Valuing Forest Ecosystem Services and Disservices- Case Study of a Protected Area in India

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Abstract:

This study seeks to estimate the value of forest ecosystem services provided by a protected area in a biodiversity hotspot in India. The novelty of the study rests in that it addresses some of the shortcomings identified in existing literature by also estimating the value of several intangible benefits ignored in most valuation studies as well as estimating the value of disservices of forests such as wild life damages and forest fires, and the added value obtained by forests as compared to from alternative landscapes for selected services. Evidence presented here suggests that the total net value of ecosystem services provided by the Nagarhole national park in Karnataka, India is quite high and significant. The total net value of benefits (i.e. value of services minus disservices) provided by the park ranges between US$13-148 million per annum or US$204-2296 per ha per annum using alternate valuation methods. More significant is that the added value of benefits from the park is higher as compared to from alternative landscapes considering just three ecosystem services i.e. water and soil conservation, and carbon sequestration services. The estimates also provide support for the viability of markets for particular ecosystem services. If these are internalised in decision making it could strengthen the economic case for conserving forests in developing countries such as India where there is great pressure to relax forest laws and divert forests to non-forest uses to fuel economic growth.

Key words:

Economic valuation; forest ecosystem services; disservices; added value; net benefits.

1.Introduction

Traditionally forests have been valued only for the tangible benefits that they provide such as timber and non timber forest products. The intangible benefits provided by forests such as watershed and soil protection, regulating climate, nutrient cycling, etc have been overlooked since these are not traded in conventional markets or difficult to value. If these values could be captured and factored in decision making it could lead to better conservation outcomes, especially in strengthening the economic case for justifying conservation of forests versus diverting them to non-forest uses.

India is home to two of the 34 biodiversity hotspots in the world, namely the Western Ghats and the Eastern Himalayas. As per India's State of Forest Report 2013, over 69 million ha is under forests, which accounts for over 21 per cent of India's total geographical area. Despite the large area under forests and also containing two biodiversity hotspots there are hardly any studies in India which have tried to assess the economic value of the services provided by its forests. Added to that with India trying to accelerate economic growth and relax forest laws, there is great pressure to divert forests to non- forests uses. Hence there is a pressing need to undertake an economic valuation of the ecosystem services, especially intangible benefits, provided by forests in India. A recent global survey indicated the shortcomings of existing forest valuation studies such as focusing on a just a few services such as soil and water conservation, carbon sequestration and recreation for which data are readily available and hence easier to calculate, not accounting for the disservices from forests and the net benefits of keeping forests intact versus the benefits from alternative uses (Ninan and Inoue, 2013a). Hence, this study seeks to estimate the value of ecosystem services provided by a forest reserve in India as well as address some of the shortcomings identified in the global survey cited above by also estimating the value of several intangible benefits ignored in most valuation studies, estimating the value of disservices of forests such as wild life damages and forest fires, and the net benefits obtained by forests as compared to from alternative landscapes for selected services. Despite the plethora of valuation work available there are very few studies that have managed to provide estimates of the ‘total net’ economic value of ecosystem services of a particular biodiversity hotspot. The study then seeks to compare these valuation estimates with the values of this area of land under best alternative uses. The majority of valuation work is still compartmentalized and piecemeal. Yet, there is an urgent policy need for more comprehensive assessments of the total economic value of entire biodiversity-rich ecosystems and more analyses on how these aggregate values compare with the opportunity cost of this land. Policymakers need such information in order to gain support for conservation funding but also in order to engage local communities and develop market-based instruments for conservation (Carrasco et al, 2014; Mullan, K., 2014; Madsen et al, 2011;; Mullan and Kontoleon, 2008) This study does exactly this and thus makes a significant contribution to fill this research gap. Further, the methodology adopted relies on existing valuation estimates and can be used as a template by researchers and policy practitioners to relatively quickly estimate the total economic value of a particular forest ecosystem of interest.

2. Study Area

For conducting this study Nagarhole National Park (also known as Rajiv Gandhi national park) located in Karnataka state in South India has been selected. The park falls within the Nilgiris biosphere of the Western Ghats biodiversity hotspot and covers an area of about 643.39 km^2. The park is rich in flora and fauna and is home to about 32 species of large mammals, 252 species of birds, 32 species of reptiles, 13 species of amphibians and 10 species of fish (Draft NTR Management Plan, 2014). The park is noteworthy for its many endangered species including the Asiatic elephant, royal Bengal tiger, leopards, Indian wild dogs, wild buffaloes, etc. The park has a good density of tiger population (about 8.4 tigers/100 km^2 in 2011) and was designated as a critical tiger reserve by the Government of India in December 2007 (Draft NTR Management Plan, 2014). It also has a good density of elephants. The vegetation of the park primarily consists of moist and dry deciduous forests (over 73%), with the rest being under semi-evergreen and scrub forests, plantations and marshy swamps (Appayya 2001)

3. Materials and Methods

Information and data for undertaking this study has been collected from the Office of the Director, Rajiv Gandhi National Park, Hunsur, Karnataka State and from the management plans prepared for the park (Appayya, 2001: Draft NTR Management Plan, 2014).Besides we have also relied on official publications of the Indian Ministry of Environment and Forests such as the State of Forest Reports, India Green House Gas Inventory Report for 2010, etc. These have been supplemented with data and information from journal articles, research reports and other publications which are cited in the text.

For valuing forest ecosystem services and disservices, economic valuation techniques have been used. Table 1 lists the ecosystem services and disservices evaluated in this study and the norms and valuation methods used to estimate these values. Due to lack of data some services such as water purification and cultural services of forests have not been estimated in this study. Hence our estimates should be considered as a lower bound value. The data used for the study are for 2013 or latest available data at the time of analysis. The estimated values in Indian Rupees have been converted into US dollars using the exchange rate of 1 US$ = Rs. 61.27 the average annual for 2014.

Table 1. Methods and norms used to estimate the value of ecosystem services and disservices

Ecosystem service	Benefit or disservice	Valuation method	Valuation procedure
1.Water conservation	Reducing surface-runoff	Alternate cost	Amount of water conserved x the economic cost of storing 1 m^3 of water in a reservoir
2.Soil conservation	Controlling soil erosion	Hedonic pricing and opportunity cost method	Two valuation procedures used:(a) Forest area valued at the amount of decline in the unit value of forest land due to loss of soil quality/nutrients (b) Avoided loss of productive forest land area due to soil erosion x opportunity cost per unit area i.e the net benefits from a community woodlot in the Malnad (Hilly) region of Karnataka state
3.Carbon sequestration	Reducing greenhouse effect	Market price and damage cost	Amount of carbon fixed x by two alternate prices: (a) Carbon price (b) Marginal social damage cost
4.Recreation	Recreation	Travel cost and Benefit transfer approach	Park entrance fees plus consumer surplus x the average number of visitors to the park during the period 2011-12 to 2013-14
5.Nutrient cycling	Accumulating nutrients	Alternate cost and market	Maintained nutrient (NPK) value valued at two alternate

		price	prices (a) Price of leaf manure in Kodagu (b) Market price of mixed chemical fertilisers in Karnataka
6.Air purification	Absorbing air pollutants (SO_2 & NO_2)	Alternate cost	SO_2 & NO_2 amount x marginal abatement cost of SO_2 & NO_2 in India
7.Biodiversity	Conserving biodiversity	Willingness to pay for participatory elephant conservation	50% of the opportunity cost of time spent for participatory elephant conservation x by the number of rural households in Virajpet Taluk, Kodagu district
8.Pollination	Facilitate and enhance crop yields	Benefit transfer approach	Avoided loss of coffee yields in US$/ha x 10% and alternatively 20% of the park area
9. NTFP benefits	Provisioning	Market/ Alternate cost	Estimated NTFP benefits appropriated by sample tribal households of the park x 10% and alternatively 25% of the park's area that is accessed by the households for extracting NTFPs
10.Grazing benefits	Provisioning	Benefit transfer approach	Estimated amount of green fodder consumed by grazing cattle x the average price of paddy, finger millet and maize straw in Hunsur Taluk in Mysore district
Ecosystem disservices			
1.Wildlife damages	Damages to humans, crop	Value of damages	Average amount of compensation paid by the

	and property	approach	State Forest department during 2010-11 to 2012-13 to local communities for wildlife damages
2. Forest Fires	Carbon emissions	Damage cost	Estimated amount of carbon fixed in the park x marginal social damage cost

Source: adapted from Xue and Tisdell, 2001; Ninan and Inoue, 2013b.

