

ECONOMIC VALUATION OF TIGER RESERVES IN INDIA

A VALUE+ APPROACH

JANUARY 2015



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Centre for Ecological Services Management (CESM),
Indian Institute of Forest Management, Bhopal



SUPPORTED BY

National Tiger Conservation Authority
Ministry of Environment, Forest & Climate Change,
Government of India,
First Floor, East Tower, NBCC Place,
Bhishma Pitamah Marg,
New Delhi - 110003, India

AUTHORS

Madhu Verma,
Professor, Indian Institute of Forest Management

Dhaval Negandhi,
Subject Expert, Indian Institute of Forest Management

Chandan Khanna,
Subject Expert, Indian Institute of Forest Management

Advait Edgaonkar,
Assistant Professor, Indian Institute of Forest Management

Ashish David,
Assistant Professor, Indian Institute of Forest Management

Gopal Kadekodi,
Honorary Professor, Centre for Multidisciplinary Research

Robert Costanza,
Chair in Public Policy, Australian National University

Rohit Singh,
Subject Expert, Indian Institute of Forest Management

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design@innomedia.in

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STUDY EXECUTION TEAM



STUDY MENTORS

Rajesh Gopal, Giridhar Kinhal, S. P. Yadav and Sanjay Kumar

LEAD AUTHORS

Madhu Verma, Dhaval Negandhi, Chandan Khanna,
Advait Edgaonkar and Ashish David

CONTRIBUTING LEAD AUTHORS

Gopal Kadekodi, Robert Costanza and Rohit Singh

STUDY ADVISORS

Anmol Kumar, E. Somanathan, Himmat Negi, Ida Kubiszewski,
N. S. Bisht, P. K. Sen, Qamar Qureshi, Rajesh Kumar,
Rucha Ghate, Swapan Mehra and Y. V. Jhala

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(Madhu Verma)

On behalf of the entire study team

Bhopal, Dated January 20, 2015.





राज्य मंत्री (स्वतंत्र प्रभार)
पर्यावरण, वन एवं जलवायु परिवर्तन
भारत सरकार

Minister of State (Independent Charge)
Environment, Forests &
Climate Change
Government of India

MESSAGE

Conservation of tiger has attracted a great deal of global attention due to its importance as an umbrella species, whereby its conservation also protects other endangered wildlife and ecosystems. Given that we have the maximum number of tigers in the wild amongst the tiger range countries, India has accepted the responsibility of ensuring its survival. The country has taken a pioneering initiative for conserving its national animal through the Project Tiger by establishing 47 tiger reserves since 1973 - covering over 2 per cent of country's geographical area, approximately 10 per cent of country's recorded forest area and more than 40 per cent of country's total protected area. In addition to ensure perpetuity of evolution in these untouched areas of wilderness, these tiger reserves provide a lot of benefits such as provisioning of clean air and water, protection of genetic information, alleviating natural hazards such as storms and floods, and mitigating climate change by storing and sequestration large amounts of carbon, among others.

The current study on 'Economic Valuation of Tiger Reserves in India: A VALUE+ Approach' executed by Indian Institute of Forest Management with initiation and support of National Tiger Conservation Authority is a first-of-its-kind study not only in the country but across the world. The study is a commendable attempt to provide an assessment of economic benefits from tiger reserves across a range of tiger landscapes in India. While a large proportion of benefits that these tiger reserves provide are difficult to estimate, the study provides quantitative and qualitative estimates of those benefits which manifest the important

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Place: New Delhi

but unaccounted national and global contribution of these tiger reserves. These findings provide adequate justification for enhanced investment in such areas which is critical to ensure continued flow of vital life-supporting ecological, economic, social and cultural services from these genetic repositories. The findings also highlight that conservation of habitats where tigers reside is perhaps as important as the number of tigers themselves. Acknowledging the information for the support of policy making from such a study, I recommend similar studies to be carried out not only across all tiger reserves in India but also across tiger range countries involving multiple agencies such as the Global Tiger Forum to highlight the benefits of conserving tiger habitats.

Altogether, the study presents much needed information for policy makers, tiger reserve managers, conservationists, academia and other stakeholders which would help in inculcating an appreciation for the benefits from conservation of tiger reserves and acknowledging their varied contribution to various ecological and economic systems. I complement NTCA and IIFM for this sincere and timely effort and extend my best wishes on the release of the study report. I am confident that the report shall be found useful by all stakeholders involved in and committed to the conservation of tigers and its habitat.


(Prakash Javadekar)

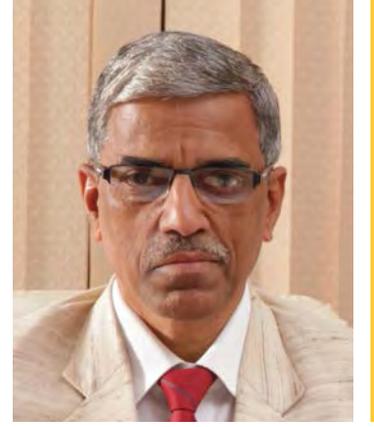
प्रकाश जावडेकर

निर्देशक

भारतीय वन प्रबंधन संस्थान

भोपाल

Director
Indian Institute of
Forest Management
Bhopal



PREFACE

Humans as apex species are facing a variety of crises due to loss of biodiversity values. While the costs of biodiversity losses are felt but they can go unnoticed at national and international levels due to non availability of robust valuation systems, leading to weaker policies. Public policies have an essential role to play in ensuring that the main types of benefits from nature are identified and applied in decision making – avoiding gross underestimation of the overall value of conservation and sustainable use of biodiversity and ecosystem services. Developing our capacity to measure and monitor biodiversity, ecosystems and the provisioning of such services is thus an essential step towards better management of our natural capital. Indian Institute of Forest Management has been aggressively pursuing development of useful policy briefs for conservation of biodiversity since its establishment. In furthering this cause, a study titled “Economic Valuation of Tiger Reserves in India: A VALUE+ Approach” initiated and supported by the National Tiger Conservation Authority, Ministry of Environment, Forests and Climate Change, Govt. of India has been undertaken by IIFM. Following a rigorous research process in collaboration with a team of experts and a thorough consultation process with relevant stakeholders, economic value of six selected tiger reserves have been provided. Areas in the report which deserve a special mention include:

- Quantitative and qualitative measures of as many as 25 ecosystem services from selected tiger reserves across various tiger landscapes of the country.
- Use of a range of summarization tools such as investment multiplier and distribution of economic values across local, national and global scale to provide context to estimated values.

- Application of a tool to map ecosystem services in two of the selected tiger reserves.
- Development of a willingness to pay instrument to estimate non-use values associated with tiger conservation in India. Estimating what it would cost to re-create a tiger reserve.

Investing in natural capital such as tiger reserves supports a wide range of economic sectors and maintains and expands our options for economic growth and sustainable development. Such investments can be a cost-effective response 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.

I take this opportunity to thank the National Tiger Conservation Authority for assigning this first-of-its-kind study to IIFM and compliment the study team for their best endeavours in bringing out this report. I hope that following the intense research process adopted, the economic value of tiger reserves is reflected in the report and it will find wide acceptance among the stakeholders. I am sure that the findings of the report will assist the policy makers appreciating the economics of tiger conservation in India. Developing and further strengthening policy frameworks for conservation of natural ecosystems and help to manage the transition to a resource efficient economy is the way forward.

(Giridhar Kinhal)

गिरधर किन्हल

Date: 20 January 2015

Place: New Delhi



KEY MESSAGES

While the underlying objective of establishing tiger reserves under the Project Tiger is to ensure continuity of natural evolutionary processes in the wild, tiger reserves also provide a range of associated economic, social, cultural and spiritual benefits, also termed as ecosystem services.

The current study attempts to provide quantitative and qualitative estimates of the natural capital stored in selected tiger reserves of India to make benefits emanating from and embedded in these tiger reserves visible to economies and society. Recognition of benefits is likely to create an evidence base which will pave the way for more targeted and enhanced investment in these repositories of genetic information.

Acknowledging our limited understanding of natural processes and their associated values, the study uses a VALUE+ approach. The 'VALUE' represents all benefits for which monetary economic valuation is possible and conducted, while the '+' represents all those benefits for which economic valuation is currently not possible either on account of lack of accepted methodologies, knowledge and/or understanding. The economic values derived in the study are thus conservative.

The study provides quantitative and qualitative estimates for as many as 25 ecosystem services from selected tiger reserves. The study findings indicate that the monetary value of flow benefits emanating from selected tiger reserves range from ₹ 8.3 to 17.6 billion annually. In terms of unit area, this translates into ₹ 50,000 to 190,000 per hectare per year. In addition, selected tiger reserves protect and conserve stock valued in the range of ₹ 22 to 656 billion.

In the light of growing awareness of life-supporting functions of many ecosystem services and advanced technology to make use of genetic diversity, the economic value of this stock is likely to appreciate rapidly.

Study findings also indicate that a large proportion of flow benefits (as well as stock) are intangible, and hence often unaccounted for in market transaction.

Adequate investment in tiger reserves is essential to ensure the flow of ecosystem services in future, and is economically rational based on the study findings.

Apart from economic valuation of ecosystem services from tiger reserves, the study also demonstrates application of InVEST – a suite of tools used for mapping ecosystem services. The results indicate potential use of InVEST in identifying ecosystem service hotspots and providing valuable management prescriptions for tiger reserve managers.

Further, while natural landscapes such as tiger reserves in all practicality can never be recreated, the study has made an attempt to estimate the cost of inaction if inadequate protection to existing tiger reserves necessitate establishment of new ones. Based on only a few associated costs, creating a new tiger reserve in the Pilbhit-Dudhwa landscape covering an area of approximately 1000 km² would cost approximately ₹ 500 billion.

In order to conserve biological diversity and ensure the flow of a wide range of ecosystem services from tiger reserves, it is essential to integrate management of tiger reserves into the broader landscape and enhance / restore ecological connectivity among these tiger reserves and their wide environment.

EXECUTIVE SUMMARY

India holds over half of the world's tiger population and is considered to have the best chance for saving the population of this magnificent animal in the wild. Conservation of India's national animal gains significance on account of its role at the apex of the food chain. Its presence is vital in regulating and perpetuating ecological processes and systems. 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 47 tiger reserves across the country, covering over 2 per cent of India's geographical area.

Besides conserving wild, tiger reserves also provide a range of associated economic, social, cultural and spiritual benefits, which are also termed as ecosystem services. Tiger reserves support human life by protecting fish nurseries and agricultural genetic material (wild cultivars) and providing cheap, clean drinking and irrigation water from forests. Tiger reserves not only help in mitigating natural disasters such as floods and cyclonic storms, but the genetic material is also a source of many medicines and drugs. Natural and cultural resources in tiger reserves are important drivers of tourism, supporting local earnings and employment. In addition, these natural landscapes play an important role in ecosystem-based approaches to climate

change adaptation and contribute to mitigation by storing and sequestering carbon.

While conservation initiatives till now have largely focused on in-situ conservation of tigers by establishing tiger reserves in India, an important aspect that needs further research is 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.

The current study provides conservative estimates of the economic value of 6 selected tiger reserves in India: Corbett, Kanha, Kaziranga, Periyar, Ranthambore and Sundarbans. These tiger reserves have been selected from different tiger landscapes of the country to provide indicative economic values associated with tiger conservation in India in various ecological and socio-economic contexts. Apart from quantitative and qualitative estimates of ecosystem services from selected tiger reserves, the study also explores other dimensions of values. It does so through mapping of ecosystem services in two of the selected tiger reserves and estimating what it would cost to re-create a tiger reserve. It is important to note that the objective of the study is neither to compare the benefits of the tiger reserve with any economic venture such as mining, nor compare the benefits across selected tiger reserves.



METHODOLOGY

Acknowledging our limited understanding of natural processes and their associated values, the study uses a VALUE+ approach. The 'VALUE' represents all benefits for which monetary economic valuation is possible and conducted based on available knowledge and information. The '+' represents all those benefits for which economic valuation is currently not possible either on account of lack of accepted methodologies, knowledge and/or understanding. The economic values derived in the study are thus conservative.

The study has used a multiplicity of frameworks including Total Economic Value; Millennium Ecosystem Assessment; Stock and Flow; and Tangible and Intangible Benefits to communicate the diverse values embedded and emanating from tiger reserves.

A rigorous research process including thorough consultation with key stakeholders has been followed for the study. These include consultation with members of the National Tiger Conservation Authority, State Forest Departments, Subject Experts, secondary sources, workshops, roundtables, expert team consultation, primary data collection and progress review process. Several national and international experts were formally involved in the study since the beginning to guide methodology development.

ECONOMIC VALUATION OF ECOSYSTEM SERVICES FROM TIGER RESERVES

Based on literature review, discussions with local and national experts and consultations with communities in and around each tiger reserve, the study identified relevant ecosystem services for each tiger reserve. Wherever unavailability of data or robust methodology limited the ability to quantify the service in monetary terms, the service has been qualitatively described to demonstrate its significance. The study has attempted to provide quantitative and qualitative estimates for as many as 25 ecosystem services from selected tiger reserves. Further, other summarization tools such as distribution of benefits across local, national and global scale and ratio of flow benefits to management costs for each tiger reserve were used to provide context to economic values.



CORBETT TIGER RESERVE

A representative of Terai-arc landscape, Corbett is referred to as the land of roar, trumpet and song (attributed to tigers, elephants and birds respectively). It is estimated that the Corbett Tiger Reserve (CTR) provides flow benefits worth ₹ 14.7 billion (₹ 1.14 lakh / hectare) annually. Important ecosystem services originating from CTR include gene-pool protection (₹ 10.65 billion year⁻¹), provisioning of water to downstream districts of Uttar Pradesh (₹ 1.61 billion year⁻¹) and water purification services to the city of New Delhi (₹ 550 million year⁻¹). Other important services emanating from Corbett include generation of employment for local communities (₹ 82 million year⁻¹), provision of habitat and refugia for wildlife (₹ 274 million year⁻¹) and sequestration of carbon (₹ 214 million year⁻¹).



KANHA TIGER RESERVE

A typical geo-physiographical representative of the Central India Highlands, Kanha is internationally renowned for successful conservation of two endangered wildlife species, viz. the Royal Bengal Tiger and the Central Indian Barasingha. It is estimated that the Kanha Tiger Reserve (KTR) provides flow benefits worth ₹ 16.5 billion (₹ 0.80 lakh / hectare) annually. Important ecosystem services originating from KTR include gene-pool protection (₹ 12.41 billion year⁻¹), provisioning of water to downstream regions (₹ 558 million year⁻¹) and provisioning of fodder in buffer areas (₹ 546 million year⁻¹). Other important services emanating from Kanha include recreation value (₹ 384 million year⁻¹), provision of habitat and refugia for wildlife (₹ 319 million year⁻¹) and sequestration of carbon (₹ 219 million year⁻¹).



KAZIRANGA TIGER RESERVE

Kaziranga is a World Heritage Site inhabited by the world's largest population of one-horned rhinoceroses. In addition, it also supports the population of tigers and elephants. It is estimated that the Kaziranga Tiger Reserve (KZTR) provides flow benefits worth ₹ 9.8 billion (₹ 0.95 lakh / hectare) annually. Important ecosystem services originating from KZTR include habitat and refugia for wildlife (₹ 5.73 billion year⁻¹) and gene-pool protection (₹ 3.49 billion year⁻¹). Other important services emanating from Kaziranga include recreation value (₹ 21 million year⁻¹), biological control (₹ 150 million year⁻¹) and sequestration of carbon (₹ 17 million year⁻¹).



PERIYAR TIGER RESERVE

Periyar Tiger Reserve is a representative of the southern western Ghats with high endemism. It is estimated that the Periyar Tiger Reserve (PTR) provides flow benefits worth ₹ 17.6 billion (₹ 1.9 lakh / hectare) annually. Important ecosystem services originating from PTR include gene-pool protection (₹ 7.86 billion year⁻¹), provisioning of water to districts of Tamil Nadu (₹ 4.05 billion year⁻¹) and provision of habitat and refugia for wildlife (₹ 3.55 billion year⁻¹). Other important services emanating from Corbett include generation of employment for local communities (₹ 25 million year⁻¹), water purification services to nearby towns and districts (₹ 483 million year⁻¹) and recreation value (₹ 425 million year⁻¹).



RANTHAMBORE TIGER RESERVE

Ranthambore is undoubtedly the most popular tiger reserve and marks the transition zone between the true desert and seasonally wet peninsular India. It is estimated that the Ranthambore Tiger Reserve (RTR) provides flow benefits worth ₹ 8.3 billion (₹ 0.56 lakh / hectare) annually. Important ecosystem services originating from RTR include gene-pool protection (₹ 7.11 billion year⁻¹), provisioning of water to the neighbouring region (₹ 115 million year⁻¹) and provisioning of habitat and refugia for wildlife (₹ 182 million year⁻¹). Other important services emanating from Ranthambore include generation of cycling of nutrients (₹ 34 million year⁻¹) and sequestration of carbon (₹ 69 million year⁻¹), apart from housing the Ganesh Temple visited by about 10 lakh pilgrims every year.



