What benefits do community forests provide, and to whom? A rapid assessment of ecosystem services from a Himalayan forest, Nepal.

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ABSTRACT

In Nepal, community forestry is part of a national strategy for livelihoods improvement and environmental protection. However, analysis of the social, economic and environmental impacts of community forestry is often limited, restricted to a narrow set of benefits (e.g. non-timber forest products) and rarely makes comparisons with alternative land-use options (e.g. agriculture). This study, conducted at Phulchoki Mountain Forest Important Bird and Biodiversity Area (IBA) in the Kathmandu Valley, used methods from the Toolkit for Site-based Ecosystem Service Assessment (TESSA) to compare multiple ecosystem service values (including carbon storage, greenhouse gas sequestration, water provision, water quality, harvested wild goods, cultivated goods and nature-based recreation) provided by the site in its current state and a plausible alternative state in which community forestry had not been implemented. We found that outcomes from community forestry have been favourable for most stakeholders, at most scales, for most services and for important biodiversity at the site. However, not all ecosystem services can be maximised simultaneously, and impacts of land-use decisions on service beneficiaries appear to differ according to socio-economic factors. The policy implications of our findings are discussed in the context of proposals to designate Phulchoki Mountain Forest IBA as part of a Conservation Area.

Keywords: beneficiaries; biodiversity conservation; community forestry; equity; livelihoods; participatory management

1. INTRODUCTION

Against a backdrop of global loss and degradation of forest (Food and Agriculture Organisation of the United Nations 2010), more effective approaches to forest management are required. In an effort to address this there has been a gradual trend towards more devolved forms of forest governance (Agrawal et al., 2008), with Nepal being one of the first countries to decentralise many aspects of forest management to local communities. Over the last 30 years, community forestry in Nepal has developed to form part of a strategy for livelihoods improvement and environmental protection. The Forest Act, 1993, provided forest-dependent communities, through local-level institutions (Community Forest User Groups, CFUGs) with legal rights over forest management. By 2009, community forests covered 25% of Nepal's forested area with almost 14,500 CFUGs (Ojha et al., 2009) most of whom are members of the Federation of Community Forestry Users, Nepal (FECOFUN). Evidence suggests that community management can lead to a marked increase in forest cover and a positive effect on biodiversity in general (Acharya, 2003).

Forests are widely recognised as providing benefits not just for the conservation of nature but also for human well-being (Myers, 1997). These benefits, referred to as ecosystem services, are realised at a range of scales, including local-level forest products, regional-level watershed services and global benefits from global climate change mitigation through carbon storage and greenhouse gas sequestration. However, at the local level it is often the case that benefits and costs are not equitably distributed. In Nepal, despite improved forest management and environmental conditions since the introduction of community forests (Baland et al., 2010; Chhetri et al., 2012), some studies suggest that the poorest and the most marginalised members of communities, including women, may receive the least benefit (Keshev & Varughese, 2000; Malla et al., 2003; Adhikari, 2005; Ojha et al., 2009).

The purpose of the study was to assess how designation of part of Phulchoki Mountain Forest Important Bird and Biodiversity Area (referred to as 'Phulchoki IBA' hereafter) as a community forest has affected the provision of a range of ecosystem services for different groups of beneficiaries by comparing the benefits received from the site under different land uses – the first approach of its kind in Nepal. We applied a newly developed toolkit (TESSA: Toolkit for Ecosystem Services Site-based Assessments; URL: http://www.birdlife.org/datazone/info/estoolkit) to measure the ecosystem services at Phulchoki IBA. To be relevant at the site scale, methods for quantifying services need to collect data relevant to decisions affecting the site (Peh et al., 2013). A number of tools and methods have been developed in recent years that can be used to assess, quantify and value ecosystem services such as: Integrated Valuation of Environmental Services and Tradeoffs (InVEST; Kareiva et al., 2011); ARtifical Intelligence for Ecosystem Services (ARIES; Villa et al., 2009); Social Values for Ecosystem Services (SolVES; Sherrouse et al. 2014); Multi-scale Integrated Models of Ecosystem Services (MIMES: http://www.afordablefutures.com/services/mimes). However, none of these enable site-scale data collection of high resolution without the need for specialist technical knowledge, long-term or highly detailed data collection or substantial costs. TESSA enables relatively rapid and inexpensive assessments by non-experts of the magnitude, monetary values (where appropriate) and distribution of ecosystem services delivered by sites, resulting in an understanding of the consequences of potential changes in land management on ecosystem service provision and consideration of the equity implications of decisions—key to achieving any social development goals—that are often overlooked in other assessments (Pagiola et al., 2005; Corbera et al., 2007a, Corbera et al., 2007b). Hence TESSA was the most appropriate method to use in this study because it suited the capacity of the national NGO (Bird Conservation Nepal, BCN) implementing the work. BCN has a developing understanding of the ecosystem services approach and significant connections through to local and national policy making. The results will be used to inform local and national decision-makers in relation to the current government proposal to designate Phulchoki IBA as part of a wider Conservation Area.

2. MATERIAL AND METHODS

2.1 Study area

Phulchoki Mountain (2 800 m asl), lying 16 km southeast of Kathmandu, is the highest peak on the rim of the Kathmandu Valley. The area experiences a short intensive rainy season (between June and September) and a relatively long dry season during the rest of the year. This climate supports four main vegetation types: *Schima-Castanopsis* forest; *Pinus roxburghii* forest; *Alnus nepalensis* forest; and *Quercus*-dominated forest. The area is recognised by Bird Conservation Nepal (BCN, BirdLife International's Partner in Nepal) as an IBA - one of 27 such sites in the country), on account of its importance for the restricted-range bird species, Spiny Babbler *Turdoides nipalensis* (Nepal's only endemic breeding bird) and Hoary throated Barwing *Actinodura nipalensis*, and significant populations of species characteristic of the Sino-Himalayan Temperate Forest biome (Baral & Inskipp 2005; BirdLife International 2013). Other species of significance include the Golden Emperor butterfly *Dilipa morgiana*, Leopard *Panthera pardus* and many threatened orchids.

Phulchoki IBA covers 4 281 ha, one third of which is managed as community forests (1 368 ha), and the rest (mainly on and around the summit) is national (state) forest. Nineteen CFUGs manage land inside the IBA boundary with almost 3000 household members. Phulchoki IBA is part of a larger forest complex covering the Phulchoki-Chandragiri part of the mid-hills biogeographic zone (Figure 1).

Most people living around the forest are dependent on subsistence farming for their livelihoods. In lowland areas rice cultivation predominates, followed either by a second crop of rice, or by wheat, potato, maize or mustard. Livestock (mainly cows, buffaloes and goats) play an essential role in the agricultural system. Past forest degradation through over-grazing, uncontrolled use of fire and over-harvesting of forest products occurred under District Forest Office management. At Phulchoki, forest cover was reduced by 60% between 1986 and 1999 (His Majesty's Government of Nepal (HMGN) & Commission of European Communities (CEC), 2000). In response, communities were given responsibility for forest management in 1995 and since then there has been substantial regeneration (Baral & Inskipp, 2005).

Phulchoki (meaning 'flower-covered hill') is a popular destination for recreational visits and pilgrimages by Nepali nationals and is an accessible site for birdwatchers. Four CFUGs around the forest have created serviced picnic sites which visitors pay to use and a fifth charges fees at a road barrier for access to their forest. The picnic sites are managed and maintained through a contract issued through a competitive bidding process open to CFUG members. Successful bidders manage the sites and retain the profits. The contract fee is used for CFUG administration, forest patrolling and community (e.g. road improvement) or social projects (e.g. school fees for poorest households).

2.2 Measuring ecosystem services

Based on the expert opinion of BCN staff, a representative from the local CFUG and the chairman of the District Forest Office (DFO), we selected harvested wild goods (non-timber and timber forest products), water provision, water quality, nature-based recreation and global climate change mitigation as the key services to measure. Methods for assessing these services are available in TESSA and are amenable to rapid assessment and measurement (Peh et al., 2013). Although a number of other services are also provided by Phulchoki IBA it was not feasible to measure these given the scope of this assessment. We used TESSA to estimate an economic value for the services provided by the IBA, with the exception of water provision and quality where we were not able to collect adequate economic data. Because we were most interested in the sensitivity of these services to alternative approaches to site management, we compared estimates of these services delivered currently with those likely to be delivered under a plausible alternative state of the site at the current time. The latter was determined through focus group discussion with the area FO, eight representatives from Godawari and 11 local CFUG members. Using a topographic map of the forest area, participants estimated how the land use would have changed had community forestry not been implemented (Table 1). They reported that some areas of the forest would have been degraded, especially through exploitation for wood products, and other areas suitable for agriculture or settlements would have been converted to these land uses as has occurred in adjacent areas. To measure the services that would have been delivered under this alternative state, sites that best reflected the expected degraded forest and agricultural expansion were selected in consultation with the DFO and CFUGs. Two sites were chosen : (1) a degraded area of national forest (state forest) north of Phulchoki IBA near Riyale, where over-exploitation of forest resources has occurred; (2) agricultural land in Bishankhunarayan five km north of Phulchoki that was converted from natural forest similar to that of adjacent community forests over the last four decades (See Figure 1).

We assessed the services delivered by Phulchoki IBA in its current state (with 1 368 ha of community forest land (CF), see above) and in its alternative state without any community forests (referred to as 'no community forestry' (No CF). Thus, the evaluation of the alternative state includes all ecosystem services measured in the current state, as well as significant new services that the alternative would provide (e.g. cultivated crops) and any goods (such as timber) that might be generated during the associated transition between states. All values were converted to 2010 United States dollars using the average mid-point exchange rate in 2010 of NR 72.365 / $1 (OANDA Corporation, 2012). After preliminary analysis of the data, a meeting with members of CFUGs and forest department staff was carried out to facilitate validation and interpretation of the results.

