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Contents

Abstract

The study examined the relative importance of forest benefits in rural households of Chittagong Hill Tracts (CHT) region in Bangladesh. Applying an ecosystem service approach, we explored the direct use across different categories and perceived importance of indirect benefits of forest and tree based ecosystem services in the livelihoods of rural people in the region. A structured questionnaire survey with 214-300 households was conducted across 3 sites (i.e. remote, intermediate and on-road sites selected based on distance to forest, market and road). Our data shows that there is a wide use of provisioning ecosystem services (i.e. fuel wood and different plant and animal sourced forest food) in the households across the sites. However, the use of provisioning services varies for subsistence and cash income across the three sites. Overall the subsistence use of different provisioning services is higher in the remote site while cash income is higher in the intermediate site (with the exception of timber at the on-road site). Our results also revealed the perceptions of the respondents about the importance of forest and trees for indirect benefits to regulating water purification, air quality, soil protection, soil fertility, crop pollination and cultural spiritual services are higher in the remote and intermediate sites where people are living close to the natural and agroforest systems compared with further away from the monoculture plantations in the on-road site. Drawing on the results in the variations in forest uses and perceived indirect benefits of ecosystem services across sites reflects the diversity of the demands and socio-cultural values towards tree management in the landscape. Our study suggests that the existing forest management could integrate diversity at a landscape scale to sustain forest benefits for households in the region.

Key words: forest and tree benefits; ecosystem service; perceptions; livelihoods; landscape

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1. Introduction

Ecosystem services are broadly defined as benefits that people obtain from ecosystems directly or indirectly and have been recognised as valuable for local livelihoods and global environmental sustainability (Costanza et al. 1998). In recent years, a number of studies have emphasised the role of the ecosystems service concept to understand the relationship of ecosystems to human well-being and to support decision-making in natural resource management (Fisher, Turner & Morling 2009). However the nature of the benefits, the beneficiaries and the highly site-specific conditions make assessments of ecosystem services within landscapes complex (Mensah et al. 2017). For instance, the carbon sequestration roles of conserved forests are valuable for global climate mitigation while the immediate benefit rests in the use of forest provisioning services for fuel wood or raw timber construction materials at a local level. Again, the services that ecosystems provide may not be generalised across the landscape because in some places deforestation contributes to annual crops while it affects quantity and quality of water flows in other places. This dynamic interaction of ecosystem services reflects the complexity of social-ecological systems and influence on the way people use and perceive the benefits as well as making appropriate decisions.

Forests (natural but also human-made or modified) are among the most important providers of ecosystem services for the entire world (Ninan & Inoue 2013) and in particular sustain rural livelihoods in various ways (HLPE 2017). The direct benefits of forest and tree based ecosystem service use (i.e. provisioning services) are important for livelihoods as well as the indirect benefits to sustain the provisioning services in the landscape (Hartter 2010; Meijaard et al. 2013). Forests and trees (i.e. agroforest) contribute to indirect ecosystem services (i.e. crop pollination, soil fertility, water purification etc.) for primary food production, and sustainable flow of these benefits depend on how people maintain trees in the landscape. However, most studies have focused on the roles of forest benefits from economic valuation or quantitative assessment of biophysical systems. As a result, monetary contributions of forest uses to reduce poverty in rural environment has been well recognised in the bulk of literature (Angelsen et al. 2014; Belcher, Achdiawan & Dewi 2015; Hogarth et al. 2013). Nevertheless, the broad spectrum of forest benefits in terms of indirect benefits that sustain the functions of ecosystems supporting livelihoods and well-being are not adequately addressed. In order to explain the roles of forests in supporting rural livelihoods and justify the current

management systems, understanding both direct and indirect benefits of ecosystem services remain important (FAO 2016; Foli et al. 2014; Hartter 2010; Kalaba 2014; Meijaard et al. 2013; Reed et al. 2017).

People's perceptions of ecosystem benefits is insightful in novel ways that are relevant to management and policy (Asah et al. 2014). Studies showed that the sustainable benefits of ecosystems depend on how people use, perceive and accordingly act to secure a wide range of provisions. Local people's perceptions reflect their acknowledgement of indirect benefits (e.g. air quality, water purification, soil protection etc.) provided by the forest, awareness about degradation of ecosystem services over time and positive attitudes towards participatory management (Yang et al. 2015). To date studies exploring the importance of forests have highlighted the roles of provisioning ecosystem services in rural livelihoods (Kalaba, Quinn & Dougill 2013b) while integrating the wide range of benefits (i.e. regulating, supporting and cultural) are limited (Mensah et al. 2017). In order to support the decision-making and effective management of forest ecosystem services in the landscape, there is a need to understand how people use and perceive the benefits of forests and trees as a part of their livelihoods and socio-cultural needs. The social and cultural construct has influence on the perceived importance and human desire to manage forests and trees for acquiring the benefits in the long-term (Chan et al. 2012).

Relationships between forest and rural livelihoods are multi-dimensional, though broadly relate to the nature of benefits and spatial contexts where it is important to people (Newton et al. 2016). The literature states that higher forest dependency of households exists within proximity to forests or remoteness from the market centre in particular in a rural context (Sunderlin et al. 2005; Sunderlin et al. 2008). Forest importance also differs with changing social-ecological systems in multifunctional landscape indicate the diversity of the roles in rural livelihoods (Sunderland et al. 2017). A recent study showed the relationship between the proximity of different forest and tree covers with the dietary diversity of the rural population in the landscape (Rowland et al. 2016). In fact forest uses vary at a broader landscape scale with regard to market access and sites - the geographical contexts in which people depend on forests (Belcher, Achdiawan & Dewi 2015; Walelign et al. 2016). Nevertheless, there is insufficient evidence to determine where forest and trees are relatively more important in terms of direct uses and indirect benefits for rural livelihoods in the landscape.

