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Making the hidden visible: Economic valuation of tiger reserves in India

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ABSTRACT

Tiger reserves in India not only support more than half of the global tiger population and are cornerstones of biodiversity conservation, they also provide a wide range of economic, social and cultural benefits in the form of ecosystem services.

Ignorance of such values influences public policies, including decisions involving investments and allocation of funding, that may impact their protection status with serious implications on human well-being.

Through economic valuation of ecosystem services from 6 tiger reserves in India, we demonstrate that enhanced investment in these tiger reserves is economically rational.

The flow benefits from selected tiger reserves range from US\$769 ha^{-1} $year^{-1}$ to US\$2923 ha^{-1} $year^{-1}$.

The usefulness of such information for developing incentive-based mechanisms and informing zoning and management of tiger reserves at the landscape level is also discussed.

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1. Background

Humans as apex species are facing a variety of crises due to loss of biodiversity values (Cardinale et al., 2012). While the costs of biodiversity losses are felt at local level, they often completely go unnoticed at national and international levels due to non availability of robust valuation systems, thereby leading to weaker policies (TEEB, 2010a). Public policies have an essential role to play in ensuring that the main types of benefits from nature are identified and used in decision making – avoiding gross underestimation of the overall value of conservation and sustainable use of biodiversity and ecosystem services. Developing capacity to measure and monitor biodiversity and ecosystems for their provisioning services is thus an essential step towards better management of our natural capital (Daily, 1997).

The value of such ecosystem goods and services is increasingly being recognized, both in terms of socio-economic benefits and in terms of their contribution to other aspects of human well-being, through direct and indirect use as well as non-use values (Costanza et al., 2014, 1997). Often these benefits cannot be measured in monetary terms, including the value of protection against natural hazards or the contribution to cultural identity and sustenance. While many feel putting a price on nature and thus commodifying it is either impossible or ethically unsound, the contrary argument that without doing so ecosystem services are at risk of being left out of economic analysis and decision-making is also difficult to contest (Kallis et al., 2013). For example, economic analysis can help in determining the quantity of goods such as fuelwood and fodder that can be allowed for extraction by local communities based on the trade-offs with other services as water regulation from the forest.

India holds about sixty percent of the world's wild tiger population wild (Jhala et al., 2015; WWF, 2016) and is considered to have the best chance for saving the population of this magnificent animal in the wild (Dinerstein et al., 2007). Conservation of India's national animal and vegetation gains significance on account of its role in the context of sustainable food chain. Its presence is vital in regulating and perpetuating ecological processes and systems (Walston et al., 2010). Tiger is also an umbrella species whereby its protection also conserves habitats of several other species, thereby ensuring continuity of natural evolutionary processes in the wild. The Project Tiger, launched in 1973 by the Government of India, now includes 50 tiger reserves across the country, covering over 2 per cent of India's geographical area (NTCA, 2015).

Originally most of the tiger reserves in India have been established to protect landscape features and wildlife including tiger and for biodiversity conservation with genetic, species and ecosystem diversity. The primary objective of establishing such tiger reserves under Project Tiger has been to ensure continuity of natural evolutionary processes (Jhala et al., 2015, 2010). However, many tiger reserves also conserve a wide range of ecosystem services and provide social, economic and cultural benefits. Often, establishment of such reserves could be justified in terms of these ecosystem services alone (Badola et al., 2010). For instance, Periyar Tiger Reserve protects watershed of Periyar Lake that irrigates more than 900 km^2 of agriculture in neighbouring rain-shadow regions (Shukla, 2011).

Tiger conservationism in India has a long history. However it is a paradox that as the emphasis on conservation movement has increased over the years with increase in tiger population, so too has the rate of loss of tiger habitat (Jhala et al., 2015, 2010). Estimating monetary values of ecosystem services from biodiversity can help in making conservation more appealing and benefits from biodiversity more visible to policy makers. Moreover, it is important to recognize that intrinsic value considerations are not the only solution to biodiversity conservation, particularly in developing regions such as India which are exposed to increasing threats to biodiversity but are home for a large majority of world's poor. Therefore, arguments based on intrinsic considerations are often trumped by the needs for survival.

