM area in the last three years multiplied by dependency ratio on forest forage and local market price of substitute goods or their equivalent
Fodder	Market price	Average fodder quantity and benefits obtained by sample user households from CBFM area in last three years multiplied by dependency weighting and local market price of fodder
Timber	Market price	Average timber quantity and benefits obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of timber
Grasses	Substitute goods price	Average quantity and benefits of grasses derived by sample user households from CBFM area in last three years multiplied by dependency weighting and local market price of substitute goods or their equivalent
Sand/boulder/gravel (SBG)	Market price	Average SBG quantity and benefits derived by sample user households from CBFM area in the last three years multiplied by dependency weighting and market price of SBG
Poles	Market price	Average quantity of poles and benefits obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of poles at local level
Bedding materials	Substitute goods price	Average quantity and benefits of bedding materials obtained by sample user households from CBFM area in last three years multiplied by dependency weighting and local market price of substitute goods or their equivalent
Agricultural implements	Market price	Average number and benefits of agricultural implements obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of agricultural implements at local level
NTFPs other than MAPs	Market price	Average NTFPs quantity and benefits obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of NTFPs at local level
Wild foods	Substitute goods price	Average quantity and benefits of wild foods obtained by sample user households from CBFM area in last three years multiplied by dependency weighting and local market price of substitute for wild goods or their equivalent

CBFM: Community-based forest management, NTFPs: Non-timber Forest Products, MAPs: Medicinal and Aromatic Plants.

bers and minutes/records of users' committees and therefore the data are reliable.

Socioeconomic data were analysed using basic statistical procedures and analysis of variance (ANOVA) to compare the means. Similarly, the total values of prioritised services (TPV_i) were computed using Eq. 2, following Sharma et al. (2015).

$$TPV_i = \sum_{i=1}^{n} (\%hhi * HH * NV_i) \tag{2}$$

Where i is a PS category, for example firewood, timber, fodder that could be 1–11, $\%hh_i$ is the percentage of households dependent on the ith PS (i.e dependency weightage). HH is the total number of households in the forest area; and NV_i is the average annual net benefits per user HH, which was calculated by subtracting the extraction and transportation cost of the services from their gross value in the local market. Household dependency and average household net benefits were obtained through the household survey (HHS) as discussed above. Table 2 above provides the details of the method used for the prioritised services.

2.3. Carbon emission from consumption of provisioning ecosystem services (PS)

Forest users harness economic benefits by consuming different provisioning services, but at the same time, while consuming these services they emit carbon into the atmosphere. In order to estimate this emission, we used the same household consumption data for all PS (except sand, boulders and gravel). These data were converted into biomass, carbon mass, and then converted into CO_2 emissions following the standard IPCC (2006) process and conversion factor (Eq. 3; (Pandey et al., 2014, 2016)). Please see Annex 3 for the biomass of all consumed PS.

$$\text{Carbon dioxide emission } (CO_2\text{e}) = \text{Total biomass of PS} * 0.47 \text{ (carbon)} * 3.67 \ (CO_2 \text{ equivalent}) \tag{3}$$

Harvested or consumed PS can store carbon for a number of years depending on their use and half-life period (Maraseni and Cockfield, 2011). For example, an item of wooded furniture or an electricity pole can store carbon for many years. However, in this analysis, we assumed that the harvested/consumed products emit carbon immediately into the atmosphere. This is a realistic assumption as about 90 % of the carbon emissions from PS is attributed to firewood, fodder, grasses, and grazing services.

In order to estimate the cost of carbon emissions, we used US dollar five per tonne carbon dioxide equivalent (USD 5/tCO_2e) following the World Bank Carbon Fund project in Nepal (GON, 2019).