In the present study, we seek to examine the variations in the use and perceived importance of forest benefits across three sites in eastern Chittagong Hill Tracts (CHT) region of Bangladesh. CHT covers the major uplands of the country with tropical evergreen and semi-evergreen forests that support the livelihoods of millions of traditional ethnic people. The region is also a particularly important social-ecological system in Bangladesh with unique biophysical, social and cultural characteristics (Ahammad & Stacey 2016). To our knowledge there have been no prior studies undertaken on the people's livelihoods and forest linkage from

ecosystem service perspective. By exploring the forest benefits across three sites, the study contributes to understanding the diversity of use and perceived importance of ecosystem services for supporting integrated landscape management. The study also provides evidence on location-specific demand of forest based ecosystem services and the opportunities for integrating the diversity of forest importance in management.

The paper proceeds as follows. First, we present the background of the study and methods. Second, we present the result for direct benefits followed by indirect benefits perceived across the three sites in the CHT region. We then conclude with discussions of the results concerning the variations of important forest based ecosystem service provisions in diverse contexts require an integrated management at a landscape scale. In the paper, the term ecosystem service for forest use and perceived importance was used following the classification of ecosystem services (MA 2005) and related studies (Ninan & Inoue 2013). Direct benefits include provisioning services such as food, fuel wood, construction materials, timber and indirect benefits (i.e. regulating air quality, water purification, crop pollination, soil protection and pest control, supporting soil fertility, and culture related aesthetic and spiritual) of the forest ecosystems services to rural households.

2. Materials and methods

2.1 Description of the study area in Chittagong Hill Tracts region of Bangladesh

Forest coverage in Bangladesh is lower than other counties in south and south-east Asia (FAO 2010) but a large proportion of the rural population depends on forests and trees for livelihoods (Abdullah et al. 2016; Motiur et al. 2006). Poverty, landlessness, low-level agricultural productivity and geographical constraints often pushes rural people to depend on forests in some way for their livelihoods (Rasul 2007). It is well documented in several studies about the uses of forests for food, energy, and income generation options (Kar & Jacobson 2012; Miah, MD et al. 2012; Misbahuzzaman & Smith-Hall 2015). Numbers of people living around forest areas whom depend upon the ecosystem services are however not currently estimated as well as the variations in dependency with respect to the contexts and types of forests.

CHT was reported for forest resources in Bangladesh and about 73% of the lands in the region have been historically managed for forest or plantation activities (Rasul 2007). Studies have documented that forest ecosystems provide diverse plant-based products including fuel wood, timber, bamboo, rattan, forage, grass, medicinal plants, wild fruits, bamboo shoot and mushrooms for local uses that contribute to household consumption or subsistence income of ethnic communities(Miah, MD et al. 2012). Forests also support communities through their hunting and gathering practices of wild animals that are largely used in some communities of the region (Miah et al. 2014). The level of forest dependency or its economic contributions in

CHT may be higher than other regions due to diversity of products and uses as well as persistent pressures for conversion of the forest into agricultural land uses (Ahammad & Stacey 2016).

As a land-scarce country coupled with population growth, sustainable forest uses are at risk to increasing challenges from agricultural cultivation, human settlement and other development interventions (Mahtab & Karim 1992). Deforestation is still higher in CHT compared to other forested areas of Bangladesh (Reddy et al. 2016), although areas of monoculture plantations have increased or remained stable since the 1990s (FAO 2014). Forest loss associated with the agriculture land-use changes caused threats to loss of ecosystem services including biodiversity, soil erosion and degradation of watersheds in CHT. Historically, shifting cultivation is a traditional form of land use of local people in the region though it has been reported as largely resulting in forest loss and associated soil erosion, watershed degradation and loss of biodiversity (Gafur et al. 2003; Miah, MMA & Islam 2007; Rahman, Rahman & Sunderland 2014). With the rise of population, limited land suitable for agricultural production and associated pressure for further farming expansion and shortening fallow cycles, this land use has turned into less productive regimes or forced by external institutional arrange to be banned. Though forest supports both direct (e.g. fuel wood) and indirect (e.g. watershed) benefits, the sustainable flow of the ecosystem services relies on the effective management of trees in the landscape.

Forest and tree benefits in changing landscapes are often less perceived and measured, but these are vital to inform the patterns and transition of ecosystem services in different contexts of a landscape (Padoch & Sunderland 2013). The present studies mainly identified income contributions of forests to livelihoods with limited understanding on the diversity of benefits at landscape scale. The landscape comprises a dynamic social and ecological systems with high level of human dependency on natural resources and may influence the demand for forest ecosystem differentially. The sustainable use and management of ecosystem services remains essential in the rural livelihoods of CHT region, but it is challenging due to difference in contexts where the people live and maintain trees in the landscape.

2.2 Selection of a landscape

The study was conducted in three sites following certain criteria applied in other studies (Deakin, Kshatriya & Sunderland 2016; Sunderland et al. 2017). In order to achieve the broader diversity and importance of forests ecosystems in the landscape, proximity to forests, access and remoteness from market were considered as proxy for 3 site selections (i.e. remote, intermediate and on-road) (Figure 1). A scoping survey was organised in 2015 to select the appropriate sites and villages following the criteria (Ahammad & Stacey

2016). We interviewed local government staff mainly from Forest and Agriculture departments as well as academics and researchers; we discussed the criteria and analysed available maps during the stage of village selection. Key informants from the selected villages (included leaders and knowledgeable community members) were interviewed for information on the village, forest area/s and human settlement.

After stratification of the sites, 12 villages were randomly selected (4 from each site under three sub-districts- Belaichari, Rowangchari and Bandarban sadar respectively). Remote site falls in Belaichari of Rangamati district; intermediate in Rowanchari and on-road in Bandarban sadar of Bandarban districts. The sites are different by location in terms of distance to market, population density, economic activities, forest types and management (Table 1).