2.2.1 Global climate change mitigation

Global climate change mitigation was estimated based on changes in carbon stocks and changes in annual greenhouse gas fluxes between the two states. For carbon in above-ground biomass, we identified the total area of different vegetation types in both the current and alternative state through consultation with local experts (DFO and CFUG members). We considered the four main forest types (*Schima-Castanopsis* forest; *Pinus roxburghii* forest; *Alnus nepalensis* forest; and *Quercus*-dominated forest), as well as rhododendron, scrubland and grassland areas. Carbon storage was estimated by applying the mean unit values for the same forest types from field data collected at nearby Shivapuri-Nagarjun National Park during November 2010 (Peh et al., in prep.) using the methods described in TESSA. Diameter at breast height of all trees ≥ 10 cm was measured from 20 transects (each 5 m x 100 m) selected by stratifying the forest types and then sampling at random, ensuring each transect was at least 200 m away from the previous one. The above-ground biomass was estimated using allometric equations from the published literature (Schroeder et al., 1997; Brown & Schroeder, 1999; Jenkins et al., 2003). Estimates of carbon stocks in the above-ground biomass of shrubland and grassland, and in below-ground biomass, litter and soils of all vegetation types were taken from the Intergovernmental Panel on Climate Change (IPCC) tier 1 database (IPCC, 2006). Estimates of deadwood carbon stock for forest were from Harmon et al., (1986). The overall economic value of these carbon stocks and how it differed between states was estimated using a range of carbon values (see SI Table 3). As a mid-point we used a value of \$81 $Mg^{-1}C$ (the US Government social cost from 2007 (Greenspan Bell & Callan, 2011) converted from \$$Mg^{-1}CO_2$ to \$$Mg^{-1}C$, and adjusted to 2010 prices based on the GDP deflator index given by International Monetary Fund, 2012). Greenhouse gas flux (CO_2, NO_2, CH_4) under the current and alternative state, in tonnes of carbon dioxide equivalent ($MgCO_2eq\ yr^{-1}$) was estimated using data for broad habitat types in Anderson-Teixeira & DeLuca (2010).

2.2.2 Water

Field analysis of hydrological ecosystem services requires sophisticated instrumentation, long-term data collection and detailed analysis, in order to account for climate variability and any progressive changes in soil and vegetation that might occur after land use change. Where this is not possible, process modelling can be used to understand the hydrological baseline and the impacts of land use change by combining knowledge of hydrological processes with locally specific data on climate, terrain and vegetation (Mulligan & Burke, 2005; Mulligan et al., 2010; Bruijnzeel et al., 2011; Mulligan, 2012). As recommended by TESSA, we used the WaterWorld Policy Support System v. 2.86 (http://www.policysupport.org/waterworld) to assess the hydrological baseline and the impacts of change, at a 1-ha spatial resolution (see SI Text, WaterWorld). The tool uses a baseline vegetation cover map (from 2010) to model water-related services. To model the likely change in water-related services as a result of the land cover change in the alternative state, we used the WaterWorld platform to input the percentage area cover of bare ground, herbaceous vegetation and forest cover for the alternative state based on the stakeholder consultation as described above. In the absence of a spatial representation of this alternative land cover, these changes were applied uniformly across the site. We focused particularly on WaterWorld outputs for changes in soil erosion and sediment load (as proxies for water quality) and annual water balance (as a proxy for water provision).

2.2.3 Harvested Wild Goods

At a community workshop, 25 participants from 763 households in six CFUGs listed 47 products harvested from the forests, ranging from medicinal plants, fruits/vegetables and other edible products to fibre, wood and flowers. Fuelwood (the main source of domestic fuel in the area), fodder (the main source of food for livestock) and leaf litter (used as livestock bedding and compost) were identified as the three most important products at community level. Thirty-five household questionnaires were conducted across the six CFUGs to gather data on the quantity and net value of harvest for the current state (using names randomly selected from the CFUG member lists). For the alternative state, 35 of 345 households in Riyale were randomly selected using a random number function in Microsoft Excel. Sample size was determined by plotting a running mean of the net economic benefit per household. The mean net value per ha for each product was calculated and applied to the total harvested area of forest in the current state and the expected harvested area of degraded forest in the alternative state. The opportunity cost of family labour was valued at zero, given the lack of alternative wage-earning opportunities.

Conversion to the alternative state would provide a large, one-off harvest of wood products (timber, charcoal and fuelwood). The volume of wood available from the deforested and degraded area was calculated by converting the above-ground living biomass (see 2.1) per ha into merchantable stock volume (m^3) using standard wood densities and biomass conversion factors (IPCC, 2006). Market prices for timber and fuelwood were obtained in Kathmandu, and costs for harvesting and transport were deducted to estimate the net one-off value of wood products generated by conversion to the alternative state.

2.2.4 Cultivated goods

There is no agricultural land inside the boundary of Phulchoki IBA or within existing community forests so we estimated the quantity and value of crop and livestock production under the alternative state only. Thirty-five household surveys were conducted in Bishankhu Narayan, which we took to be representative of local farming regimes. Data were obtained for the three most important crop types: rice, wheat and maize. A mean net value (market value minus costs of harvesting, processing and transport) per ha of land was calculated and applied to the area of agricultural land that was expected under the alternative state. As above, the opportunity cost of family labour was valued at zero, given the lack of alternative wage-earning opportunities.

2.2.5. Nature-based recreation

Benefits from recreation were assessed through entrance surveys at four picnic sites in Phulchoki IBA which are owned and managed by four CFUGs. In addition, surveys were conducted at a barrier on the road leading up to Phulchoki peak, where a fifth CFUG charges a fee for access to the forest for picnicking and other recreational activities. Thirty-two groups were interviewed to collect data on the number of visits and the associated expenditure of visitors. No international visitors were intercepted. Annual visitor numbers and income from entrance fees to the forest (both at the picnic sites and at the road barrier) were obtained from five CFUGs. A mean annual spend per person was calculated and used to estimate the total annual spend based on the annual number of visits. The approach used was based on market expenditure, not on another frequently used approach - the Travel-Cost Method (Parsons, 2013) which estimates the non-marketed welfare costs incurred by each visitor in travelling to a site for recreational purposes. Both approaches are valid (Wells, 1997) but non-market valuation is conceptually much harder for stakeholders to grasp hence the avoidance in this study. Visitors were presented with a description of the alternative state and asked if they would still visit the site under this land cover change. The nature-based recreation value of the site in its current state was then estimated as the difference in value between the visitation for the current state and for the alternative state.

3. RESULTS

3.1 Global climate change mitigation

Carbon storage in the current state (CF) is estimated at over 1.2 million Mg for Phulchoki IBA (SI Table 1) and the area sequesters an estimated 28 000 $MgCO_2eq$ annually (SI Table 2). As a result of forest degradation and conversion in the alternative state (No CF), carbon storage would decrease by an estimated 64% to less than 450 000 Mg and sequestration would reduce by an estimated 50% to 14 000 $MgCO_2eq\ yr^{-1}$. This results in a potential loss in stock value of $64 million and in sequestration of $304 000 yr^{-1} applying the US Government social cost value of carbon.

3.2 Water

The WaterWorld model outputs suggested that transition from the current state (CF) to the alternative state (No CF) would lead to a mean decrease in actual evapotranspiration (AET) across Phulchoki IBA of 25mm yr^{-1} (18% of the baseline value of 2100mm yr^{-1}). Cloud water interception (CWI, *sensu* Bruijnzeel et al., 2011) would also decrease by around 30 mm yr^{-1} on average for the site (18% of baseline). The opposing effects of both AET and CWI increasing mean that the overall impact on water quantity would be negligible, with overall simulated water balance estimated to decrease by around 5.3 mm yr^{-1} (only 0.14% of the baseline). Within the site some areas show increased and others decreased water balance, according to terrain and initial tree cover conditions (see SI Text).

The impacts of the plausible alternative state on water quality are more significant. WaterWorld estimates an increase in gross soil and channel erosion between the current and alternative states of Phulchoki IBA of 24mm yr^{-1} (see SI Text). Replacing the forested area with a human land-use (cropland) would also increase inputs of organic and inorganic non-point source pollutants (e.g. fertilisers, herbicides, pesticides and manures), which would be expected to affect the water quality from the site. Under the alternative state of the site, agricultural and urban impacts on the quality of available water are represented in WaterWorld's index of the human footprint on water quality, which varies between 0 (no human influence on quality) and 100% (Mulligan, 2009). In the alternative state, the human footprint increases from the current state (CF) by 40% for water used immediately adjacent to the forest compared to the present, reflecting the change in land use (see Figure 2).Water that is polluted or which has a high sediment load is expected to have a cost in terms of impacts on human health, the maintenance costs of water distribution networks, or water treatment. The economic valuation of this is, however, beyond the scope of this study.

3.3 Harvested Wild Goods

We estimated that 1 300 Mg of fuelwood, 980 Mg of fodder and 840 Mg of leaf litter is harvested annually from the community forests within Phulchoki IBA based on questionnaire responses. Respondents in community meetings reported that availability was stable or increasing although this was not verified as part of the study.