SUNDARBANS TIGER RESERVE

Sundarbans forms the largest contiguous track of mangrove forest found anywhere in the world and is the only mangrove forest inhabited by tigers. It is estimated that the Sundarbans Tiger Reserve (STR) provides flow benefits worth ₹ 12.8 billion (₹ 0.50 lakh / hectare) annually. Important ecosystem services originating from STR include nursery function (₹ 5.17 billion year⁻¹), gene-pool protection (₹ 2.87 billion year⁻¹), provisioning of fish (₹ 1.6 billion year⁻¹) and waste assimilation services (₹ 1.5 billion year⁻¹). Other important services emanating from Sundarbans include generation of employment for local communities (₹ 36 million year⁻¹), moderation of cyclonic storms (₹ 275 million year⁻¹), provision of habitat and refugia for wildlife (₹ 360 million year⁻¹) and sequestration of carbon (₹ 462 million year⁻¹).

MAPPING OF ECOSYSTEM SERVICES

In the last few years, the ecosystem valuation process has evolved from analytical models to GIS-based spatial simulation models. These simulation models are able to comprehend the local ecosystem characteristics in a better way; thus enriching the overall valuation. Such a mapping of ecosystem services can provide very useful management prescriptions for tiger reserve managements to optimize benefits from the tiger reserve. The current study applies one of the most widely used tools for mapping ecosystem services, Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) developed by the Natural Capital Project at Stanford University.

InVEST is a data-hungry tool. On account of paucity of time for collecting the required information, InVEST could only be applied at two of the selected tiger reserves: Kanha and Periyar. Further, 3 of the 17 models in the InVEST 3.0 package were applied at these two tiger reserves. These include the Carbon Storage and Sequestration: Climate Regulation Model, the Water Yield: Reservoir Hydropower Production Model and the Sediment Retention: Avoided Dredging and Water Purification Model.

The results of the InVEST exercise are envisaged to assist in identification of ecosystem service hotspots within tiger reserves and thus better equip tiger reserve managers in conservation and management of such areas. Its application in all tiger reserves across the country is thus highly recommended but will require standardized collection of specific input data necessary for InVEST models.



COST OF RE-CREATING A TIGER RESERVE AND WILLINGNESS TO PAY FOR TIGER CONSERVATION

While natural landscapes such as tiger reserves in all practicality can never be recreated, the study has made an attempt to estimate the cost of inaction if inadequate protection to existing tiger reserves necessitate establishment of new ones. Based on the objective of maximum conservation gain and minimum human distress, a patch of 1069 km² in the Pilbhit-Dudhwa landscape was identified for a hypothetical exercise and basic minimum costs for establishing a tiger reserve on the patch were estimated.

The major costs involved include land acquisition, rehabilitation, resettlement and habitat development. The conservative cost estimate based on categories of costs included is approximately equal to ₹ 491,800 million, which translates to approximately ₹ 4.62 million hectare⁻¹. It is important to note that the estimate only includes a handful of costs and does not account for many other costs due to paucity of required information. Further, even after incurring such an astronomical cost, it cannot be guaranteed that the new area would be able to conserve genetic repository comparable to any existing tiger reserve.

Further, an online survey to assess the willingness to pay for tiger conservation was also carried out in the study. While this was an attempt to provide an indication of non-use values associated with tiger conservation, limitations in seeking responses from a representative sample and low response rate to the survey meant that the results cannot be extrapolated to draw any meaningful conclusions at the national level. Considering the fact that a large proportion of respondents were willing to pay for tiger conservation, a dedicated study may be required to objectively estimate the same.



CONCLUSIONS & WAY FORWARD

The study findings indicate that the monetary values of flow benefits emanating from selected tiger reserves range from ₹ 8.3 to 17.6 billion annually. In terms of unit area, this translates into ₹ 50,000 to 190,000 per hectare per year. In addition, selected tiger reserves protect and conserve stock valued in the range of ₹ 22 to 656 billion. In the light of growing awareness of life-supporting functions of many ecosystem services and advanced technology to make use of genetic diversity, the economic value of this stock is likely to appreciate rapidly. Study findings also indicate that a large proportion of flow benefits (as well as stock) are intangible, and hence often unaccounted for in market transaction. Economic valuation can help in recognizing these intangibles and hence have been considered in policy actions. Further, adequate investment in natural capital contained in tiger reserves is essential to ensure the flow of ecosystem services in future, and is economically rational based on the study findings.

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. Local authorities, including tiger reserve managers, are intermediaries between actors with diverse social and economic interests. A proper understanding 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. Where justified by broader benefit, economic valuation consequently can help in establishing effective policies and mechanisms for payment of ecosystem services to equitably share benefits and costs of conservation.

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. Further, it is essential to integrate management of tiger reserves into the broader landscape and enhance / restore ecological connectivity among these tiger reserves and their wide 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.

selected tiger reserves
provide flow benefits
in the range of

₹ 50000

TO

₹ 190000

hectare⁻¹ year⁻¹

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GLOSSARY

Benefits Transfer Approach:

Economic valuation approach in which estimates obtained in one context are used to estimate values in a different context after due adjustment.

Biodiversity: The variability among living organisms, including terrestrial, marine, and other aquatic ecosystems. Biodiversity includes diversity within species, between species, and between ecosystems.

Canopy: The cover of branches and foliage formed by the crowns of trees.

Canopy Density: The relative completeness of canopy usually expressed as a decimal coefficient, taking closed canopy as unit.

Cultural Services: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection and aesthetic experience.

Discount Rate: A rate used to determine the present value of future benefits.

Direct-use Value (of ecosystems): The benefits derived from the services provided by an ecosystem that are used directly by an economic agent. These include consumptive uses (e.g. harvesting goods) and non-consumptive uses (e.g. enjoyment of scenic beauty).

Double Counting of Services: Erroneously including the same service more than once in an analysis.

Ecosystem Services: The direct and indirect contributions of ecosystems to human well-being. The concept 'ecosystem goods and services' is synonymous with ecosystem services.

Existence Value: The value that individuals place on knowing that a resource exists, even if they never use that resource (also sometimes known as conservation value or passive use value).

Forest Inventory: The measurement of certain parameters of forests to assess the growing stand and stock and other characteristics of forests.

Growing Stock: The sum (by number or volume) of all the trees growing/ living in the forest or a specific part of it.

Human Well-being: Concept prominently used in the Millennium Ecosystem Assessment –it describes elements largely agreed to constitute 'a good life', including basic material goods, freedom and choice, health and bodily well-being, cordial social relations, security, peace of mind, and spiritual experience.

Incentives (disincentives), economic: A material reward (or punishment) in return for acting in a particular way which is beneficial (or harmful) to a set goal.

Indirect-use Value (of ecosystems): The benefits derived from the goods and services provided by an ecosystem that are used indirectly by an economic agent. For example, the purification of drinking water filtered by soils.

Moderately Dense Forest (MDF): All lands with forest cover having a canopy density between 40 and 70%.

Natural Capital: An economic metaphor for the limited stocks of physical and biological resources found on earth, and of the limited capacity of ecosystems to provide ecosystem services.

Net Present Value (NPV): The NPV of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values (PVs) of the individual cash flows.

Non-use Value: Benefits which do not arise from direct or indirect use.

Open Forest (OF): All lands with forest cover having a canopy density between 10 and 40%.

Opportunity Costs: Foregone benefits of not using land/ecosystems in a different way, e.g. the potential income from agriculture when conserving a forest.

Option Value: The value of preserving the option to use services in the future either by oneself (option value) or by others or heirs (bequest value). Quasi-option value represents the value of avoiding irreversible decisions till new information reveals whether certain ecosystem functions have values which society is not currently aware of.

Precautionary Principle: If an action has a suspected risk of causing harm to the environment, in the absence of scientific consensus that the action is harmful, the burden of proof that it is not harmful falls on those taking an act.

Provisioning Services: The products obtained from ecosystems, including, for example, genetic resources, food, fibre and fresh water.

Public Goods: A good or service in which the benefit received by any one party does not diminish the availability of the benefits to others, and where access to the good cannot be restricted.

Regulating Services: The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water and some human diseases.

Resilience (of ecosystems): Their ability to function and provide critical ecosystem services under changing conditions.

Social Cost of Carbon: Estimate of the economic damages associated with increase in carbon dioxide emissions.

Supporting Services: Ecosystem services that are necessary for the production of all other ecosystem services such as biomass production, soil formation and retention, nutrient cycling, etc.

Threshold/Tipping Point: A point or level at which ecosystems change, sometimes irreversibly, to a significantly different state, seriously affecting their capacity to deliver certain ecosystem services.

Total Economic Value (TEV): A framework for considering various constituents of value, including direct use value, indirect use value, option value, quasi-option value, and existence value.

Trade-offs: A choice that involves losing one quality or service (of an ecosystem) in return for gaining another quality or service. Many decisions affecting ecosystems involve trade-offs, sometimes mainly in the long term.

Valuation, Economic: The process of estimating a value for a particular good or service in a certain context in monetary terms.

Very Dense Forest (VDF): All lands with forest cover having a canopy density of 70 per cent and above.

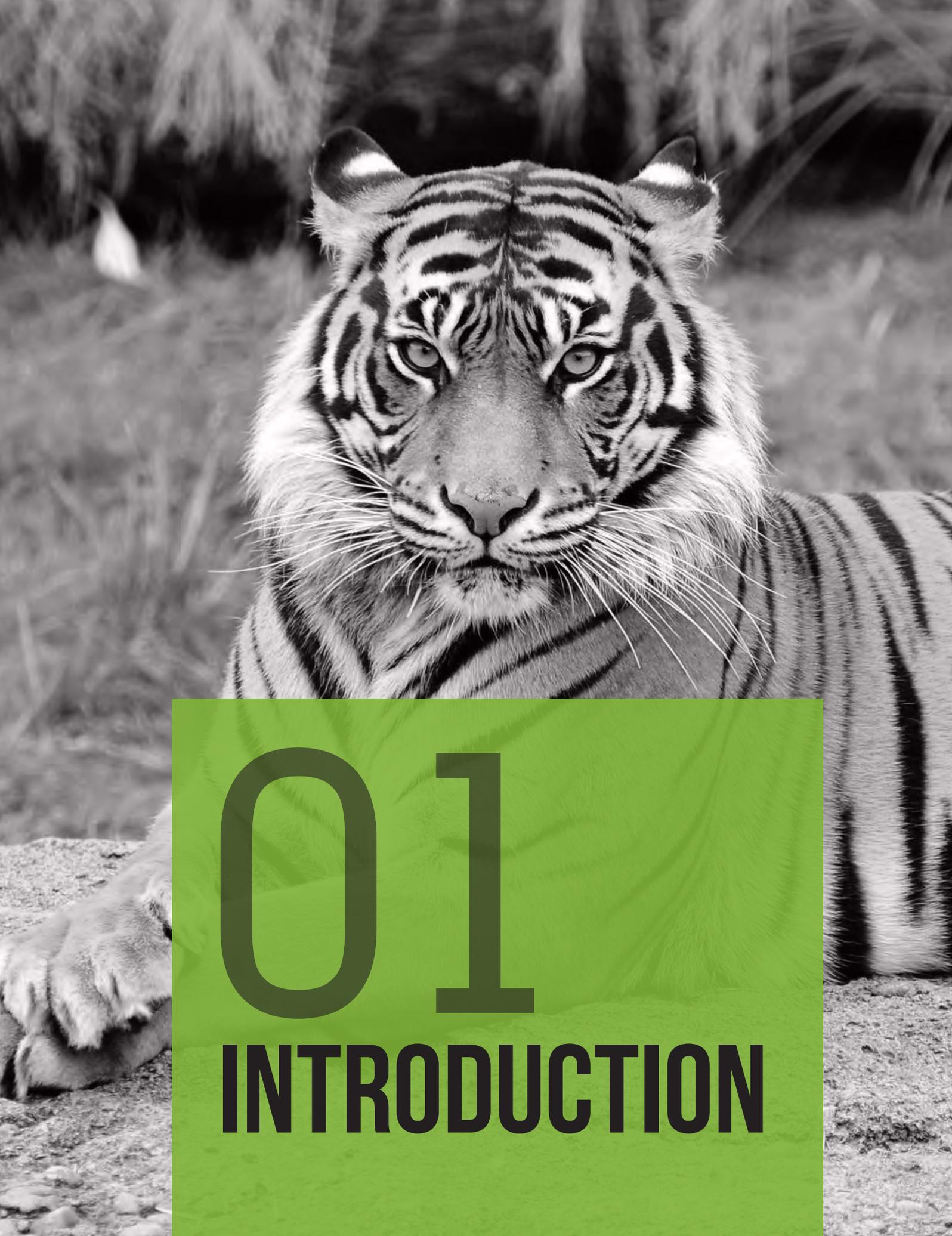
Willingness-to-Pay (WTP): Estimate of the amount people are prepared to pay in exchange for a certain state or good for which there is normally no market price (e.g. WTP for protection of an endangered species).



ACRONYMS

ACU	Adult Cattle Unit	KL	Kilo Litres	RTR	Ranthambore Tiger Reserve
AET	Actual Evapo-Transpiration	KTDC	Kerala Tourism Development Corporation	RUSLE	Revised Universal Soil Loss Equation
AGB	Above Ground Biomass	KTR	Kanha Tiger Reserve	SCI	Selection-Cum-Improvement
AWC	Available Water Content	kWH	Kilo Watt Hour	SOM	Soil Organic Matter
BES	Biodiversity and Ecosystem Services	KZNP	Kaziranga National Park	SRTM	Shuttle Radar Topography Mission
BGB	Below Ground Biomass	KZTR	Kaziranga Tiger Reserve	STPF	Special Tiger Protection Force
CBET	Community-Based Eco-Tourism	LPCD	Litres Per Capita Per Day	STR	Sundarbans Tiger Reserve
CTH	Critical Tiger Habitat (Core Area)	LPG	Liquefied Petroleum Gas	TCM	Travel Cost Method
CTR	Corbett Tiger Reserve	LULC	Land Use Land Cover	TDDF	Tropical Dry Deciduous Forests
CVM	Contingent Valuation Method	MA	Millennium Ecosystem Assessment	TEEB	The Economics of Ecosystem and Biodiversity
DAP	Diammonium Phosphate	MAI	Mean Annual Increment	TEF	Tropical Evergreen Forests
DEM	Digital Elevation Model	MDF	Moderately Dense Forest	TEV	Total Economic Value
DW	Dead Wood	MLD	Million Litres a Day	TMDF	Tropical Moist Deciduous Forests
EDC	Eco-Development Committee	MoEFCC	Ministry of Environment, Forests and Climate Change	TSEF	Tropical Semi-Evergreen Forests
FAO	United Nations Food and Agricultural Organization	MSP	Minimum Support Price	UNEP	United Nations Environment Programme
FSI	Forest Survey of India	MW	Mega Watt	UNESCO	United Nations Educational, Scientific and Cultural Organization
FTG	Forest Type Group	NABARD	National Bank for Agriculture and Rural Development	USD	United States Dollar
GIS	Geographic Information System	NAEB	National Afforestation and Eco-development Board	USGS	United States Geological Survey
GPS	Global Positioning System	NPK	Nitrogen Phosphorus Potassium	USLE	Universal Soil Loss Equation
ICIMOD	International Centre for Integrated Mountain Development	NPV	Net Present Value	VDF	Very Dense Forest
IEDP	India Eco-Development Project	NTCA	National Tiger Conservation Authority	WC	Working Circle
IIFM	Indian Institute of Forest Management	NWFP	Non-wood Forest Produce	WII	Wildlife Institute of India
IPCC	Intergovernmental Panel on Climate Change	OF	Open Forest	WPI	Wholesale Price Index
IT	Information Technology	PAWC	Plant Available Water Content	WTA	Willingness to Accept
IUCN	International Union for Conservation of Nature	PET	Potential Evapo-Transpiration	WTP	Willingness to Pay
JNNRUM	Jawaharlal Nehru National Urban Renewal Mission	PPP	Purchasing Power Parity	WWF	World Wide Fund for Nature
		PTR	Periyar Tiger Reserve		





01

INTRODUCTION



KEY MESSAGES

Conservation of India's national animal, tiger, gains significance on account of its role at the apex of the food chain. Its presence is vital in regulating and perpetuating ecological processes and systems. 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 47 tiger reserves across the country, covering over 2 per cent of India's geographical area.

Besides conserving wild, tiger reserves also provide a range of associated economic, social, cultural and spiritual benefits, which are also termed as ecosystem services. While conservation initiatives till now have largely focused on in-situ conservation of tigers by establishing tiger reserves in India, an important aspect that needs further research is 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.

The current study provides conservative estimates of the economic value of 6 selected tiger reserves in India. Apart from quantitative and qualitative estimates of ecosystem services from selected tiger reserves, the study also explores other dimensions of values. It does so through mapping of ecosystem services in two of the selected tiger reserves and estimating what it would cost to re-create a tiger reserve.

It is important to note that that the objective of the study is neither to compare the benefits of the tiger reserve with any economic venture such as mining, nor compare the benefits across selected tiger reserves.