While conservation initiatives till now have largely focused on in-situ conservation of tigers by establishing tiger reserves in India, there has not been any major assessment of the economic value of tiger reserves in terms of ensuring the flow of essential ecosystem services that subsequently accrue to local, regional, national as well as global beneficiaries. In the light of growing developmental pressures, there is an urgent need to provide stronger argument for conservation of the wild and thereby good reasons for enhanced investment in these tiger reserves. Economic valuation is increasing being used as a tool to communicate the values emanating from natural ecosystems to the policy-makers as well as the need to invest in green endowment and thus help in prioritizing investments and allocation of funding at state and national level (TEEB, 2010b). Further, many benefits from tiger reserves flow outside the administrative boundaries of tiger reserve and economic valuation can help reflect the true value of benefits accruing outside.

A pilot study was thus commissioned with the support of the National Tiger Conservation Authority to highlight the economic contribution of tiger reserves to the society and mainstream concerns associated with tiger conservation in policy debates (Verma et al., 2015). In this paper, we outline the methodology used for estimating economic values of various ecosystem services for selected tiger reserves in India and present the results.

We still do not have adequate information or understanding about ecosystems, all the species, and the various ways in which these enhance human well-being that we can objectively estimate

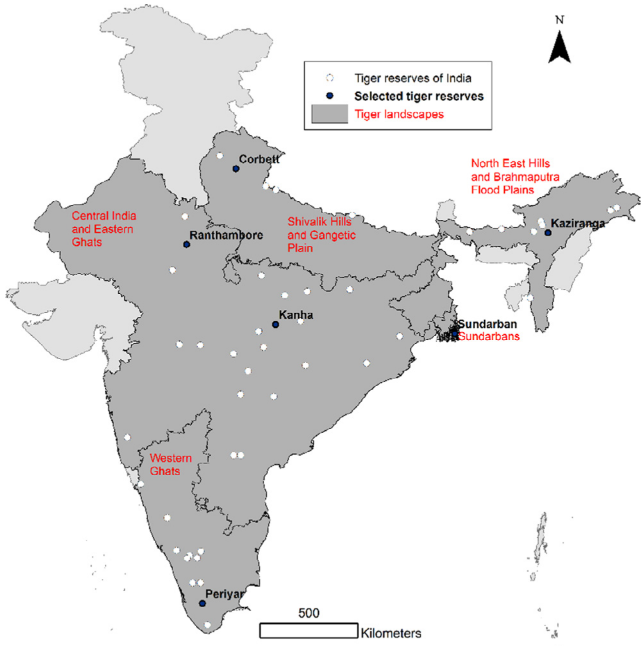

Fig. 1. Tiger Reserves selected for the study.

a value for each of them. There are also ethical issues inherent in the process, the intrinsic value i.e., the value of wild species in their own right (Vucetich et al., 2015). However, recognition of even a conservative estimate of some of these intangible benefits from tiger reserves is likely to demonstrate their significance and provide adequate justification for conservation of these tiger habitats. The underlying objective of the initiative was to make the hidden benefits emanating from and embedded in tiger reserves visible to economies and society. It is argued that recognition of benefits is likely to create an evidence base line which will pave the way for more targeted and enhanced investment in these repositories of genetic information (Emerton et al., 2006).

2. Study sites

To demonstrate the significance of their economic values, tiger reserves are selected from different tiger landscapes with distinct landscape diversity. Further, to account for differences in ecological conditions in the Central India and Eastern Ghats landscape, two tiger reserves were selected from this landscape. In addition, diversity in terms of ecosystems, forest type, socio-economic conditions and availability of data to conduct the exercise also influenced the selection of sites for the study. Based on these screening criteria, the six tiger reserves selected for the study are Corbett Tiger Reserve (CTR), Kanha Tiger Reserve (KTR), Kaziranga Tiger Reserve (KZTR), Periyar Tiger Reserve (PTR), Ranthambore Tiger Reserve (RTR) and Sundarbans Tiger Reserve (STR) (See Fig. 1). A summary of background information for selected tiger reserves is given in Table 1.

3. Methodology

When it comes to valuation and classifying ecosystem services, a multiplicity of frameworks exist in literature, including Total Economic Value (Pearce and Moran, 1994); Millennium Ecosystem Assessment (Hassan et al., 2005); Stock and Flow (Costanza, 2008); and Tangible and Intangible Benefits to communicate the diverse values of tiger reserves to different categories of target groups, such as policy-makers, non-governmental organizations and general citizens. A rigorous research process including thorough consultation with key stakeholders, the National Tiger Conservation Authority, State Forest Departments, Subject Experts, along with collection of data from secondary sources was followed. Several national and international experts were formally involved in the study since the beginning to guide the methodology. Most of the ecosystem services from tiger reserves emerge only in the long run after demarcating the boundaries of the reserves. However, at any cross section of time, say over one year, it is possible to estimate the incremental value of the ecosystem services. Averaging those over a cross-section of such tiger reserves would provide the annual contributions exclusively emerging on account of demarcating tiger reserve areas. Such an empirical approach is adopted in this study. No attempt has been made to estimate the contribution of tiger reserves over their life time.