3. Results

3.1. Economic valuation of PS

The overall annual values of 11 different PS harvested in both CBFM are summarised in Fig. 2. A household, on average, generated USD 231/year from these services. Among the PS, firewood constituted the highest financial benefits (USD 61/HH/year) followed by timber (USD 45/HH/year), and grazing services (USD 42/HH/year). Other

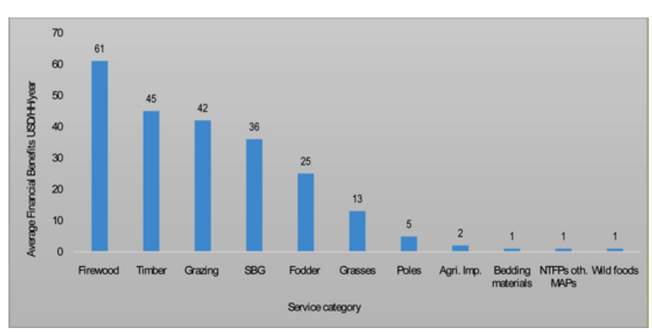

Fig. 2. Average value of different provisioning ecosystem services (USD/HH/year) (SBG: Sand/Boulder/Gravel; Agri. Imp.: Agricultural Implements).

PS such as agricultural implements (AI), NTFPs other than MAPs, and wild foods on average generated low financial values ranging from USD 2.0 to USD 1/HH/year. The utilisation patterns vary by management modality, users' socio-economic situation and proximity to forest area.

Among the management modalities, average benefits to the CF users are much higher than for CFM. For example CF users derive USD 402/HH/year from the use of PS, while CFM users generate almost half that (USD 227/HH/year) from provisioning ecosystem services. In the CF, wealthier users living near forests receive the highest financial benefits from all PS (USD 1214/HH/year) followed by poor people living in the same area (USD 630/HH/year) (see Table 3). The biggest difference is in the values derived from timber, but the rich users derive greater benefits in all categories. People living farther from a CF area show the opposite trend. The distant poor users obtain higher financial benefits (USD 189/HH/year) compared to the distant rich users (USD 109/HH/year).

Similarly, the difference between net benefits for the nearby rich and nearby poor is much less for CFM than for CF. The distant rich do, however obtain more benefits from CFM, which is the reverse of the situation with CF. Wealthier users at farther distance receive higher benefits from the PS, (USD 80/HH/year) compared to poor users (Table 3).

3.2. Carbon emission from the consumption of provisioning services

In our study, an average household, regardless of their modality and spatial distribution, emits 6.2 tCO_2 per year from the consumption of all 10 different PS (Table 4 and Fig. 3). As expected, the emission pattern from the consumption of all PS varies by CBFM modality, socio-economic status and spatial distance from forests.

A household in CF emits one and half times higher carbon (7.5 tCO_2/HH/year) than a household in CFM (5.0 tCO_2/HH/year) from the consumption of PS. Similarly, a rich household living near a CF area releases the highest amount of carbon (13.52 tCO_2/year) followed by a poor household living in the same area (11.63 tCO_2/HH/year). In contrast, a rich household living a greater distance from a forest area releases the least (< 1 tCO_2/HH/year). In the case of CFM, the trend is similar to that of CF although the emission rate for all households in a CFM is lower in both rich and poor categories (Rich: 8 tCO_2/HH/year and poor: 7.5 tCO_2/HH/year).

4. Discussion

4.1. Economic contribution of PS in different sub-groups

Our results suggest that PS from CBFM of *Siwalik* region contributed significant financial benefits to different sub-groups. Results revealed that firewood contributed the highest financial benefits in both types

Table 3
Average contribution of provisioning ecosystem services by relative wealth and distance from forest (in USD/HH/year).

Category	CF Nearby		CF Distant		CFM Nearby		CFM Distant	
	Rich (n = 32)	Poor (n = 31)	Rich (n = 31)	Poor (n = 31)	Rich (n = 32)	Poor (n = 31)	Rich (n = 33)	Poor (n = 32)
Firewood	150	136	25	82	161	158	5	14
Grazing	217.4	214.2	3	31	121	121	0	0
Fodder	170	131	4	41	76	63	0	0
Timber	499	20	40	0	140	40	40	0
Grasses	85	74	0	11	33	40	0	0
Sand/boulder/gravel	0	0	25	0	74	49	25	25
Poles	36	27	9	18	5	5	9	0
Bedding materials	43	22	1	5	2	2	0	0
Agricultural implements	4.26	3.75	1.95	0.5	4.4	9.7	0.1	0.1
NTFPs other than MAPs	7	2	1	0	1	0	1	1
Wild foods	1	1	0	0	1	1	0	0
Total (USD/HH/year)	1214	630	109	189	617	488	80	39

CF: Community Forest, CFM: Collaborative Forest Management, NTFPs: Non-timber Forest Products, MAPs: Medicinal and Aromatic Plants.