4. Valuation of Ecosystem Services and Disservices

Water Conservation

A simple and straightforward method to estimate the amount of rainfall water that is intercepted and conserved in a forest is to deduct the average evaporation/run-off rates from the average annual precipitation received in the area. Evaporation and run off rates vary depending on several factors such as forest and site characteristics, canopy cover, soil profile, amount, pattern and intensity of rainfall events, topography, etc. A study in a forest region in Uttara Kannada district of the Western Ghats estimated the average evaporation/run offs rates to be on average 38.75% during 2004 and 2005 (Krishnaswamy et al, 2013).Using this parameter and the average annual precipitation for the Nagarhole national park which is 1208 mm for the park area falling within Kodagu district and 777 mm for the park area falling within Mysore district the average annual rainfall that is intercepted and conserved in the park is estimated to be about 399,896,101 m^3 (Table 1).

Table 1: Amount of Rainfall Conserved in Nagarhole National Park, India

Park area falling within	Average Annual Rainfall in m	Evaporation /Run Off Rates (%)	Average Annual Rainfall Retained in m	Park Area in km^2	Total Average Annual Rainfall Retained in the Park in m^3
Kodagu District	1.208	38.75	0.7399	354.95	262,627,505
Mysore district	0.777	38.75	0.4759	288.44	137,268,596
Total					399,896,101

Note: 1 Km^2 = 1,000,000 m^2

We now need to estimate the economic value of the water conserved in the park. In the literature one finds that researchers have used a variety of methods and proxies to estimate this value namely (1) the economic cost of storing water in man-made reservoirs or dams (e.g. Xue and Tisdell, 2001; Biao et al, 2010; Ninan and Inoue, 2013a, 2013b), (2) the shadow price of water derived from optimization models that related groundwater recharge rates to forest conservation (e.g. Kaiser and Roumasset, 2002), (3) the price of water or electricity (e.g. Guo et al, 2001), and (4) the averted flood damage costs to assess the flood protection benefits of forests (e.g. Kramer et al, 1997: MRC, 2001: Ruitenbeek, 1989). In order to estimate the annual value of the rainwater conserved in the Nagarhole National Park we use the economic cost of storing water in a man-made reservoir. For this purpose we have considered the Kabini dam project which lies between Nagarhole and Bandipur national parks in Karnataka, India. The Kabini project consists of three dams, the Kabini dam and two smaller dams namely Sagaredoddakare and Upper Nugu. While construction of the main Kabini dam was completed in 1974 that of other dams were completed subsequently. The gross storage capacity of these three dams put together is about 1,140,064,536 $m^{3.}$ As per official statistics the total cumulative expenditure on the Kabini project till the end of March 2014 was Indian Rupees (Rs) 8,964,600,000. As per the dam authorities the annual maintenance cost for the project is about Rs. 470 per acre (or Rs. 1160/ha). The irrigation potential created by the project to date is about 44,222 ha. Using these parameters the total annual maintenance cost for the Kabini project is thus estimated at about Rs. 51,358,310 (i.e. Rs. 1160/ha x 44,222 ha). Using the above figures the discounted costs of the Kabini project is about Rs. 664,502,985 (at 5% discount rate; assumed project life of 80 years) at 2013-14 prices. Thus the discounted cost per m^3 of water stored in the Kabini dams is about Rs. 664,502,985 ÷ 1,140,064,536 m^3 = Rs. 0.5829 per m^3. In annuity terms this works to about Rs. 0.03 per m^3 of water stored in the dams. Using these parameters the annual value of the water stored in Nagarhole national park is 399,896,101 m^3 x Rs. 0.03/m^3 i.e. about Rs. 11,996,883.03 or US$ 195,803.54 per annum (1 US$ = Rs. 61.27 average annual for 2014).

Soil Conservation

Soil protection is another important function provided by forests. Broadly three approaches have been used to value the soil protection function of forests. These are: (1) Replacement cost approach, (2) Hedonic pricing method, and (3) Opportunity cost approach. Under the first approach researchers estimate the amount of soil nutrients lost due to soil erosion and then use the value of chemical fertilisers needed to replace these lost nutrients. Nahuelhual et al (2007) used this approach to estimate the soil protection functions of the Chilean temperate forests. But this requires field level data on nutrient composition of forest soils which is not readily available or use the benefit transfer approach and use data from a comparable forest site. Alternatively one may use the hedonic pricing method and find out how loss of soil quality or productivity impacts on forest land prices. This differential in the forest land price attributable to loss of soil quality or productivity is then used to estimate the soil protection function of forests. A recent study used this method to estimate the soil protection function of the Oku Aizu forest ecosystem reserve in Japan (Ninan and Inoue, 2013b). Another method is to use the opportunity cost approach. Xue and Tisdell (2001) and Ninan and Inoue (2013b) used this approach to value the soil protection function of the Changbaishan mountain biosphere reserve in Northeast China, and the Oku Aizu forest ecosystem reserve in Japan respectively. Taking into account the difference in soil erosion rates between woody and non-woody lands and the average thickness of forest soils they estimated the avoided loss of productive forest lands due to the presence of the forest and then used the income from timber in China or the average net income of forestry households in Japan to value the soil protection function of the forest.

For our study we may use the latter two approaches. However using the first approach was more challenging for the India case study than for Japan. This is because unlike in Japan where almost fifty per cent of forests are privately owned, and where selling of forest lands are not uncommon, prices of forest lands are readily available in official publications of the Government of Japan, whereas in India’s case all forests are owned by the state, and no sale transactions of forest lands take place. Hence no market prices for forest lands are available for India. In these circumstances we need to use a proxy for forest land prices. In the Hunsur taluk close to the Nagarhole national park according to locals the market prices of irrigated or fertile land is about Rs. 7,50,000 per acre whereas that for unirrigated or dry lands is about Rs. 4,50,000 per acre. The mid value of the average of these two prices (i.e. Rs 7,50,000 + Rs. 4,50,000 = Rs.12,00,000 ÷ 2 is Rs. 6,00,000 per acre (i.e. Rs. 14,82,580 per ha). We may use this (Rs. 14,82,580/ha) as a proxy to reflect forest land prices. It is interesting to note that following a directive from India's Supreme Court and based on the recommendations of an expert group the government of India fixed Net Present Value (NPV) rates of between Rs 4,38,000 to Rs.10,43,000 per ha for different categories of forests for diversion of forests to non-forest uses in 2008. This amount is to be paid into a common fund maintained by the central government which is to be used for afforestation and environmental conservation programmes. While approving this the Supreme Court had asked the government of India to revise these NPVs every three years. Recently the Indian Institute of Forest Management had proposed fixing revised NPV rates ranging between Rs.9,87,000 to Rs. 55,55,000 per ha for different categories of forests for facilitating diversion of forest to non-forest uses by the government. The next step is to find out how loss of soil quality or productivity impacts on forest land prices. Leave alone India even globally there are hardly any studies which shed any light on this. Though a few studies in the US, Canada, and Europe have tried to assess the parameters influencing forestland prices, they have not examined the role of soil quality or productivity per se on property prices (Ninan and Inoue, 2013b). But one study in the US observed a positive association between soil productivity and farm land prices on the urban fringe near Chicago (Chicoine, 1981). A decline in forest soil quality will impact on growth of trees and biomass, game potential, etc. In this context, a study in the US noted that quality of land and tree cover, gaming potential, etc., led to a maximum of 17 % increase in forestland prices (Snyder et al., 2008). Keeping this in mind, and taking the mid value of this parameter (i.e. 17 % / 2 = 8.5%) it is assumed that a decline in soil quality will lead to a 8.5% decline in the unit value of forestland. This works to: Rs. 14,82,580/ha x 8.5 % = Rs. 126,019.3/ha. Using this approach the economic value of the soil protection function of the Nagarhole national park is estimated to be: Rs. 126,019.3/ha x 64,339 ha = Rs. 8,107,955,742 or US$ 132,331,577.3 per annum.