Based on literature review, discussions with local and national experts and consultations with communities in and around each tiger reserve, relevant ecosystem services for each tiger reserve were separately identified. Wherever unavailability of data or robust methodology is limited to quantify the ecosystem services in monetary terms, the same was qualitatively described to demonstrate its significance. An attempt has been made to provide quantitative and qualitative estimates for 25 ecosystem services from the selected tiger reserves. Further, other summarization tools such as distribution of benefits across local, national and glo-

Table 1
Background information on selected tiger reserves.

Information	CTR	KTR	KZTR	PTR	RTR	STR
Year of establishment	1973	1973	2006	1978	1973	1973
Core Area (km^2)	821.99	917.43	625.58	881.00	1113.36	1699.62
Buffer Area (km^2)	466.32	1134.36	548.00	44.00	297.93	885.27
Total Area (km^2)	1288.31	2051.79	1173.58	925.00	1411.29	2584.89
Dominant ecosystems	Tropical Deciduous Forests, Grasslands and Rivers	Tropical Dry Deciduous Forests, and Meadows	Short and tall grasslands, River Floodplain, Woodlands	Tropical Evergreen Forests, and Rivers	Tropical Dry Deciduous Forests and Rivers	Mangrove Forests, Estuaries, Coastal
Other species (indicative list)	Elephant, Birds, Gharial	Hard Ground Barasingha, Leopard	Rhinoceros, Elephant, Wild Buffalo, Swamp Deer	Elephants, Nilgiri languor, Malabar giant squirrel, lion-tailed macaque	Wild dog, Mongoose, Marsh Crocodile	Gangetic River Dolphin, River Terrapin, Olive riley turtle
Other significance			WHS			WHS

CTR: Corbett Tiger Reserve; KTR: Kanha Tiger Reserve; KZTR: Kaziranga Tiger Reserve; PTR: Periyar Tiger Reserve; RTR: Ranthambore Tiger Reserve; STR: Sundarbans Tiger Reserve; WHS: World Heritage Sites are placed recognized by UNESCO as sites of outstanding universal value.

bal scale and ratio of flow benefits to management costs for each tiger reserve has been used to provide context to estimated economic values.

The following section briefly describes the methodology used for derivation of each of the ecosystem services values. Supplementary material provides more detailed information on the methodology including calculation formula, variables used and sources of data.

3.1. Employment generation

Tiger reserves are sources of employment. Apart from the staff involved in operation of day-to-day activities, tiger reserves provide valuable opportunities of employment for the local community. Considering the lack of employment opportunities at such remote places, a regular source of employment in the Tiger Reserve is highly valued by the local community. The economic value of employment has been estimated in terms of man-days generated by the tiger reserve for management as well as community-based eco-tourism. The local wage rate for unskilled labor prescribed by relevant administrative authorities has been used to derive site-specific economic values from employment generation.

3.2. Agriculture

Many of the tiger reserves are inhabited by people who may be involved in various occupations, including agriculture. While linkages of tiger reserve and agricultural productivity within the Reserve is often difficult to establish on account of paucity of information, wherever available, using such information from the surrounding areas has been used to estimate the economic value of agriculture inside a tiger reserve.

3.3. Fishing

Several tiger reserves have large water bodies which enable communities to fish. It may be noted that extraction of products from tiger reserves, including fishing is only allowed from the buffer areas of tiger reserves. The economic value of fishing has been estimated in the study using production estimates and local market price. Wherever production estimates from a reliable source were not available, secondary estimates were used to derive probable production figures and values.

3.4. Fuelwood

A large proportion of communities living inside and along the fringe villages of the tiger reserves are often dependent on the tiger reserve for fuelwood and energy requirements. As in the case of other products, extraction of fuelwood, wherever allowed, is only permitted from the buffer area of a tiger reserve. Fuelwood extraction in such tiger reserves is often regulated by the Eco-Development Committees (EDCs) and hence extraction estimates are generally documented. These estimates have been used in conjunction with the local market price of fuelwood to obtain its economic value.