Table 4
Household carbon emissions (kg CO_2/HH/year) from consumption of 10 different provisioning ecosystem services.

Category	CF Nearby		CF Distant		CFM Nearby		CFM Distant	
	Rich (n = 32)	Poor (n = 31)	Rich (n = 31)	Poor (n = 31)	Rich (n = 32)	Poor (n = 31)	Rich (n = 33)	Poor (n = 32)
Firewood	2307	2097	378	1258	2475	2433	84	629
Fodder	2785	2685	84	839	1552	1300	965	755
Timber	1074	43	86	0	301	86	86	0
Grazing	2396	2685	101	805	1732	1920	0	0
Grasses	2517	2727	0	420	1217	1468	881	881
Poles	347	258	86	172	43	43	86	0
Ag. Imp.	195	191	7	123	485	230	0	0
NTFPs other than MAPs	15	3	2	0	2	0	2	2
Bedding materials	1879	940	34	235	101	67	104	34
Wild foods	3	2	0	0	3	2	0	0
Total (kg CO_2/HH/year)	13,515	11,630	776	3852	7909	7549	2207	2300

CF: Community Forest, CFM: Collaborative Forest Management, NTFPs: Non-timber Forest Products, MAPs: Medicinal and Aromatic Plants; Ag. Imp: Agricultural implements.

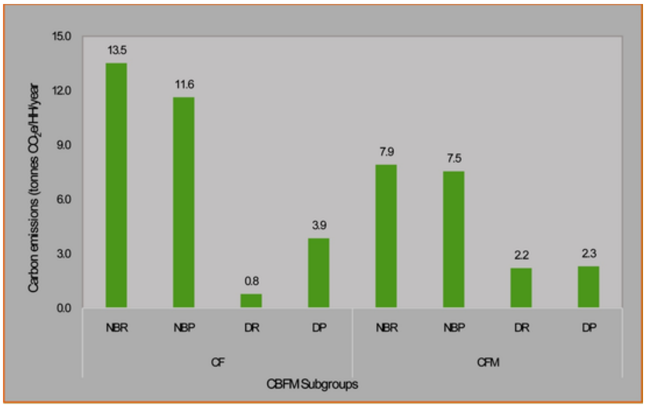

Fig. 3. Household carbon emissions (tonnes CO_2 /HH/year) from consumption of 10 different provisioning ecosystem services, CF: Community Forest, CFM: Collaborative Forest Management and CBFM: Community Based Forest Management Systems, NBR: Nearby Rich, NBP: Nearby Poor, DR: Distant Rich, DP: Distant Poor.

of CBFM. The results reflect a trend in developing countries where fuelwood is the prime source of energy irrespective of household well-being. As substantiated by FAO (2018) about 2.4 billion people globally use fuelwood for cooking and heating purposes, similar to the results of our study. Other studies also report similar findings for fuelwood use (Angelsen et al., 2014; Ahammad et al., 2019).

None of the previous studies performed disaggregated assessments of PS considering rich/poor and nearby/distant users in CBFM (CF/CFM). Therefore, we compare our overall results with aggregated results from other global research. For instance, our results (USD 231/HH/year) are similar to those reported by Sumarga et al. (2015) (P = USD 224) in a study conducted in Central Kalimantan, Indonesia. Some studies estimated lower economic values ranging from USD 31–162 (Kunwar et al., 2010; Basnyat et al., 2012; Lakerveld et al., 2015; Mukul et al., 2016; Chauhan et al., 2017; Rai et al., 2017), while other studies estimated higher financial returns ranging from USD 359 to USD 6045 (Sapkota and Odén, 2008; Pant et al., 2012; Schaafsma et al., 2014; Mutoko et al., 2015; Ninan and Kontoleon, 2016; Tilahun et al., 2016; Kibria et al., 2017; Chaudhary et al., 2018) from the PS.