Alternatively we may use the opportunity cost approach to assess the soil protection function of the national park. To undertake this we need information on the soil erosion rates of woody versus non-woody lands or an alternate landscape and the average soil thickness of forests soils (Xue and Tisdell, 2001). A study by Saravanan et al (2010) in Katteri watershed in the Nilgiris region (Nagarhole national park falls within the Nilgiris biosphere) tried to assess the soil erosion rates across different land use categories in the watershed using the universal soil loss equation, GIS and remote sensing data. Their study estimated the average soil loss in the evergreen dense forests of Katteri watershed at 4.3 tonnes per hectare per year as against 7.8 tonnes per ha per year in degraded forest lands. The difference between the two is: 7.8 – 4.3 = 3.5 tonnes/ha/year. Using this parameter the avoided soil loss in the national park due to the presence of the forest is: 3.5 tonnes/ha/year x 64339 ha = 225,186.5 tonnes/ha/year/. In order to estimate the avoided loss of productive forest land in the park we need to convert the above from tonnes (density of weight) to volumetric basis and then divide by the average soil thickness of forest soils. Since soil is denser than water, 1 m^3 of soil will weigh approximately 1.5 tonnes. This will, of course, vary between 1.2 to 1.7 tonnes for different soils and levels of compaction (www.ask.com/science/much-cubic-meter-soil-weigh-e48660fa83d913ab) Using this parameter the volume of avoided soil loss in the park is estimated at: 225,186.5

tonnes/ha/year ÷ 1.5 tonnes = 150,124.33 m^3. A study by Kuriakose et al (2009) in the Aruvikkal catchment in the Western Ghats estimated the average soil depth of the forest soils to be 1.25 m. Using this the avoided loss of productive forest land area in the park is estimated at: 150,124.33 m^3 ÷ 1.25 m = 120,099.46 m^2 i.e. about 12.01 ha. In order to value the foregone benefits we rely on a study conducted by Nadkarni et al (1994) which assessed the viability of social forestry (community woodlots) projects in Karnataka state, India. One of the projects evaluated by them was located in the Western Ghats region. The study noted that the NPV (full benefits, net of all costs including foregone grazing benefits) of a social forestry project in the region was Rs, 12,97,000 per ha (at 5% discount rate; cash flows summed over 50 years) at 1989-90 prices. In annuity terms this works to Rs 71,045.43 per ha per year at 1989-90 prices or Rs. 353,806.24 per ha per year at 2013-14 prices (with base 1993-94 = 100). Using this, the annual economic value of the avoided loss of productive forest land in the Nagarhole national park due to soil erosion is alternatively estimated at: Rs. 353,806.24 x 12.01 ha = Rs. 4,249,212.94 or US$ 69,352.26.

Carbon Sequestration

Deforestation is a major contributor to greenhouse gas emissions. According to a study by Van der Werf et al (2009) between 12 to 20% of greenhouse gas emissions every year is attributable to deforestation alone. Forests thus provide another vital service, namely, carbon sequestration. Forests regulate the atmosphere by storing carbon and releasing oxygen. When forests are cut or burn due to natural or anthropogenic factors the carbon that they store is released into the atmosphere as carbon dioxide, adding to greenhouse gas emissions. To estimate the carbon sequestered by the forests we need information on the growing stock of forests and other parameters such as biomass expansion factor (BEF) to account for non-stem biomass such as branches twigs and foliage, woody density and root to shoot density, etc. Forest Survey of India (FSI) collect forest inventory data every two years based on remote sensing data and sample surveys. Although India has been collecting such data since 1965 there are several infirmities in the data. For instance FSI in its India State of Forest Report for 2013 notes that prior to 1981 different sampling designs were followed in different parts of the country (FSI, 2013, p.45). Further until 2001 the inventory was carried out in different parts of the country in different time periods which affected its comparability and estimating the growing stock of forests at the national level. Hence FSI revised its methodology and launched a National Forest Inventory in 2002 so as to generate national level estimates of growing stock of forests. The FSI has been endeavoring to improve the quality and coverage of its forest inventory data for India. The FSI data for 2013 is not comparable with that for previous years due to the change in sample units and methods. During the period 2008-10 forest inventory data was not collected or deferred since the FSI based on the recommendations of FSI's Technical Advisory Committee decided to concentrate on two important studies, namely 'Production and Consumption of Wood' and 'Missing Components of Biomass' (FSI, 2011, p.49). Hence FSI data for 2011 present forest inventory data collected only for trees outside forest area whereas for forest areas they were estimated through an alternate approach and extrapolation on which not much light is shed in the report. Further FSI 2013 notes that due to changes in the volume equations used for estimating the growing stock in some physiographic zones including the Western Ghats region, the growing stock reports a decline (FSI 2013, p.52). Whether this decline is real or due to the use of revised volume equations is difficult to say. Keeping these limitations in mind we have relied on FSI's forest inventory data of earlier years to estimate the changes in the growing stock of the forests. FSI presents data on the growing stock of forests for different states of India and 14 physiographic zones including for the Western Ghats region where our park is located. As per the FSI data for 2003 the growing stock in the Western Ghats region was estimated at about 458.469 million m^3 whereas as per FSI data for 2009 the growing stock rose to 461.78 million m^3. Taking into account the recorded forest area of the Western Ghats at 33960 km^2 for 2003 and 32399 km^2 for 2009 respectively, the per ha growing stock of the forests in the Western Ghats region are estimated at 135 m^3/ha for 2003 and 142.53 m^3/ha for 2009. Based on these figures the annual increase in the growing stock of forests in the Western Ghats over the period 2003 to 2009 works to about: 142.53 – 135 m^3/ha = 7.53 $\div$ 6 = 1.255 m^3/ha/year. Since data on growing stock are not available for Nagarhole national park, we may use these figures to estimate the carbon sink services provided by the park. While some researchers use the benefit transfer approach to estimate the carbon fixed in forests, others use a rather crude method and after taking into account only the standing or stem volume of broad forest species and sometimes the BEF also, they calculate the carbon fraction of the dry matter of the living biomass and then arrive at the carbon fixed in the forest site under study (e.g. Lal and Singh, 2003; Xue and Tisdell, 2001). However, ideally one ought to take into account not only the growing stock of forests but also other parameters such as biomass expansion factor, wood and root-to-shoot density and then calculate the carbon fraction of the dry matter of the living biomass to arrive at the carbon fixed in the forest (Ninan and Inoue, 2013b). Such a method was used to calculate the carbon sink services provided by a forest reserve in Japan (Ninan and Inoue, 2013b). However, unlike for Japan where such data are readily available, such data are lacking for India. For instance the National

Greenhouse Gas Inventory reports for Japan provide details of the area under major forest species, BEF, wood and root-to-shoot density for important forest species of Japan, etc. (see for example MoE, Japan, 2010). Local forest offices in Japan are also able to provide information on the composition of forests under their jurisdiction in terms of area under major forest species, growing stock of major forest species, etc. Unlike for Japan, the India Greenhouse Gas Emissions 2007 report does not furnish any data and information on the above parameters (MoEF, India, 2010). All that it presents is the area under different land use categories including under forests and the estimated changes in carbon stocks in 2007 and 2005. It mentions that it has used GIS and remote sensing data to estimate GHG emissions and the type of equations used to estimate the biomass changes in India's forests. The basic data used to estimate these equations are not furnished in the report. If one looks at the State of India's Forest Reports published every two years by the FSI, it only gives data on the area under different categories of forests in terms of their legal/protected status or crown canopy cover (e.g. dense and open forests, scrubs, etc) across different states and physiographic zones, growing stock of forests across states and physiographic zones and the percentage share of major forest species to this growing stock at the national level only. However, FSI data don't provide information on BEF, wood and root-to-shoot density which are necessary to calculate the carbon fixed in the forests. Hence, we have to rely on the default values recommended by the 2006 IPCC Guidelines for National Greenhouse Inventories for forest lands (Chapter 4, Forest land). Using these data the carbon fixed in Nagarhole national park is estimated at over 37,934 tonnes per year (see Table 2).