3.5. Fodder/grazing

Depending on the tiger reserve, communities living inside and along the fringe villages may have grazing rights for their cattle in the buffer areas. Wherever applicable, the numbers of Adult Cattle Units (ACUs) dependent on tiger reserves for grazing were obtained through various reliable sources, including EDCs. Using standard forage quantity (Pandey, 2011) and the local market price of fodder, the economic value of provisioning of fodder has been estimated.

3.6. Timber

Sustainable harvesting of timber is discontinued in most of the tiger reserves in India. However, wherever applicable, the estimates of annual coupe from local management plans have been used in conjunction with the local market price of timber with due adjustments for management and transportation costs (Verma et al., 2014) to arrive at the economic value of timber obtained from tiger reserves. Existing timber biomass in the tiger reserves represents the stock benefits. Using the same method of pricing timber as mentioned above, existing growing stock of timber in tiger reserves (FSI, 2013a) is used to estimate the stock value of timber, additionally.

3.7. Non-wood forest produce (NWFP)

Many of the tiger reserves in India allow extraction of certain non-wood forest produce such as honey, *kendu* leaves etc., from the buffer areas. As such extractions are generally regulated through Eco-Development Committees (EDCs) attached to the reserves

hence the estimates of annual extraction have been obtained from relevant tiger reserve authorities such as offices of the Field Director of individual tiger reserves and Eco-Development Committees. The local market prices of such products have then been subsequently used to derive their economic values.

3.8. Gene-pool protection

The economic value of gene-pool protection is envisaged in terms of its biological information value and its insurance value. On account of lack of site-specific studies for estimating the economic value of gene-pool conservation, the method of benefits transfer has been used. Based on unit area values of gene-pool conservation for different types of ecosystems from a recent meta-analysis study (Costanza et al., 2014), the economic value for gene-pool protection has been derived. This helps to arrive at a futuristic value of an ecosystem to contribute to the growth of humanity through use of ecosystem / biodiversity.

3.9. Carbon storage

Tiger reserves are highly effective enablers to maintain carbon stored in forests, wetlands and other ecosystems in order to combat climate change. A recent study (FSI, 2013b) conducted by the Forest Survey of India has been used to obtain physical stock of carbon stored in different types of forests within these tiger reserves. Secondary sources were used to obtain stock of carbon stored in other types of ecosystems. To obtain the economic value of this physical stock, a recent study conducted at Yale University that has estimated the social cost / value of carbon for India has been used. According to a study (Nordhaus, 2011, p. 36), the social cost of carbon for India at a low discount rate is equal to USD 37.17 (2005 International) per ton of carbon. Necessary adjustments for Purchasing Power Parity[1] and inflation[2] have been subsequently made on the Social Cost of Carbon for India. It may be noted that this estimate is conservative considering that a literature review of the social cost of carbon indicate the estimates in the range of USD 55–250 per ton of carbon (Johnson and Hope, 2012).

[1] PPP for India with respect to the United States of America in 2005 = 15.66 (World Health Organization, 2005).

[2] WPI based on 2004–05 as base year: 2005 = 103.37; September 2014 = 185.

3.10. Carbon sequestration

Tiger Reserves are not only storehouses of carbon but they also add to their existing stock annually due to their effectiveness in reducing or halting land cover changes. Two approaches have been used in the study to estimate the physical quantity of carbon sequestered in selected tiger reserves. Firstly, the quantity of growing stock in forest ecosystems is used in conjunction with the forest type group physical rotation period derived from a recent study (Verma et al., 2014) to estimate the annual quantity of carbon sequestered. Alternatively, reliable secondary sources, wherever available, have been used to estimate carbon sequestration in the tiger reserves. Once the physical quantity of annual carbon sequestration has been obtained — either through derivation from growing stock or from secondary sources — the method described earlier for carbon stock in terms of the social cost of carbon for India has been used to estimate its economic value.

3.11. Water provisioning

The role of forests in augmenting water flow is widely acknowledged (Bruijnzeel, 1990; Le Maitre et al., 2014). The presence or absence of forests, has a profound impact on the hydrological processes at the watershed level. Two of the tiger reserves selected contain hydropower dams (and reservoirs) and cater to the needs of electricity generation and irrigation to a large service-shed. However, the benefits of anthropomorphic activities such as dams have not been attributed to the value of the tiger reserve, as the economics of such investments lead to energy generation and downstream agriculture, both of which are outside the domain of tiger reserves. The contribution of tiger reserves in enabling such infrastructure to generate these values have however been accounted for. For example the benefits of water recharge in streams, preventing siltation of reservoir, among others to a dam inside the tiger reserve can be attributed to the reserve and therefore, have been considered.