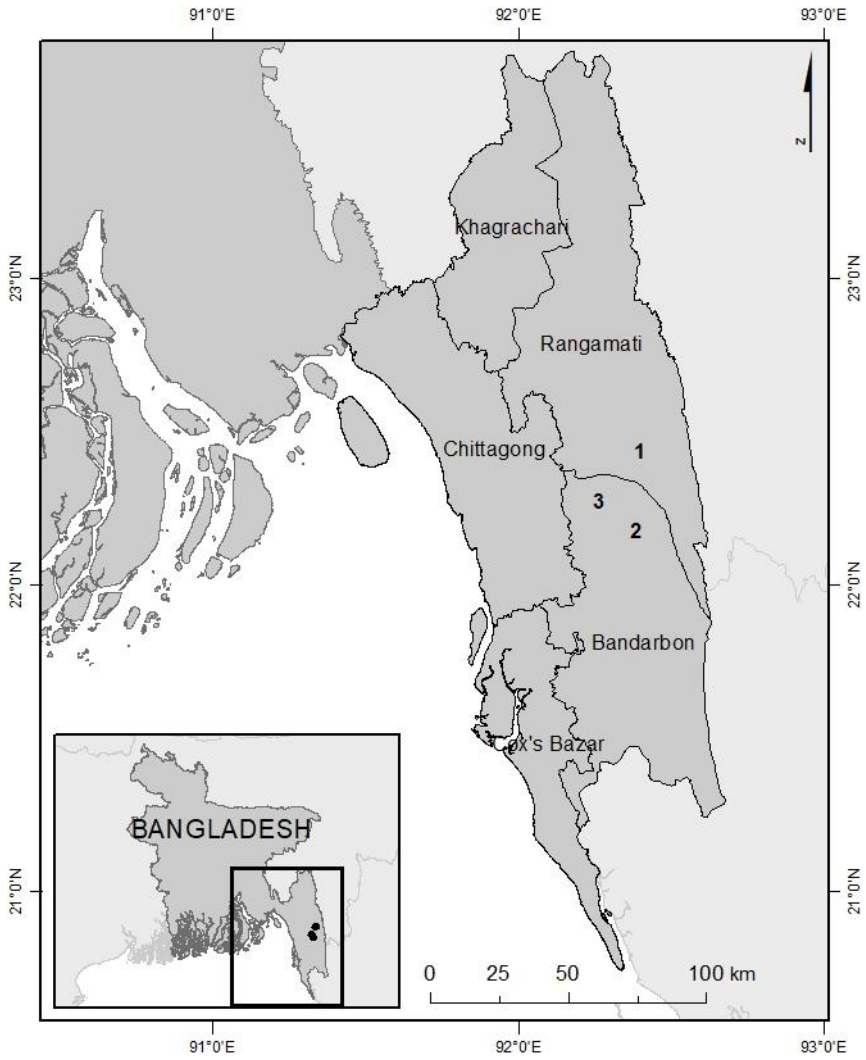

Figure 1: Three study sites (remote, intermediate and on-road) in Chittagong Hill Tracts region of Bangladesh

Table 1: Basic social, ecological, economic and institutional features across 3 sites in Chittagong Hill Tracts region

	Remote	Intermediate	On-road
Population density (per sq. km.)	38 nos.	62 nos.	176 nos.
Elevation/altitudes (meter)	100-350	70-172	50-90
Age of villages (settlement years)	25-30	30-50	>50
Main economic activities	Subsistence farming, forest product harvesting and trade, day labour	Farming, forest product harvesting and trade, fruit-tree gardening, day labour and employment	Farming, day labour, forest trade, employment, small business, land rent
Forest types (ecological)	Secondary forests (tropical evergreen and semi-evergreen); Plantation	Mixture of forest types: mostly secondary forests with small natural forest, industrial and private plantation	Mostly industrial and private plantation
Forest management	State owned forest reserve (Rhainkhyong reserve and Kaptai National Park)	State and private plantations and community owned forest reserve	State and private plantations
Distance to forests (km)	<0.5	0.5-5	>5
Distance to sub-district/district market (km/time)	80 km/2-3 hours travel by boat	45 km/0.5-1 hour by motorbike	5 km/30 minutes by motorbike

2.3 Final data collection and analysis

The data was collected at the sampled households in 12 villages of the three sites during 2015-16. We applied structured household surveys on the use of direct benefits and perceived indirect benefits of forest and trees. Over 50 percent of the households in each village were randomly sampled for the interviews. A total 300 sample households were split in equal size across three sites (n=100), intermediate (n=100) and on-road site (n=100) (Table 2). Following the study Kalaba, Quinn and Dougill (2013a), the households were interviewed for the direct benefits of the provisioning ecosystem service use (i.e. subsistence or cash) in a year. Over 90 percent of household heads and respondents in the survey were male. The respondents provided information on the types of provisioning services (forest products) that they used in their households for self-consumption and income generation. Of the 300 sample households, information on income contributions of forest was gathered from 159 households.

Table 2: Numbers of villages and HHs surveyed in 3 sites during 2015-2016

	Remote	Intermediate	On-road	Total	Final analysis
Nos. of villages surveyed	4	4	4	12	12
Nos. of HHs surveyed (direct ecosystem services)	100	100	100	300	289
Nos. of HHs surveyed (indirect ecosystem services)	70	70	74	214	214

For the indirect benefits of forest ecosystem services, 214 respondents were interviewed on their perceptions about important indirect benefits of forest and tree contributions in their landscape following the study (Martin-Lopez et al. 2012). The household respondents were asked to identify the particular indirect ecosystem service associated with the presence of forest and trees. Before initiating the household surveys, a list of direct and indirect benefits of ecosystem services was identified during a focus group discussions and provided to the respondents.