1973

Project Tiger Launched

09

Tiger Reserves in 1973

47

Tiger Reserves in 2014

68000

square kilometres area covered by tiger reserves

1.1 BACKGROUND

India holds over half of the world's tiger population and is considered to have the best chance for saving population of this magnificent animal in the wild. The aim of The Project Tiger, launched by the Government of India in 1973, is to conserve the tiger, its national animal. From 9 tiger reserves since its formative years, the coverage of The Project Tiger has increased to 47 at present, spread out in 18 tiger range states incorporating an area of more than 68,000 km². This amounts to more than two per cent of the country's geographical area.

The tiger is a unique animal which plays a pivotal role in the health and diversity of an ecosystem. It is a top predator being at the apex of the food chain and is vital in regulating and perpetuating ecological processes and systems. Therefore the presence of tigers in the forest is an indicator of the well-being of the ecosystem. Protection of tigers in forests also protects habitats of several other species. In addition, indirect benefits of

tiger conservation include protection of rivers and other water sources, prevention of soil erosion and improvement of ecosystem services such as pollination, water table retention and a range of other services which benefit mankind.

The amendment to the Wildlife (Protection) Act 1972 in 2006 for the first time defined "core" and "buffer" areas of a tiger reserve, the former being the critical or inviolate area and later, the peripheral area to foster coexistence with local people for safeguarding the integrity of the core and made it mandatory to have a Tiger Conservation Plan for each Tiger Reserve for ensuring the protection of tiger reserves and the livelihood and other interests of the people living in tiger bearing forests or tiger reserves. Effective management of tiger reserves thus also ensures flow of vital tangible resources from ecosystems that communities residing inside and in the adjoining areas of tiger reserves are often greatly dependent on.

The change in numbers of this top predator is believed to have a cascading / multiplying



effect on the population of other species, quality of forest ecosystems and hence on the flow of a wide array of ecosystem services. While conservation initiatives till now have largely focused on in-situ conservation of tigers by establishing tiger reserves in India, an important aspect that needs further research is assessment of the economic value of tiger reserves by ensuring the flow of essential ecosystem services. In addition to conservation of this flagship species, many life-supporting services emanate from these tiger reserves which not only benefit the human population residing in the vicinity but also the country at large which needs to be estimated and internalized.

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. Economic valuation is increasing being used as a tool to communicate the need to invest in green endowment to the policy-makers and thus help in prioritizing investments and allocation of funding at state and national



level. Further, many benefits from tiger reserves flow outside the administrative boundaries of tiger reserve and benefits accruing outside the notified tiger reserve through economic valuation is essential to reflect their true value.

1.2 STUDY OBJECTIVES

To internalize the concerns raised above, this study intends to estimate the economic value of 6 tiger reserves in India to highlight the importance of investing in natural capital. The specific objectives of the study include:

- Estimate the economic value of ecosystem services emanating from 6 selected tiger reserves in India using scientific and objective parameters.
- Application of Spatial Mapping tools to understand flow of Ecosystem Services – A pilot study at two of the selected tiger reserves using “InVEST” mapping package.
- Estimate the cost of inaction through cost of creating a tiger reserve and willingness to pay for tiger conservation.

It is important to note that here that the objective of the study is neither to compare the benefits of the tiger reserve with any economic venture such as mining, nor compare the benefits across selected tiger reserves.

1.3 SITE SELECTION

With an aim of incorporating conservation objectives into land use planning across landscapes so as to ensure the long term survival of free ranging tigers which serve as an umbrella species for conservation of forest biodiversity, forests in India have been classified into the following tiger landscape complexes:

- Shivalik Hills and the Gangetic Plain
- Central India and Eastern Ghats
- Western Ghats

Economic valuation of ecosystem services is increasing being used as a tool to communicate the value of natural capital and help in prioritizing investments

- North-Eastern Hills and Brahmaputra Plains, and
- Sundarbans

Acknowledging the significance of the current study in demonstrating the economic value associated with tiger

reserves, the study has selected a tiger reserve from each of the tiger landscapes listed above to represent landscape diversity. Further, to account for differences in ecological conditions in

KEY LEARNING



Tiger reserves selected for the study represent great **ecological** and **socio-economic diversity**.

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 include: Corbett Tiger Reserve, Kanha Tiger Reserve, Kaziranga Tiger Reserve, Periyar Tiger Reserve, Ranthambore Tiger Reserve and Sundarbans Tiger Reserve. As depicted in Figure 1 below, these tiger reserves represent great diversity in terms of tiger landscapes, ecosystems, and socio-economic conditions.

1.4 STRUCTURE OF THE REPORT

The report is broadly structured in terms of the objectives listed earlier. The following chapter discusses the overall study methodology as well as methodology used for each of the four study objectives. Chapter 3 then discusses the direct use values of ecosystem services for each of the selected tiger reserves. Discussion in Chapter 4 revolves around how the concept of economic valuation of ecosystem services can be internalized further by mapping ecosystem services using a tool called InVEST for two of the selected tiger reserves. Chapter 5 then demonstrates the cost of inaction in conserving the existing tiger reserves through estimating the cost of creating a tiger reserve from scratch. It also presents the results of a short online survey conducted to estimate the mean willingness to pay for tiger conservation. Chapter 6 finally summarizes the findings, provides conclusions and discusses the way forward.

CORBETT

KANHA

KAZIRANGA

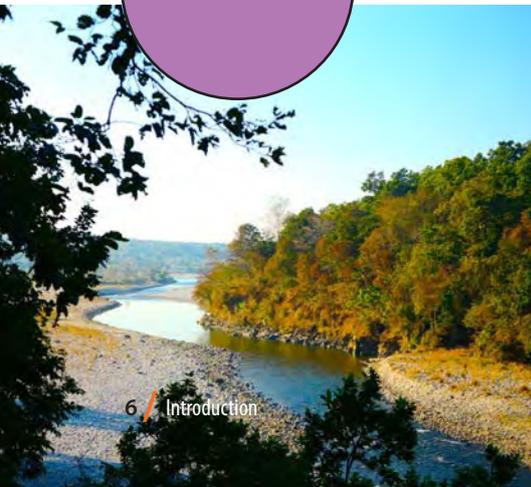
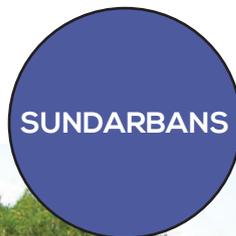
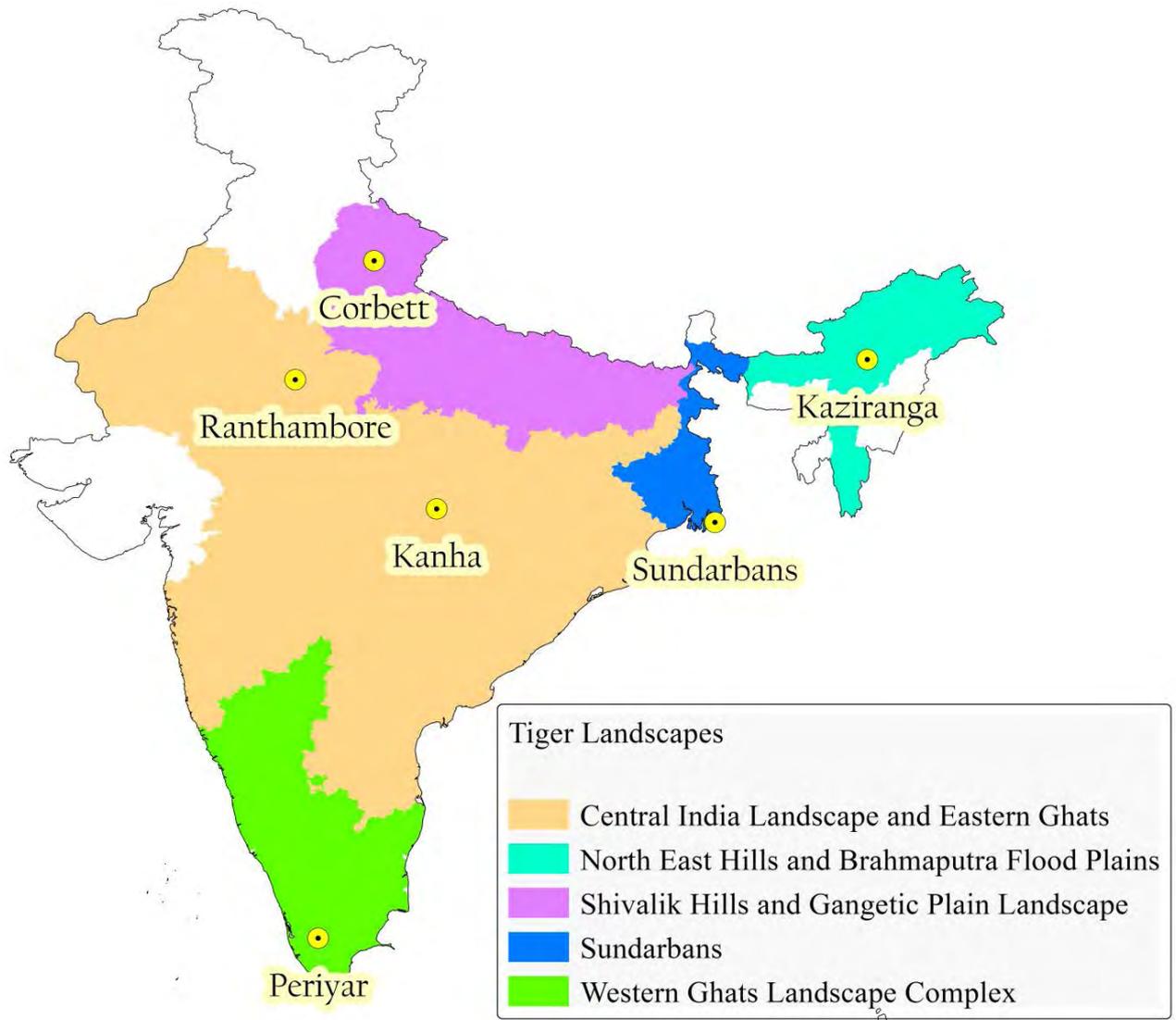
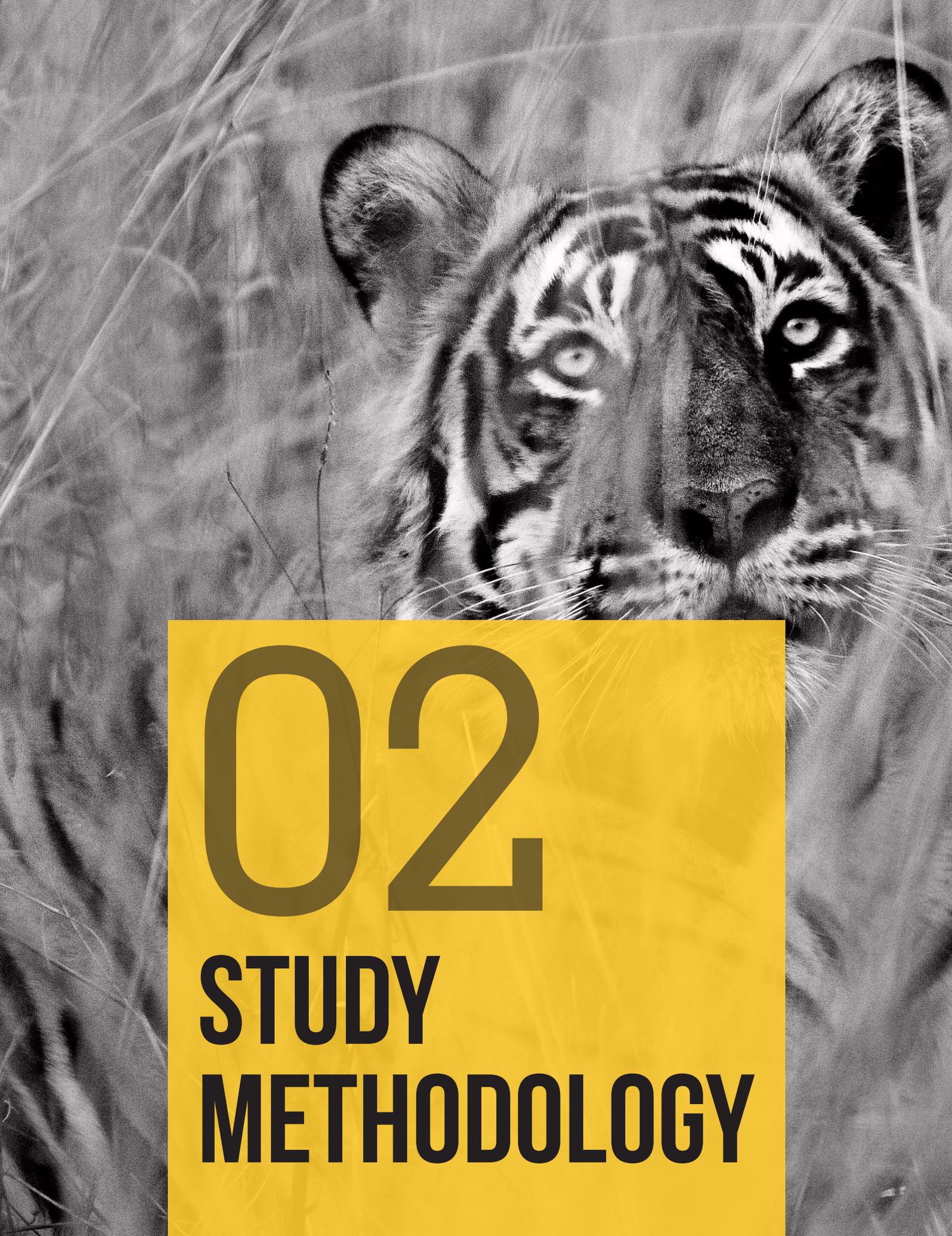


Figure 1
Selected Tiger Reserves for the Study





02

STUDY

METHODOLOGY



KEY MESSAGES

Acknowledging our limited understanding of natural processes and their associated values, the study uses a VALUE+ approach. The 'VALUE' represents all benefits for which monetary economic valuation is possible and conducted based on available knowledge and information. The '+' represents all those benefits for which economic valuation is currently not possible either on account of lack of accepted methodologies, knowledge and/or understanding. The economic values derived in the study are thus conservative.

The study has used a multiplicity of frameworks including Total Economic Value; Millennium Ecosystem Assessment; Stock and Flow; and Tangible and Intangible Benefits to communicate the diverse values embedded and emanating from tiger reserves.

A rigorous research process including thorough consultation with key stakeholders has been followed for the study. These include consultation with members of the National Tiger Conservation Authority, State Forest Departments, Subject Experts, secondary sources, workshops, roundtables, expert team consultation, primary data collection and progress review process. Several national and international experts were formally involved in the study since the beginning to guide methodology development.

2.1 PROJECT METHODOLOGY AND DATA COLLECTION TOOLS

A rigorous research process including thorough consultation with key stakeholders has been followed for the study. These include consultation with members of the National Tiger Conservation Authority, State Forest Departments, Subject Experts, secondary sources, workshops, roundtables, expert team consultation, primary data collection and progress review process. A number of national and international experts were formally involved in the study since the beginning to guide development of methodology used for estimating the economic value of tiger reserves, amongst other aspects such as supporting collection of data and reviewing draft versions of the report.

To begin the study, Tiger Conservation Plans (TCPs) of all selected tiger reserves were studied in detail to identify the ecological and

socio-economic context, important ecosystem services and data sources. After initial review of literature and individual consultation meetings with key stakeholders, a Launch and Methodology Workshop was conducted in New Delhi during 24-25 March 2014. All national and international experts, Field Directors of respective tiger reserves, members of National Tiger Conservation Authority, Principal Chief Conservator of Forests (Wildlife) of respective states along with other important experts on wildlife ecology, community involvement and economic valuation, participated in the methodology workshop and discussed the draft methodology for the study. Based on the discussions and suggestions, the study methodology was appropriately modified.

In addition to this, field visits were conducted to each of the tiger reserves to understand tiger-reserve specific context and incorporate particular issues relevant to each tiger reserve. These field visits which included survey of major types of ecosystems and understanding interactions between them, short-listing of major ecosystem services from each tiger reserve, collection of data already available at the Field

Director's Office such as micro-plans, older management plans, geospatial files, consultation meetings with research institutions and Non-Governmental / Community-based Organizations working in and around the tiger reserve for getting other relevant data, and interactions with villagers to understand linkage between ecosystem services from tiger reserves and livelihoods.

Since the beginning of the study, a number of progress review meetings were conducted with the National Tiger Conservation Authority to appraise the study progress and discuss methodological issues. Based on these discussions, the need for additional study components were realized and these have been subsequently evolved such as cost of re-creating a tiger reserve, which were not envisaged at study inception. The components have helped in holistically addressing various dimensions of looking at the 'value' of tiger reserves in India.

2.2 STUDY FRAMEWORK

Natural ecosystems more generally, and tiger reserves specifically, supply numerous goods — such as food, medicinal plants, building materials — and services, such as soil conservation and provision of clean water.

Increasingly, the value of such ecosystem goods and services is 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. 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 ecosystem values can be theoretical, they can be converted to indicate benefits when they are received by an individual or a community. For example, the value of trees in the water filtration process adds a benefit to a community that derives its clean drinking water from that source. Research suggests that for a wide range of these benefits, natural ecosystems remain the most cost-effective delivery mechanisms¹⁻⁴. In cases where particular ecosystems have unique aesthetic, cultural and spiritual values, they are literally irreplaceable⁵.