Two approaches have been used to estimate the value of provisioning of water. In tiger reserves where there is a reservoir, the marginal agricultural productivity due to irrigation benefits is estimated. In other tiger reserves, the additional water recharge on account of reduced runoff is estimated on the basis of a simple water balance equation (Kumar et al., 2006a). This is then used with the economic value of water for agriculture to estimate the economic value of additional water recharge. The price of water in India derived by a widely quoted study (Bhatia et al., 2000) at ₹[3] 8.5 per m^3 has been used. The estimate includes the economic cost of procuring water as well as its distribution and environmental costs. Adjusting the estimate by the Wholesale Price Indices, the current economic value of water used in the study is ₹ 18.43/m^3.

3.12. Water purification

Natural ecosystems within tiger reserves filter out and decompose organic wastes introduced into inland water, coastal and marine ecosystems. In doing so, tiger reserves avoid the cost of establishment and operation of water purification plants. Many of the tiger reserves are located upstream of rivers and streams that cater to drinking water requirements of numerous people. Wherever applicable, annual drinking water requirements met by the tiger reserve without the need of a water treatment plant have been estimated using guidelines provided by India's National Commission on Urbanization. Using the average cost of treating water for domestic supply from different Municipalities in India (Mathur and Thakur, 2003), the economic value of water purification services is estimated.

[3] Conversion Rate: 1 US$ = ₹ 65.

3.13. Soil conservation/sediment regulation

Due to dense canopy cover and thick humus layer on ground, tiger reserves play an important role in arresting soil erosion. The economic value of soil conservation has been estimated using the avoided offsite costs from sedimentation. Secondary literature has been used extensively to estimate the incremental contribution of ecosystems within tiger reserves in arresting soil erosion compared to managed ecosystems (Kumar et al., 2006a). The physical quantity of soil erosion avoided is used together with cost estimates by the Central Water Commission on earth excavation costs to derive the economic value of soil conservation services.

3.14. Nutrient cycling/retention

Forests and other natural ecosystems of tiger reserves prevent a significant erosion into nearby rivers and streams. An indirect benefit of avoidance of soil erosion is retention of nutrients which would have been lost forever along with the soil run-off. The natural ecosystems of tiger reserves however ensure that the flow of nutrients is regulated and their loss is avoided. One scientific approach for assessing this ecosystem service is to use the replacement cost of fertilizers (Croitoru, 2007; Eshwara Reddy et al., 2012; IIED, 2003; Johnson et al., 2001; Kumar et al., 2006b; Ninan and Inoue, 2013; Perrot-Maitre and Esq, 2001; Verweij et al., 2009), which has been deployed here.

Owing to soil erosion in the absence of forests, the nutrients will be lost along with sediments. Depending on the context and landscape of tiger reserves, the economic value of nutrient cycling or nutrient retention ecosystem service has been estimated. The approaches, however, are largely the same. Using estimates of soil erosion avoided and concentration of NPK (nitrogen, phosphorus and potassium) in soil derived from secondary sources, the physical quantity of nutrient loss avoided by tiger reserves is estimated. This physical estimate is then used along with the prevailing local price of NPK fertilizers in India to obtain the economic value of nutrient cycling/retention service from tiger reserves.

3.15. Biological control

Forests and other natural ecosystems within the tiger reserves moderate the risk of infectious diseases by regulating the populations of disease organisms (viruses, bacteria and parasites), their hosts, or the intermediate disease vectors (e.g. rodents and insects). On account of lack of site-specific studies for estimating the economic value of this ecosystem service related to biological control including regulation of diseases, the method of benefits transfer has been used. Based on unit area values of biological control for different types of ecosystems from a recent meta-analysis study (Costanza et al., 2014), the economic value of biological control has been derived.

3.16. Moderation of extreme events

Natural vegetation within the tiger reserves has the potential to dramatically reduce the damage caused by cyclone storms, large waves or flash floods. The economic value of this ecosystem service from tiger reserves has been estimated through two components – damage to life and damage to property. Using secondary literature, estimates of these components at the tiger reserve or neighboring regions is identified. Using the benefit transfer method, the estimates are then derived for the tiger reserves wherever applicable.