Table 2. Estimated Annual Amount of Carbon Fixed in Nagarhole National Park, India

Above ground biomass in m^3/ha/year (Vj)	Biomass Expansion Factor (BEF)	Wood density (Dj)	Root to Shoot density (Rj)	Carbon fraction (CF)	Area under forests in Nagarhole national park in ha	Total Carbon fixed in Nagarhole national park in tonnes per year
1.2544	1.45	0.5314	0.22	0.5	64339	37,934

Notes:

1. The carbon stock (C) in the biomass is calculated by multiplying the standing or stem volume of each tree species (Vj) with wood density (Dj), biomass expansion factor (BEF), root-to-shoot density (Rj) and carbon fraction (CF) of dry matter of the living biomass. The formula is as follows: C= Σj [(Vj.Dj.BEFj).(1+Rj). CF].(see MoE (Ministry of Environment, Japan,2010, Chapter 7,7–8).
2. Using this formula the carbon fixed in the park is derived as follows: (1.2544 x 0.5314 x 1.45) x 1.22 x 0.5 x 64339 ha = 37,934.10 tonnes/year.
3. The wood density (D) has been calculated by taking the average of the default values indicated by the 2006 IPCC guidelines for some forest species for the Asia region that grow in the Nagarhole national park. These are *Butea monospema* (0.48); *Arto carpus, sp* (0.58), *Mangifera sp* (0.52), *Syzgium sp* ((0.73), *Azadirachta sp* (0.52), *Dalbergia latifolia* (0.64), *Spathodea campanulata* (0.25). Average of these values is 0.5314.
4. The root-to-shoot density (0.22) is the average of the default values (0.20-0.24)

indicated by the 2006 IPCC guidelines for Tropical moist deciduous forests.

5. The BEF value recommended by the 2006 IPCC guidelines for conversion of net annual increments of forest biomass for natural forests in the humid tropics is about 1.45 (average of default values indicated for different growing stock levels).

After estimating the amount of carbon fixed in the forest site under study, researchers have used three alternate methods to value the carbon sequestration services. These are namely (1) Carbon tax method or Carbon price, (2) Cost of afforestation method, and (3) Marginal social damage cost i.e. the economic value of the damage caused by the emission of an additional metric tonne of carbon into the atmosphere. We may use the carbon price method and alternatively the marginal social damage cost approach to value the carbon sequestration services provided by the Nagarhole national park. A recent World Bank report (2014) notes that carbon prices across emissions trading and crediting schemes in different countries ranged from under US\$1/tCO_2 in the Mexican carbon tax upto US\$ 168/tCO_2 in the Swedish carbon tax. It further notes that prices in emissions trading schemes tend to be lower, clustering around US\$ 12/tCO_2 (World Bank, 2014.p.17). The World Bank recently paid a price of US\$ 4/t in temporary carbon credits (tCER) for Africa’s first big (Clean Development Mechanism) CDM forest carbon project in Ethiopia (www.carbonpositive.net, 2010). A recent assessment notes that between 2009 and 2011 about 3674 CDM projects were registered globally (Charan, Tata Power, undated). Of this about 558 CDM projects were registered in India alone. The averages prices (CER prices in €/tonne) paid for these CDM projects ranged between €6-15 in 2009, €11-15 in 2010 and €6-13 in 2011 (Charan, Tata Power, undated). Taking the mid values of these prices of CDM projects, the average CER price for the period 2009-2011 works to about €8.61 (i.e.US$11.5 using the average annual US$ - € exchange rate of 0.75 for 2014). Estimates of the social cost of carbon show wide variations across studies. For instance Frankhauser (1994) notes the marginal social damage costs across various studies range between US$ 6–45/tC with an average of US$ 20/tC. Pearce (2001) too notes the wide range of carbon prices and observes that using high prices may overestimate the carbon sink services of forests. Hence, his study used a price of US$ 10/tC. However, marginal costs should have increased dramatically since 1994, along with carbon flows and atmospheric carbon stocks. A study by Johnson and Hope (2012) suggests marginal costs in the US$ 55–250/t range. The US government uses an official estimate of the social cost of carbon to estimate carbon emission reduction benefits for proposed environmental standards expected to reduce CO_2 emissions (Johnson, Yeh and Hope, 2013). The US government uses values of $11, $33 and $52 per metric ton (values updated from $5, $21 and $35 used in 2010) of CO_2, classifying the middle value as the central value and the other two values for uses in sensitivity analyses (Johnson, Yeh and Hope, 2013). Keeping the above discussion in view we use three alternate prices US$ 10, $20 and $33 to value the carbon fixed (i.e. 37,934 tonnes/year) in the Nagarhole national park. Thus using these alternate values the economic value of the carbon sequestration services provided by the park are respectively US$ 379,340, US$ 758,680 and US$ 1,251,822 per year.

In our above analysis however we have only considered the carbon stored in the above ground biomass and not in the below ground biomass and forest soils. A number of studies suggest that old growth forests store considerable amount of carbon in forest soils. (Zhou et al., 2006; Luyssaert et al., 2008). However due to lack of data and difficulties in estimating the soil carbon accumulated in the forest soil we have not accounted for this.

To that extent our estimate of the carbon fixed in the Nagarhole national park may be considered as a lower bound value. However we may note here that the India Greenhouse Gas Emissions 2007 report estimated the soil carbon stock for forest lands in India at 4292 million tons in 2007 (MoEF, 2010.p.36). Taking into account the estimated area under forests in India (69.16 million ha) this works to an average of over 62 tons/ha of carbon stored in forests soils in India. As per the estimates in this report about 59 % of carbon stocks in forests lands in India are accounted by forest soils, 32% by the above ground biomass and the remaining 9% by the below ground biomass (MoEF, India, 2010).

Recreation

Forests are also valued for the many recreational benefits that they provide such as viewing wildlife and nature, safari hunting, boating and angling, hiking, etc. Studies suggest that the consumer surpluses obtained by visitors to parks and nature reserves and producer surpluses obtained by the tourist industry are considerable (Pearce and Moran, 1994).These findings have been used to justify revision of park entrance fees and augment park and government revenues from national parks and forest reserves. The Nagarhole national park which is located in the Western Ghats biodiversity hotspot is noteworthy for its rich flora and fauna including many endangered species as noted earlier, and also for the many recreational benefits that it provides. Although the entire park area of 643.39 km^2 was notified as a core zone or critical tiger habitat in December 2007, tourism is permitted in some parts. As per the information furnished by the park authorities during the three year period 2011-12 to 2013-14 on average about 69,681 persons visited the park annually. Of them over 91% were domestic visitors and the remaining about 9% were foreign tourists. The total revenue earned from these visitors during this period was an average of Rs. 24,909,731 per year (i.e. US$ 406,556.73 per year).