Most of the tiger reserves in India have been established originally 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 the



KEY LEARNING

The study methodology has been developed following **rigorous research process** including **consultations** with many **stakeholders**.



KEY LEARNING

In addition to ensuring continuity of **natural evolutionary processes**, tiger reserves provide a range of **other benefits**.

Project Tiger has been to ensure continuity of natural evolutionary processes. However, many tiger reserves also conserve a wide range of ecosystem services and provide other social, economic and cultural benefits. Often, establishment of such reserves could be justified in terms of these ecosystem services alone.

The current study acknowledges the fact that in spite of our increased appreciation of many of nature's functions and processes, we still have limited understanding of how we benefit from nature. There is inherent ambiguity and uncertainty about the most appropriate economic valuation method that often leads to underestimation of benefits we receive from nature. Conceding that although the current study attempted to estimate the economic value of several benefits we receive from tiger reserves, admittedly there are several services for which the economic value could not or cannot be estimated monetarily. The latter includes many benefits which can only be quantified in biophysical terms or those which can only be qualitatively described. Thus, the estimated value for any tiger reserve should be looked at through the 'VALUE+' approach. The 'VALUE' represents all benefits for which monetary economic valuation is possible and conducted based on available knowledge and information. The '+' represents all those benefits for which economic valuation is currently not possible due either on account of lack of accepted methodologies, knowledge and/or understanding. This approach used in the study is further articulated in the Table below.



KEY LEARNING

The study **adopts a VALUE+ approach**. The economic values represent the **minimum estimates**.

Table 1

Category of Benefits from Tiger Reserves Considered in the Study (adapted⁶)

Category of Benefits	Description
I	Benefits which can be assessed and monetized using available ecological models and appropriate economic valuation methods, including benefits transfer
II	Benefits which cannot be monetized, but can be quantified in biophysical terms using available ecological models and for which some indicator(s) of economic benefits exist
III	Benefits which can be quantified in biophysical terms but for which no indicators of economic benefits exist
IV	Benefits which can be qualitatively described even if they cannot be quantified
V	Benefits which have important non-economic values

To suit various contexts and differential needs for decision-making, various frameworks on valuation have been proposed.

In order to consider the categories of benefits derived from tiger reserves as shown in Table 1, the study uses four frameworks under which different benefits have been categorized and estimated/qualified. These are listed below and described briefly in the context of this study in the following sections.

- Total Economic Value (TEV)
- Millennium Ecosystem Assessment (MA)
- Stock and Flow Benefits
- Tangibles and Intangibles Benefits

2.2.1 TOTAL ECONOMIC VALUE (TEV)

In the context of this study, TEV refers to the gain in well-being or welfare from the tiger reserves captured by the net sum of the willingness to pay (WTP) or willingness to accept (WTA) and is comprised of use and non-use values.

2.2.1.1 DIRECT USE VALUE

This refers to the consumptive use through extraction of resources from tiger reserves (e.g. food, timber, NWFP) and non-consumptive use without

resource extraction (e.g. recreation, landscape amenity). As the core area of any tiger reserve is an inviolate area, the consumptive use of direct use value refers to resources extracted only from the buffer area of the tiger reserve, if

any. Many benefits in this category may be traded in the market (e.g. timber) or may also be non-marketable (e.g. deriving inspiration from nature).

2.2.1.2 INDIRECT USE VALUE

These refer to indirect benefits and include key life-supporting functions performed by the tiger reserves such as regulation of climate, regulation of water quality and quantity, pollination, among others. Measuring these values is often more challenging than measuring direct use values on account of lack of information, market and / or understanding.

2.2.1.3 OPTION VALUE

This refers to the value people place on having the option to postpone the use a resource (directly or indirectly) for the future even if they are not using it currently. In the study context, these refer to, inter alia, the value of genetic information stored in the biodiversity of tiger reserves which may be of great pharmaceutical or agricultural value in future. These values can also be thought of as a form of insurance which these tiger reserves provide through resilience and ensuring continuity of natural evolution processes.

2.2.1.4 NON-USE VALUE

These values stand for non-utility benefits and also referred to as passive values, derived simply from the knowledge that natural environment is maintained. Broadly, these can be categorized into bequest and existence value. While bequest value refers to value associated with passing a resource to future generations, the existence value is derived merely from the intrinsic existence of a resource. In the study context, bequest values may refer to the value an

KEY LEARNING



Extractive uses from tiger reserves are **limited to buffer areas** only.



KEY LEARNING

Economic values can be broadly **categorized into use and non-use values.**

may attach just from knowing from the fact that tigers exist in wild, although she may not actually plan the use of it to derive any pleasure or satisfaction for herself.

2.2.2 MILLENNIUM ECOSYSTEM ASSESSMENT

The Millennium Ecosystem Assessment⁷ (MA) has identified four overarching categories of benefits provided by ecosystems. These include:

- **Provisioning Services:** Products obtained from tiger reserves such as fisheries and timber
- **Regulating Services:** Benefits obtained from regulation of ecosystem processes such as water and climate regulation

individual places from the fact that her grandchildren will have the opportunity, say, to see a rhinoceros in wild, and the existence value may refer to the value an individual

- **Cultural Services:** Non-material benefits people obtain from tiger reserves through spiritual enrichment, cognitive development, recreation and aesthetic experiences such as sacred sites and wildlife safari

- **Supporting Services:** Services that are necessary for the production of provisioning, regulating and cultural services such as soil formation and retention

These ecosystem services are directly linked to various components of human well-being such as security (e.g. access to resources, avoidance or mitigation of disaster), basic materials for a good life (e.g. provision of nutritious food, shelter, employment opportunities), health (e.g. access to clean air and water, emotional and spiritual well-being), and cordial social relations (e.g. social cohesion). This is further depicted in Figure 2.



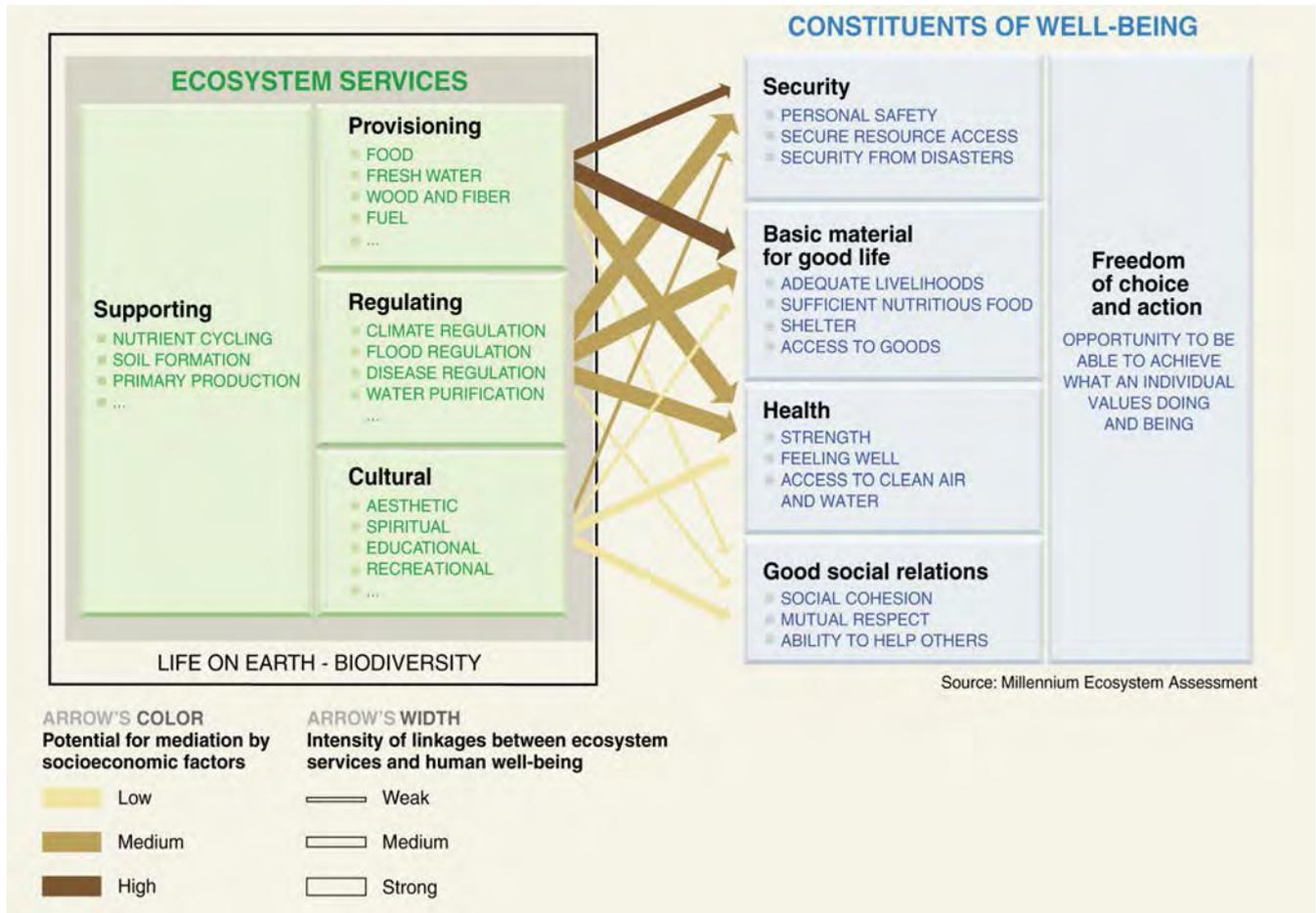
KEY LEARNING

Ecosystem services have been classified into **provisioning, regulating, cultural and supporting services**



Figure 2

Ecosystem Services and Human Well-being⁷



KEY LEARNING

Stock refers to **potential future uses of a resource**

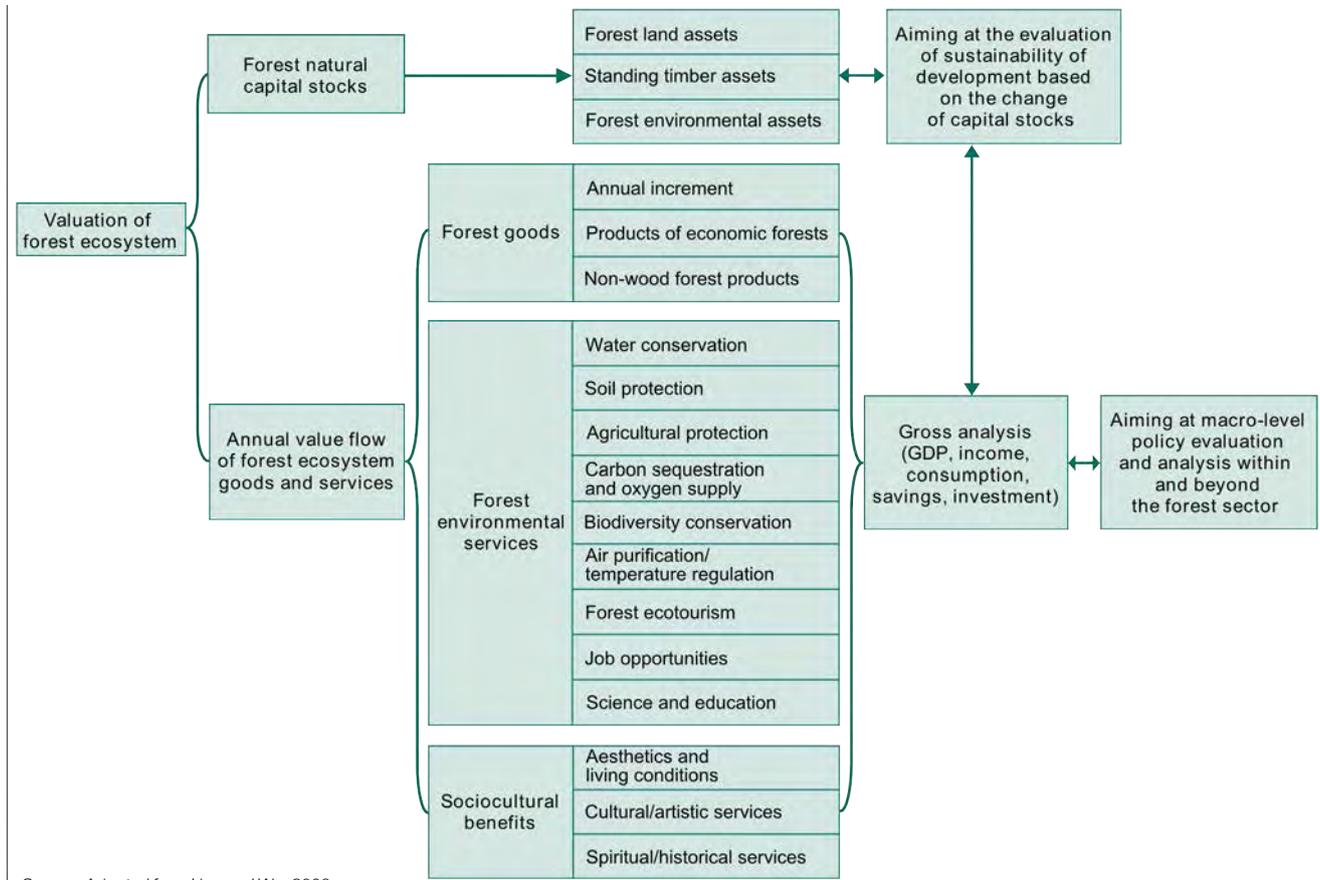
2.2.3 STOCK AND FLOW BENEFITS

The benefits from tiger reserves can also be categorized into stock and flow benefits. Broadly, stock benefits refer to potential supply, while flow benefits refer to real feasible flow of benefits. In the study context, standing timber and carbon stock refer to stock benefits, while carbon sequestration can be referred to as a flow benefit (See Figure 3).



Figure 3

Differentiation of Stock and Flow Benefits from Forest Ecosystems⁸



Source: Adapted from Hou and Wu, 2008.

2.2.4 TANGIBLE AND INTANGIBLE BENEFITS

Broadly, tangible benefits from ecosystems refer to goods obtained from the tiger reserves while intangible benefits include the set of services which improve human well-being indirectly. While tangible benefits may be of great importance, especially to the local community, the current study has put special focus on intangible benefits as many of these are not marketed and perhaps not appropriately managed. The study is a deliberate attempt to factor intangibles in our decision-making calculus.



2.3 VALUATION APPROACHES

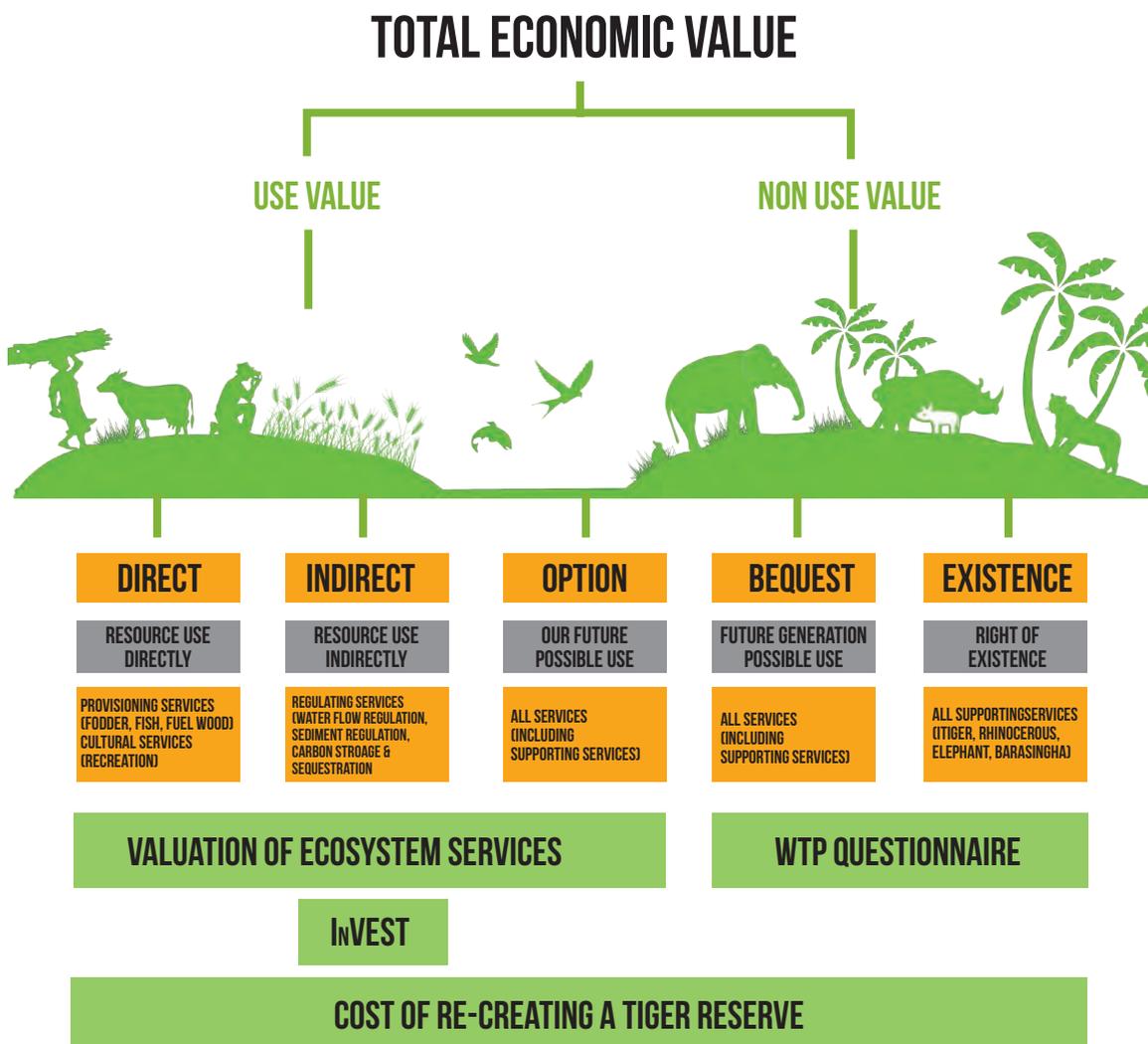
Acknowledging that our current understanding about the role of biodiversity in the tiger reserves in ensuring human well-being is rudimentary to say the least, the study has adopted the ‘VALUE+’ approach as mentioned earlier. While recognizing that economic value of all the categories of benefits cannot be estimated, different approaches may be required to put together for those services which can be estimated to a certain degree of certainty. The study thus uses the following four valuation approaches to demonstrate the economic value of tiger reserves.