In the current state (CF), the net present value of these three products from Phulchoki IBA, based on their replacement cost, is an estimated \$330 000 yr^{-1}. Of this harvest value, 99% is currently obtained from the community forest area (1 368 ha, 32% of the site) where these goods are worth \$244 ha^{-1} yr^{-1}. Unmanaged, illegal harvesting of wild goods from the 636 ha of degraded national forest (15% of total site) is relatively small in comparison (\$31 ha^{-1} yr^{-1}) whilst the value of wild goods harvested from farmland under the alternative state (No CF) would be only \$22 ha^{-1} yr^{-1}. Due to the loss of good quality forest in the alternative state, the annual value of these goods decreases by 70% to \$99 000 yr^{-1}. However, deforestation and degradation of the forest would result in a one-off benefit from wood products (likely to be a combination of timber, charcoal and fuelwood) amounting to an estimated \$5.3 million (SI Table 4). We acknowledge that obtaining values per household would provide more robust estimates, provided household numbers are known and access is restricted to these users only. However, we were unable to obtain reliable data on household numbers accessing the degraded national forest since there is no regulation or monitoring of access or harvest. Hence in the interest of consistency of units, calculations for harvested wild goods were applied per ha of forest rather than per household.

3.4 Cultivated goods

The current state of Phulchoki IBA has no cropland. It was estimated that the alternative state (No CF) would include 1 082 ha (24% of the total area) of cropland (Table 1). From surveys of adjacent agricultural lands, we estimated that the mean annual net benefit from this area, comprised of food and fodder crops and grazing on field margins, would be \$920,000 yr^{-1}.

3.5 Nature-based recreation

According to data provided by the CFUGs, in 2010 over 140 000 people visited the Phulchoki IBA or its picnic sites. The majority of visitors come in large organised groups from Kathmandu and the adjacent districts, demonstrating the importance of the site for recreation. Analysis indicates that recreation at Phulchoki IBA provides direct net income to the five CFUGs of \$8 000 yr^{-1} (average income of \$1 600 yr^{-1} per CFUG) by charging visitors to access the picnic areas. By comparison, in a recent survey of CFUG income in Nepal's Gorkha District, Chhetri et al., (2012) found incomes of 41 CFUGs to average \$280 yr^{-1}). Additional benefits from recreation to the wider economy increases the value to \$998 000 yr^{-1} through visitor expenditure on food, drink, wood for camp fires and local transport. Visit numbers would reduce by 75% in the alternative state (No CF) reducing benefits from recreation to \$249 000 yr^{-1}, revealing a nature-based recreation value of the current state as \$749 000 yr^{-1}.

3.6 Overall summary of results

Stakeholders suggest that in the absence of community forestry, the land would be gradually converted to a mixture of degraded forest, cropland and urban areas (Table 1). As a result, ecosystem service stocks and flows would be affected in different ways. Water provision would not significantly change but water quality would decline, resulting in increased pollution (Figure 2) and higher treatment costs (not estimated here). Greenhouse gas sequestration, water quality, harvested wild goods and revenues from recreational visitors would decline, although there would be an increase in benefits from agriculture (Figure 3a). Carbon stocks would be lost but conversely there would be a one-off gain from wood products (Figure 3b). For the services measured in economic terms, the annual net economic value of the current state (CF) of Phulchoki IBA was greater than the alternative state (No CF) by \$364 000 yr^{-1} or \$800 ha^{-1} yr^{-1} (SI Table 3). This is significant even though it represents an underestimate of the true value because many services (including water-related services that were assessed here) are not included in this economic valuation. However, the result is highly sensitive to carbon price used - for instance, applying the UK Government value of \$310 Mg^{-1} C (Department of Energy and Climate Change, 2009: converted from \$$Mg^{-1}CO_2$ to \$$Mg^{-1}C$, and adjusted to 2010 prices based on the GDP deflator index given by International Monetary Fund, 2012) would result in a net benefit of more than \$1 100 000 yr^{-1} yet applying the lower carbon value of \$54 Mg^{-1} C based on the EU Emissions Trading System in 2010 results in a net value of \$230 000 yr^{-1}.

Table 2 summarises how local, national and global stakeholders would be affected were the forest to be degraded and partly converted to farmland, based on reports from the community meetings. The lack of community rights and regulations associated with state forestry means it is more likely that outsiders would be able to clear the land (gaining from the one-off benefit of wood products) and convert it to agriculture. Local communities would suffer the greatest costs from reduced water quality, reduced incomes from recreational visits and less access to harvested wild goods. Global stakeholders would experience societal costs through loss of global climate change mitigation services.

Although biodiversity was not surveyed specifically as part of this study, monitoring data collected by BCN on the key bird species and their forest habitats (BCN &

Department of National Parks and Wildlife Conservation (DNPWC), 2012) suggest that pressures on biodiversity at Phulchoki IBA have reduced and that its state has improved over recent years (2004–2011), i.e. under community forestry. In the alternative state (No CF), ,it is expected that the state of much of the forest-dependent fauna and flora for which Phulchoki IBA is valued would have worsened, as forest was continually degraded and converted to farmland and residential areas, which these species cannot tolerate.

3.7 Uncertainty

These results have varying levels of uncertainty related to the accuracy and precision of the data, because TESSA uses relatively rapid methods that do not require high levels of expertise or technology. However, most of this uncertainty does not affect the overall results which present the percentage change for each ecosystem service between the two states. For each metric, the error should be the same for both the current (CF) and alternative (No CF) state. The most significant source of uncertainty relates to the realism of the plausible alternative state. We attempted to minimise this uncertainty by consulting widely with informed local stakeholders including communities and forestry officials and by verifying the information with the local partner. We also took into consideration the changes that have already occurred in adjacent areas.

To reflect differences in the uncertainty associated with our estimates for each service, we used a simple scale of 'high' 'medium' and 'low' to assess the degree of error, as recommended in TESSA. Based on these standards, our confidence is 'medium' for all services apart from those relating to water treatment costs and the value of wood products from conversion, which is rated 'low' (see SI Table 5).

4. DISCUSSION

This study used a newly developed toolkit for ecosystem service assessments (TESSA) for the rapid collection of data on the impact that a past management decision (the creation of community forest areas) has had on the provision of ecosystem services from Phulchoki IBA. We compared two different states of the site as 'snapshots' in time for which real data could be collected. This contrasts with alternative methods based on modelled scenarios of projections into the future. We did not assess variation in service delivery through time since this requires detailed consideration of relevant time horizons and discount rates, which add complexity beyond the scope of this assessment. We recognise that we have not addressed issues of sustainability or resilience, although the long-term delivery of services is obviously an important factor for responsible decision-making. We were also unable to collect reliable data on costs associated with forest management, so this study should not be taken to represent a full cost-benefit analysis. However, we were able to collect useful data from relatively simple analyses, from which we were able to draw some interesting and highly relevant conclusions.

For example, Figure 2 shows the simple output of the water modelling tool (WaterWorld) used to assess the change in water-related services between the two states. This tool provides a quick and reliable analysis of water-related services that would otherwise require advanced hydrological knowledge and substantial fieldwork to determine. Although minimal change in water provision was estimated using the method, a decrease in water quality was evident if the site were to be converted to the alternative state (No CF). This would primarily affect the people living in and around Phulchoki IBA by reducing the water quality by as much as 40% in some areas. The increased erosion, sedimentation and pollution levels in the rivers would lead to reduced profitability from farming and increased risk to human health, impacts that must be considered in any management decision.

Our study shows that intact forest provides increased benefits overall compared with degraded forest and small-scale agricultural land. We found that while local people are now capturing (and controlling) most of the benefits from Phulchoki IBA from harvested wild goods and recreational visitors, as well as the benefits from improved water quality compared to the alternative state (No CF), there are other benefits that accrue to more distant users, such as the global benefit of climate change mitigation from carbon storage and greenhouse gas sequestration. Investments through grants and international aid or through Payment for Ecosystem Services (PES) can be seen as one way of paying local people for the global ecosystem services that their forest management is providing. Nowhere is this issue more prominent than in discussions around payment for carbon storage and sequestration through Reducing Emissions from Deforestation and Forest Degradation (REDD+). Project-level schemes under the voluntary carbon market are already underway in Nepal, often building on the experience of CFUGs (De Gryze & Durschinger, 2009). However, widespread implementation of REDD+ is some years away and there are concerns about how effective it will be in addressing local livelihood issues and biodiversity conservation (Venter et al., 2009; Sandbrook et al., 2010).

Benefits accrued locally are the dominant factor affecting local attitudes and investment in forest management and conservation, with harvested wild goods and nature-based recreation of particular significance in this case. In 2004, BCN recognised that communities were receiving little benefit from the thousands of visitors coming to the forest each year, and that other institutions (e.g. the Botanic Gardens) were not providing the amenities that visitors wanted. Benefits were being received nationally, rather than at the local level. In 2005, BCN obtained a grant from the Whitley Fund for Nature and worked closely with the International Centre for Integrated Mountain Development (ICIMOD) and FECOFUN to provide the initial investment for training and infrastructure development that has enabled the CFUGs to develop picnic sites, and so capture some of the benefit from visitors at the local level. Benefits to the CFUGs from harvested wild goods have also increased despite these resources being taken from a smaller area than in the alternative state (No CF). The total harvest of wild goods is higher (and more sustainable) under the current state (CF) than under the alternative state (No CF). This agrees with an earlier study which surveyed nearly 4000 households surrounding Phulchoki and Chandragiri forests in which respondents said that community forestry had had a positive impact on the availability of forest resources (HMGN & CEC, 2000, Volume 2: Appendix 5). The list of 47 products harvested from this forest indicates that local people value and indeed depend on the forest biodiversity as has been shown in more detailed studies in Nepal (Parker & Thapa, 2012). CFUGs have rights to regulated extraction of resources and now have more control over who uses them. Members patrol the forest to regulate use and protect their natural assets, and as a result more benefits are now captured locally. An additional consideration is that, in the absence of community forestry, trends suggest that use of the national forest would have been poorly regulated and unsustainable, and therefore illegal (some use of harvested wild goods and freshwater resources from national forests is usually permitted within limits). Unregulated, illegal use brings with it the associated risk and fear of fines, imprisonment and harassment from enforcement officers. The issue of legal rights of access is likely to be critical in the way that benefits from more secure tenure are perceived.