For analysis, the data collected on forest based ecosystem services were grouped according to the direct (use) and indirect benefits (perceived importance) at site level. After data cleaning, we used the information for 289 households for final analysis on understanding their uses of provisioning ecosystem services. Direct benefits were further grouped into different provisioning ecosystem services (e.g. fuel wood, timber, bamboo, wild plant and animal foods, thatch and broom grass) and their uses (subsistence and cash) at site level. According to the types of provisioning services, the proportions of the respondents were calculated. Indirect benefits that the respondents identified to be important were classified by 'regulating' (air quality, water purification, crop pollination, soil protection, pest control and soil fertility) and 'cultural' (spiritual and aesthetic) services. According to the types of regulating and cultural services, the proportions of household respondents were grouped.

Descriptive statistics were conducted with Statistical Package for Social Sciences (SPSS) to calculate the proportions of households who used the provisioning services and perceived the indirect benefits. To examine the associations of forest ecosystem service uses (direct) and perceived benefits (indirect) with sites, a chi-square test of independence was conducted. Z-test was then used to draw a comparison between the proportions of the households for the use and perceived importance of particular ecosystem service at site level (Kalaba, Quinn & Dougill 2013a).

3. RESULTS

3.1. General patterns of provisioning ecosystem service use at households

The surveyed households used forest provisioning ecosystem services for subsistence and cash income. Fuel wood, different plant and animal-sourced foods, bamboo (raw and processed), fodder for livestock, timber, roof thatch and broom grass were the important provisioning services that the households used for subsistence purposes during one year. The most common use of services was fuel wood and foods in 92% and 84% of the surveyed households respectively. Forest ecosystems provide a range raw food products of both plant and animal originated to all ethnic communities in the studied landscape. Over 80% of surveyed households used vegetables and fish in forest ecosystems for a significant part of their diet. Bamboo, timber and thatch grass were the important construction materials that 65%, 45% and 33% respondents reported for their household use. 52% households reported they used forests for grazing of their livestock and collecting fodders. Apart from that 30% households collected broom grass for own uses.

Forest provisioning services used for cash income in households were mainly bamboo, timber, fuel wood, broom grass and wild foods. Bamboo and timber were the highest cash sources among the provisioning services that 35% and 27% of the households used respectively followed by fuel wood (16.6%), broom grass (14.9%) and foods (15%). Timber provided the highest cash income to the households. The average cash income of the households received from the timber was 507 USD/yr; three times higher than bamboo at 156 USD/yr. The income from foods, fuel wood and broom grass was less than 20 USD/yr.

3.2. Site level comparisons of provisioning ecosystem service use

The use of forest provisioning services for subsistence and cash income was different across the three study sites (Table 3). In terms of subsistence use, fuel wood and food were high in demand followed by bamboo, timber, broom grass and roof thatch regardless of the site. There was no significant difference for self-consumption of bamboo and timber construction materials across the sites. But the use of fuel wood, food and roof thatch has close association with site level. A high proportion of households used fuel wood (98.9%) in remote villages than households in intermediate ($Z=2.7$; $p<0.05$) and on-road ($Z=2.3$; $p<0.05$). However, grass used for roof and thatch is more collected in the households of remote villages than intermediate ($Z=2.5$; $p<0.05$) and on-road sites ($Z=4.4$; $p<0.05$).

A high proportion of households (42.4%) in remote and intermediate sites (49.5%) reported on income through using bamboo and timber than the on-road site (only 15%). Further analysis showed a significant

difference on more use of bamboo for cash income in the households of intermediate and remote sites than the on-road site (remote: Z=4.2; p<0.05 and intermediate: Z=5.2; p<0.05). The use of timber was significantly higher in the households of on-road and intermediate sites than the remote site (on-road: Z=4.1; p<0.05 and intermediate: Z=3.2; p<0.05). The proportion of households that used fuel wood and food for income also vary at site level. Relatively more households in the intermediate site used fuel wood than remote (Z= 3.158; p<0.01) and on-road sites (Z=2.8; p<0.05). Further analysis shows that the income contributions of different provisioning services were different across the sites. Forest income was high in the households of the intermediate site followed by remote and on-road sites. Timber provided the largest cash income in the on-road site (799 USD) than intermediate (695 USD) and remote (298 USD) sites.

Table 3: Site level comparisons of household (%) used forest provisioning ecosystem services for subsistence and cash purposes

	Provisioning Ecosystem services	Remote (n=92)	Intermediate (n=97)	On-road (n=100)	Chi-square	p-Value
Subsistence use	Bamboo	56.5	64.9	70	3.8	>0.05
	Fuel wood	98.9	85.6	92	7.0	<0.05
	Food	95	86	77	11.9	<0.05
	Broom grass	19.6	56.7	14	49.8	<0.05
	Thatching grass	48.9	30.9	19	19.7	<0.05
	Timber	45.7	52.6	37	4.9	>0.05
	Fodder for livestock	64.1	53.6	38	13.3	<0.05
Cash use	Bamboo	42.4	49.5	15	28.6	<0.05
	Fuel wood	9.8	27.8	12	13.5	<0.05
	Food	17.4	24.7	4	16.9	<0.05
	Timber	12	31.9	38	17.3	<0.05
	Broom grass	7.6	21.6	15	7.4	<0.05

More households used forest food in intermediate and remote sites than the on-road site (Z=4.2; p<0.05 and Z=3; p<0.05). There was more subsistence use of forest foods at remote site except bamboo shoots consumed higher in intermediate and on-road sites (Table 4). It was observed for food that high proportions of households (95%) in remote site used than intermediate (Z=2.1; p<0.05) and on-road (Z=3.4; p<0.05). Forest sourced foods ie. vegetable, wild fruit, mushroom and animal also showed a significant association at site level. The use of forest for fodder was higher in remote site as it was significantly different from on-road (Z=3.6; p<0.05).