Despite the higher priority and the financial contribution of timber to the national economy, this study found that timber contributed the second-highest financial benefits only for a small section of the sub-groups. For example, the wealthier users living near a CF derived an average income of USD 499 from timber, which is almost 15 % of their total income (annual income USD 3532), whereas the poor households living in the same area derived USD 20/HH/year that is 1.5 % of their annual income (USD1395). Several studies globally recognised a wide range of financial benefits deriving from timber services. Other global studies found similarly low and high economic benefits from timber services. For instance, Sharma et al. (2015) reported only USD 5.4/HH/year from timber in the *Koshi Tappu* area of Nepal, which is significantly lower than our findings. Other studies reported similar findings to our study, of USD 56–69/HH/year (Pant et al., 2012; Sumarga et al., 2015; Tilahun et al., 2016), while some studies estimated a higher financial benefit from timber services ranging from USD 85 to USD 6045/HH/year (Adekola et al., 2015; Chauhan et al., 2017; Rai et al., 2017).

Our study suggests that the financial benefits of PS vary based on management modality, socio-economic status and spatial distance from a forest area. Average benefit derived from the use of PS to CF is higher than for CFM. This could be ascribed to the differences in access/control over resources, use/management rights, forest-HH ratio, benefit sharing arrangements, and distance from forest area (Jhaveri and Adhikari, 2015; Acharya et al., 2019a). For example, forest users in a CF can access and harvest PS throughout the year as per their management plan, while CFM users can only access these services during specified times within certain months. Similarly, there is a huge difference in forest-HH ratio among these two management modalities. In the CF, forest-HH ratio is almost 0.99 (GON, 2006-, 2016) whereas the ratio in the CFM is 0.087 (GON, 2016). High forest-HH ratio means that there will be potential for higher forest service extraction, collection and use which in -turn derives high financial returns. Furthermore, the benefit sharing arrangements also differ between these two modalities. For instance, all incomes of the CF from all PS go directly to local users except for a few commercial transactions of *Acacia catechu* and *Shorea robusta*; in contrast, in the case of CFM, 50 % of timber income goes to national and local government (Acharya et al., 2019a).

Similarly, rich households living near a CF area receive the highest PS (USD 1214/year) followed by poor household living in the same area (USD 630/year). We observed significant differences in the financial benefits among sub-groups living in the same area, mainly due to their differences in timber consumption. Rich households living near forest areas utilised more timber in comparison to poor households, mainly due to adverse land tenure problems experienced by poor household and their housing costs and requirements. More than 80 % of poor households do not hold a secure land ownership certificate or an official land entitlement in *Sarlahi* district including in the study site (DPR, 2014; Singh, 2017). Moreover, as noted in Table 1, average household income of poor households, regardless of forest management modality and distance from forests, is less than half that of rich households. Therefore, poor households cannot build permanent and multi-storeyed houses. In contrast, rich users have secure land tenure and can easily build multi-storeyed houses and therefore consume more timber.

4.2. Carbon emission from consumption of PS

In our study area, an average household emits 6.2 tCO_2e annually from the use of all 10 different PS. As expected, the users from CF emit higher amounts of CO_2e compared to users from CFM, as the community forestry rules and regulations allow them to consume more forest products compared to the users of CFM. Most of the carbon emissions of all subgroups come from the consumption the four PS, namely, firewood, fodder, grasses, and grazing services. Because of their heavy daily use, these services account for higher amounts of biomass being used, resulting in higher carbon emissions from their consumption. To our knowledge, no previous study has considered the disaggregated emissions from the use of PS in the CBFM. That is why no comparable findings/results are available for evaluation and discussion.