However, it is not just the total volume or value of net benefits that matter. Differences between services provided to different groups of stakeholders under the current (CF) and alternative (No CF) states have important implications for decision-makers in terms of the fairness of outcomes. Table 2 demonstrates that whilst some stakeholders may benefit from changes to land use, others will lose out. Trade-offs between different beneficiary groups have often been overlooked in previous studies despite being a critical factor in understanding the impacts of change (Kari & Korhonen-Kurki, 2013). Although household surveys of use of harvested wild goods did not capture differentiating factors (wealth, education, ethnicity etc.) in a way that could be analysed quantitatively, focus group discussions with the community and interviews conducted during this study proved highly valuable in this regard. They provided information on some of the distributional issues that arise from changes in ecosystem service benefits following changes in land use and governance. This qualitative data adds important context to the results obtained in the assessment. In nearly all the households interviewed, harvested wild goods were collected by women, who have to travel further and search longer the more the forest becomes degraded (I. Thapa, pers comm.,. 2011). Women also have responsibility for collecting water for household use. Therefore the protection and enhancement of these ecosystem services through community forestry has especially benefitted women. We were told by the CFUGs that the poorest households are most reliant on the harvesting of forest products, and that the introduction of community forestry, with controls on extraction, had initially affected them (negatively) the most—many increased the time they spent as paid labourers to compensate. However, all CFUG members agree that access is now more secure, there is less competition from outsiders, no risk of fines, and harvesting is more sustainable and therefore more certain into the future. Restrictions linked to community forestry appear to have impacted poorer households in the short term, but in the longer term, and in the absence of community forestry, we can expect that such households would have been more seriously affected as forests became degraded or converted to farmland. However, the socio-economic status of poorer households means that they are still vulnerable. Any future income-generating initiatives such as community-based tourism should help achieve social development objectives by focusing on engaging the poorer and more vulnerable community members.

Social differences within communities are important when considering trade-offs between ecosystem services and stakeholders (Vira et al., 2012). Although anyone from the community can join the CFUG, individuals' needs and interests may differ. Most households (over 90%) are CFUG members (B. M Ghimire, pers. comm., 2010), including relatively wealthier households, whose members work in Kathmandu city or elsewhere, and who rarely make use of their quotas to harvest from the forest. These same households, who are no longer dependent on the harvesting of wild goods, are arguing for the harvest quotas to be reduced as they have developed a new set of values in relation to the forest. As CFUG members they now seek recognition for their contribution to conserving the natural heritage and take pride in the biodiversity conservation status of the forest, rather than the provisioning services it provides to local people. Poorer households, on the other hand, are pressing the District Forest Office (which must approve the community forest operational plans every 5 years) for harvest periods to be extended. As with other studies of community forests in Nepal (e.g. McDougall et al., 2013), we find that marginalisation of women and poorer community members is potentially an issue under current governance structures.

Use of forest resources is also differentiated by caste and ethnic group. CFUG participants in the discussion informed us that prior to the creation of the community forest, heavy use of forest resources was made by some of the poorest people, including those in Kami (blacksmiths) and Sunar (goldsmiths) castes (both so-called 'untouchables'), from communities adjacent to the forest, and from further afield, for the production of charcoal (much of it illegal). Community forestry has restricted their access and had a disproportionate impact on these users, although Kami and Sunar living locally and that are members of a CFUG can still collect fuelwood and other forest products during the prescribed periods (I. Thapa, pers comm., 2011). Some illegal use has also shifted to areas of national forest, at higher elevations, and well outside the community forest boundary. This issue of 'leakage' has been discussed extensively in the climate change literature (Wunder, 2008).

Habitat degradation and unsustainable resource use are often driven by the one-off capture of resource stocks in order to realise short-term private economic gains (often by a small and powerful elite) at the cost of long-term social benefits. Our results show how degradation and deforestation of Phulchoki IBA would have created revenue from timber stocks (SI Table 4) but that the timber value in the alternative state (No CF) was significantly less than the current state (CF) value of carbon stocks even with the sensitivity analysis of carbon price. This may not always be the case since carbon prices are highly variable and there is currently no standard to apply. As shown in SI Table 3, carbon prices can have a significant effect on the outcome of an economic valuation which must be considered with caution in ecosystem service assessments.

5. CONCLUSION

The results of this study show that community forestry has had benefits for people as well as for biodiversity conservation. However, there are equity issues that need to be addressed through facilitation and support from FECOFUN and other organisations such as BCN who have worked with communities in this area for several years. The results are also relevant to recent attempts to develop the southern hills of the Kathmandu Valley, including Phulchoki IBA, as a Conservation Area. In 2000, in response to concerns over forest degradation in the wider region, plans were made to designate Phulchoki and the forested Chandragiri Hills (32 428 ha) as a Conservation Area (HMGN & CEC, 2000), combining protected area designation with an integrated rural development programme. However, there was concern from CFUGs that creating such a Conservation Area under the jurisdiction of the DNPWC would take away their rights to access and manage the forests. Similar perceptions have been recorded in other areas of Nepal where people’s attitudes to protected areas have been explored (Allendorf, 2007). Although the programme did not go ahead at that time, owing to political instability in government, these plans were revived in 2006 and again more recently (Anon., 2011). Conservation strategies should recognise both the positive and negative impacts of land use decisions on people's lives and should consider evidence from case studies such as this, which suggests that secure use rights through community management provide benefits for local communities whilst also securing the conservation of biodiversity and wider ecosystem service benefits.

Estimating the value of ecosystem services and identifying the importance of conservation in providing benefits to local communities can facilitate understanding and create more awareness amongst decision-makers leading to appropriate conservation-related outcomes which have public support. Rapid assessments using tools such as TESSA can be used to show how ecosystem service data for multiple services can be collected and analysed to provide useful insights into the socio-economic impacts of land use change at a site level.

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REFERENCES

Acharya, K.P. (2003) *Conserving biodiversity and improving livelihoods: The case of community forestry in Nepal*. International Conference on Rural Livelihoods, Forests and Biodiversity; 2003 May 19 -23, Bonn, Germany.

Adhikari, B. (2005) Poverty, property rights and collective action: understanding the distributive aspects of common property resource management. *Environment and Development Economics* **10**: 7–31. http://dx.doi.org/10.1017/S1355770X04001755

Agrawal, A. Chhatre, A. & Hardin, R. (2008) Changing Governance of the World's Forests. *Science* **320**: 1460 -1462. DOI: 10.1126/science.1155369

Allendorf, T.D. (2007) Residents' attitudes toward three protected areas in southwestern Nepal *Biodivers Conserv* **16**: 2087-2102. DOI: 10.1007/s10531-006-9092-z

Anderson-Teixeira, K. J. & E. H. DeLucia. (2010) The greenhouse gas value of ecosystems. *Glol Chang Biol* **17:** 425-438. DOI: 10.1111/j.1365-2486.2010.02220.x

Anon. (2011) New Conservation Areas Shortly. *The Himalayan Times* 4 December 2011 [Online] Available at: http://www.thehimalayantimes.com/fullNews.php?headline=New+conservation++areas+shortly&NewsID=311577 [Accessed 11 May 2012].

Baland, J-M. Bardhan, P. Das S. & Mookherjee, D. (2010) Forests to the people: decentralization and forest degradation in the Indian Himalayas. *World Dev* **38** (11): 1642-1656.

Baral, H.S. & Inskipp, C. (2005) *Important Bird Areas in Nepal: key sites for conservation*. Kathmandu, Nepal and Cambridge, UK: Bird Conservation Nepal & BirdLife International.

Bird Conservation Nepal (BCN) & Department of National Parks and Wildlife Conservation (DNPWC). (2012) *Conserving biodiversity and delivering ecosystem services at Important Bird Areas in Nepal*. Kathmandu, Nepal and Cambridge, UK: BCN & DNPWC.

BirdLife International (2013) *Important Bird Areas factsheet: Phulchoki Mountain forests*. [www document]. URL: http://www.birdlife.org/datazone/sitefactsheet.php?id=14340 [Accessed 9 August 2013]

Brown, S. L. & Schroeder P. E. (1999) Spatial patterns of aboveground production and mortality of woody biomass for eastern US forests. *Ecol Appl* **9**: 968-980. http://dx.doi.org/10.1890/1051-0761(1999)009%5B0968:SPOAPA%5D2.0.CO;2

Bruijnzeel, L.A. Mulligan, M. & Scatena, F.S (2011) Hydrometeorology of tropical montane cloud forests: Emerging patterns. *Hydrol Process* **25**(3): 465- 498. DOI: 10.1002/hyp.7974

Chhetri, B.B.K. Lund, J.F & Nielsen, Ø.J. (2012) The public finance potential of community forestry in Nepal. *Ecol Econ* **73**: 113-121. http://dx.doi.org/10.1016/j.ecolecon.2011.09.023

Corbera, E. Brown, K. & Adger, W.N. (2007a) The Equity and Legitimacy of Markets for Ecosystem Services. *Dev Change* **38**(4): 587–613.s DOI: 10.1111/j.1467-7660.2007.00425.x

Corbera, E. Kosoyc, N. & Martínez Tunad, M. (2007b) Equity implications of marketing ecosystem services in protected areas and rural communities: Case studies from Meso-America. *Glob Environ Change* **17**(3-4): 365-380. http://dx.doi.org/10.1016/j.gloenvcha.2006.12.005

Department of Energy and Climate Change. (2009) *Carbon Valuation in UK Policy Appraisal: A Revised Approach*. London, UK: DECC.