To estimate the recreational benefits researchers have used three methods namely (1) Travel cost method (TCM), (2) Contingent valuation method (CVM) and (3) Benefit transfer (BT) approach. While TCM uses data on actual costs (including opportunity cost of time) incurred by visitors to recreation sites/national parks to estimate the consumer (visitor) demand for recreation, CVM uses data from simulated or hypothetical markets to estimate how much consumers or visitors are willing to pay to enjoy a recreational benefit or how much amount they are willing to accept as compensation to avoid the loss of a recreational benefit. BT approach is used when one is unable to conduct a primary study to estimate recreational benefits. For instance, Nahuelhual et al (2007) used the BT approach to estimate the recreational benefits provided by the Chilean temperate forests. For our purpose we may rely on a study conducted by Manoharan (1996) in the Periyar tiger reserve in Kerala state which estimated the recreational benefits provided by the park. Both Periyar and Nagarhole national parks are located in the Western Ghats biodiversity spot and both are also notified as critical tiger habitats. Using CVM Manoharan estimated the mean consumer surplus per visitor of visitors to the Periyar tiger reserve to be Rs. 9.9 for domestic visitors and Rs. 140 for foreign visitors (around 1995-96 prices). This is about Rs. 27.13 per visitor for domestic visitors and Rs. 383.6 per visitor for foreign visitors in terms of 2013-14 prices (with 1993-94=100). The entry fees to Nagarhole national park as on date is Rs 200 per person for domestic visitors and Rs 1000 for foreign visitors. Taking into account these current park entry fees and the mean consumer surplus per visitor indicated by Manoharan’s study the mean willingness to pay for enjoying the recreational benefits provided by Nagarhole national park is Rs 227.13 per person for domestic visitors and Rs. 1383.60 per person for foreign visitors. Using these parameters the economic value of the recreational benefits provided by the Nagarhole national park is estimated at: 63,650 persons x Rs.227.13 = Rs. 14,456,825 for domestic visitors and 6031 persons x Rs. 1383.60 = Rs. 8,344,492 for foreign visitors to the park, making a total of about Rs. 22,801,317 or about US$ 372,145. It is seen that the actual revenues realized by the Park authorities from visitors to the park (i.e. Rs. 24.9 million or US$ 0.41 million) is much higher than our estimated value of the recreation benefits of the park. This can be explained by the fact that we have used only the basic entry fees to calculate the willingness to pay (as discussed above) and value the recreational benefits of the park. However, the entry fees are higher for those visitors who visit the park with a still or video camera. Further visitors brought in by private safari operators and who use the vehicles of these safari operators instead of the vehicles provided by the park authorities are charged higher tariffs. However information about these are not available. We also have no information about the producer surpluses accruing to the tourist industry in the study area. To that extent our estimates of the recreational benefits provided by the park should be considered as a lower bound.

Nutrient Cycling

Nutrient cycling is another important function provided by forests. Essentially it involves the movement and exchange of organic and inorganic matter back into the production of living matter (en.wikipedia.org/wiki/Nutrient_cycle). Trees help facilitate nutrient cycling by absorbing mineral nutrients from the soil as they grow and accumulate them in their bodies (Xue and Tisdell, 2001). As seasons change, some accumulated nutrients will return to the soil in withered branches and leaves, and the rest are conserved in the stem and roots. Estimating the nutrient cycling function of forests is not easy because nutrient values vary depending on tree species and age, forest, soil and site characteristics, seasons, and forest management practice.

Using the parameters and formula (omitting the step involving calculation of the carbon fraction of the dry matter of the living biomass) presented earlier in Table 2 the total aboveground biomass accumulated in the Nagarhole national park is estimated at: (1.2544 m^3/ha/year x 0.5314 x 1.45) x 1.22 = 1.1792 t/ha/year x 64,339 ha = i.e. about 75,869 tonnes/year. We now need to calculate the nutrient values of the forest biomass. This is assessed by studying the nutrient composition of litter and forest soils in terms of NPK (Nitrogen, Phosphorous and Potash). A study by Eshwara Reddy et al (2012) has assessed the nutrient value of litter in the natural forests of Kodagu in the Central Western Ghats close to where our park is located. They studied the nutrient turnover of litter during the pre and post monsoon seasons for different forest types i.e. evergreen/semi-evergreen, moist and dry deciduous forests in their study site. They found no significant difference in the nutrient values over the two seasons for all forest types studied. As per data furnished in the Management Plan for Nagarhole national park (2000-2010) about 1.45 % of the park area is under semi-evergreen forests, over 49% under moist deciduous forests and the remaining 49.5% under dry deciduous and other forest types (Appayya, 2001). The estimated aboveground biomass in the park (i.e. 75,869 t/year) is apportioned across the above three forest types in terms of these proportions. As per Eshwara Reddy et al (2012) the proportion of the major nutrients (i.e. NPK) in litter studied in permanent one ha plots of different forest types in their study area was 1.81%, 1.53% and 1.44% for semi-evergreen, moist deciduous and dry deciduous/other forest types. Using these parameters the nutrients accumulated in the park in terms of NPK is estimated at about 1130 tonnes/year (Table 3)

Table 3. Estimated annual quantity of nutrients (NPK) accumulated in Nagarhole National Park, India

Forest Types	Park area in ha	Share in park area (%)	Aboveground Biomass (tonnes/year)	NPK (%)	Total NPK (tonnes/year)
Semi-evergreen	934.5	1.4	1100	1.81	19.91
Moist deciduous	31580.8	49.1	37244	1.53	569.83
Dry deciduous and other forest types	31823.7	49.5	37525	1.44	540.36
Total	64339	100	75869	-	1130

Note:

1. As per Eshwara Reddy et al (2012) the major nutrient composition in leaf litter in permanent one ha plots of different forest types in their study site in the central Western Ghats, India was as follows: Semi-evergreen: N-1.140%; P- 0.075%; K – 0.595% i.e. NPK – 1.81%; For moist deciduous forests these proportions were: N- 0.955%; P- 0.067; K- 0.510 i.e. NPK – 1.53%; for dry deciduous forests these proportions were: N – 0.855%; P – 0.0595% K – 0.495 i.e. NPK – 1.44 %.
2. The approximate relative share of different forest types in Nagarhole national park presented in column 1 are based on interpretation of satellite imagery data for January

2000 that is presented in the management plan of the park (Appayya, 2001).

To value the nutrient accumulation services provided by the park we have used the average price of mixed fertilisers in India and alternatively the price of green fertilisers (leaf manure). The price of mixed fertilisers in India in 2014 was Rs.21,600/tonne. Using this price the annual economic value of the nutrient cycling services works out to: 1130 tonnes/year x Rs. 21,600/tonne = about Rs. 24,408,000 or US$ 398,368. Alternatively if we may use the price of leaf manure to value the nutrient cycling services. According to local farmers the price of (processed) leaf manure in Kodagu is about Rs.10 per kg (Rs.10,000/tonne).Using this alternate price the economic value of the nutrient cycling services provided by the park is about: 1130 tonnes/year x Rs.10,000/tonne = about Rs. 11,300,000 or US$ 184,430