In total, consumption of these four services constituted almost 90 % of total emissions from PS. If these services could be completely replaced or substituted by other means, up to USD 27.9/HH/year (90 % of 6.2 tCO_2@USD 5/ tCO_2) could be earned at the current carbon price of the World Bank (GON, 2019). However, the carbon emissions vary by the wealth class and distance from the forest area. Users living near forest areas emit the highest amount of CO_2, compared to users living farther from a forest. Similarly, in CF, rich users living adjacent to a forest emit almost 14 tCO_2/HH/year while rich users living far from a forest emit 1 tCO_2/HH/year. These two user types can earn up to USD 63/HH/year and USD 4.5/HH/year respectively, because of not consuming the four main PS. However, producing less emission from distant forests users does not necessarily mean that they are environmentally friendly global citizens. They might have been meeting their consumption demands from some other private sources.

4.3. Policy implications of the study

The results of this study could be useful in guiding the future of the CBFM system considering the complex socioeconomic situation of the landscape promoting multifunctional *Siwalik* landscapes. Since all users in the CF are equally responsible for protection, management and use of the forests' ES, their contributions are not equally reflected in the distribution of benefits from these services to different subgroups due to the unequal use of timber services. One can argue that there is a different level of levies charged for different categories of users (i.e. for different species of timber: rich USD 0.15 – USD 0.55/cft, poor: 0.1–0.25/cft). Despite the difference in the levels of levies charged, this might not be sufficient to sustain the forest ecosystem services in the long run. Therefore, it is imperative to incorporate equity issues based on the contribution to ecosystem services management in the forests.

Likewise, the Ministry of Forests and Environment (MOFE) is currently focusing on timber management through Scientific Forest Management (Government of Nepal 2016). However, the current valuation exercise revealed that services derived from timber do not generate high financial returns for many subgroups in the studied CBFM. Therefore, it is essential to revise the CBFM management plan considering the needs, financial returns and aspirations of all subgroups, and to focus on fuelwood, fodder, grasses and grazing services demand. For this, CBFM can: i) promote cultivation of fuelwood species in the CBFM and other public lands; ii) make a plan focusing on fuelwood enrichment plantations in the forest area; iii) promote agroforestry practices through extension services; iv) reduce, replace and switch over the fuelwood demand through supplying improved stoves, and instituting biogas and hydroelectricity programmes as suggested by the ERPD or the President Chure Terai Madesh Conservation and Development Board (PCTMCDB, 2017; GON, 2019).

Moreover, reducing emissions from CBFM remains a key concern in Nepal. MOFE has aimed to reduce, replace and switch over the demand for these services through policies, strategies and programmes (MFSC, 2015, 2016; GON, 2019). For instance, the REDD Implementation Centre (REDDIC) under the Forest Carbon Partnership Facility (FCPF) is currently implementing an Emissions Reduction Programme (ERP) in 13 Western Terai Districts. The programme's aim is to reduce the total 35.6 $MtCO_2e$ through seven different strategic interventions. Out of these, three interventions first, improve management practices of existing CBFM, second expanding access to alternative energy with biogas, third, through supply of improved stoves are planned to reduce 21.6 million tonnes carbon dioxide equivalent ($MtCO_2e$) in districts adjacent the study sites (Acharya et al., 2015; GON, 2019). Similarly, the President Chure-Tarai-Madhesh Conservation and Development Programme (PCTMCDB) has proposed i) promotion of private plantations on private and public lands; ii) promotion of alternative energy through biogas, solar and micro-hydro; and iii) the extension of access to national hydro-electricity (PCTMCDB, 2017). Recently, the Nepal Electricity Authority requested the public to use hydroelectricity instead of other types of fuel for cooking purposes. These activities (i-iii) could be helpful in reducing carbon emissions resulting from the burning of fuelwood. Moreover, PCTMCDB has also planned: i) to control or manage grazing in the CBFM; and ii) to promote commercial animal husbandry (PCTMCDB, 2017). These activities can be promoted through planting multipurpose indigenous fodder species such as Badahar (*Artocarpus lakoocha*), Tanki *(Bauhunia purpurea*), Koiralo (*Bauhinia variegata*) and some exotic leguminous species such as Bhatmase (*Flemingia congesta Roxb*.), and Gliricidia (*Gliricidia sepium*). This could be a helpful strategy for reducing carbon emissions from the consumption of fodder, grazing and grasses in the CBFM.