3.17. Pollination

Tiger reserves provide natural habitats to pollinators which consequently help in increasing the quantity and quality of pollinator-dependent crops in the surrounding areas of tiger reserves. On account of lack of site-specific studies for estimating the economic value of pollination, the method of benefits transfer has been used. Based on unit area values of pollination for different types of ecosystems from a recent meta-analysis study (Costanza et al., 2014), the economic value of the pollination service has been derived.

3.18. Nursery function

Some tiger reserves provide suitable reproduction habitats for various species. While this service pertains to all types of wildlife, the current study has limited its scope to nursery function for aquatic animals, specifically for marine catch. Using secondary estimates and models developed at other sites, the quantity of off-shore marine catch attributable to a unit area of tiger reserve is estimated (I. Nagelkerken et al., 2002; Tse et al., 2008). Together with the local market price of catch, the economic value of nursery function from tiger reserve are derived.

3.19. Habitat/refugia

Tiger reserves provide suitable living space and food for wild animals. Further, intact natural ecosystems within the tiger reserves with their buffering functions (e.g. cooling effects, interception of precipitation and evapo-transpiration, water storage and wind shield) significantly contribute to the mitigation of, and adaptation to extreme weather events. For example, the shade of riparian forests can help reduce thermal stress to aquatic life as climate warming intensifies (FAO, 2013). In an attempt to move beyond instrumental value, the economic value of habitat/refugia for wildlife is envisaged. On account of lack of site-specific studies for estimating the economic value of habitat/refugia, the method of benefits transfer has been used. Based on unit area values of habitat/refugia for different types of ecosystems from a recent meta-analysis study (Costanza et al., 2014), the economic value of this tiger related ecosystem service has been derived.

3.20. Cultural heritage

Tribal settlements within tiger reserves also inherit a cultural heritage that needs to be preserved. The hidden value of indigenous knowledge inherited among local communities residing in these natural landscapes is still to be explored and used as a sustainable development indicator by academicians and development practitioners (Díaz et al., 2015). Because of the lack of appropriate valuation methodologies for valuing such qualitative services, quantification in terms of support for those tribal population and their endemism is used to reflect the cultural heritage value associated with tiger reserves.

3.21. Recreation

Tiger reserves are major tourist attractions. Acknowledging that receipts from gate fees do not adequately represent the utility derived by tourists in visiting such places, consumer surplus using a travel cost method has been derived from various secondary studies. Using the latest tourist visiting rates, the economic value of recreation services from tiger reserves has been estimated.

3.22. Spiritual tourism

Forests have an inseparable relation with the myths, rituals, ethos and festivals of communities living in fringe areas as well as those at a distance (Dudley et al., 2005). Many places of pilgrimage and worship are located inside tiger reserves in India. While avoiding quantification of economic value for this service, the number of pilgrims visiting such places inside the tiger reserve has been used to qualitatively represent the value of a tiger reserve.

3.23. Research, education and nature interpretation

Tiger reserves are one of the most sought-after places for conducting research due to their wilderness and long history of relatively undisturbed natural processes. The pristine tracks of natural landscapes provide an outdoor or live laboratory on many conservation practices and ecological processes. Such advancement in knowledge of the natural laws can ultimately be used for the benefit of humankind. Further, in the backdrop of climate change and associated adaptations required by ecological systems and human beings, tiger reserves also have high option value for providing a suitable environment for research and thereby gain important insights that may be critical for our survival (Dudley et al., 2010). Due to limitations in available methodologies for estimating its monetary value, the ecosystem service of research, education and nature interpretation has been qualitatively described in terms of number of Ph.D. Thesis, M.Sc. Thesis, research and technical papers on various ecology related issues.

3.24. Gas regulation

Natural ecosystems within the tiger reserves regulate chemical composition of various atmospheric gases such as oxygen, ozone and sulphur oxides. On account of lack of site-specific studies for estimating the economic value of gas regulation, the method of benefits transfer has been used. Based on unit area values of gas regulation for different types of ecosystems from a recent meta-analysis study (Costanza et al., 2014), the economic value of this ecosystem service has been derived.