Air Purification

Trees also play an important role in reducing air pollution. Trees can remove gaseous air pollutants such as sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) either through uptake via leaf stomata or the plant surface (Nowak, 2000). Once inside the leaf, these gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner leaf surfaces (Nowak, 2000). Further trees can also remove pollution by intercepting airborne particles. The pollution absorption capacity of trees varies depending on tree, forest and site characteristics, location, seasons and weather conditions, pollution levels, etc. There are very few studies which have tried to value the air pollutant absorption function of forests. A study in China indicated average annual absorption rates for SO_2 at 88.65 kgs and 215.6 kgs per ha for broadleaved and coniferous forests respectively (Xue and Tisdell, 2001). Another study of air pollution removal by urban trees in Guangzhou, China indicated removal rates of 23.8,24.3 and 88.8 kgs per ha per annum for SO_2, NO_2 and total suspended particulates in recreational areas of the city (Jim and Chen,2008). A study of dry deposition rates of SO_2 in a Japanese cypress forest in Shiga prefecture suggested annual deposition rates of 3.1 to 3.5 kgs per ha (Obote et al.,2002). Another study which studied the gas sink services of field and mountainous areas in Japan indicated annual absorption rates of SO_2 and NO_2 at 10.8 and 15.6 kgs per ha respectively (IRA (Institute of Research in Agriculture), 2001; Yoshida, 2001). A literature search for similar studies for India revealed only one study which sheds some light on the role played by trees in absorbing air pollution. This study tried to assess the role played by trees in absorbing air pollutants in Nagpur city (Dhadse et al, undated). The study tried to assess the annual average value of SO_2 and NO_2 concentration in the ambient air in residential, industrial and commercial areas of Nagpur. The study noted that the residential areas of the city had a good tree cover (800 trees/ha) as compared to industrial (200 trees/ha) and commercial areas (< 100 trees/ha). The study found that both SO_2 and NO_2 levels were lower in the residential areas as compared to the commercial areas (i.e. SO_2 6 $\mu g/m^3$ and 7 $\mu g/m^3$ and NO_2 - 18 $\mu g/m^3$ and 21$\mu g/m^3$ respectively). Although this testifies to the positive role played by trees in absorbing air pollutants in the Indian context also, we don't have estimates on a per ha basis. Hence we rely on the Japan study cited above to assess the air pollutant absorption functions of the park. Using these estimates the quantity of SO_2 absorbed by the park is estimated at about: 10.8 kgs/ha x 64,339 ha = about 694.9 tonnes; and the quantity of NO_2 at 15.6 kgs/ha x 64,339 ha = about 1,003.7 tonnes.

To value this we need to use the engineering cost or abatement cost of controlling SO_2

and NO_2. For this we rely on a study by Pandey (2005) which estimated the abatement costs for various pollutants for selected industries in India. Taking the average abatement cost for 13 industries studied, the study noted that the abatement cost for SO_2 and NO_2 was Rs. 7,096 and Rs. 15,595 per ton (at 1987 prices) respectively which is Rs. 40,305 and Rs. 88,580 per ton respectively in 2013-14 prices (with base 1993-94 = 100). Using these prices the economic value of the SO_2 absorbed by the park annually is estimated at about: 694.9 tonnes x Rs. 40,305 = about Rs. 28,007,945 or US$ 457,123 and of NO_2 at about: 1003.7 tonnes x Rs. 88,580 = about Rs. 88,907,746 or US$ 1,451,081. The combined values for the two pollutants is Rs.116,915,691 or US$ 1,908,204.

Biodiversity

Nagarhole national park is located in the Western Ghats biodiversity hotspot which is noteworthy for its rich flora and fauna as noted earlier. The Western Ghats is home to many endemic or endangered species. For estimating the (local) biodiversity value of the park we rely on a previous study in the park which tried to assess the local community's willingness to pay for participatory elephant conservation (Ninan et al, 2007; Ninan and Sathyapalan, 2005). This study conducted a socio-economic and contingent valuation survey among 125 farmers of Maldari village (Kodagu district) adjoining the Nagarhole national park. This village was selected because of a high proportion of the village area being under forests and coffee, prominence of man-animal conflicts, etc. In the CVM survey the respondents were asked as to how much they were willing to pay in terms of spending time for participatory elephant conservation. The Asian elephant was chosen for the CVM survey since they are a threatened species. The time that the respondents were willing to spend for participatory elephant conservation was then valued using the opportunity cost of time in terms of their foregone income. The study revealed that overall the respondents were willing to pay Rs. 6003 per household per year (at 1999 prices) for participatory elephant conservation. This is about Rs 13,748 per household per year in terms of 2013-14 prices (with base 1993-94 = 100). We may use this estimate and extrapolate for the local residents of Virajpet taluk of Kodagu district where our sample village is located. As per the population census of 2011 the rural population of this taluk was estimated at about 175,824 persons. Taking the average size of households to be 5 the number of rural households in Virajpet taluk is estimated at about 35,165 households. Because of distant decay effects on values we use only 50% of the above value (i.e. 50% of Rs. 13,748 = Rs. 6874) to extrapolate and estimate the biodiversity value of the park to the local communities of Virajpet taluk, Kodagu. Based on this parameter the biodiversity value of the park is estimated at about Rs. 6874 x 35,165 households per year which is about Rs. 241,724,210 or US$ 3,945,229.

Pollination

Pollination is another important service provided by forest ecosystems. They are critical for facilitating and enhancing crop yields. Bees, birds, bats, etc. are important pollinators. There does not seem to be any study in India which has tried to assess the economic value of the pollination services provided by forests. Two recent studies from Indonesia (Priess et al, 2007) and Costa Rica (Ricketts et al, 2004) have tried to assess the avoided loss of coffee yields due to the pollination services (only forest bees considered) provided by forests. The estimated values of pollination services was

US$ 205 and US$ 434 respectively in 2010 PPP US$ (Ninan and Inoue, 2013a). In terms of 2014 US$ these values are US$ 319.5 and US$ 348.3 respectively. There are coffee estates around the western periphery of the Nagarhole national park that falls within Kodagu district. We may use the average of the above two values (US$ 348.3/ha) to estimate the pollination services (i.e avoided loss of coffee yields) provided by the park. However it may incorrect to use this estimate and extrapolate for the entire park area falling within Kodagu district. One of the parameters used by the researchers to estimate the pollination service in the above two studies is the distance between the forest boundary and coffee estates. Keeping this into account we extrapolate the above estimate for only 10 % of the park area (i.e. 10% of 35,495 ha = 3549.5 ha) that falls within Kodagu district and alternatively for only 20% (7099 ha).On this basis the avoided loss of coffee yields due to pollination services provided by the Nagarhole national park is estimated at: US$ 348.3/ha x 3549.5 ha = US$ 1,236,291 per year and alternatively US$ 348.3/ha x 7099 ha = US$ 2,472,581.7 per year

NTFP Benefits

Tribal and other communities residing within and on the periphery of the Nagarhole national park depend on it for non-timber forest products (NTFPs), although as per Indian forest laws such activities are not permitted in national parks. For estimating the NTFP benefits obtained by the local communities from the park we rely on an earlier study conducted in this park which estimated the NTFP benefits appropriated by the tribals living within and outside the park (Ninan et al, 2007). As per this study which surveyed 100 tribal households living within and outside the park, the tribal households collected NTFPs valued at Rs 7212.4 per ha per year (in 1999 prices) assuming that they accessed 10% of the park's area for collecting NTFPs and Rs. 2884.9 per ha per year under the alternate assumption that they accessed 25% of the park's area for collecting NTFPs. These are Rs.16516.40 and Rs. 6606.42 per ha per year respectively in terms of 2013-14 prices (with base 1993-94=100).Using these two alternate estimates the economic value of the NTFP benefits appropriate by the tribal communities from the Nagarhole national park is estimated at: Rs. 16516.40 x 6433.9 ha (10% of the park area) = about Rs. 106,264,866 or US$ 1,734,370 and in the alternate case: Rs. 6606.42 x 16084.75 ha (25% of the park area) = about Rs. 106,262,614 or US$ 1,734,334 per year.