De Gryze, S. & Durschinger, L. (2009) *Payment for Ecosystem Services: Developing Forest Carbon Projects in Nepal*. A case study under the TRANSLINKS program, EnterpriseWorks/VITA.

Food and Agriculture Organization of the United Nations (2010) *Global Forest Resources Assessment. Main report*. Rome, Italy: FAO.

Greenspan Bell, R. & Callan, D. (2011) *More than Meets the Eye: The Social Cost of Carbon in U.S. Climate Policy, in Plain English*. *Policy Brief*. Washington DC, USA: World Resources Institute.

Harmon, M. E. Franklin, J. F. Swanson, F. J. Sollins, P. Gregory, S. V. Lattin, J. D. Anderson, N. H. Cline, S. P. Aumen, N. G. Sedell, J. R. Lienkaemper, G. W. Cromack, K. & Cummins. K. W. (1986) Ecology of coarse woody debris in temperate ecosystems *Adv. Ecol. Res.* **15**: 133-302.

His Majesty's Government of Nepal & Commission of European Communities. (2000) *Proposal for Phulchoki-Chandragiri biodiversity conservation area project*. Kathmandu, Nepal: HMGN and CEC.

International Monetary Fund, World Economic Outlook Database, October 2012. [Online] Available at: http://www.imf.org/external/pubs/ft/weo/2012/02/weodata/index.aspx [Accessed: 14 November 2012].

Intergovernmental Panel on Climate Change (2006) *IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme*. eds. H. S. Eggleston, L. Buendia, K. Miwa, T. Ngara & K. Tanabe. Japan, IGES.

Jenkins, J. C., Chojnacky, D. C. Heath, L. S. & Birdsey, R. A. (2003) National-scale biomass estimators for United States tree species. *Forest Science* **49**: 12-35.

Kareiva, P., Tallis, H., Ricketts, T.H., Daily, G.C. & Polasky, S. (2011) *Natural Capital: Theory and Practice of Mapping Ecosystem Services* Oxford, UK: Oxford University Press

Kari, S. & Korhonen-Kurki, K. (2013) Framing local outcomes of biodiversity conservation through ecosystem services: A case study from Ranomafana, Madagascar *Ecosystem Services* **3**: e32-39. http://dx.doi.org/10.1016/j.ecoser.2012.12.003

Keshav, K. & Varughese, G. (2000) Quantifying the Benefits of Community Forestry in Nepal: Towards Development of a Participatory Methodology of Economic Valuation. *8th Conference of the International Association for the Study of Common Property: Constituting the Commons: Crafting Sustainable Commons in the New Millennium*. Indiana, USA, 31 May – 4 June, 2000. [Online] Available at: http://www.forestrynepal.org/article/publications/474 [Accessed 8 August 2011].

Malla, Y. B. Neupane, H.R. & Branney, P.J. (2003) Why aren't poor people benefiting more from community forestry? *Journal of Forest and Livelihood* **3**(1): 78-93.

McDougall, C.L., Leeuwis, C., Bhattarai, T., Maharjan, M.R. & Jiggins, J. Engaging women and the poor: adaptive collaborative governance of community forests in Nepal *Agriculture and Human Values* (2013) DOI: http://dx.doi.org/10.1007/s10460-013-9434-x.

Mulligan, M. & Burke, S.M. (2005) FIESTA: Fog Interception for the Enhancement of Streamflow in Tropical Areas. [Online] Available at: http://www.ambiotek.com/fiesta [Accessed 21 January 2012]

Mulligan, M. (2009) The human water quality footprint: agricultural, industrial, and urban impacts on the quality of available water globally and in the Andean region. Proceedings of the International Conference on Integrated Water Resource Management and Climate Change. Cali, Colombia.

Mulligan, M. Rubiano, J. Hyman, G. White, D. Garcia, J. Saravia, M. Gabriel Leon, J. Selvaraj, J.J. Gutierrez, T. & Saenz-Cruz, L.L. (2010) The Andes 'basin': biophysical and developmental diversity in a climate of change. *Water International* **35**(5): 472-492. DOI:10.1080/02508060.2010.516330

Mulligan, M. (2012) WaterWorld: a self-parameterising, physically-based model for application in data-poor but problem-rich environments globally *Hydrology Research* **44** (5) 748–769. Doi:10.2166/nh.2012.217

Myers, N. (1997) The World's Forests and their Ecosystem Services. In *Nature's Services: Societal Dependence on Natural Ecosystems*, ed. G. Daily, pp. 215-236.Washington DC, USA: Island Press.

OANDA Corporation 2012. Historical Exchange Rates. Available at: http://www.oanda.com/currency/historical-rates/ [Accessed: 13 November 2012].

Ojha, H., Persha, L. and Chhatre, A. (2009) Community Forestry in Nepal: A Policy Innovation for Local Livelihoods. *IFPRI Discussion Paper 00913*. Available at: http://www.ifpri.org/sites/default/files/publications/ifpridp00913.pdf [Accessed 14 June 2012]

Pagiola, S. Arcenas, A. & Platais, G. (2005) Can Payments for Environmental Services Help Reduce Poverty? An Exploration of the Issues and the Evidence to Date from Latin America. *World Dev* **33**(2): 237- 253. http://dx.doi.org/10.1016/j.worlddev.2004.07.011

Parker, P., & Thapa, B. (2012) Natural Resource Dependency and Decentralized Conservation Within Kanchenjunga Conservation Area Project, Nepal *Environ Manage* **49:** 435-444. DOI: http://dx.doi.org/10.1007/s00267-011-9791-4.

Parsons G.R. (2013) Travel Cost Methods. In: Shogren, J.F., (ed.) Encyclopedia of Energy, Natural Resource, and Environmental Economics, volume 3, pp. 349-358 Amsterdam: Elsevier.

Peh, K. S.-H. Balmford, A. P., Bradbury, R. B., Brown, C., Butchart, S. H. M., Hughes, F. M. R., Stattersfield, A. J., Thomas, D.H.L., Walpole, M., Bayliss, J., Gowing, D., Jones, J.P.G., Lewis, S.L., Mulligan, M., Pandeya, B., Strateford, C., Thompson, J.R., Turner, K., Vira, B., Willcock, S. & Birch, J. C. TESSA: A toolkit for rapid assessment of ecosystem services at sites of biodiversity conservation importance *Ecosystem Services* (2013) http://dx.doi.org/10.1016/j.ecoser.2013.06.003.

Peh, K. S.-H., Balmford, A.P., Basnyat, M., Bhattarai, G.P., Bradbury, R.B., Brown, C., Butchart, S.H.M., Dhakal, M., Gurung, H., Hughes, F.M.R., Mulligan, M., Pandey, B., Stattersfield, A.J., Thapa, I., Thomas, D.H.L., Walpole, M., & Birch, J.C. (in prep.) Biodiversity conservation and ecosystem service co-benefits at the site scale: a rapid assessment from a Himalayan protected area in Nepal. *Biol Conserv,* xx, xx-xx.

Sandbrook, C., Nelson, F., Adams, W.M. & Agrawal, A. (2010) Carbon, forests and the REDD paradox. *Oryx* **44**(3): 330- 334. http://dx.doi.org/10.1017/S0030605310000475

Schroeder, P., S. Brown, J. M. Mo, R. Birdsey, & C. Cieszewski. (1997) Biomass estimation fortemperate broadleaf forests of the United States using inventory data. *Forest Science* **43**: 424-434.

Sherrouse, B.C., Semmens, D.J., & Clement, J.M. (2014) An application of Social Values for Ecosystem Services (SolVES) to three national forests in Colorado and Wyoming: *Ecological Indicators* **36**: 68-79.

Venter, O., Laurance, W.F., Iwamura, T.,Wilson, K.A., Fuller, R.A & Possingham, H.P. (2009) Harnessing Carbon Payments to Protect Biodiversity *Science* **326**(5958): 1368. DOI: 10.1126/science.1180289

Villa, F., Ceroni, M., Bagstad, K., Johnson, G. & Krivov, S. (2009) ARIES (Artificial Intelligence for Ecosystem Services): A new tool for ecosystem services assessment, planning, and valuation. Proceedings of the 11th Annual BIOECON Conference on Economic Instruments to Enhance the Conservation and Sustainable Use of Biodiversity, Venice, Italy, September, 2009.

Vira, B., Adams, W.A., Agarwal, C., Badiger, S., Hope, R.A., Krishnaswamy, J. & Kumar, C. (2012) Negotiating Trade-offs. Choices about Ecosystem Services for Poverty Alleviation *Economic & Political Weekly* **47**(9): 67-76.

Wells, Michael P. Economic perspectives on nature tourism, conservation and development. No. 50. Environment Department, World Bank, 1997.

Wunder, S. (2008) Chapter 7. How do we deal with leakage? In: *Moving ahead with REDD: issues, options and implications*. Ed. A. Angelsen, pp. 65-75. Bogor, Indonesia: CIFOR.

FIGURE AND TABLE LEGENDS

Table 1. Land cover change. Estimated land cover for the current and alternative states of Phulchoki IBA Numbers in brackets represents the area of land that is under community forestry management..