1. Economic valuation of ecosystem services through widely accepted valuation methodologies, benefits transfer where required, and scenarios based on widely quoted economic valuation studies.
2. Mapping ecosystem services using a tool called InVEST at two study sites to demonstrate how valuation of tiger reserves can be relevant for the management of a tiger reserve further through mapping of ecosystem services.
3. A cost-based approach which seeks to estimate what it would cost to recreate a tiger reserve from scratch to the present level.
4. A short online survey carried out to estimate the willingness to pay for tiger conservation.

The frameworks used in the study and the valuation approaches used are related as shown in the Figure 4 below.

Figure 4

Valuation Frameworks and Associated Approaches Used in the study



The linkages of various approaches used in the study and study deliverables are tabulated below.

Table 2
Approaches Used in the Study and Study Deliverables

Valuation Approach	Study Deliverable
Economic valuation of ecosystem services	Estimate economic value of selected tiger reserves
Use of benefits transfer approaches	
Mapping ecosystem services with the help of InVEST	Mapping ecosystem services in two tiger reserves
Contingent Valuation Survey	Estimate the willingness to pay for tiger conservation
Cost-based approach to estimate what it would take to re-create a tiger reserve	Cost of re-creating a tiger reserve

2.4 METHODOLOGY: ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

Following the Millennium Ecosystem Assessment framework, major ecosystem services from each tiger reserve have been identified and their economic values have been estimated. The following sections discuss the methodologies used for economic valuation of each ecosystem service. It may be noted that not all the services listed here may be applicable in a particular tiger reserve.

2.4.1 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 is highly valued by the local community. The economic value of employment has been estimated in the study in terms of man-days generated by the tiger reserve for management as well as community-based eco-tourism. The local wage rate has been used to derive site-specific economic values from employment generated.

2.4.2 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 is often difficult to establish on account of paucity of information, wherever available, the same has been used to estimate the economic value of agriculture inside a tiger reserve that can be attributed to the tiger reserve.

2.4.3 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 the local market price of the produce. Wherever production estimates from a reliable source were not available, secondary estimates were used to derive probable production figures.

2.4.4 FUEL WOOD

A large proportion of communities living inside and along the fringe villages of the tiger reserves are often dependent on the tiger reserve for fuel wood and energy requirements. As in the case of other products, extraction of fuel wood,

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.

wherever allowed, is only permitted from the buffer area of the tiger reserve. Fuel wood extraction in these tiger reserves is often regulated by the Eco-Development Committees (EDCs) and hence extraction estimates are generally documented. These estimates have been used by the study in conjunction with the local market price of fuel wood to obtain its economic value.

2.4.5 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 sources. Using standard forage quantity and the local market price of fodder, the economic value of provisioning of fodder from tiger reserves has been estimated.

2.4.6 TIMBER

Sustainable harvesting of timber is discontinued in most of the tiger reserves. However, wherever applicable, the estimates of annual coupe have been used in conjunction with the local market price of timber with due adjustments for management and transportation costs to arrive at the economic value of timber obtained from tiger reserves. Existing timber biomass in the tiger reserves also represents the stock benefits. Using the same method of pricing timber as described earlier, existing growing stock of timber in tiger reserves is used to estimate the stock value of timber.

2.4.7 NON-WOOD FOREST PRODUCE (NWFP)

Many of the tiger reserves in India allow extraction of certain non-wood forest produce such as honey 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. The local market prices of such products have then been subsequently used to derive their economic values.

2.4.8 GENE-POOL PROTECTION

The economic value of gene-pool protection is envisaged in the study in terms of its biological information value and its insurance value. These are further discussed briefly.

2.4.8.1 BIOLOGICAL INFORMATION VALUE



POLICY QUESTION

Is the information stored in genetic diversity of any economic value?

Existing biodiversity within the tiger reserves, especially endemism and speciation, is the result of evolutionary processes over thousands of years. This diversity thus embodies a stock of information. Since the evolutionary process has occurred in various environmental contexts, the diversity of natural organisms embodies characteristics that make them resilient to further 'natural' change⁹. Natural organisms, especially endemic species, have evolved an astounding variety of chemical compounds to escape predators, capture prey, enhance reproductive success and fight infections. These compounds have proved to be of great value when adapted for various human uses, especially the pharmaceutical industry¹⁰. For example, leukemia is today treated with medicines derived from the rosy periwinkle of Madagascar, and the bark of the Pacific yew tree is the source of

The economic value of gene-pool protection can be envisaged in terms of its **biological information value** and **insurance value**.



KEY LEARNING

Biodiversity is the source of new **pharmaceutical drugs and wild cultivars**.

a treatment for ovarian cancer¹¹. Further, with recent advances in biotechnology, the researchers are now better equipped to investigate these organisms at the genetic level; thereby increasing its potential for future product leads manifolds.

Biodiversity is not only a source of new drugs with large market potential but is also a very important source of germplasm for agricultural crops¹². These germplasm may enhance resistance to disease, drought, and salinity among other shocks to enhance productivity or other desirable traits of farm stock^{13,14}. The wild cultivars and crop wild varieties serve as the world's repositories of crop genetic diversity and represent a vital source of genes that can ensure future food security.

In the studies on the Green Revolution, it was shown that the genetic diversity in the plant population could significantly increase the productivity of agriculture¹⁵. Tiger reserves thus provide an insurance cover for agriculture. In our country where the majority of the workforce is employed in agriculture, this insurance is of paramount importance.

For example, a disease carried by the brown plant virus had threatened the Asian rice species with the danger of destroying a large proportion of the crop. The International Rice Research Institute in the Philippines in their effort to develop a form of rice resistant to the virus found a local wild variety of rice that was not used commercially but was resistant to the virus. The resistant gene was successfully identified and transferred to the commercial rice varieties, thereby yielding commercial rice resistant to the threatening disease¹⁵. Such cultivars for different crops are found in these tiger reserves which could be potentially useful in future.



KEY LEARNING

In the face of **climate change**, tiger reserves have a significant value in terms of **guaranteeing resilience**.

2.4.8.2 INSURANCE VALUE

The insurance value of tiger reserves relates to the role of biodiversity in guaranteeing resilience of ecological systems at the local, regional, and national scale, and thereby guaranteeing service provision in the future. It is widely agreed that high biodiversity and more complexity in a system leads to higher adaptability and resistance to environmental changes^{10,16-19}. This value of biodiversity is likely to become increasingly important over time as climate change impacts may subject these reserves to further external shocks.

While it is relatively easy to identify the benefits obtained from individual components of biodiversity and its associated information value, it is particularly difficult to describe and estimate the benefits of variability itself². Diversity not only lends more resilience to the system by providing a kind of natural insurance against risks, it also increases the likelihood of finding useful products as the number of natural expressions (information) increase with higher biodiversity. More diverse ecosystems are thus likely to contain economically useful plants, animals or biological compounds^{4,20-23}

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 study²⁴, the economic value of this ecosystem service has been derived for the selected tiger reserves.

2.4.9 CARBON STORAGE

Tiger reserves are highly effective tools to maintain carbon stored in forests, wetlands and other ecosystems in order to combat climate change. A recent study²⁵ 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. On account of the inability to collect primary data exclusively for this study, secondary sources were used to obtain stock of carbon stored in other types of ecosystem in a particular tiger reserve, if any.

To obtain the economic value of this physical stock, a recent study²⁶ conducted at Yale University that has estimated the social cost / value of carbon for India has been used. The release of greenhouse gases including CO₂ creates global warming effects and translates into economic costs and losses in the form of health damages or damages to infrastructure, agriculture, fisheries and other production

sectors. The social cost of carbon aims to estimate the cost of these effects. According to the quoted study, the social cost of carbon

?
POLICY QUESTION
What is **social cost of carbon?**

for India at a low discount rate is equal to USD 37.17 (2005 International). The influential and widely accepted Stern Review suggests a price of USD 85 per ton of CO₂e estimated based on damage cost approach. This is equivalent to USD 23.16 per ton of carbon in contrast to USD 37.17 as used in this study. A recent review of the social cost of carbon has found estimates in the range of USD 55-250 per ton of carbon²⁷. Necessary adjustments for Purchasing Power Parity¹ and inflation² were subsequently made on the Social Cost of Carbon for India.

2.4.10 CARBON SEQUESTRATION

Tiger Reserves are not only storehouses of carbon but also add to their existing stock annually due to their effectiveness in reducing or halting land cover change. 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 study²⁹ 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

1. PPP for India with respect to the United States of America in 2005 = 15.66²⁸

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



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.

2.4.11 WATER PROVISIONING

The role of forests in augmenting water flow is widely acknowledged. The presence or absence of forests, has a profound impact on the hydrological processes at the

Tiger reserves have a significant role in **mitigation of and adapting to climate change.**



watershed level. When precipitation falls on a forested landscape, it is intercepted by the dense canopy cover, thereby reducing its intensity. Some of the water that reaches the land surface evaporates back, some goes away as run-off and some of it is absorbed back by the roots of the trees and moves out into the atmosphere through transpiration. After the soil moisture reaches its field or saturation capacity, the remaining water recharges the groundwater table.

Two of the tiger reserves selected for the study have hydropower dam (and a reservoir) within them and cater to needs of electricity and irrigation to a large service-shed. The study does not include the benefits of anthropomorphic activities such as a dam in the value of the tiger reserve. 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 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 equation³⁰. 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 varies across states in India and depends on the types of uses and has been estimated by a widely quoted study at ₹ 8.5 per m³ of water³¹. The estimate not only includes the economic cost of procuring water but also includes the distribution and environmental costs. Adjusting the estimate according to the Wholesale Price Index, the current economic value of water used in the study is ₹ 18.43 / m³.



2.4.12 WATER PURIFICATION

Natural ecosystems within the 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 a water purification plant. Many of the tiger reserves are located upstream of rivers and streams that cater to drinking water requirements numerous people. In the study, 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 India³², the economic value of water purification services from tiger reserves is estimated.



KEY LEARNING

In absence of natural purification processes, an artificial treatment plant would be required.

₹ 18.43

per cubic metre

Economic value of
water for agriculture

₹ 10.00

per cubic metre

Cost of treating water
for domestic supply

₹ 58.31

per cubic metre

Sediment excavation cost

2.4.13 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 in the study has been estimated using the avoided offsite costs from sedimentation. Secondary literature has been used extensively to estimate the marginal contribution of ecosystems within tiger reserves in arresting soil erosion compared to managed ecosystems. 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 from tiger reserves.

In addition, the off-site costs of soil erosion include roadway, sewer and basement siltation, drainage disruption, undermining of foundations and pavements, gulying of roads, earth dam failures, eutrophication of waterways, siltation of channels, loss of wildlife habitat, disruption of stream ecology, among others which have not been considered here³³.

2.4.14 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. The natural ecosystems of tiger reserves however ensure that the flow of nutrients is regulated and their loss is avoided. In scientific literature, the ecosystem service is mostly estimated using the replacement cost of fertilizers³⁴⁻⁴¹, and a similar approach has been used here.

Owing to soil erosion in the absence of forests, the nutrients will be lost along with sediments. The litter also has significant nutrient concentration and if these forests had not been there, nutrients would further leach from this litter nutrient pool. However, due to paucity of data on the nutrient composition of litter, this aspect has not been considered in the study.

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 subsidized price of NPK fertilizers in India to obtain the economic value of nutrient cycling / retention service from tiger reserves.

2.4.15 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). There is growing evidence that deforestation results in an increased spread and/or incidence of human infectious diseases^{42,43}. On account of lack of site-specific studies for estimating the economic value of the ecosystem service related to biological control which includes 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 study²⁴, the economic value of the ecosystem service has been derived for the selected tiger reserves.

2.4.16 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 in two components – damage to life and damage to property. Using secondary literature, estimates of these components at the tiger reserve or

neighbouring regions is identified. Using the benefit transfer method, the estimates are then derived for the tiger reserves wherever applicable.

2.4.17 POLLINATION

Tiger reserves provide a natural habitat 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 study²⁴, the economic value of the ecosystem service has been derived for the selected tiger reserves.

2.4.18 NURSERY FUNCTION

Some tiger reserves provide a suitable reproduction habitat 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 offshore marine catch attributable to a unit area of tiger reserve is estimated. This is further used with the local market price of catch to derive the economic value of nursery function from tiger reserve.

2.4.19 HABITAT / REFUGIA

KEY LEARNING



Tiger reserves also provide **non-instrumental benefits** such as **habitat and refugia for wildlife**.

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

Tiger reserves are major tourist attractions, generating large **income for the local and state economy.**

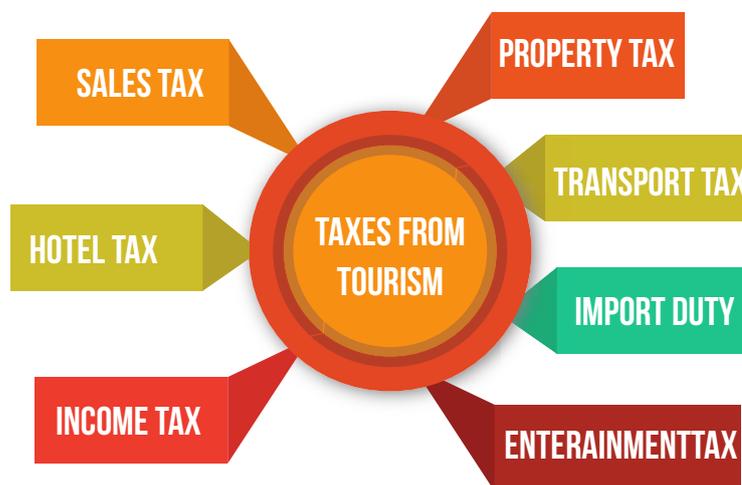
Tribal settlements within these tiger reserves inherit a cultural heritage that needs to be preserved.

effects, interception of precipitation and evapo-transpiration, water storage and wind shield) can 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 intensifies⁴⁴. 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 study²⁴, the economic value of this ecosystem service has been derived for the selected tiger reserves.

2.4.20 CULTURAL HERITAGE

The tribal settlements within these tiger reserves also inherit a cultural heritage that needs to be preserved. The hidden value of indigenous knowledge contained among local communities residing in these natural landscapes is still to be explored and used as a sustainable development component by academicians and development practitioners. On account of appropriate valuation methodologies for valuing such services, qualitative quantification in terms of tribal population and their endemism is used to reflect the cultural heritage value associated with tiger reserves.

Figure 5
Taxes from Tourism



2.4.21 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 derived using the 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. Forest cover also influences microclimatic variables such as solar radiation, air and soil temperature, wind and air humidity. Compared to the open ground, forest cover buffers the daily and seasonal temperature differences and thereby alleviating microclimatic extremes⁴⁴. Such pleasant climatic conditions add to the recreational experience of tourists visiting such tiger reserves.

Tourism from tiger reserves is an important resource for generating revenue for the respective states. The state government receives tax income from the tourism sector directly in the form of sales tax and import duty on tourist spending and indirectly through property, profits and income taxes. It is estimated that for every rupee spent by tourists, the central and state governments in India receive 15 paise as taxes⁴⁵. Further, the tourism employment multiplier for India is about 1.8 and the tourism output multiplier for India is about 2.1⁴⁶, further demonstrating the high economic value of recreation services from these tiger reserves.



KEY LEARNING

Tourism supports more than 20 **dependent sectors** in towns and **villages near tiger reserves**.

In addition to economic value derived by tourists visiting the tiger reserve, there are about 20 dependent sectors in towns and villages adjoining tiger reserves such as tailor shops, paan shops, souvenir shops, photographers, those employed in transport, among others which are directly dependent on tourism. Owing to paucity of data, the contribution of tiger reserves to these petty sectors has not been estimated.