Grazing Benefits

Forests including protected areas are treated as open access resources and used by local communities for grazing their cattle. This is true of Nagarhole national park as well. To estimate the grazing benefits appropriated by the local communities from the park we rely on an earlier study conducted in the Dandeli Wildlife sanctuary also located in the Western Ghats region in north Karnataka which surveyed 100 farming cum pastoral households to assess the extent of their dependence on the forests for grazing and other benefits (Ninan et al, 2007). For estimating the green fodder consumed by cattle while free grazing we relied on the estimates of the green fodder needs of different categories of livestock (i.e. an average of 13 kgs of green fodder/natural herbage per head per day) made by the National Wastelands Development Board in its Report on Fodder and Grasses (1987) and assumptions regarding how much green fodder cattle will consume while free grazing i.e. 50% of their green fodder needs by free grazing during half the year including the rainy season and only 25% of it during the rest of the year (cited in Ninan et al, 2007). Using these norms the study noted that an average adult cow while free grazing consumes about 1779.38 kgs of green fodder or natural herbage per year from the forest. Crop residues such as paddy straw produced on the farms and purchased feeds are assumed to supplement and meet the rest of the daily feeding needs of the livestock maintained by the households (Ninan et al, 2007). As per the park authorities there are about 60,000 cattle in and around the Nagarhole national park. Since we don't have information about the composition of this cattle population in terms of age and other parameters we assume that they are equivalent to about 60,000 standard cattle units. Using the above parameter it is estimated that the amount of fodder/natural herbage consumed by the cattle population while free grazing in the park is about: 60,000 x 1.7794 tonne = 106,764 tonnes/year. In the Hunsur area near the park the average price of paddy, finger millet and sorghum straws are Rs.2500, Rs 2000 and Rs. 1000 per tonne respectively. We may take the average of these three prices (Rs. 1833.33/tonne) to estimate the economic value of the grazing benefits appropriated by the local communities from the park. This is estimated at: 106,764 tonnes/year x Rs. 1833.33/tonne = about Rs.195,733,644 per year or US$ 3,194,608 per year of grazing benefits from the Nagarhole national park.

Disservices

A recent global survey of forest valuation studies reveals that disservices of forest ecosystems such as the damages caused by wildlife to humans, farms and property in the vicinity of forests, and health hazards due to forest fires, have received scant attention in the literature (Ninan and Inoue, 2013a). However, there are few exceptions to this. For instance Bandara and Tisdell (2002) discuss the economics of viewing Asian elephants as an agricultural pest. Another study by Ninan and Sathyapalan (2005) attempts to assess the cost of damages caused by wildlife borne by coffee growers in the Western Ghats of India. For our study we may evaluate the disservices provided by the park due to damages caused by wildlife and forest fires arising from natural or human induced factors. Data furnished by the park authorities reveal that during the period 2011-12 to 2013-14, the State Forest department paid an average of about Rs. 7,772,600 (about US$ 126,858) per year as compensation to the local communities for damages caused by wildlife to their crops and property. In viewing this we may note that an earlier study by us revealed that almost 75% of the households surveyed in a coffee growing village near the park didn’t file any application for claiming compensation for wildlife damages due to the high transaction costs for obtaining such compensation (Ninan and Sathyapalan, 2005). Further even those who filed and received compensation complained that the amounts paid to them were less than 10% of the actual cost of damages incurred by them. Given the general tendency for people to inflate their compensation claims it is difficult to adjudge whether the actual costs borne by the local communities due to wildlife attacks are higher than implied by the above figure.

Forest fires are another disservice that we consider for our analysis. However, whether forest fires caused by natural or man-made factors are a service or disservice is debatable and depends on the context. In areas where slash and burn or shifting cultivation is prevalent, fires are part of the shifting cultivation cycle which facilitates the previously cultivated area to rejuvenate and recoup its fertility. Some ecosystems (sometimes called fire dependent ecosystems), require periodic fires to sustain themselves over the long periods of time called fire return intervals (Loomis,pers.comm). A study by Schmerbeck et al (2015) among rural households in Chittor district in Andhra Pradesh, India notes that regular burning of forests is crucial for local livelihoods. During the dry season it is also common for local forest staff to make fire lines as a fire prevention measure in forests. However, sometimes this could go awry and cause bigger fires aided by strong winds, extreme heat, etc. Whatever arguments are made in support of the beneficial effects of forest fires, in protected areas fires result in loss of biodiversity, disruption of nutrient cycles, landscape changes etc. Prasad et al (2008) observe that in addition to alteration of landscape, vegetation fires are also one of the major causes of greenhouse gas emissions, aerosols and smoke pollution which impact on atmospheric chemistry, visibility and health. Forest fires have been reported in Nagarhole national park caused by natural and man-made factors including sometimes due to arson caused by local communities due to conflicts with the state over access and use of forest resources. As per the park authorities during 2012 an area of about 2080 ha in the park or an average of 693.33 ha per year during the last three years was affected by fires. Based on data presented in Table 2 it is noted that the carbon captured in the park is about 0.59 tC/ha/year. Using this the carbon emissions due to forest fires in the park is estimated at about: 693.33 ha x 0.59 tC/ha/year = 409 tC/year. Using the price of US$ 20 (see discussion in earlier section) the damage cost of carbon emissions due to forest fire in the Nagarhole national park is estimated at: 409 tC/year x US$ 20 = about US$ 8180 per year.

Added value by forest ecosystems.

Another lacuna of most forest valuation studies is that they fail to shed light on the added value or additional benefits provided by forests compared to the benefits of converting them to an alternative use (Ninan and Inoue, 2013a;2013b). For instance, even an orchard can sequester carbon. The issue therefore is how much extra carbon is sequestered in forests compared to its alternative uses. Understanding the net benefits and opportunity costs of conserving an ecosystem is also relevant when assessing its economic value (Chomitz and Kumari, 1998). Beukering et al.'s study (2003) of the Leuser national park in Indonesia is noteworthy in that they examine the benefits of the park under three alternative scenarios – deforestation, conservation, and selective use. Their results revealed that the conservation option is the most beneficial (US$ 9540 million) followed by selective use (US$ 9100 million) and deforestation (US$ 6960 million). Another study notes that the added value of carbon stored in the aboveground biomass and soils in forests in Japan as compared to in croplands ranged between US$ 236-1182/ha using alternate carbon prices of US$ 4 and US$ 20/tC (Ninan and Inoue, 2013b).Similarly the extra value of air pollutants (SO_2 and NO_2) absorbed by forests in Japan compared to paddy lands was about US$ 23/ha (Ninan and Inoue, 2013b).

Due to lack of data we are able to estimate the additional benefits provided by our study site only in respect of water and soil conservation and carbon sequestration. As per Krishnaswamy et al (2013) the evapotranspiration/run-off rates in degraded forests in their study sites in the Malnad (Hilly) area of Uttara Kannada district in Karnataka was about 64.1% compared to 38.75% in evergreen forests. Using this parameter (64.1%) instead of 38.75% in column 3 of Table 1, the total average annual rainfall retained in the park (assuming degradation scenario) would be about 234,387,731 m^3. Using the estimated amount of rainwater conserved in the park (399,896,101 m^3) presented in Table 1 the additional rainwater retained in the park due to the forest as compared to a degraded forest is estimated at: 399,896,101 m^3 – 234,387.731 m^3 = about 165,508,370 m^3. Multiplying this with the annual cost of storing water in Kabini dam (Rs.0.03/m^3) discussed earlier, the additional value of water retained in the Nagarhole national park due to the forest is: Rs.4,965,251 i.e. US$ 81,039 per year or US$ 1.26/ha/year.