Table 4: Site level difference of forest food used at households (%)

Forest sourced wild foods		Remote (n=92)	Intermediate (n=97)	On-road (n=100)	Chi square	p-value
Subsistence	Vegetable	95	86	77	11.9	<0.05
	Fish/crab	86	84	82	0.5	>0.05
	Wild fruit	63	30	35	24.5	<0.05
	Mushroom	48	35	29	7.5	<0.05
	Bamboo shoot	33	63	61	21.7	<0.05
	Wild animal	33	38	12	18.8	<0.05
Cash	Vegetable	15	0	1	16.9	<0.05
	Fish/crab	11	2	3	10.7	<0.05
	Wild fruit	13	2	1	17	<0.05
	Wild animals	15	0	1	27.7	<0.05
	Bamboo shoot	7	10	5	2.2	>0.05

3.3. Perceived indirect benefits of forest ecosystem services

The perceived importance of forests and trees for indirect ecosystem service provisions were different with regard to the types of ecosystem services and sites. Overall the respondents' perceptions of indirect benefits of maintaining forests and trees in their landscape were regulating services (i.e. regulating air quality, fresh water purification, crop pollination, pest and disease control, supporting soil fertility and protection) and cultural services (i.e. spiritual and aesthetic). The highest proportion of the respondents identified fresh water purification (73%) followed by regulating air quality (55%), soil protection (54%), soil fertility (53%), pest and disease control (42%), crop pollination (38%), aesthetic (36%) and spiritual (29%) as important indirect benefits (Table 5).

Table 5: Comparison on the perceptions of indirect benefits of forests across sites

Indirect benefits of ecosystem services	Number of respondents Total (N=214)	Site			Chi-square	p-Value
		Remote (n=70)	Intermediate (n=70)	On-road (n=74)		
Regulating service						
Air regulation	117 (55)	52 (74)	42 (60)	23 (31)	28.28	<0.001
Water purification	157 (73)	62 (89)	55 (79)	40 (54)	23.38	<0.001
Crop pollination	81 (38)	30 (37)	29 (41)	22 (30)	3.2	>0.05
Pest and disease control	90 (42)	39 (56)	30 (43)	21 (28)	11.05	<0.01
Soil protection	115 (54)	47 (67)	31 (44)	37 (50)	7.9	<0.05

Indirect benefits of ecosystem services	Number of respondents Total (N=214)	Site			Chi-square	p-Value
		Remote (n=70)	Intermediate (n=70)	On-road (n=74)		
Soil fertility	113 (53)	36 (51)	28 (40)	33 (45)	20.61	<0.001
Cultural service						
Spiritual	62 (29)	23 (33)	21 (30)	18 (24)	1.33	>0.05
Aesthetic	77 (36)	17 (24)	27 (39)	33 (45)	6.74	<0.05

Further analysis also showed that the perceived importance of the forest benefits was different among the respondents with regard to site level. More respondents in remote and intermediate sites acknowledged ecosystem services than the on-road site. With exception to crop pollination service, a significant association was found with remote site for the high proportions of the respondents perceived all other indirect ecosystem service. Among all of the indirect benefits, over half of the respondents valued the regulation of fresh water as the most important contribution of the forests, regardless of site.

4. DISCUSSION

4.1. Site-level variations in use of provisioning ecosystem services

The patterns of use and importance of provisioning services vary with respect to the sites in the landscape of the current study was similar to the findings reported in previous studies (Kalaba, Quinn & Dougill 2013a; Mensah et al. 2017). Overall use of forest ecosystems were relatively high in remote and intermediate sites. Both the subsistence and cash contributions of forest resources were also higher across the households in these two sites than the on-road site. The finding in the study is similar to Belcher, Achdiawan and Dewi (2015) in that forests are more important for subsistence than cash income in the relatively remote and highly-forested sites, while only subsistence use is dominant around the low-forest on-road site. However fuel wood and food consumption are not significantly different across the sites though there is a slight decrease in their collection or use around the villages close to town centres. With reference to the previous study that remote communities have a higher dependency (Sunderlin et al. 2008) and their close connectedness (Martin-Lopez et al. 2012) on forest ecosystems; our study also supports the fact/notion that there was relatively more use of forest provisioning ecosystem services in remote sites within the landscape.

The role of access to forest edges and markets were important factors for high extraction of forest products (Kamanga, Vedeld & Sjaastad 2009), though we observed different patterns in CHT. Initially our study

supports the conclusion reached elsewhere; that there is relatively more use of forest provisioning ecosystem services within the closest distance to forest edge, in remote and intermediate sites. While with an increasing distance to forest edge, the overall extraction of the provisioning services was found to be less in the on-road site though it is closely located around markets. This result is opposite to the view on potential roles of market influences on the extraction of forest resources (Mamo, Sjaastad & Vedeld 2007). To this point also a slightly different point can be drawn from our study for the intermediate site which has relatively more access to forests and but less access to market than the on-road site. Overall extraction of forest resources for economic benefits was high in the intermediate site than the remote and on-road sites.