5. Conclusion

This study estimated the financial benefits accruing from the prioritised provisioning ecosystem services (PS) in the *Siwalik* landscape of Nepal for different subgroups in two dominant community-based forest management systems (CBFMS). The findings reveal that a household, on average, receives the equivalent of USD 231/year from 11 different provisioning ecosystem services, generating a total of USD 5.30 million by managing 3130 ha of forests. Community Forestry (CF) users on average generate the highest financial returns compared to collaborative forestry (CFM) users, mainly due to differences in the level of access, rights, forest-household ratio, benefit sharing arrangements and distance from a forest area. Irrespective of the management modality, forest users living near the forests accrue the highest financial benefits compared to those living more distant from a forest. This difference can be mainly attributed to high amount of firewood, grazing, timber and fodder used.

Consumption of 10 PS accounts for an average of 6.2 tCO_2 emissions per household per year. Average CF users emit about 1.5 times more carbon than CFM users. About 90 % of carbon emissions is attributed to four PS, namely, firewood, fodder, grasses, and grazing services. Therefore, fulfilng the demand of these four services by other means could be instrumental in reducing carbon emissions from CBFMS.

The findings also suggest that there is some disparity in financial benefits and carbon emissions among the different subgroups. As time and effort expended by all these sub-groups in the conservation and management of forests are almost similar, this disparity can lead to disputes, thereby giving rise to unsustainability in forest management. Various sub-groups in the CF are charged levies with different rates for goods and services, but these differential rates cannot adequately sustain the forest ecosystem services. Therefore, incorporating the carbon issue and forest management costs of different subgroups in designing levies could generate more sustainable environmental and financial outcomes.

Author contributions

Author Contributions: R.P.A., conceptualisation and writing; T.N.M., overall guidance and framing the concept; G.C., overall guidance and framing the concept.

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Declaration of Competing Interest

The authors declare no conflicts of interest.

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Appendix A.

Total households and sample households in the studied CBFM

CBFM Types	Rural/Municipality	Total HH in the CBFM				Sampled HH	
		Nearby		Distant		Nearby	
		Rich	Poor	Rich	Poor	Rich	Poor
CF	1	120	114	249	236	32	3(
CFM	21	4794	4699	9322	9138	32	31

CF: Community Forest, CFM: Collaborative Forest Management, HH: Households

Appendix B.

Questionnaire for household survey

A General information:	
CBFM name:	Code:
Full name of Respondent:	Date: / /2018
HH GPS Coordinates: Latitude:	Longitude: HH Number:
Address:	Sex/Age:
Family size:	Education (No of years):

(Please tick (√) answer or write the answer in the given field)

B.	Socio-economic information				
1.1	Name of household head			Male	
1.2	Name of district:				
1.3	Name of VDC			Ward No.	
1.5	Name of settlement/Tole:				
1.6	Age:				
1.7	Sex:	Male		Female	
1.8	Marital status:	Married	Unmarried	Separated	Widowed
1.9	Caste/Ethnicity:		Brahmin/Chhetri /Dashnami	Janajati	Dalit
1.10	Religion:	Hindu	Buddhist	Muslim	Christian
1.11	Details of family members:			HH size:	
	Name	Age*	Sex	Education*	Occupation
1					
2					
3					
	Please add				
	* Illiterate = 1, Literate but not school educated = 2, Primary/lower se school educated = 4, College & above = 5				
	* Child <5 year = 1, Young 6–14 = 2, Adult 16–59 = 3, Old 60-abov				
1.12	Who is mostly involved in economic decisions in your house?			Female	
1.13	Are female members of your household represented in groups/organization?				
1.14	Sources of income and expenditure in the family				