2.4.22 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. 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.

2.4.23 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.

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 issues conducted by different organizations such as the Wildlife Institute of India, Zoological Survey of India, Botanical Survey of India, Forest Survey of India, among several others.

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.

2.4.24 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 study²⁴, the economic value of the ecosystem service has been derived for the selected tiger reserves.

2.4.25 WASTE ASSIMILATION

Similar to water purification services in Section 2.4.12, natural vegetation and biota within these tiger reserves break down xenic nutrients and compounds and help in pollution control and detoxification. Wherever relevant data was available, the economic value of this ecosystem service has been estimated in the study 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 study²⁴, the economic value of the ecosystem service has been derived for the selected tiger reserves.



2.4.26 ECOSYSTEM SERVICES ACROSS TIGER RESERVES

Based on literature review, discussions with local and national experts and consultations with communities in and around each tiger reserve, the study identified relevant ecosystem services for each tiger reserve (Table 3). Wherever unavailability of data or robust methodology limited the ability to quantify the service in monetary terms, the service has been qualitatively described to demonstrate its significance.

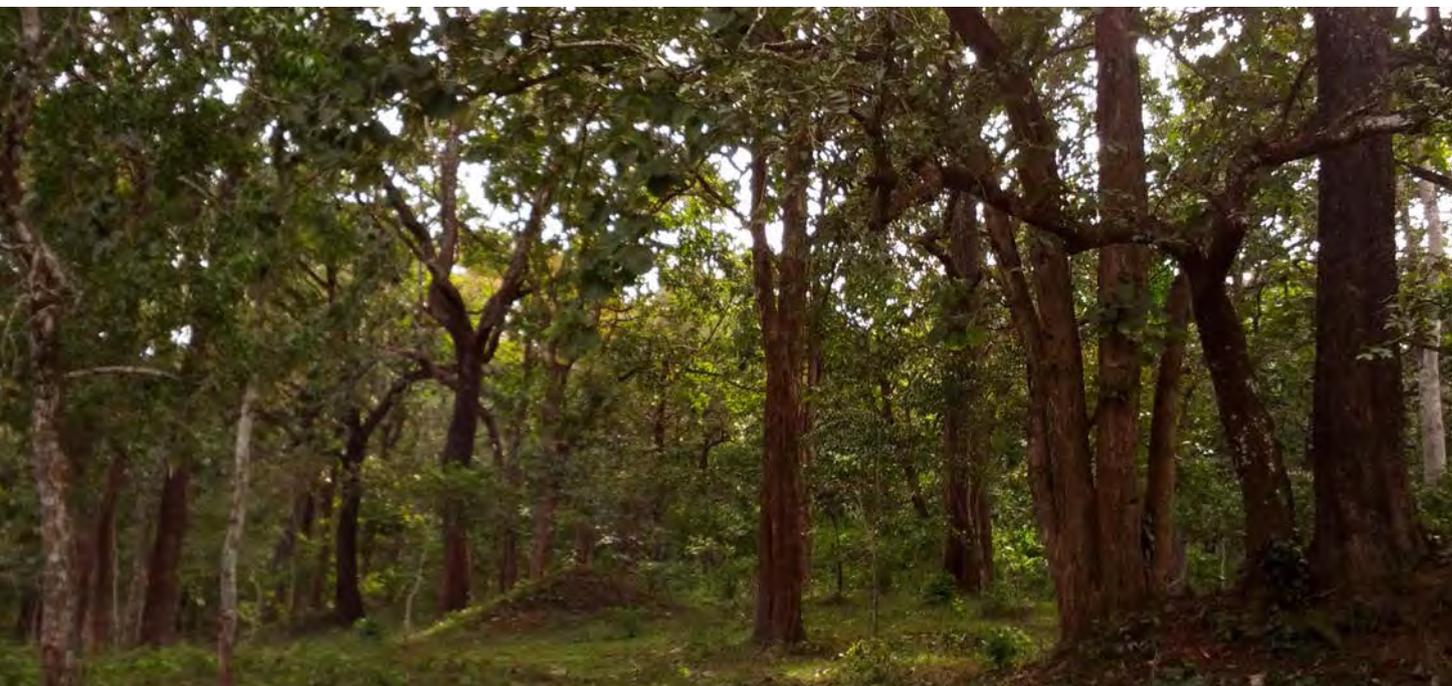


Table 3

Relevant Ecosystem Services Across Tiger Reserves

Ecosystem Service / Benefit from Tiger Reserves	Corbett	Kanha	Kaziranga	Periyar	Ranthambore	Sundarbans
Employment generation	●			●		●
Agriculture				●		
Fishing				●		●
Fuel wood	●	●		●		
Fodder / grazing	●	●		●		
Timber	●	●		●		
Standing timber	●	●	●	●	●	●
Non-Wood Forest Produce		●		●		●
Gene-pool protection	●	●	●	●	●	●
Carbon storage	●	●	●	●	●	●
Carbon sequestration	●	●	●	●	●	●
Water provisioning	●	●		●	●	
Water purification	●			●	○	
Soil conservation / sediment regulation	●	●		●	●	
Nutrient cycling / retention	●	●		●	●	●
Biological control	●	●	●	●	●	●
Moderation of extreme events	○			○		●
Pollination	●	●	●	●	●	●
Nursery function	○		○			●
Habitat / refugia	●	●	●	●	●	●
Cultural heritage	●		●	●	●	●
Recreation	●	●	●	●	●	●
Spiritual tourism				○	○	
Research, education and nature interpretation	○	○	○	○	○	○
Gas regulation	●	●	●	●	●	●
Waste assimilation	●	●	●	●	●	●
●	Estimated in monetary terms		○	Qualitatively described		



POLICY QUESTION

Can all services included here be considered directly additive?

2.4.27 AGGREGATION

The categories of benefits (ecosystem services) derived from each tiger reserve have been carefully identified to ensure that the estimated Total Economic Value components represent compatible forest uses under the current management practices in the tiger reserve. Doing so avoids

the pitfall of double-counting to which such valuation studies are prone to^{47,48}.

2.4.28 INVESTMENT MULTIPLIER

To demonstrate the benefits of investing in natural capital, the aggregate flow benefits from each tiger reserve is compared with its management costs to obtain an 'Investment multiplier'. The aggregate flow benefits are derived from the ecosystem services that are possible to value in monetary terms. The management costs are derived from the reserve-wise sanctions by the National Tiger Conservation Authority⁴⁹. Broadly, the 'Investment multiplier' demonstrates the quantum of benefits derived from each tiger reserve by spending 1 rupee in its management costs.

2.4.29 DISTRIBUTION OF BENEFITS ACROSS STAKEHOLDERS

As mentioned earlier, the benefits from tiger reserves are not limited to its boundaries, but often flow well-beyond local, sub-national or even national units. As a result, to understand the distribution of benefits from each tiger reserve, broad assumptions have been made on the per centage of benefits from each ecosystem service accruing at local, national and global scales (See Table 4). These assumptions have been made based on discussions with stakeholders and existing literature with the aim to initiate discussions on how benefits from tiger reserves may be distributed and what kind of instruments may help in equitable distribution of the same.



POLICY QUESTION

How are benefit distributed across local, national and global levels?

To demonstrate the benefits of investing in natural capital, the aggregate flow benefits from each tiger reserve is compared with its management costs to obtain an **'Investment multiplier'**



Table 4

Assumptions for Benefits Accruing at Different Spatial Scales

Ecosystem Services	Local	National	Global
Employment generation	100%		
Agriculture	80%	20%	
Fishing	70%	30%	
Fuel wood	100%		
Grazing	100%		
Timber	50%	50%	
Standing timber		100%	
NWFP	80%	20%	
Gene-pool		50%	50%
Carbon storage		30%	70%
Carbon sequestration		30%	70%
Water provisioning	30%	70%	
Water purification	30%	70%	
Sediment regulation	30%	70%	
Nutrient cycling	30%	70%	
Biological control	70%	20%	10%
Moderation of extreme events	70%	30%	
Pollination	70%	30%	
Nursery		30%	70%
Habitat for species		30%	70%
Cultural heritage	60%	30%	10%
Recreation		80%	20%
Spiritual tourism	50%	40%	10%
Research, education & nature int	20%	60%	20%
Gas regulation	30%	60%	10%
Waste assimilation	30%	70%	

Quantitative and qualitative estimates for as many as **25 ecosystem services** from selected tiger reserves are provided in the study. Although, not all services may be applicable at each of the tiger reserve.

2.4.30 SYSTEM DIAGRAMS

Many of the benefits received from tiger reserves are non-marketed, indirect and accrued to people far from their site of generation. The benefits are thus often difficult to attribute to one or the other tiger reserves. In order to help in clearly establishing the linkages between tiger reserves and natural processes within them and the benefits generated, the study has made an attempt to visualize one tiger reserve, i.e. Periyar Tiger Reserve in terms of a system with energy flows among its components, as the single most common denominator. Given the fact that within the Periyar Tiger Reserve, there are several links between soils, water, trees, biomass, biodiversity, wildlife and so on, quantification of energy inputs and outputs in each such linkage in great detail was beyond the scope of this study. The approach has helped in

KEY LEARNING



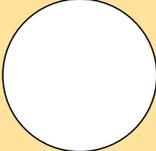
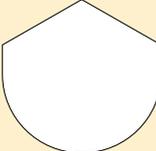
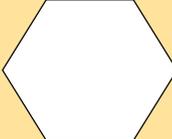
The **benefits** originating from tiger reserves flow well **beyond its boundaries**.



estimating at least the minimal economic value of services originating from the Periyar Tiger Reserve.

The system conceptualization is developed based on symbols briefly described below and helps in identification of important ecosystem services from the Periyar Tiger Reserve. It may be noted that some of the ecosystem services discussed in later sections relate to damage avoided and hence are not shown as a direct benefit emanating from the system, but marked in red.

Table 5
Symbols Used for Development of System Diagrams

Symbol	Description
	Energy source from outside
	Energy storage tank delivers energy flow to pathways
	Energy interaction, where two kinds of energy are required to produce high quality energy flow
	Producer unit converts and concentrates solar energy; it is self-maintaining
	Consumer unit uses high-quality energy and is self-maintaining

2.5 METHODOLOGY: COST OF RE-CREATING A TIGER RESERVE

The ecological services provided by the tiger reserves have a high impact on the surrounding areas. This section tries to assess the costs involved in re-creating a tiger reserve, if needed, from scratch at a place where forests having tigers once stood. Though it is practically impossible to re-create a new tiger reserve anywhere as the complexity involved in doing so is too high for humans to deal with, but this exercise still tries to derive approximate and major cost for this. The tiger reserves, we see in the country today, are forests which have evolved for centuries. Considering the time frame it would require to build a new tiger reserve from nothing again shows the impracticality of this thought. Moreover there would be a huge number of factors which are active in such area which humans are still unaware of.

The costs considered in this exercise are only for the establishment of a new tiger reserve. The time factor of the same has not been considered, primarily because we yet don't know how much time it would require to raise a tiger habitat from scratch, which would further evolve to the likes of other tiger reserves in India. Another factor that has not been considered in this exercise is the operational cost. It is assumed that once the tiger reserve is established, the operational cost would be borne by the Central and State Governments, just like the other tiger reserves. It is undisputed that creating new patches of such forest would, in the real world, be ideal on the aspect of conservation only if the existing ones are preserved as well. But the idea of clearing one forest and attempting to re-create the same elsewhere is a farfetched thought.

Selecting probable sites to be assessed for this exercise was a critical task. The aspects to be looked at, before selecting a final site, were based on the following points:



1. The new tiger reserve would have massive conservation impacts or conservation gains.
2. Ensuring minimum human distress because of relocation and rehabilitation.

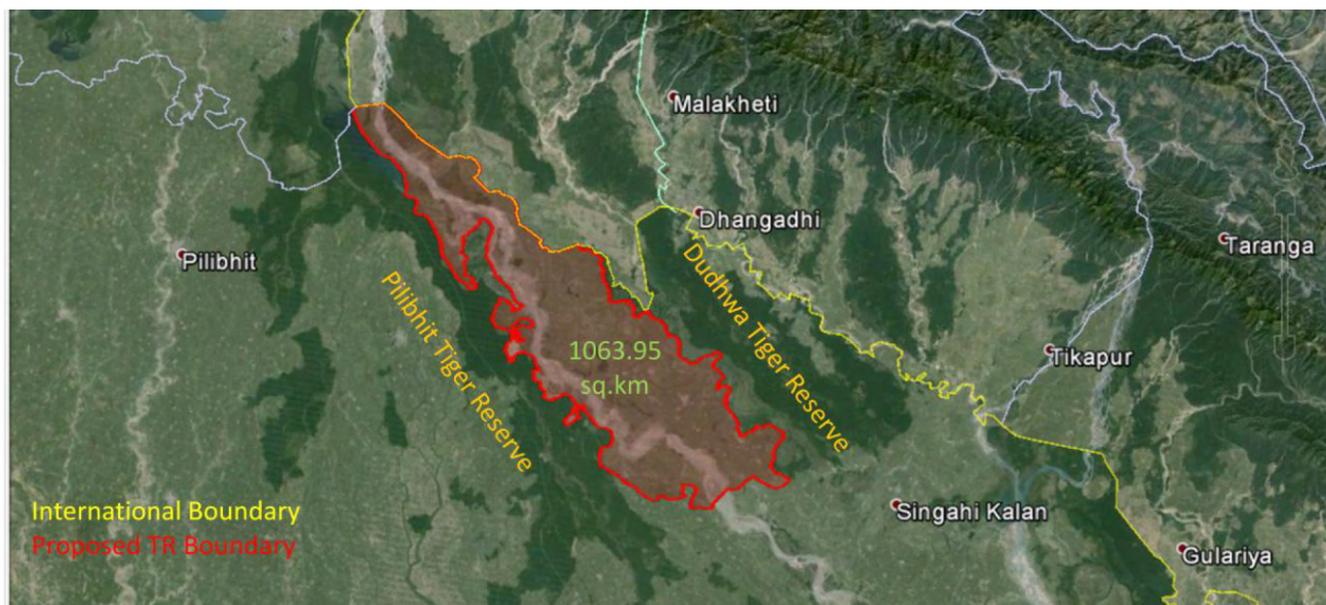
Three different sites were identified considering these two aspects. All the sites provided a huge conservational gain in terms of contiguity of forests, a site where tigers once existed but are now locally extinct and acquiring the site would cause the least possible human distress. The considered sites were:

1. Tadoba-Indravati Landscape
2. Pilibhit-Dudhwa Landscape
3. Melghat-Yawal Landscape

2.5.1 WHY PILIBHIT-DUDHWA AREA?

Figure 6

Site Considered for Assessing the Cost of Re-creating a Tiger Reserve



During expert consultations, these sites were discussed in detail on how considering any would be beneficial to the ecology while taking care of the negative impacts on the socio-economic aspects as well. Selecting the Tadoba-Indravati landscape would have impacted the city of Nagpur as it was in proximity of the land considered for the re-creation of a tiger reserve. Although this site would have been ideal if only conservational gains were to be considered as central India has the highest density of tiger reserves and wildlife sanctuaries. On the flip side, selecting this site would have caused immense human distress. For the Melghat-Yawal Landscape, the exercise tried to assess the gains and losses in joining Melghat Tiger Reserve and Yawal Wildlife Sanctuary. Though the earlier studies⁵⁰, it was observed that this was one of the regions of India where the tiger reserve density is least. The studies also show that the tigers once existed in this area but are no longer seen now. It would have been ideal to bring back tigers to this region. But the population density in this site is very high. Major land use is agriculture and the farm sizes are small. Taking this site for re-creating a tiger reserve here would have caused substantial human distress. Another factor to look at in this perspective is the forest area of Madhya Pradesh. The state already has a huge area under forests and may be reluctant to divert the remaining of the revenue land for a new tiger reserve. Finally, Pilibhit-Dudhwa Landscape, falling in the Terai Arc Landscape, was selected amongst the other options.

The cost of re-creating a tiger reserve considers only few associated costs. Even after incurring these, it cannot be guaranteed that the new area would be able to conserve genetic repository comparable to any tiger reserve.

Pilibhit and Dudhwa Tiger Reserves fall in the Terai Arc Landscape which is situated at the foothills of the Great Himalayas. Spread across three states of India, namely Uttarakhand, Uttar Pradesh and Bihar, Terai Arc Landscape stretches over an area of 810 km. between Yamuna and Bhagmati rivers. Although the area spreads over 49,000 km², an area of only about 30,000 km² lies in India. The rest is contributed by Nepal. This area is majorly covered by forests which accounts for half of the land use. Different varieties of vegetations like sal forests, riverine forests, mixed forests, grasslands and open scrubs may be found in this region. The Terai Arc Landscape conserves not only tigers but also other species like Asiatic elephants, swamp deer, the great Indian rhinoceros and Gangetic dolphins which was one of the major advantages in selecting this site among the other options. Thus, this landscape offers a lot in terms of conservation in India. The other major land use after forests in this region is agriculture. The agri productivity of this area is quite high. The main forces behind this productivity are availability of water, fertile soil and large farm sizes. Tiger reserves play a vital role in improving the soil quality of this area.