3.25. Waste assimilation

Similar to water purification services, natural vegetation and biota within these tiger reserves break down xenic nutrients and compounds and help in pollution control and detoxification. Wherever relevant data were available, the economic value of this ecosystem service has been estimated using the avoided cost approach of establishing and operating a waste treatment plant. In case of paucity of data for estimating the economic value of waste assimilation, the method of benefits transfer has been used. Based on unit area values of waste assimilation for different types of ecosystems from a recent meta-analysis study (Costanza et al., 2014), the economic value of waste assimilation service has been derived.

4. Results

Based on the methodology described above, the estimated economic values for various ecosystem services at each of the selected tiger reserve can be read in Table 2. The values are derived for the year 2014 and the exchange rate used is 1 US$ = INR 65. The findings indicate that the monetary value of flow benefits emanating from selected tiger reserves range from US$ 128 million to US$ 271 million annually. In terms of unit area, this translates into US$ 862 to US$ 2923 per hectare per year. In addition, selected tiger reserves protect and conserve stocks valued in the range of US$ 344 million to US$ 10.08 billion.

Table 2
Estimated economic value of various ecosystem services in selected tiger reserves for the year 2014.

Ecosystem Service/Tiger Reserve (million US$)	Corbett	Kanha	Kaziranga	Periyar	Ranthambore	Sundarbans
Employment Generation	1.3			0.4		0.6
Agriculture				0.3		
Fishing				0.05		24.6
Fuelwood	0.004	1.7		0.1		
Grazing	0.4	8.4		0.05		
Timber	0.01	5.3		0.01		
Standing stock	3863.1	2658.2	329.2	4611.4	679.8	9672.3
NWFP		1.1		0.03		0.1
Gene-pool Protection	163.8	190.9	53.7	120.9	109.2	44.2
Carbon Storage	163.8	315.4	15.2	257.8	77.1	370.8
Carbon Sequestration	3.3	3.4	0.3	2.8	1.0	7.1
Water Provisioning	24.8	8.6		62.3	1.8	
Water Purification	8.5			7.4		
Sediment Regulation	0.2	0.3		0.2	0.1	
Nutrient Cycling/Retention	0.8	0.9		0.6	0.5	45.7
Biological Control	1.2	1.4	2.3	2.0	0.8	1.6
Moderation of Extreme Events						4.2
Pollination	3.2	3.8	1.3	2.6	2.2	4.3
Nursery Function						79.5
Habitat/Refugia	4.2	4.9	88.2	54.8	2.8	5.5
Recreation	0.5	5.9	0.3	6.5		0.6
Gas Regulation	1.3	1.5	0.4	0.9	0.9	1.7
Waste Assimilation	13.0	15.1	3.6	9.1	8.6	23.1
Stock benefits (million US$)	4026.9	2973.5	344.5	4869.2	756.9	10088.8
Flow benefits (million US$/yr)	226.5	253.1	150.1	271.1	127.9	197.0
Flow benefits per hectare (US$/ha/yr)	1754	1231	1462	2923	862	769
Management costs (million US$/yr)	0.57	0.93	0.75	0.59	0.47	0.37
Investment multiplier	401	273	200	459	273	530
Distribution of flow benefits: Local-National-Global (%)	8-53-39	10-49-41	2-38-59	10-52-38	4-51-45	16-39-44
Proportion of unmarketed benefits (%)	99	94	100	100	100	87

In terms of attractiveness for enhanced investment in these tiger reserves, the estimates show that the investment multiplier, i.e. the ratio of flow benefits to management costs for each tiger reserve, range from 200 to 530. It was also found that the quantum of benefits realized from tiger reserves at local level is many folds smaller than those accruing at the national and global level, those accruing at national and global level being generally similar.

The findings also indicate that a large proportion of flow benefits (as well as stock) from tiger reserves are intangible, and hence often unaccounted for in market transaction. For example, Sundarbans Tiger Reserve provides waste assimilation services to the city of Kolkata, but this service is not traded in the market. Kaziranga Tiger Reserve's unique wetland ecosystems serve as important nurseries for numerous fish population including Indian Major Carps and recharge the fish stocks in the Brahmaputra river and its tributaries following annual flooding. This service is neither recognized nor valued in the market.

This marks the first major attempt to estimate economic values from a number protected areas in India with consistent framework and methodology. Considering this and the fact that no primary data was collected, availability of existing data was encountered as the biggest challenge for the analysis. For some tiger reserves and a few of the ecosystem services, unavailability of local data led us to use data available at a larger scale or outside the landscape in an attempt to demonstrate the full array of ecosystem services emanating from tiger reserves. While attempts were made to adjust the data to suit local context, there remains considerable scope to refine estimates for few reserves and ecosystem services based on local data such as opportunity cost of extracting forest products.