Previous studies mentioned that the physical context of the landscape in particular surrounding land uses and forest conditions (Mensah et al. 2017) where rural people are living has a strong influence on their utilisation of diverse forest and tree resources (Belcher, Achdiawan & Dewi 2015; Kamanga, Vedeld & Sjaastad 2009). People in remote and intermediate sites accessed available plant and animal-sourced foods due to diverse forest types including natural and agroforests that are low along the road site. The positive relationships between the diverse food sources and accessibility to forests in the study also resemble recent findings of (Ickowitz et al. 2014; Rowland et al. 2016). Higher forest and tree cover is related to better access to dietary diversity and availability of micro-nutrient rich wild foods in households. Furthermore, as the level of food insecurity is comparatively higher in remote villages of the study, these diverse food sources remain important for rural households to minimise the risks reported in several studies (Kalaba, Quinn & Dougill 2013b; McSweeney 2005). On the other hand, increasing monoculture crop and plantations reduced availability and accessibility to forest food in the on-road site and the alternative use of the provisioning ecosystem services to cope with food shortage.

A landscape comprising of different forest and tree management may affect the accessibility of the local community to provisioning ecosystem services at the site level. People living in the remote site of the landscape have more open-access to state forests and used the provisioning ecosystem services relatively higher than others. In terms of income benefits, forest use in households are relatively higher in remote and intermediate sites. This agrees partially with other studies which also showed higher economic benefits received by people in state forest owned areas (Jagger et al. 2014). As in the current study, the highest forest income derived from raw construction material timber was associated with the managed private plantations as well as access to market in the on-road and intermediate sites. People only have access to state owned forests in remote sites while there are diverse regimes including private, state and customary ownership of trees in intermediate sites. On the other hand, there is mostly privately-owned forest regime within on-road sites that are only accessible by a less number of people. Diversity of these regimes at the

site levels not only determined the availability and accessibility of forests, but also the implications for livelihood outcomes.

4.2. Perceived indirect benefits of forest ecosystem services

Forest ecosystems contribute to several indirect benefits and has been evident from the perceptions of the surveyed households in the landscape of CHT. Previous studies reported that rural people perceive forest as a range of indirect benefits related to their environmental, social and cultural well-being (Fritz-Vietta 2016; Meijaard et al. 2013; Sheil & Wunder 2002). The important indirect benefits of maintaining forest and trees perceived by the respondents were regulating services (fresh water purification, regulating air quality, crop pollination and pest controls), supporting services (soil protection and soil fertility) and cultural services (aesthetic and spiritual). Studies showed that the watershed degradation posed a severe threat to a sustainable supply of fresh water in CHT. Though the linkage between forest loss and its implications for fresh water was not studied for the region, but the respondents identified with the conservation of natural forests being important in protecting the health of watershed.

Taking into account the respondents' location along forests, the perceptions of indirect benefits differed across the sites which was also discussed in various studies (Hartter 2010; Meijaard et al. 2013; Muhamad et al. 2014). The spatial context of the household settlement, in particular its proximity to the forest/s has influences on access to particular benefit, accrued experiences and attitudes towards the overall ecosystem services. A significant difference was found between the respondents of the remote site to other sites with regard to their appreciation for regulating air quality, water purification, soil fertility and soil protection in the study site. Evidently there was strong association of perceptions of the respondents on indirect ecosystem services with the remote site located within less than 1 km of natural forest/s. The human habitations along with the proximity to the source of benefits were important determinants (Cuni-Sanchez et al. 2016), but the type of forest and tree based ecosystem also likely affect the perceptions in our study sites. People living in the remote site identified that soil fertility of their lands is related to the presence of natural forests. On the other hand, people in the on-road site had negative perceptions on the roles of planted forest ecosystems to soil health and biodiversity loss. The contrasting views across the sites imply not only the location, but also the patterns of forested ecosystems that influence people's relative perceptions and demand for particular ecosystem services.

5. Conclusions and policy recommendations

By applying ecosystem service concept, we have explored the variations of forest benefit types and access at different sites in the CHT region of Bangladesh. In general forest based provisioning ecosystem services were used across the rural population in their livelihoods surveyed regardless of their location-specific contexts in the landscape. But in particular, we have observed that the uses and the types provisioning services are significantly different within the population based on their site in which they were located. It was evident that more people within close proximity to forests used provisioning services and also perceived indirect ecosystem service provisions than others. While lower forest dependency of people in the on-road site implied less accessibility to the ecosystem service provisions. They also had relatively low appreciation towards the environmental benefits of planted ecosystems in recent years.

This difference of forest benefits across the sites is a useful source of information to look further into who uses the forest most and where, as well as how the existing policy or management integrates this diversity of the landscape. The fact is that the existing forest management in the region is largely fragmented among state, community and private stakeholders. Different management goals of the local communities and the state is likely to increase trade-offs within the forest based ecosystem service and increase vulnerability of social-ecological systems in the region. To this point, a critical need is to further focus on the trends of ecosystem services relating to different forest and land management at a landscape scale. Finally, an integrated approach combining the demand of rural communities across diverse social and ecological contexts might support sustainable forest uses and ecosystem service provisions in the region. In fact, the supply of both direct and indirect ecosystem service provisions is inter-connected and depends on better management of forests and trees in the landscape.

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References

Abdullah, MAN, Stacey, N, Garnett, S & Myers, B 2016, 'Economic dependence on mangrove forest resources for livelihoods in the Sundarbans, Bangladesh', *Forest Policy and Economics*, vol. 64, pp. 15-24.

Ahammad, R & Stacey, N 2016, 'Forest and agrarian change in the Chittagong Hill Tracts region of Bangladesh', in E Deakin, M Kshatriya & T Sunderland (eds), *Agrarian change in tropical landscapes*, Center for International Forestry Research, Bogor, Indonesia

Angelsen, A, Jagger, P, Babigumira, R, Belcher, B, Hogarth, NJ, Bauch, S, Börner, J, Smith-Hall, C & Wunder, S 2014, 'Environmental Income and Rural Livelihoods: A Global-Comparative Analysis', *World Development*, vol. 64, pp. S12-S28.

Asah, ST, Guerry, AD, Blahna, DJ & Lawler, JJ 2014, 'Perception, acquisition and use of ecosystem services: Human behavior, and ecosystem management and policy implications', *Ecosystem Services*, vol. 10, pp. 180-186.