	Sources of Income			Expenditure	
	Sources	Amount (NRs)		Items	A
	Ag product sell			Food	
	Horti. product sell			Clothing	
	Livestock rearing			Education	
	Other animal products			Health	
	Daily labour			Agriculture purpose	
	Remittance			Festivals	
	Salary (private/govt/pension/social grants			Land purposes	
	Own business			Purchase of livestock	
	Fishing			Buying other physical assets	
	Selling of NTFPs/MAPs			Setting of own business	
	Selling firewood			Interest paid	
	Others specify			Others (specify)	
C.1	**Information related to provisioning services**				
1.15	**Do you have private forests? If yes:**			**Yes**	**No**
	How many trees/ha?				
	What percentage of your forest product demand is filled by your own private forests?				
Are you or your family members involved in forest products or services collection from CF? If Yes? Please answer 1.15.					
1.16	Which of the following services do you receive from forests?				
S.N	Sources	Amount (in local unit)/year (average of last 3 years)	How much of that is sold/year (average of last 3 years)	Average local market price (average of last 3 years)	I v i
1	Timber (cft)				
2	Poles (No)				
3	Firewood (*Bhari*)				
4	Fodder (*Bhari*)				
5	Thatching materials (*Bhari*)				
6	Grasses (*Bhari*)				
7	Bedding materials (*Bhari*)				
8	Thatching materials (*Bhari*)				
9	Leaf litter (*Bhari*)				
10	Agricultural implements (No)				
11	Medicinal and aromatic plants -MAPs (kg)				
12	NTFPs other than MAPs (kg)				
14	Sand boulders gravel (truck loads)				

15	Wild foods (kg)
16	Wild animals (kg)
17.	Others (specify)

Table A1
Procedure of Conversion of harvested provisioning ES into dry biomass (in kg).

Category	Local unit	Conversion	Biomass conversion procedure	Estimation of carbon	Conversion in CO_2 equivalent
Firewood	*Bhari*	*kg*	*Bhari* is converted into biomass multiplied by 25.	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Grazing	*Bhari*	*kg*	First total grasses required for each category of livestock calculated in *Bhari*. Then dependency ratio of forage on CBFM was calculated. The forage (Bhari) is converted to biomass multiplied by 20	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Fodder	***Bhari***	*kg*	Average of fodder quantity harvested by sample user households from CBFM area in last three years multiplied by 20	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Timber	Cubic feet	*kg*	Average timber quantity obtained by sample user households from CBFM area in the last three years multiplied by 25.6	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Grasses	*Bhari*	*kg*	Average quantity of grasses harvested by sample user households from CBFM area in last three years multiplied by 20	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Poles	No	*kg*	Average quantity of poles harvested by sample user households from CBFM area in the last three years multiplied by 25.6	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Bedding materials	*Bhari*	*kg*	Average quantity of bedding materials collected by sample user households from CBFM area in last three years multiplied by 20	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Agriculture implements	No	*kg*	Average number and benefits of agriculture implements derived by sample user households from CBFM area in the last three years multiplied by weights of each of the agriculture implements	Biomass multiplied by 0.47	Carbon multiplied by 3.67
NTFPs other than MAPs	kg	*kg*	Average NTFP quantity obtained by sample user households from CBFM area in the last three years	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Wild foods	kg	*kg*	Average quantity of wild foods obtained by sample user households from CBFM area in last three years	Biomass multiplied by 0.47	Carbon multiplied by 3.67

C.2	*Information related to grazing animals*						
1.17 Are you or your family members do take your animals in forests? If Yes, please p these information?							
SN	Animals	In last 3 years					
		No	Total feed de-mand (*Bhari*)	Price/*Bhari at local market*	% from CF	% from Pri-vate	% buy from other source
1	Cow						
2	Ox						
3	Male buffalo						
4	Female buffalo						
5	Goat						
6	Horse/donkey						
7	Sheep						
8	Pig						
9	Others specify						

Thank you very much for your response and time!!!!

Appendix C.

Table A1

Appendix D. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104647.

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