Dependency of people on forests in this area is quite high. People are dependent on the collection of fuelwood, fodder and grasses uses in rope-making for their livelihoods. Apart from these, other Non Timber Forest Produce are also collected from these areas such as fruits, medicinal plants and honey. In the last few decades the population in this region has grown at an alarming rate which has led to fragmentation of forest lands, encroachments and forest degradation. The ecological services which were once provided by this landscape are not even worth comparing. Not only are the ecological services being lost but the increased anthropogenic pressure has led to people being involved in poaching

and illicit trade of animal parts. With the shrinking habitat, the wild animals are now straying into the human habitations and causing damages. Man-animal conflict is a common occurrence in this area. Curbing these issues is a major challenge for the ministry and the forest departments of this region.

Pilibhit Tiger Reserve and Dudhwa Tiger Reserve are separated by two districts of Uttar Pradesh, namely Pilibhit and Kheri. Since the major land use in these districts is agriculture, it would require a large agricultural land to be acquired and then turned into a tiger reserve. The average size of the farms in this area is larger than compared to the other two proposed site. Larger farm size would mean less number of people dependent on one farm area and would ultimately mean less people to relocate. This is one of the important reasons why this area was selected over the other two sites. The land rates in the two districts range from a minimum of 8 lakh to 12 lakh per hectare.

Following the guidelines of NTCA, which say that the Critical Tiger Habitat (CTH) should ideally be of an area of 800-1200 sq. km. The site identified for the re-creating exercise stretches to an area of 1063.95 sq. km. It not only provides connectivity to the two reserves but allays the issue of man-animal conflict which is high in this area. There have been cases of livestock and minor human damages due to the wildlife in this region. This new tiger reserve will provide more area for the movement of wildlife which will reduce the incidents of wildlife straying into human habitations. Another political advantage would be the running of tiger reserve along the national boundary between India and Nepal which will add protection to the country boundary and would restrict trespassing.

The first step in the selection of an actual site for the tiger reserve was drawing polygons to represent the selected area.

The polygons were drawn stretching from the boundaries of Pilibhit Tiger Reserve to Dudhwa Tiger Reserve. Villages were identified using Bhuvan Portal and subsequently the boundaries of the new tiger reserve were created. The objective here was to identify a land area which could provide a contiguous patch of forest between the two existing tiger reserves spreading a minimal possible area to be acquired. This gave a final land area of around 1063.95 km².

To estimate the cost of re-creating a tiger reserve, major cost heads were identified which included land acquisition, rehabilitations and resettlement, habitat development, park fencing, infrastructure and tourism and cost-estimates were developed based on review of literature and consultation with authorities from selected tiger reserves.

2.5.2 WILLINGNESS TO PAY QUESTIONNAIRE

Further, a short online survey was carried out to assess the willingness to pay for

tiger conservation. Owing to resource limitations, it was decided to conduct the survey through internet-based social media websites like www.facebook.com, www.twitter.com, and others. The survey progressed with a snowball sampling approach where the initial respondent requested various people in his/her social group; by tagging them and requesting them to respond to the questionnaire. A total of 215 responses were collected over a period of 15 days. For the initial 115 respondents the BID value was kept as ₹ 100 per month for a period of 5 years, whereas for the next 100 responses the BID value was increased to ₹ 300 per month for a period of 5 years. The BID amount reflects the monetary contribution that the respondent pledges to pay for conservation of tigers in the country. It was proposed that this levy would be charged by adding the amount to every household's electricity bill. All the responses received were analysed and cleaned for data gaps. Twenty responses were rejected because of gaps in the information received.



03

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES





KEY MESSAGES

Based on literature review, discussions with local and national experts and consultations with communities in and around each tiger reserve, the study identified relevant ecosystem services for each tiger reserve. Wherever unavailability of data or robust methodology limited the ability to quantify the service in monetary terms, the service has been qualitatively described to demonstrate its significance. The study has attempted to provide quantitative and qualitative estimates for as many as 25 ecosystem services from selected tiger reserves. Further, other summarization tools such as distribution of benefits across local, national and global scale and ratio of flow benefits to management costs for each tiger reserve were used to provide context to economic values.



CORBETT TIGER RESERVE



KEY MESSAGES

A representative of Terai-arc landscape, Corbett is referred to as the land of roar, trumpet and song (attributed to tigers, elephants and birds respectively).

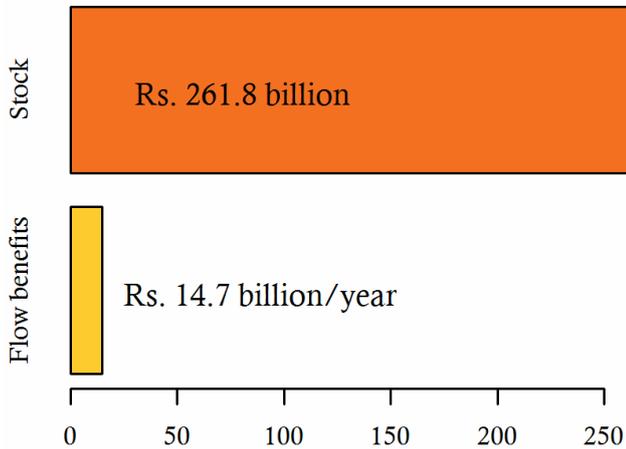
Important ecosystem services originating from Corbett include gene-pool protection (₹10.65 billion year⁻¹), provisioning of water to downstream districts of Uttar Pradesh (₹1.61 billion year⁻¹) and water purification services to the city of New Delhi (₹ 550 million year⁻¹).

Other important services emanating from Corbett include generation of employment for local communities (₹ 82 million year⁻¹), provision of habitat and refugia for wildlife (₹ 274 million year⁻¹) and sequestration of carbon (₹ 214 million year⁻¹).

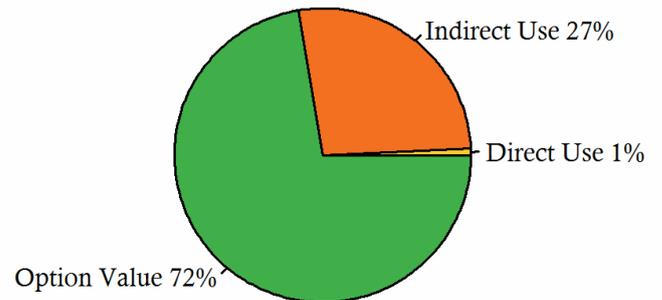
ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

3.1 CORBETT TIGER RESERVE

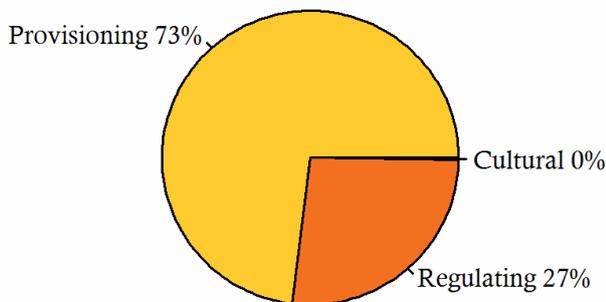
STOCK AND FLOW



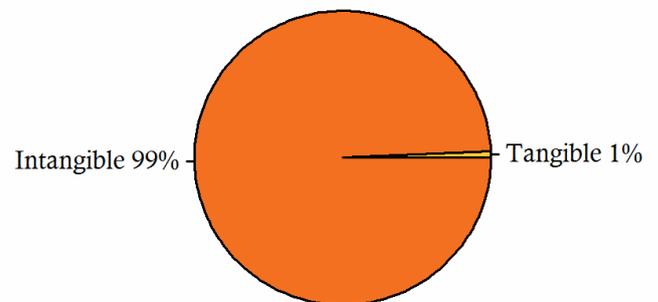
TYPE OF VALUE



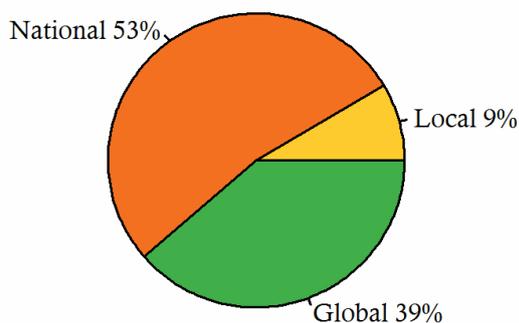
TYPE OF ECOSYSTEM SERVICE



TANGIBLES AND INTANGIBLES



DISTRIBUTION OF VALUE



Flow benefits per hectare per year
(Rs. lakh)

1.14

Flow benefits as a ratio of
management costs

368

3.1.1 SITE SPECIFICATION

3.1.1.1 LOCATION AND LANDSCAPE

Referred to as the land of roar, trumpet and song (attributed to tigers, elephants and birds respectively), Corbett Tiger Reserve (CTR) is situated in northern India and is a representative of the Terai-arc landscape. CTR is also one of the last surviving stretches of untouched sub-Himalayan wilderness. Located in three districts of the State of Uttarakhand — Pauri Garhwal, Nainital and Almora — CTR extends over an area of 1288 km² (822 km² of core zone and 466 km² of buffer zone), including the nearly 82 km² water spread area of the Ramganga reservoir created by construction of the Kalagarh dam on Ramganga river⁵¹. The core area of CTR comprises the Corbett National Park (521 km²) and the Sonanadi Wildlife Sanctuary (301 km²).

woodlands and Khair Sissoo forests which used to provide extensive grazing ground for the ungulates have now shrunk to about 600 hectares owing to submergence in the Ramganga reservoir. Grassland vegetation occupies nearly one-fifth of the tiger reserve area.

3.1.1.2 HISTORY

In May, 1934 Sir Malcolm Hailey, Governor United Provinces suggested creation of a National Park by legislative authority with the object of game preservation. Following the suggestion, a Game Sanctuary was established in 1934 which was later turned into Hailey National Park with an area of about 320 km² in 1935. This was the first national park of the Asian mainland and third throughout the world after Yellowstone National Park and Kruger National Park. To compensate for the submergence area due to the proposed Kalagarh dam, the boundaries of

Figure 7
Corbett Tiger Reserve



The tiger reserve is characterized by interplay of rivers, grasslands (*chaurs*) and forests of *Shorea robusta* (*sal*). The *sal* forests extend to about three quarters of the total area of tiger reserve. Major types of forests found in CTR include the Tropical Moist Deciduous Forests and the Tropical Dry Deciduous Forests. The once extensive alluvial savannah

the National Park were revised in 1966, bringing the total area of the park to 521 km². Regular forestry operations as per working plan prescriptions were carried on till the National Park was included in one of the nine tiger reserves initially selected for the Project Tiger in 1973.

3.1.1.3 TOPOGRAPHY AND CLIMATE

The terrain of the CTR is generally undulating, comprising a series of ridges running northwest to southeast interspersed with several valleys. The Ramganga, Palain, Mandal and Sonanadi rivers flow through these valleys. The weather in the tiger reserve is temperate. The temperature varies from 5 °C to 30 °C during the winter and mornings are often foggy. Summer temperatures normally do not rise above 40 °C. Rainfall ranges from light during the dry season to heavy during the monsoon.

3.1.1.4 RIVERS

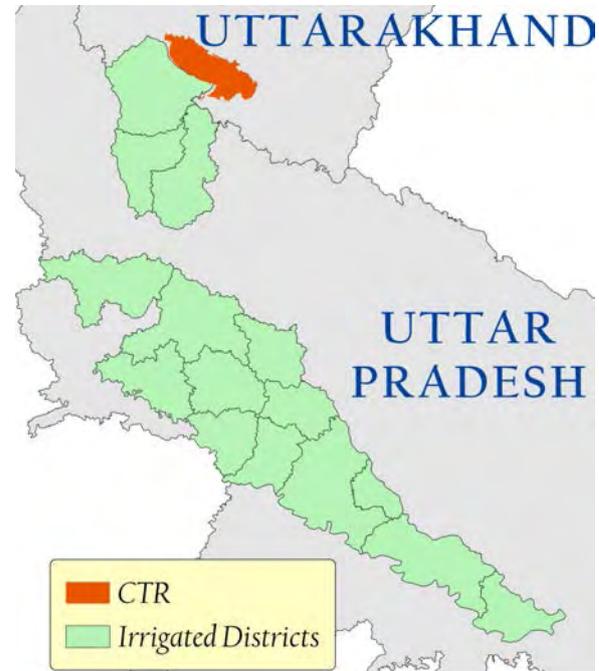
The Ramganga river is the perennial and basic water source for CTR. It originates in the outer Himalayas of Chamoli district and continues through the Himalayas for about 150 kilometres to the foothills before entering CTR. The three major tributaries of Ramganga — Sonanadi, Mandal and Palain — confluence with Ramganga at different spots in CTR (See Figure 7). The river Sonanadi enters the park from the northwest and meets with the Ramganga in the reservoir. River Mandal which holds its significance as a vital breeding ground for endangered masheer fish, runs along the northern region of CTR before it confluences with Ramganga. Palain enters CTR from the northeast and meets Ramganga at the north of the Ramganga reservoir. In addition to these rivers, the Kosi River, runs along the eastern region of CTR and is a perennial river like Ramganga. The Kosi River is also frequently visited by wild animals.

The Ramganga River was dammed inside CTR with the construction of Kalagar dam in 1974 mainly for augmenting the supply of irrigation water in the *Rabi* season under the low Ganga canal system. The dam is also used for generating hydropower electricity with a capacity of 198 (66 x 3) MW⁵². Currently, the Ramganga reservoir caters to aggregate irrigation requirements of 6 lakh hectares in various districts of Uttar Pradesh downstream⁵³.

The Ramganga reservoir caters to aggregate irrigation requirements of 6 lakh hectares in various districts of Uttar Pradesh downstream

Figure 8

Irrigation from the Ramganga Reservoir



3.1.1.5 BIODIVERSITY

CTR offers diverse habitats such as grassland, pure sal forests, rich miscellaneous forests, a large water body (the backwater of Kalagarh Dam), the Ramganga lotic ecosystem, vast stretches dry and rocky beds of numerous sots (rivulets), and others.

The tiger reserve is also home to 40 species from IUCN Red List among which 4 are Critical, 10 are Endangered and 26 are Vulnerable⁵¹. Arguably, apart from having the highest tiger density in the world (9.4 tigers / km² at the landscape level)⁵⁴, CTR has one of the world's most significant populations of Asiatic Elephants⁵⁵. It is a paradise for birdwatchers with close to 600 species of birds⁵¹. Floral diversity of CTR is very rich as the major portion of the reserve is confined to the Bhabar tract of Shiwalik formation. There are 617 species of the flora under 410 genera 111 families of Angiosperms (32 Monocot and 463 Dicots), 1 Gymnosperm and 22 Fern and fern allies⁵¹. The Ramganga River sustains a variety of aquatic life, including fishes in CTR. In addition to terrestrial biodiversity, CTR is considered to be one of India's most crucial *gharial* breeding sites⁵¹.

3.1.1.6 TOURISM

The rich biodiversity of CTR attracts several of tourists from across the globe. Every year, CTR receives more than two lakh tourists and generates revenues of over 74 million from gate receipts alone for the forest department (See Table 6). Apart from 89 nature guides, there are 25 room attendants, 227 Gypsy drivers and 50 Canteen attendants who derive direct employment from tourism in CTR. The impetus provided to the economy of Ramnagar and other adjacent areas from the tourism activities through backward and forward linkages is likely to be in many orders of magnitude. Tourism in CTR is largely confined to the southern and eastern boundary, and so are the associated benefits of employment from tourism.

Table 6
Tourist Visitation and Revenues to CTR56

Year	Indians	Foreigners	Total	Total Revenue from Gate Receipts (₹million)
2009-10	189988	8217	198205	44.4
2010-11	182019	7774	189793	64.2
2011-12	202528	7734	210262	70.2
2012-13	200656	6654	207310	60.9
2013-14	206413	5262	211675	74.8

3.1.1.7 SOCIO-ECONOMIC SITUATION

While there are no permanent settlements / villages inside the core area of the tiger reserve, about 250 Gujjar families camp inside the Sonanadi Sanctuary, now part of the core area of CTR⁵¹. Gujjars are nomadic Muslim folk with cattle rearing (mainly buffaloes) as their principal occupation. They are not only dependent on CTR for fodder of livestock, but also for poles for building shelter for themselves and their cattle. The tiger reserve is in the process of constituting the Special Tiger Protection Force (STPF) as a part of which 30 per cent of the forest guards will be recruited from local Gujjar communities to generate employment opportunities. On account of unavailability of undisturbed wildlife corridor along the southern and northern boundary of the reserve, cases of man-animal conflict characterize these regions of CTR.

The buffer zone of CTR is contiguous to the core zone (See Figure 7). There are 46 *chacks* (small revenue villages), 3 *khattas* and Gujjar *deras* (shelter for cattle) in this zone. Most of the *chacks* are abandoned by villagers and transformed into jungle. Agriculture and cattle rearing are the principal livelihood activities for people living in this area. The land is fertile and most farmers have adopted the modern style of farming. A large proportion of households live in *pucca* houses and while the use of LPG is becoming increasingly common, the traditional style of cooking in a fireplace is still preferred. The cattle population is very high and most of the cattle are low milk-producing traditional breeds. Stall feeding is not common. Dependence on forest resources among villages on the northern boundary is high compared to the villages on the southern boundary.