Belcher, B, Achdiawan, R & Dewi, S 2015, 'Forest-Based Livelihoods Strategies Conditioned by Market Remoteness and Forest Proximity in Jharkhand, India', *World Development*, vol. 66, pp. 269-279.

Chan, KMA, Guerry, AD, Balvanera, P, Klain, S, Satterfield, T, Basurto, X, Bostrom, A, Chuenpagdee, R, Gould, R, Halpern, BS, Hannahs, N, Levine, J, Norton, B, Ruckelshaus, M, Russell, R, Tam, J & Woodside, U 2012, 'Where are cultural and social in ecosystem services? A framework for constructive engagement', *BioScience*, vol. 62, no. 8, pp. 744-756.

Costanza, R, d'Arge, R, de Groot, R, Farber, S, Grasso, M, Hannon, B, Limburg, K, Naeem, S, O'Neill, RV, Paruelo, J, Raskin, RG, Sutton, P & van den Belt, M 1998, 'The value of ecosystem services: putting the issues in perspective', *Ecological Economics*, vol. 25, pp. 67-72.

Cuni-Sanchez, A, Pfeifer, M, Marchant, R & Burgess, ND 2016, 'Ethnic and locational differences in ecosystem service values: Insights from the communities in forest islands in the desert', *Ecosystem Services*, vol. 19, pp. 42-50.

Deakin, L, Kshatriya, M & Sunderland, T 2016, *Agrarian change in tropical landscapes*, CIFOR.

FAO 2010, *Global forest resources assessment*, 163, Food and Agriculture Organization of the United Nations.

FAO 2014, *Global forest resources assessment 2015*.

FAO 2016, *State of the World's Forests 2016. Forests and agriculture: land-use challenges and opportunities*, FaAOotU Nations.

Fisher, B, Turner, RK & Morling, P 2009, 'Defining and classifying ecosystem services for decision making', *Ecological Economics*, vol. 68, no. 3, pp. 643-653.

Foli, S, Reed, J, Clendenning, J, Petrokofsky, G, Padoch, C & Sunderland, T 2014, 'To what extent does the presence of forests and trees contribute to food production in humid and dry forest landscapes?: a systematic review protocol', *Environmental Evidence*, vol. 3, no. 1, p. 15.

Fritz-Vietta, NVM 2016, 'What can forest values tell us about human well-being? Insights from two biosphere reserves in Madagascar', *Landscape and Urban Planning*, vol. 147, pp. 28-37.

Gafur, A, Jensen, J, Borggaard, O & Petersend, L 2003, 'Runoff and losses of soil and nutrients from small watersheds under shifting cultivation (Jhum) in the Chittagong Hill Tracts of Bangladesh', *Journal of Hydrology*, vol. 274, pp. 30–46.

Hartter, J 2010, 'Resource Use and Ecosystem Services in a Forest Park Landscape', *Society & Natural Resources*, vol. 23, no. 3, pp. 207-223.

HLPE 2017, *Sustainable forestry for food security and nutrition*, HLPoEoFSa Nutrition.

Hogarth, NJ, Belcher, B, Campbell, B & Stacey, N 2013, 'The Role of Forest-Related Income in Household Economies and Rural Livelihoods in the Border-Region of Southern China', *World Development*, vol. 43, pp. 111-123.

Ickowitz, A, Powell, B, Salim, MA & Sunderland, TCH 2014, 'Dietary quality and tree cover in Africa', *Global Environmental Change*, vol. 24, pp. 287-294.

Jagger, P, Luckert, MK, Duchelle, AE, Lund, JF & Sunderlin, WD 2014, 'Tenure and forest income: Observations from a global study on forests and poverty', *World Development*, vol. 64, pp. S43-S55.

Kalaba, FK 2014, 'A conceptual framework for understanding forest socio-ecological systems', *Biodiversity and Conservation*, vol. 23, no. 14, pp. 3391-3403.

Kalaba, FK, Quinn, CH & Dougill, AJ 2013a, 'Contribution of forest provisioning ecosystem services to rural livelihoods in the Miombo woodlands of Zambia', *Population and Environment*, vol. 35, no. 2, pp. 159-182.

Kalaba, FK, Quinn, CH & Dougill, AJ 2013b, 'The role of forest provisioning ecosystem services in coping with household stresses and shocks in Miombo woodlands, Zambia', *Ecosystem Services*, vol. 5, pp. 143-148.

Kamanga, P, Vedeld, P & Sjaastad, E 2009, 'Forest incomes and rural livelihoods in Chiradzulu District, Malawi', *Ecological Economics*, vol. 68, no. 3, pp. 613-624.

Kar, S & Jacobson, MG 2012, 'NTFP income contribution to household economy and related socio-economic factors: Lessons from Bangladesh', *Forest Policy and Economics*, vol. 14, no. 1, pp. 136-142.

MA 2005, *Ecosystems and human wellbeing: Synthesis*, W Island Press, DC.

Mahtab, FU & Karim, Z 1992, 'Population and agricultural land use: towards a sustainable food production system in Bangladesh', *Ambio*, vol. 21, no. 1, pp. 50-55.

Mamo, G, Sjaastad, E & Vedeld, P 2007, 'Economic dependence on forest resources: A case from Dendi District, Ethiopia', *Forest Policy and Economics*, vol. 9, no. 8, pp. 916-927.

Martin-Lopez, B, Iniesta-Arandia, I, Garcia-Llorente, M, Palomo, I, Casado-Arzuaga, I, Amo, DG, Gomez-Baggethun, E, Oteros-Rozas, E, Palacios-Agundez, I, Willaarts, B, Gonzalez, JA, Santos-Martin, F, Onaindia, M, Lopez-Santiago, C & Montes, C 2012, 'Uncovering ecosystem service bundles through social preferences', *PLoS One*, vol. 7, no. 6, p. e38970.