Table 2. Impacts of change in service provision on different beneficiaries. The magnitude of change in delivery of different services, if the site were converted from the current (CF) to the alternative state (no CF), is shown for beneficiaries at the local, national and global scale. Positive symbols indicate increases, negative symbols indicate decreases, and number of symbols indicates relative magnitude of change (bands for setting symbols are: 0-25% = one, 26-75% = two, >75%= three).

SI Table 1. Carbon storage (Mg) for current and alternative states in five pools (above-ground living biomass, below-ground biomass in roots, dead wood, leaf litter and soil) for each land cover type.

SI Table 2. Greenhouse gas flux in metric tonnes (Mg) of carbon dioxide equivalent per year.

SI Table 3. Economic values for ecosystem service flows and stocks under the current and alternative states.

SI Table 4. Estimated economic one-off benefit of harvesting wood products during conversion to the alternative state (no CF).

SI Table 5. Level of confidence for each ecosystem service assessed in the study. Table and level of confidence notes adapted from the guidance in TESSA (Peh et al. 2013) p. 126.

Figure 1. Study site. Location of Phulchoki Mountain Forest IBA (inset black boundary) and the Phulchoki-Chandragiri Forest Complex (dotted boundary), Nepal. Forested areas are depicted in dark grey.

Figure 2. Impacts of change on water quality. The increase in WaterWorld's index of the human footprint on water quality (% change) following the change in land use from the current to the alternative state. Paler shading shows higher impact on water quality.

Figure 3. Ecosystem services change. Ecosystem service values for the current (CF) and alternative state (no CF) of Phulchoki Mountain Forest IBA for: (a) annual flows (US \$ yr-1) for greenhouse gas sequestration, water provision, water quality, nature-based recreation, cultivated goods and harvested wild goods; and (b) one-off stock changes (US \$) for carbon storage (dotted), timber (hatched) and fuelwood (black).

Table

	Current state (CF) area (ha)	**Alternative state (No CF) area (ha)**
Mixed broadleaf forest	2029 (633)	0
Degraded forest	734 (98)	2456
Pine	1106 (470)	0
Scrubland	412 (167)	0
Cropland	0	1082
Grassland	0	0
Bare ground	0	111
Urban areas	0	631
	4281	**4281**

Table

Ecosystem service	Location of beneficiaries: Local	National	Global
Change in annual flows if converted			
Greenhouse gas sequestration			--
Water provision	=		
Water quality (water treatment cost)	-		
Harvested wild goods	--		
Cultivated crops		+++	
Fodder for livestock		+++	
Nature-based recreation	---		
Change in stock if converted			
Carbon storage			--
Wood products		+++	

Supporting Information Text

WaterWorld

WaterWorld is a web-based simulation model for understanding the geographical distribution of hydrological ecosystem services for any site globally. It combines a harmonized global gridded database derived from ground-based and remote sensing sources, with models for the operation of hydrological processes and tools for the implementation of scenarios for change or policy interventions. WaterWorld is a self-parameterising model (having all of the data necessary for application), though if users have better data then they can use those. WaterWorld calculates a monthly and annual hydrological water balance based on average climatology over the last 50 years and land cover in 2000. The resulting baseline distribution of water balance varies spatially with climate, landscape and vegetation cover and properties. It is delivered using a simple web-based interface for analysis through a series of simple steps. A baseline hydrological analysis for a catchment can be produced within 15 minutes and an analysis of the impacts of scenarios for change or the impact of policy interventions can be realised within another 15 minutes. Results can be visualised and interpreted online using geobrowsers and charts, or can be downloaded for further analysis in spreadsheets or Geographical Information Systems (GIS). Though it is simple to use, the model is sophisticated enough to handle the types of policy issues experienced in the CPWF basins. In circumstances where local data availability is poor, WaterWorld can be a very effective alternative to more detailed models which require a significant parameterisation effort, which may not always be possible.

Typical applications of WaterWorld include the following:

(a) Understanding the hydrological baseline for a basin
(b) Mapping water supply and demand by pixel, basin, administrative area or other unit
(c) Understanding area of water scarcity or seasons of water scarcity
(d) Analysing the impacts of multiple (ensemble) scenarios for climate change
(e) Understanding climate change uncertainty in a basin by running ensemble scenarios
(f) Examining the impacts of scenarios for land use change such as agricultural development, changes to crop types, reforestation, the designation of protected areas
(g) Examining the impact of land management practices such as implementation of buffer strips, terracing, check dams, contour ploughing, eco-efficient techniques
(h) Examining the impact of water management such as changing water treatment ot sanitation capacity and infrastructure, installation of dams
(i) Examining the role of the industrial and extractive sector in water quality

Change in water balance

The areas showing an increase in water balance have a much greater decrease in evapotranspiration than the decrease in fog inputs on deforestation. These are the highly exposed higher altitudes (>2300m) where the forest loss leads to a greater decrease in evapotransiration. Water balance declines in the shaded valleys where the change in forest cover reduces evapotranspiration by less than the reduction in fog inputs. The data provided do not indicate whether land cover change would lead to decreases in dry season flows or increases in flood frequency or magnitude, as this requires detailed information on subsurface properties and processes which are unavailable for this site and would also depend on the manner in which new land uses were managed in the long term.

Gross soil erosion

The increase in gross soil erosion would have implications for agricultural sustainability (without significant investments in erosion control) and also for sedimentation and water quality downstream. This erosion would lead to small increases in sediment deposition in sub-catchments (Strahler order 6) draining to the north (towards Kathmandu) of between 0.01 and 1.4 mm yr^{-1} and a much higher 24 mm yr^{-1} for those draining to the south from the IBA (away from Kathmandu).

Table

Habitat type	Current state (CF) (ha)	Proportion	Above-ground C		Below-ground C		Litter C		Dead wood C		Soil C		Grand total
			C (Mg/ha)	Total (Mg)	CF	Total (Mg)	C (Mg/ha)	Total (Mg)	C (Mg/ha)	Total (Mg)	C (Mg/ha)	Total (Mg)	Total (Mg)
Mixed broadleaf forest	2 029	0.47	283.62	575 399	0.30	172 620	28.2	57 211	18.6	37 735	34	68 978	911 943
Degraded forest	734	0.17	57.19	41 992	0.30	12 598	28.2	20 706	18.4	13 510	34	24 965	113 772
Pine forest	1 106	0.26	51.85	57 336	0.29	16 628	20.3	22 448	16.2	17 914	34	37 598	151 924
Shrubland	412	0.10	24.00	9 892	2.80	27 697	0.0	0	0	0	34	14 013	51 602
Cropland	0	0.00	1.15	0	2.80	0	0.0	0	0	0	34	0	0
Grassland	0	0.00	1.00	0	0.00	0	0.0	0	0	0	34	0	0
Bareground	0	0.00	0.00	0	0.00	0	0.0	0	0	0	34	0	0
Built up	0	0.00	0.00	0	0	0	0.0	0	0	0	34	0	0
Total	**4 281**			**684 620**		**229 542**		**100 365**		**69 160**		**145 554**	**1 229 241**

Habitat type	Alt. state (No CF) (ha)	Proportion	Above-ground C		Below-ground C		Litter C		Dead wood C		Soil C		Grand total
			C (Mg/ha)	Total (Mg)	CF	Total (Mg)	C (Mg/ha)	Total (Mg)	C (Mg/ha)	Total(Mg)	C (Mg/ha)	Total (Mg)	
Mixed broadleaf forest	0	0.00	283.62	0	0.30	0	28.2	0	18.6	0	34	0	0
Degraded forest	2 456	0.57	57.19	140 466	0.30	42 140	28.2	69 263	18.4	45 193	34	83 509	380 571
Pine forest	0	0.00	51.85	0	0.29	0	20.3	0	16.2	0	34	0	0
Shrubland	0	0.00	24.00	0	2.80	0	0.0	0	0	0	34	0	0
Cropland	1 082	0.25	1.15	1 245	2.80	3 485	0.0	0	0	0	34	36 802	41 532
Grassland	0	0.00	1.00	0		0	0.0	0	0	0	34	0	0
Bareground	111	0.03	0.00	0		0	0.0	0	0	0	34	3 780	3 780
Built up	631	0.15	0.00	0		0	0.0	0	0	0	34	21 463	21 463
Total	**4 281**			**141 711**		**45 625**		**69 263**		**45 193**		**145 554**	**447 346**

Table

Habitat type	Current state (CF)	Carbon dioxide flux		Methane flux		Nitrous oxide flux	
	(ha)	(kmol ha^{-1} yr^{-1})	total (kmol yr^{-1})	(kmol ha^{-1} yr^{-1})	total (kmol yr^{-1})	(kmol ha^{-1} yr^{-1})	total (kmol yr^{-1})
Mixed broadleaf forest	2 029	-155	-314 459	-0.23	-467	0.026	53
Degraded forest	734	-155	-113 811	-0.23	-169	0.026	19
Pine forest	1 106	-155	-171 401	-0.23	-254	0.026	29
Shrubland	412	-141	-58 114	-0.19	-78	0.013	5
Cropland	0	0	0	-0.13	0	0.151	0
Grassland	0	-34	0	-0.15	0	0.013	0
Bareground	0	0	0	0	0	0	0
Built up	0	0	0	0	0	0	0
Total flux			-657 785		-968		106
CO_2 equivalent ($MgCo_2Eq$) yr^{-1}			-28 943		0.000		1 380
Total balance (MgCo2Eq) yr^{-1}							-27 563