For estimating the soil protection function of the park we had relied on the estimates of Sarvanan et al (2010) in Katteri watershed in Kodagu district near our study site. As per their study the difference in the soil erosion rates between evergreen dense forests and degraded forest was 3.5 tonnes/ha/year which we used for estimating the soil protection function of the Nagarhole national park. If on the other had we use their estimates of soil loss rates in croplands to assess the soil protection function of the park, the difference between the soil erosion rates in evergreen dense forests (7.8 t/ha/year) and croplands (67.6 t/ha/year) will be 63.3 tonnes/ha/year. Using this parameter the avoided quantity of soil loss in the park would be about 63.3 t/ha/year x 64339 ha = 4,072,658.7 tonnes/ha/year. As discussed earlier to estimate the avoided loss of productive forest land area we divide this amount in tonnes by 1.5 tonne (since soil is denser than water) to convert the soil loss into volumetric basis: i.e. 4,072,658.7 t/ha/year ÷ 1.5 tonnes = 2,715,105.8 m^3. This divided by the average thickness of forest soils (1.25 m) = 2,172,084.64 m^2 ÷ 10,000 m^2 = about 217.2 ha. Based on the estimates of the foregone benefits discussed earlier (Rs 353,806.24/ha/year) the economic value of the avoided loss of productive forest land in the Nagarhole national park in this case would be: 217.2 ha x Rs. 353,806.24 = Rs. 76,850,253.39 or US$ 1,254,288.45 per year i.e US$ 19.5/ha/year. If we compare this with the earlier example where we assessed the economic value (US$ 1.08/ha/year) taking into account the soil erosion rates of evergreen forest versus degraded forests, the added value of soil protection benefits provided by forests compared to croplands is over US$ 18.4/ha/year.

For assessing the carbon sequestration benefits of forests versus alternate landscapes we have relied on a study by CAFNET in India which evaluated the carbon sequestration in a forest compared to coffee plantation in Kodagu district (CAFNET, 2011). Based on observations from sample plots studied by them the carbon sequestered in the forest plot was estimated at 196 tC/ha as against an average of 177.25 tC/ha in coffee plots growing both arabica and robusta varieties of coffee. Based on these parameters the additional carbon stored in forest is: 196 - 177.25 tC/ha = 18.75 tC/ha. This valued at US$ 20/tC indicates that forests store more carbon worth about US$ 375/ha than coffee plantations. Another study in two villages in Uttara Kannada district in the Western Ghats region showed that in the sample plots studied the total carbon stock in natural forest was 43.5 tC/ha as compared to 4 tC/ha in agricultural bunds and homestead gardens, and 27.5 tC/ha in private forests (Murthy et al, 2011). Using these parameters, the additional carbon stored in natural forest was 39.5 tC/ha as compared to agricultural bunds/homestead gardens and 16 tC/ha as compared to that in a private forest. Multiplying this with US$ 20/ha gives us a value of US$ 790/ha (natural forests compared with agricultural bunds/homestead gardens) and alternatively US$ 320/ha (comparing natural forests with private forests). Thus overall the carbon stored in natural forests is more than for alternate land uses ranging between US$ 320-790/ha. These are the stock value of carbon. Due to lack of data we are unable to shed light on the flow value of carbon in forests as compared to alternate land uses. Thus taking into account only three services i.e. water and soil conservation and carbon sequestration we note that the benefits from forests are higher than from alternate land uses.

5. Total Economic Value of Ecosystem Services and Disservices

A summary of the estimated values of ecosystem services and disservices provided by the Nagarhole national park is presented in Table 4. Estimate 1 presents the lower of the estimated values using the alternate valuation methods described in Table 1 whereas estimate 2 presents the higher of the estimated values using the alternate valuation methods. As per the alternate estimates the total net value of benefits (i.e. value of services minus disserves) provided by the park ranges between US$13-148 million per annum. In per ha terms the net benefit ranges between US$ 204-2296 per annum. It is worth noting here that Costanza et al (1997) estimated the average annual value of the ecosystem services from global forests at US$ 969/ha i.e. 2010 US$ 1430 (Ninan and Inoue, 2013a: Ninan, 2014).The added value of benefits from the park is higher as compared to from alternative landscapes (US$ 1.3-18.4/ha/year) for water and soil conservation; for carbon sequestration this added value ranges US$ 320-790/ha (stock value) for carbon sequestration services.

Table 4: Summary of the total economic value of ecosystem services and disservices provided by the Nagarhole national park, India.

	Ecosystem Service	Estimate 1 US$ Million	Estimate 2 US$ Million	Added value of benefits from park (forest) compared to alternative landscapes US$/ha/year	Alternative landscape considered
1.	Water conservation	0.196	0.196	1.26	Degraded forest
2.	Soil protection	0.069	132.33	18.4	Croplands

3.	Carbon sequestration	0.379	0.759 (1.251)	US$/ha: 1) 375 2) 320 3) 790	1).Coffee plantation 2).Private forests 3).Agricultural bunds/homestead gardens. (Stock value)
4.	Recreation	0.410	0.410	-	
5.	Nutrient cycling	0.184	0.398	-	
6.	Air purification	1.908	1.908	-	
7.	Biodiversity	3.945	3.945	-	
8.	Pollination	1.236	2.473	-	
9.	NTFPs	1.734	1.734	-	
10.	Grazing	3.195	3.195	-	
	Total	13.256	147.348 (147.84)		
	Disservices:				
11.	Wildlife damages	0.13	0.13		
12.	Forest fires	0.008	0.008		
	Total	0.138	0.138		
	Total Value (Net)	13.118	147.21 (147.70)		
	Per ha annual value in	204	2288 (2296)		

	US$ (Net)				

Notes:

1. Estimate 1 includes the lower of the two sets of the estimated value of ecosystem services using alternate methods. *Soil conservation*: Avoided loss of productive forest land area due to soil erosion x opportunity cost per unit area i.e. the net benefits from a community woodlot in the Malnad (Hilly) region of Karnataka state; *Carbon sequestration*: valued at US$ 10/tC; *Nutrient cycling*: Maintained nutrient (NPK) value valued at price of leaf manure in Kodagu; *Pollination service:* Avoided loss of coffee yields in US$/ha x 10% of the park area: *NTFP benefits:* Estimated NTFP benefits appropriated by sample tribal households of the park x 10% of the park's area that is accessed by the households for extracting NTFPs: for other services and disservices refer Table 1.

2. Estimate 2 includes the higher of the two sets of the estimated value of ecosystem services using alternate methods. *Soil conservation*: Forest area valued at the amount of decline in the unit value of forest land due to loss of soil quality/nutrients; *Carbon sequestration* valued at US$ 20/tC and alternatively US$ 33/tC (figure in parenthesis); *Nutrient cycling*: Maintained nutrient (NPK) value valued at market price of mixed chemical fertilisers in Karnataka; *Pollination service:* Avoided loss of coffee yields in US$/ha x 20% of the park area; *NTFP benefits:* Estimated NTFP benefits appropriated by sample tribal households of the park x 25% of the park's area that is accessed by the households for extracting NTFPs; for other services and disservices refer Table 1.

3. Added value of benefits from park compared to alternate landscapes (column 5): for water and soil conservation estimated values are the flow value in US$/ha/year; for carbon sequestration estimated values are stock value in US$/ha.

4. The estimated values in Indian Rupees have been converted into US dollars using the exchange rate of 1 US$ = Rs. 61.27 the average annual for 2014.

6. Conclusion

Evidence presented here suggest that the value of ecosystem services provided by the Nagarhole national park in Karnataka, India is quite high and significant. The total net value of benefits (i.e. value of services minus disserves) provided by the park ranges between US$13-148 million per annum or US$204-2296 per ha per annum using alternate valuation methods. More significant is that the added value of benefits from the park is higher as compared to from alternative landscapes considering just three ecosystem services i.e. water and soil conservation, and carbon sequestration services. If these are internalised in decision making it could strengthen the economic case for conserving forests in developing countries such as India where there is great pressure to relax forest laws and divert forests to non-forest uses to fuel economic growth. The estimates also provide support for the viability of markets for particular ecosystem services. The development of such markets requires additional institutional reforms such as changes with respect to property rights, as well as reforms in land and labour markets (Gorsjean and Kontoleon 2009). The main policy challenge of the future concerns how to promote conservation and develop such markets so that those bearing the cost of conservation are adequately compensated. The undertaking of comprehensive evaluation studies, as done in this paper, is the first necessary step in this process.

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