McSweeney, K 2005, 'Natural insurance, forest access, and compounded misfortune: Forest resources in smallholder coping strategies before and after Hurricane Mitch, northeastern Honduras', *World Development*, vol. 33, no. 9, pp. 1453-1471.

Meijaard, E, Abram, NK, Wells, JA, Pellier, AS, Ancrenaz, M, Gaveau, DL, Runting, RK & Mengersen, K 2013, 'People's perceptions about the importance of forests on Borneo', *PLoS One*, vol. 8, no. 9, p. e73008.

Mensah, S, Veldtman, R, Assogbadjo, AE, Ham, C, Glèlè Kakaï, R & Seifert, T 2017, 'Ecosystem service importance and use vary with socio-environmental factors: A study from household-surveys in local communities of South Africa', *Ecosystem Services*, vol. 23, pp. 1-8.

Miah, MD, Chakma, S, Koike, M & Muhammed, N 2012, 'Contribution of forests to the livelihood of the Chakma community in the Chittagong Hill Tracts of Bangladesh', *Journal of Forest Research*, vol. 17, no. 6, pp. 449-457.

Miah, MMA & Islam, MF 2007, *From slash-and-burn to sustainability – a study from the Chittagong Hill Tracts of Bangladesh*, N South Asian Network for Development and Environmental Economics (SANDEE).

Misbahuzzaman, K & Smith-Hall, C 2015, 'Role of forest income in rural household livelihoods: The case of village common forest communities in the Chittagong Hill Tracts, Bangladesh', *Small-scale Forestry*, vol. 14, no. 3, pp. 315-330.

Motiur, RM, Furukawa, Y, Kawata, I, Rahman, M & Alam, M 2006, 'Role of homestead forests in household economy and factors affecting forest production: a case study in southwest Bangladesh', *Journal of Forest Research*, vol. 11, no. 2, pp. 89-97.

Muhamad, D, Okubo, S, Harashina, K, Parikesit, Gunawan, B & Takeuchi, K 2014, 'Living close to forests enhances people′s perception of ecosystem services in a forest–agricultural landscape of West Java, Indonesia', *Ecosystem Services*, vol. 8, pp. 197-206.

Newton, P, Miller, DC, Byenkya, MAA & Agrawal, A 2016, 'Who are forest-dependent people? A taxonomy to aid livelihood and land use decision-making in forested regions', *Land Use Policy*, vol. 57, pp. 388-395.

Ninan, KN & Inoue, M 2013, 'Valuing forest ecosystem services: What we know and what we don't', *Ecological Economics*, vol. 93, pp. 137-149.

Rahman, SA, Rahman, MF & Sunderland, T 2014, 'Increasing tree cover in degrading landscapes: 'Integration' and 'Intensification' of smallholder forest culture in the Alutilla Valley, Matiranga, Bangladesh', *Small-scale Forestry*, vol. 13, no. 2, pp. 237-249.

Rasul, G 2007, 'Political ecology of the degradation of forest commons in the Chittagong Hill Tracts of Bangladesh', *Environmental Conservation*, vol. 34, no. 02, p. 153.

Reddy, CS, Pasha, SV, Jha, CS, Diwakar, PG & Dadhwal, VK 2016, 'Development of national database on long-term deforestation (1930–2014) in Bangladesh', *Global and Planetary Change*, vol. 139, pp. 173-182.

Reed, J, van Vianen, J, Foli, S, Clendenning, J, Yang, K, MacDonald, M, Petrokofsky, G, Padoch, C & Sunderland, T 2017, 'Trees for life: The ecosystem service contribution of trees to food production and livelihoods in the tropics', *Forest Policy and Economics*.

Rowland, D, Ickowitz, AMY, Powell, B, Nasi, R & Sunderland, T 2016, 'Forest foods and healthy diets: quantifying the contributions', *Environmental Conservation*, pp. 1-13.

Sheil, D & Wunder, S 2002, 'The value of tropical forest to local communities: Complications, caveats, and cautions', *Conservation Ecology*, vol. 6, no. 2, p. 9.

Sunderland, T, Abdoulaye, R, Ahammad, R, Asaha, S, Baudron, F, Deakin, E, Duriaux, J-Y, Eddy, I, Foli, S, Gumbo, D, Khatun, K, Kondwani, M, Kshatriya, M, Leonald, L, Rowland, D, Stacey, N, Tomscha, S, Yang, K, Gergel, S & Van Vianen, J 2017, 'A methodological approach for assessing cross-site landscape change: Understanding socio-ecological systems', *Forest Policy and Economics*.

Sunderlin, WD, Angelsen, A, Belcher, B, Burgers, P, Nasi, R, Santoso, L & Wunder, S 2005, 'Livelihoods, forests, and conservation in developing countries: An Overview', *World Development*, vol. 33, no. 9, pp. 1383-1402.

Sunderlin, WD, Dewi, S, Puntodewo, A, Muller, D, Angelsen, A & Epprecht, M 2008, 'Why forests are important for global poverty alleviation: a spatial explanation', *Ecology and Society*, vol. 13, no. 2, p. 24.

Walelign, SZ, Pouliot, M, Larsen, HO & Smith-Hall, C 2016, 'Combining household income and asset data to identify livelihood strategies and their Dynamics', *The Journal of Development Studies*, pp. 1-19.

Yang, H, Harrison, R, Yi, Z, Goodale, E, Zhao, M & Xu, J 2015, 'Changing perceptions of forest value and attitudes toward management of a recently established nature reserve: A case study in southwest China', *Forests*, vol. 6, no. 9, pp. 3136-3164.