Habitat type	Alternative state (No CF)	Carbon dioxide flux		Methane flux		Nitrous oxide flux	
	(ha)	(kmol ha^{-1} yr^{-1})	total (kmol yr^{-1})	(kmol ha^{-1} yr^{-1})	total (kmol yr^{-1})	(kmol ha^{-1} yr^{-1})	total (kmol yr^{-1})
Mixed broadleaf forest	0	-155	0	-0.23	0	0.026	0
Degraded forest	2 456	-155	-380 701	-0.23	-565	0.026	64
Pine forest	0	-155	0	-0.23	0	0.026	0
Shrubland	0	-141	0	-0.19	0	0.013	0
Cropland	1 082	0	0	-0.13	-141	0.151	163
Grassland	0	-34	0	-0.15	0	0.013	0
Bareground	111	0	0	0	0	0	0
Built up	631	0	0	0	0	0	0
Total flux			-380 701		-706		227
CO_2 equivalent ($MgCo_2Eq$) yr^{-1}			-16 750		0.000		2 960
Total balance (MgCo2Eq) yr^{-1}							-13 790

Table

	Current state ($ 000's) (CF)	Alternative state ($ 000's) (No CF)	Net benefit of current state ($ 000's)
Service (flow)			
GHG sequestration ($ yr -1) EU ETS[a]	460	230	230
GHG sequestration ($ yr -1) US Govt[b]	609	305	304
GHG sequestration ($ yr -1) UK Govt[c]	2 300	1 200	1 100
Harvested wild goods ($ yr -1)	330	99	231
Cultivated goods ($ yr -1)	0	920	*- 920*
Nature-based recreation ($ yr^{-1})	998	249	749
Net annual benefit ($ yr^{-1})	1 937	1 573	364
Net annual benefit ($ ha^{-1} yr^{-1})	0.45	0.37	0.09
Service (stock)			
Carbon ($) - EU ETS[1]	75 000	27 000	48 000
Carbon ($) - US Govt[2]	100 000	36 000	64 000
Carbon ($) - UK Govt[3]	380 000	140 000	240 000
One-off wood products ($)	0	5 300	*-5 300*
Net stock benefit ($)	100 000	41 300	58 700
Net stock benefit ($ ha^{-1})	23	10	14

[a] EU ETS is the EU Emissions Trading System. The carbon price used was the average value from 1 Jan – 31 Dec 2010 (EUR13.09) as reported in http://www.pointcarbon.com/aboutus/pressroom/pressreleases/1.1714530. Euros were converted to US dollars at the rate of 1US$ = 0.785EUR based on IRS Yearly Average Currency Exchange Rates for translating foreign currency into US dollars.
[b] US Government value was sourced from Greenspan Bell et al. 2009. The 2007 value ($21 CO_2eq yr^{-1}) was converted to 2010 values based on the International Monetary Fund, World Economic Outlook Database, April 2012
[c] UK Government value was sourced from DECC 2009. The 2009 value ($83 CO_2eq yr^{-1}) was converted to 2010 values based on the International Monetary Fund, World Economic Outlook Database, April 2012

Table

Source of wood product (above-ground living biomass)	**Biomass (Mg/ha)**	**Area (ha)[c]**	**Total biomass (Mg)**	**Wood Density (Mg/m3)[d]**	**biomass conversion expansion factor (BCEF)[e]**	**merchantable growing stock volume (m3)**	**Price ($/m3)[f]**	**Costs ($/m3)**	**Total value ($)**
Oak-dominated broadleaf forest[a]	23[b]	1 175	27 519	0.58	-	15 961	342	85	4 095 716
Pine forest (roxburghii)[a]	18[b]	650	12 019	0.38	-	4 567	342	85	1 171 991
Fuelwood removal	114	1 722	196 991	-	3.33	59 156	0.13	0	7 694
									5 275 401

[a] Oak and pine are used for felling according to the Nepalese tree field guide (Discovering Trees in Nepal and the Himalayas by Adrian and Jimmie Storrs published by Sahayogi Press, Kathmandu in 1984)
[b] Only trees with DBH 24-36cm were included in biomass calculations as per local timber yards reporting that this was the main range size for harvested timber species
[c] Area of each forest type lost is calculated based on its current proportional area of the site (of the total area of pine and oak forest, 64% is oak and 36% pine). Area of forest used for fuelwood is the toal area that becomes degraded in the alternative state.
[d] Wood density conversion is taken from IPCC 2006 Table 4.14 as the mean value for Quercus sp (0.58) and Pinus radiata (mean 0.38)
[e] BCEF is taken from IPCC 2006 Table 4.5 as the value for temperate hardwoods <20 growing stock level
[f] Data on price obtained from visiting local timber yards and taking the average price for planks of each wood type.

Table

Level of confidence	Description	Service considered	Reason for selecting confidence level
High	Estimate is based on (a) existing data that are recently derived from the specific site; and/or (b) data from field measurements that use protocols provided in this toolkit (or more sophisticated approaches), with large and unbiased sample sizes; and/or (c) peer-reviewed published data derived recently from similar habitat near the site; and for all three data sources based on sound methods in terms of accuracy and precision level, judged in relation to site boundary definition, area stratification, type, number and distribution of measurement plots, and measurement frequency.		
Medium	Estimate is based on (a) existing data that are recently derived from reasonable sampling effort and that are treated critically with their methodological limitations acknowledged; and/or (b) data from field measurements that used protocols provided in this toolkit but are derived from relatively low sample size and precision level, or are subject to minor measurement and sampling errors; and/or (c) published data derived from similar habitat within your site's climate domain and region. Also estimate based on data from the look-up tables that used region-specific sources based on compilation of the data sources is reasonably complete. Certain types of estimate based on modelling tools would fall into this class.	GHG sequestration	Greenhouse gas sequestration was based on standard look-up tables and thus cannot be higher than ‘medium’.
		Harvested wild goods	Data on harvested wild goods was derived using individual questionnaires that used protocols provided in the toolkit but from relatively low sample size.
		Cultivated goods	Data on cultivated goods was derived using individual questionnaires that used protocols provided in the toolkit but from relatively low sample size.
		Nature-based recreation	Nature-based recreation was based on existing published data combined with field surveys that used protocols provided in the toolkit but from a relatively low sample size.
		Carbon storage	For carbon in above ground biomass, estimates were calculated using data from field measurements derived from a related study in similar habitat within the site's climate domain and region (Shivapuri-Nagarjun National Park) and certainty is ranked as ‘medium’.
Low	Estimate is based on (a) existing data that are derived from unknown methodology or poor sampling techniques (i.e., data are poorly representative, inadequately sampled, inappropriately stratified etc.); and/or (b) data derived from an area that may not be a good surrogate for the site (e.g. moderately different habitat, very distant site, very old data) or data that are highly uncertain (e.g. substantial range between upper and lower confidence limits) ; and/or estimate is based from the look-up tables that used habitat-specific sources, and not based on the region-specific; based on sparse compilation of data sources.	Water quality	A water modelling tool was used to estimate water yield and water quality using the best available global datasets. We were unable to supplement the model with any empirical data from the site so certainty is ranked as ‘low’.
		Water provision	A water modelling tool was used to estimate water yield and water quality using the best available global datasets. We were unable to supplement the model with any empirical data from the site so certainty is ranked as ‘low’.
		One-off wood products	Values for one-off stock benefits from wood products were obtained from a small sample of informed individuals so this is ranked as ‘low’.

Figure
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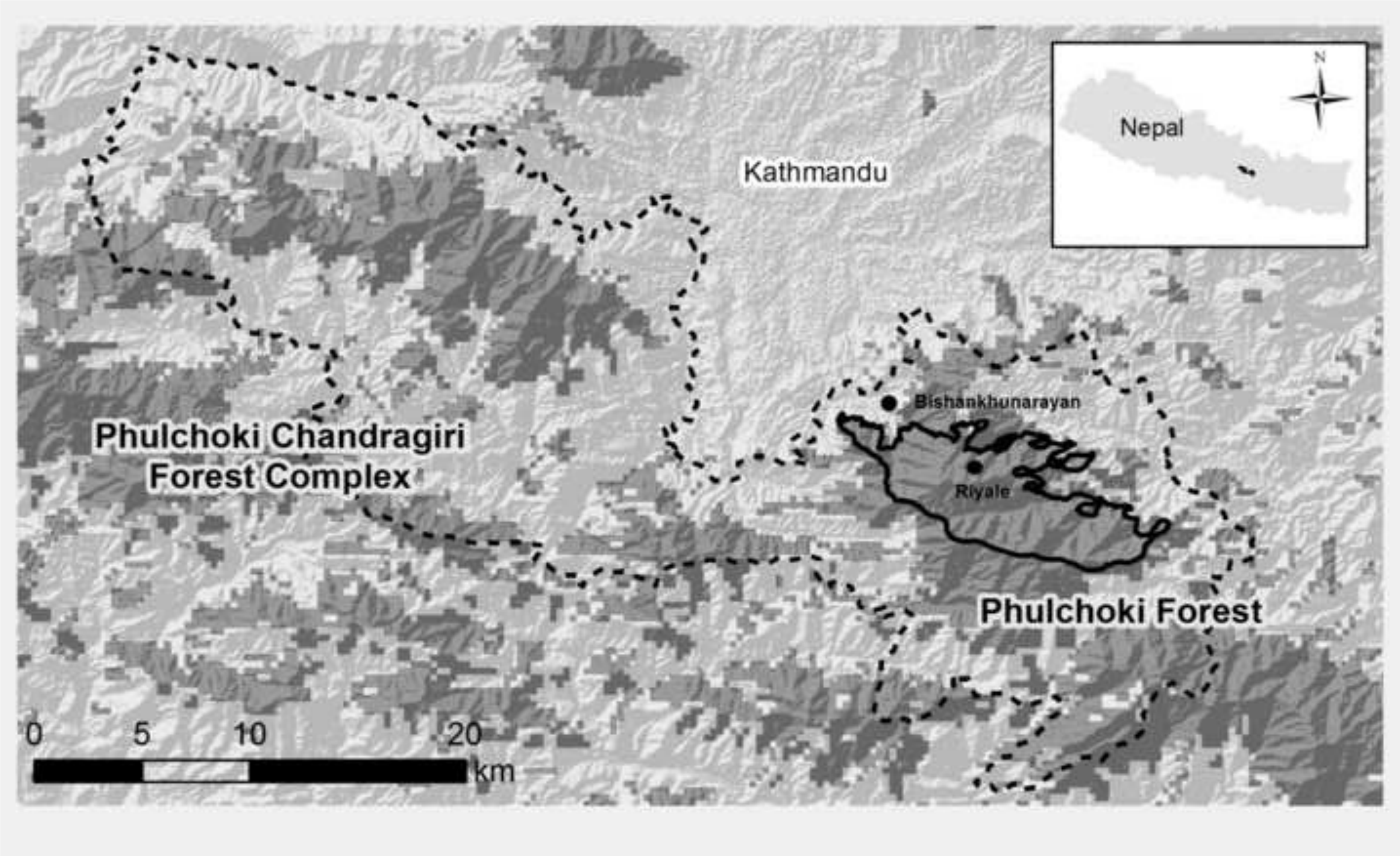