5. Discussion

We argue that demonstration of hidden values of tiger reserves is imperative to help decision-makers recognize the folly of environmental destruction and work to safeguard these biodiversity havens. Although it could be possible to argue that the a particular tiger reserve, for instance say Sundarbans delta should be protected for its intrinsic value, it is logical, and perhaps far more effective to add the utilitarian argument that Sundarbans also provide valuable services in protecting coastal development from storms and acting as nurseries for fishes worth billions of dollars. Below we briefly discuss implications of improved understanding of significant economic values from tiger reserves on policy as well as practices on protected areas.

5.1. Policy

Where justified by broader benefits, economic valuation can help in establishing effective policies and mechanisms on payment for ecosystem services to equitably share benefits and costs of conservation. Once again, Periyar or Kanha tiger reserve can be illustratively cited as good cases of recreation benefits, as viewed from their values. This need is also resonated by the finding that while costs of establishing and maintaining tiger reserves are generally local, the benefits are mostly realized at the national and global level, thus creating barriers for their effective protection.

In the light of growing awareness of life-supporting functions of many ecosystem services and advanced technology to make use of genetic diversity, benefits such as gene-pool protection are likely to appreciate rapidly. Economic valuation can help in uncovering and recognizing these intangible values and hence can be considered in policy actions. Further, adequate investment on natural capital contained in tiger reserves is essential to ensure the flow of ecosystem services in future, and is economically rational based on the findings. The survey estimates of Investment Multipliers from Kaziranga or Kanha or Ranthambore are good illustration on enhancing investments rates in tiger reserves.

5.2. Practice

A focus on ecosystem services also has the potential to inform zoning and management of tiger reserves at the local landscape level, create partnerships with other local policy-makers to improve effectiveness and ameliorate funding for such areas. For instance, from the limited survey experience, for instance, water provisioning in Periyar has enabled local reserve managers to become part and parcel of the local communities. Local authorities, including tiger reserve managers, are intermediaries between actors with diverse social and economic interests. A proper analysis of what ecosystem services are available from a tiger reserve and who has access to them can therefore assist in understanding how costs and benefits of conservation are distributed, and thus help in addressing conflicts related to tiger reserves.

Further in order to conserve biological diversity and ensure the flow of a wide range of ecosystem services from tiger reserves, it is imperative to expand the network of tiger reserves as to make them comprehensive and representative. It is essential to integrate management of tiger reserves into the broader landscape and ecological connectivity among the tiger reserves and their wider environment. Connectivity and exchange of gene-flow is critical for increasing ecosystem resilience, their ability to mitigate environmental risks, e.g. by supporting ecosystem-based adaptation to climate change.

The findings also demonstrate that investing in natural capital such as tiger reserves supports a wide range of economic sectors and expands our options for economic growth and sustainable development. Such investments can be cost-effective responses to the climate change crisis, offer value for money, support local economies, create jobs and maintain ecosystem benefits for the long term. Biodiversity and ecosystem services in these tiger reserves are natural assets with a key role to play in future economic strategies seeking to promote growth and prosperity in India.

As articulated earlier, this is one of the first attempts to estimate economic values of protected areas in India. We hope that the analysis demonstrates how such an analysis can help in protected area management as well as in designing appropriate policies that help in meeting conservation as well as development objectives in India simultaneously. We also hope that the research community will be motivated to take up further research to refine such estimates and highlight a wider array of values from protected areas that matter to people. Some of the areas for further research include better understanding of water-related linkages between protected area status and waterbodies, value of genetic information such as cultivars, value of protected areas in adapting to climate change, and cultural and inspirational benefits.

6. Conclusion

The paper presents the methodology used for estimating economic values of various ecosystem services emanating from six tiger reserves in India and the estimates so derived. The findings indicate that although tiger reserves make a large contribution to local and national economies, inadequate assessment of these values can substantially impact their protection status. The paper also shows that enhanced investment in these tiger reserves is economically rational and has the potential to further enhance the benefits accrued from them. It is however important to emphasise that economic valuation is not a panacea for all contemporary tiger conservation issues. It is just one of the whole orchestra of instruments available for effecting the complex task of sustainably managing tiger reserves in India.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecoser.2017.05.006.

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