Figure


40
35
30
25
20
15
10
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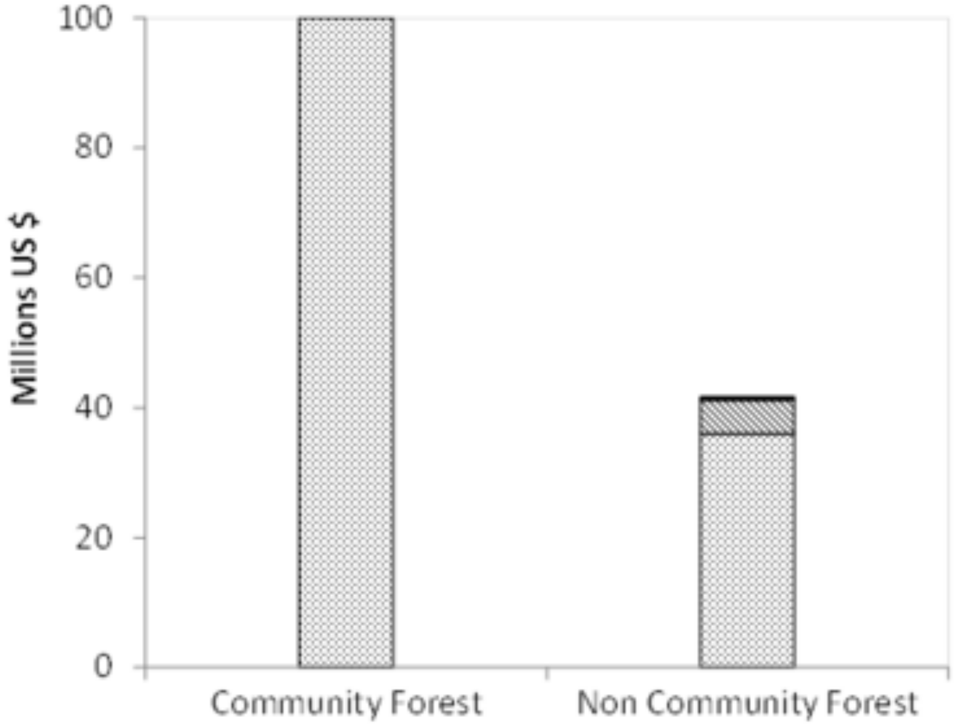
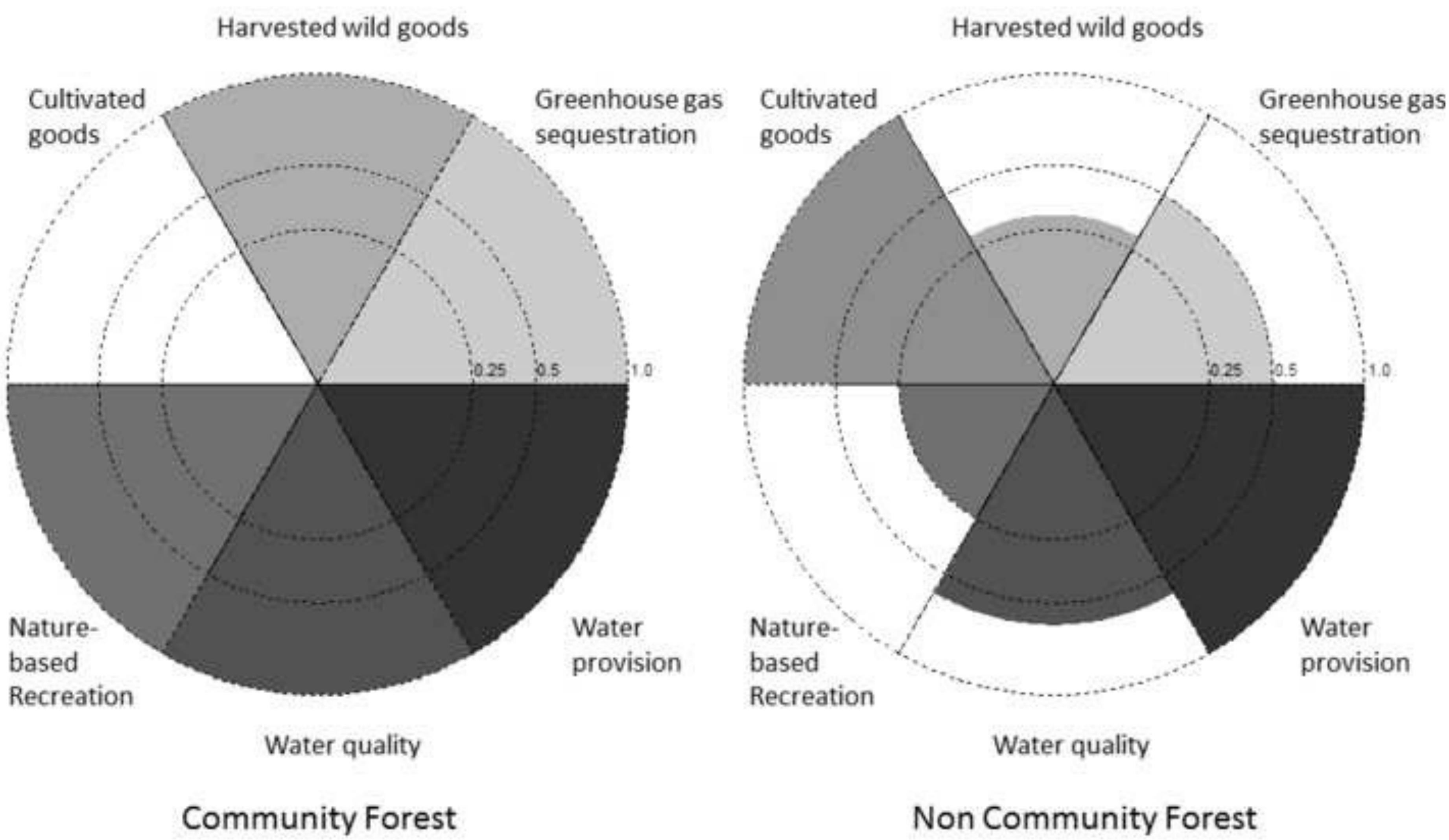
Kalimate
Kalimati
Sheopuri Lekh
Shivapuri
Khadka
Sialmati Khola
Nagmati Khola
Nagarjong Reserve Forest
Katmandu Kathmandu
Nagarjun Royal Forest
Dharmpur
Balaju
Rajnikunj Gokarna Reserved Forest
Naubise
Chhauni Military Cantonment
Bodha Nath Stupa Bauddhanath
Sankhu
Chhauni
Kantipur
Baudha Baudhanath Stupa
Nagarkot
Katmandu International
Kalamati River
Kalimate River
Pashupatinath
Thankot Thankot
Bishnumati Khola
Thimi Bhatgoan Badagaon
Bishnumati River
Bhatgaon
Jawalakhel
Central Nepal Valley
Bhaktapur
Nakhu Khola
Central Valley Godavari Khola
Lubhu
Lamodihi
Bungmati
Banepa
Banepa Bazar Panepa
Markhu
Dhulikhel
Pharpin
Chapagaon
Godavri Godauari
Pharping
Chapagaun
Dakshinkali
Kulikhani
Lalitpur
Phulchoki
Fulchok
Panaoti
Patan
Phulchauki Danda
Phulchok
Panauti Village
Thisapani
Thisapani Garhi
Tikabhairab
Kulekhani
Kulikhani Khola

Figure


Millions US $
100
80
60
40
20
0
Community Forest
Non Community Forest

Figure


Harvested wild goods
Cultivated goods
Greenhouse gas sequestration
0.25
0.5
1.0
Nature-based Recreation
Water provision
Water quality
Community Forest
Harvested wild goods
Cultivated goods
Greenhouse gas sequestration
0.25
0.5
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Nature-based Recreation
Water provision
Water quality
Non Community Forest