The socio-economic development of Gujjars and other communities living in buffer and adjoining areas is carried out in CTR through 62 Eco-Development Committees (EDCs)⁵¹. All the villages have functioning EDCs and capacity building of these EDCs by providing training on communication skills, creation of cooperatives and SHGs, account keeping, and income generation activities is a regular feature. While the landscape barring the tiger reserve is one of the most important commercial timber producers of India, commercial harvesting of timber is not practised in CTR⁵¹. Villagers have, however, been granted limited bonafide use of forests, especially to gather fuel wood and grass, in the buffer areas.

3.1.2 VALUATION OF ECOSYSTEM SERVICES FROM THE CORBETT TIGER RESERVE

3.1.2.1 EMPLOYMENT GENERATION

3.1.2.1.1 EMPLOYMENT IN MANAGEMENT OF CTR

Employment in management activities of CTR is an important livelihood for people living in and around the tiger reserve. On an average, 125,000 man-days were generated in the Ramnagar Forest Division of CTR annually for activities requiring casual labour in the last 5 years (Table 7). In addition, a greater number of local people are proposed for employment as protection force as a part of an initiative called the Operation Lord. The data for other forest divisions, i.e. Kalagarh is not available and hence the derived estimate represents a lower bound figure.

Table 7

Number of Man-days Generated in Ramnagar Forest Division of CTR⁵⁶

Year	2009-10	2010-11	2011-12	2012-13	2013-14
Number of Man-days	91308	182671	132929	124742	99254

Considering a local wage rate of ₹ 300 per man-day for casual labour based on discussions with the local community⁵⁶, the economic value of employment generated from employment as casual labour in management and maintenance of CTR is approximately equal to ₹ 37.5 million annually.

150000

man-days

local employment generated annually

100

quintals

dead-wood provided every month to villages in and around the buffer zone

3000

adult cattle units

dependent on buffer zone for fodder requirements

3.1.2.1.2 EMPLOYMENT IN COMMUNITY-BASED ECO-TOURISM (CBET)

The Gypsies and Canter operated for safari inside CTR also provide employment opportunities to local communities. There are about 237 Gypsies and 5 Canters operating in CTR⁵⁶. At least two people — one guide and one driver — receive daily employment in each of these vehicles. Thus, an estimated of 150,000 man-days are further generated for employment of local communities in addition to those generated through casual labour for reserve maintenance. Consider the same local wage rate of ₹ 300 per man-day, the economic value of employment generated through community-based eco-tourism is approximately equal to ₹ 45 million annually.

The total economic value of CTR in terms of providing employment opportunities to local communities through casual labour and community-based eco-tourism is thus approximately equal to ₹ 82.5 million annually.

3.1.2.2 AGRICULTURE

Major crops grown in the buffer zone and in the near vicinity of CTR include paddy, wheat, maize, sugarcane, pulses. In addition, horticulture crops such as mango, litchi, guava and papaya are also grown in the region that benefit from various functions of CTR such as groundwater recharge. However, on account of paucity of information that can objectively establish linkages between agricultural productivity and CTR, the economic value of agriculture in CTR attributable to the tiger reserve has not been estimated in monetary terms.

3.1.2.3 FISHING

Fishing is not allowed within CTR and hence the economic value of this ecosystem service has not been estimated for CTR.

3.1.2.4 FUEL WOOD

Although no formal collection of fuel wood is allowed in CTR either from core or buffer, the Uttarakhand Forest Development Corporation carries out extraction of dried and fallen timber from the areas outside the Sonanadi Wildlife Sanctuary. From the Kalagadh forest division of CTR, approximately 100 quintals of dead wood are provided to villages in the vicinity of the buffer zone every month to support their fuel wood requirements⁵⁶. Assuming an average price of ₹ 2 / kilogram of fuel wood, the economic value of annual fuel wood distributed from CTR is approximately equal to ₹ 0.24 million.





3.1.2.5 GRAZING

Only Gujjar families who are traditionally pastoralists are allowed to graze their cattle in the buffer areas of CTR. According to available estimates, there are about 830 buffaloes and 100 cows in the Ramnagar Forest Division and about 1750 Adult Cattle Units in the Kalagarh Forest Division of CTR⁵⁶. Considering one cow as one Adult Cattle Unit and one buffalo as 1.3 Adult Cattle Unit⁵⁷, the total number of Adult Cattle Units in CTR that are allowed to be grazed is equal to 2929. Assuming an average daily forage quantity of 22 kilograms / cattle⁵⁸, the total annual quantity of fodder harvested from CTR is approximately equal to 23,500 ton. Assuming an average local market price of ₹ 1 / kilogram of fodder, the economic value of annual fodder provisioning services provided by CTR is approximately equal to ₹ 23.50 million.

3.1.2.6 TIMBER

As mentioned earlier, no working of forests in CTR is practised, either in core or buffer, for timber production⁵¹. However, some villages in Kalagarh Forest Division are given usufruct rights for harvesting timber to be used as building materials for their houses. In 2013-14, 16 villages aggregately harvested 72 cubic metres (cum) of timber from

CTR⁵⁶. The landscape barring the tiger reserve is one of the most important commercial timber producers of India with timber from the area fetching high market prices. However, on account of lack of data on timber species-wise harvest, a conservative estimate of ₹ 10,000 per cum results in an economic value of ₹ 0.72 million annually from timber harvesting in CTR.

3.1.2.6.1 STANDING STOCK

While the flow value of timber from CTR is approximately equal to ₹ 0.72 million annually, the standing stock of timber has a significant economic value. Using the growing stock estimates of Tropical Moist Deciduous Forests from the forest inventory database⁵⁹ of the Forest Survey of India and estimates for forest area under different canopy cover densities⁶⁰, it is estimated that about 12.55 million cubic metres of standing stock of timber are contained in CTR. The economic value of this resource using an average price of timber at ₹ 25,000 / cubic metre and accounting for maintenance and transportation costs at 20 per cent of market price is approximately equal to ₹ 251.10 billion. The calculations for estimating the economic value of standing timber stock of CTR are as shown in Table 8 below.

Table 8
Standing Stock of Timber in CTR

Canopy Cover Density Class	Growing Stock (cum / ha)	Area (km ²)	Total Stock (million cum)	Economic Value (₹ billion)
VDF	175.52	289.3	5.08	101.54
MDF	90.98	782.8	7.12	142.43
OF	36.44	97.7	0.36	7.12
TOTAL		1169.8	12.55	251.10

3.1.2.7 NON-WOOD FOREST PRODUCE (NWFP)

No collection of non-wood forest produce is practised either in core or buffer areas of CTR and hence the economic value of NWFP from CTR has not been estimated.

3.1.2.8 GENE-POOL PROTECTION

Using estimates of economic value of gene-pool protection for tropical forests (₹ 91,020 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1170 km² of forests of CTR is equal to ₹ 10.65 billion / year.

3.1.2.9 CARBON STORAGE

While the forest area under different canopy cover density classes is available for CTR, further disaggregation across forest type groups (Tropical Moist Deciduous Forests and Tropical Dry Deciduous Forests) is not available. The carbon stock per unit area for Tropical Moist Deciduous Forests for the State of Uttarakhand has thus been used to estimate the amount of carbon stored in CTR.

Table 9

Carbon Stock in Tropical Moist Deciduous Forests of Uttarakhand²⁵

Carbon Stock (tonnes C / hectare)						
Canopy Cover Density Class	Above Ground Biomass (AGB)	Below Ground Biomass (BGB)	Dead Wood (DW)	Litter	Soil Organic Matter (SOM)	Total
VDF	39.76	8.18	1.17	3.12	47.72	99.95
MDF	31.23	6.42	0.82	3.18	40.87	82.53
OF	13.32	2.74	0.40	1.95	36.93	55.34

According to an exercise carried out to map forest canopy cover in CTR by the Forest Survey of India⁶⁰, Very Dense Forests (VDF) cover 289 km², Moderately Dense Forests (MDF) cover 783 km², and Open Forests (OF) cover 98 km² of area in CTR. About 118 km² of area within the tiger reserve is non-forest. Using these estimates in conjunction with carbon stock in various carbon pools as shown in Table 9, the total carbon stored in CTR is approximately equal to 9.89 million tonnes. Valued in terms of the social cost of carbon for India by making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of carbon stored in CTR is estimated to be ₹ 10.65 billion.

3.1.2.10 CARBON SEQUESTRATION

Apart from storing 9.89 million tonnes of carbon, forests of CTR sequester carbon on an annual basis. As no primary study estimating carbon sequestration in CTR exists, the same has been estimated here based on the forest inventory database of the Forest Survey of India. The total biomass for Tropical Moist Deciduous Forests in different canopy cover densities i.e. Very Dense Forests, Moderately Dense Forests and Open Forests has been taken from the forest inventory database⁵⁹. Based on total biomass per unit area, the mean annual increment (MAI) has been estimated using the Von Mantel Formula⁶¹ and the physical rotation period estimated in a recent study for Tropical Moist Deciduous Forests⁶². Assuming a biomass-to-carbon conversion ratio of 50%⁶³, the mean annual increment in above ground biomass has been converted to carbon sequestered in dry matter.

About **10 million tonnes** of carbon is stored in forests of CTR. In addition, about **200 kilo tonnes** of carbon is sequestered annually.

Using this methodology, the total carbon sequestered in the forests of CTR by aggregating across different canopy cover density classes is equal to 198.82 kilo tonnes annually. The derivation of the same is as shown below in Table 10.

Table 10
Carbon Sequestration in CTR

Canopy Cover Density	Total Biomass (t/ha)	MAI (t ha ⁻¹ yr ⁻¹)	Annual Carbon Sequestration (tC ha ⁻¹ yr ⁻¹)	Area (km ²)	Total Carbon Sequestration ('000 tC yr ⁻¹)
VDF	158.68	5.04	2.52	289.3	72.86
MDF	96.10	3.05	1.53	782.8	119.41
OF	42.29	1.34	0.67	97.7	6.56
				1169.8	198.82

Using the social cost of carbon for India and making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of annual carbon sequestered in CTR is estimated to be ₹ 214.10 million.

3.1.2.11 WATER PROVISIONING

The dense and deep root system of forest soils, dense under-storey and the high porosity of its essentially organic horizons in CTR make for excellent water infiltration and retention capacity. Surface runoff is minimal and groundwater recharge more efficient, resulting in regular stream flow to the Ramganga reservoir during the year. The water from the Ramganga reservoir irrigates about 600,000 hectares in 15 districts of Kashiram Nagar, Eta, Farukhabad, Mainpuri, Kannauj, Firozabad, Oria, Kanpur (rural), Fatehpur, Etawah, Kanpur, Kaushambi, Bijnaur, Moradabad and J. P. Nagar in Uttar Pradesh⁵³. These districts are heavily dependent on irrigation for agricultural production. Assuming that it would be possible to carry out rainfed agriculture in these areas even without getting water from the Ramganga reservoir and the water from the reservoir is used to take second (Rabi) crop in these agricultural areas, the economic value of water from CTR is estimated using the production function approach. Such an approach has been used globally to value forests for the water catchment benefits⁶⁴. To avoid over-complexity, it is assumed that rice is cultivated in the area irrigated by the Ramganga reservoir. Assuming an average yield of 2.2 tonnes / hectare for paddy⁶⁵ and Minimum Support Price of ₹ 13,100 / ton⁶⁶, the estimates of total value of additional agricultural production in the irrigated area by the Ramganga reservoir is approximately equal to ₹ 1729 million annually.

Assuming that 50% of the value of this agricultural production can be attributed to irrigation⁶⁷, the total economic value of irrigation water from CTR estimated through the production function approach for additional agricultural production is approximately equal to ₹ 865 million annually.

In addition, the Kalagarh dam is used for production of hydro-electricity. The current capacity of the hydropower unit is 198 MW (3 x 66 MW) and average annual electricity production of the last five years through the unit is approximately equal to 300 Million KWH⁵². Conservatively assuming an average unit price of ₹ 2.5 / KWH, the economic value of annual electricity produced through the water from CTR is approximately equal to ₹ 750 million.

The economic value of agricultural production and hydropower electricity generated through the water from CTR is thus approximately equal to ₹ 1,615 million.

3.1.2.12 WATER PURIFICATION

Owing to natural filtration processes, the water derived from the catchment of the Ramganga reservoir that includes CTR does not need any artificial treatment before supply. The reservoir annually contributes about 190 million m³ of drinking water to the city of New Delhi⁵³. This service of natural water purification is a benefit in terms of water purification costs avoided^{2,34,68,69}. The canal system used to irrigate 600,000 hectares in downstream districts of Uttar Pradesh also contribute to drinking water requirements in these areas, but due to paucity of data, this has not been included in calculations.

Assuming an average cost of treating water for domestic supply at ₹ 10 / m³ based on estimates for different municipalities in India³², the avoided cost of purifying 190 million m³ of water annually is approximately equal to ₹ 1900 million. About 900 km² out of 3107 km² of catchment of Ramganga Reservoir falls in CTR⁷⁰ and hence the proportional water purification benefits attributable to CTR is equal to ₹ 550 million annually.

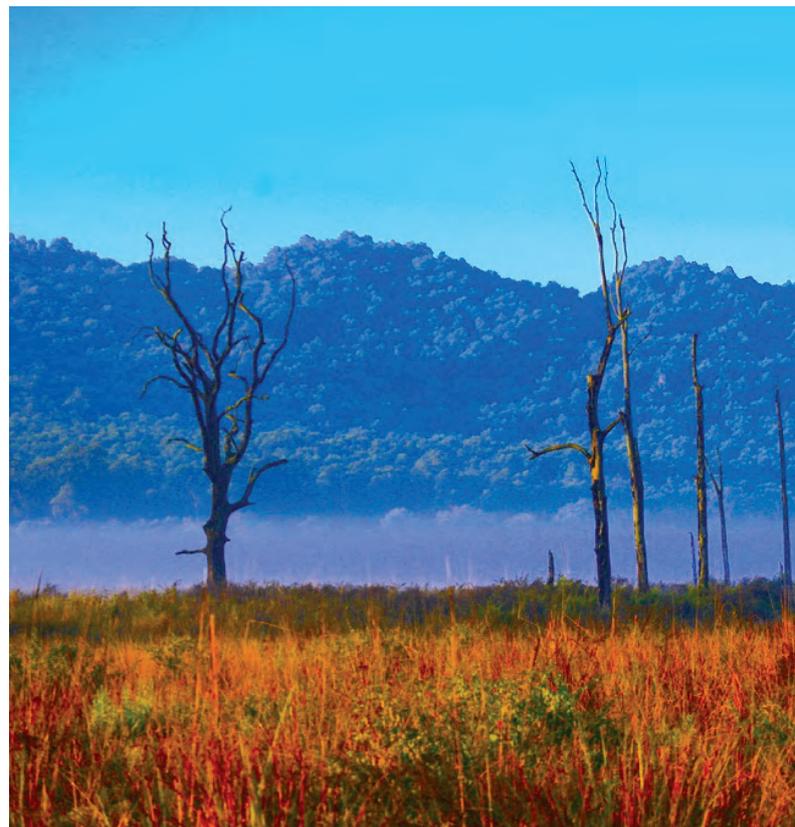
3.1.2.13 SEDIMENT REGULATION

As stated earlier, the Ramganga Reservoir is a lifeline for downstream districts of the State of Uttar Pradesh and Delhi for irrigation and drinking water. Vegetation of CTR, especially forests, protects soil and reduces erosion rates. Deep tree roots stabilize slopes of this undulating terrain and give the soil mechanical support which can help to prevent shallow mass movements. In the absence of forests in the catchment of the Ramganga reservoir, the sediment load in the rivers and streams draining into the reservoir is likely to increase manifold. The increased sediment load will lead to decrease in the capacity of the reservoir. Technological measures will then be needed to dredge the reservoir and excavate the sediment load in the reservoir to ensure deriving maximum benefits from the reservoir. The forests of CTR, and even the grasslands surrounding the reservoir to an extent, play this important role of minimizing the sediment load in the streams that eventually flow into the Ramganga Reservoir. This avoided cost of dredging the reservoir can be directly attributed as an economic value of the CTR⁷¹⁻⁷³. In addition, the off-site costs of soil erosion include roadway, sewer and basement siltation, drainage disruption, undermining of foundations and pavements, gulying of roads, earth dam failures,

eutrophication of waterways, siltation of channels, loss of wildlife habitat, disruption of stream ecology, among others which have not been considered here³³.

It has been estimated that forests in the lower Himalayas prevent 12.5 tonnes of soil erosion per hectare per annum⁴¹. These rates of avoided erosion have been used here to estimate avoided sedimentation into the Ramganga Reservoir. As stated earlier, about 900 km² of catchment of the reservoir falls within CTR. On account of lack of land use data for the catchment area falling within CTR, it is assumed that the proportion of forests to non-forests is the same in this region as in the CTR, i.e. 90 per cent of area is covered with forests.

The total forested area in the catchment of the Ramganga Reservoir falling within CTR thus derived is approximately equal to 810 km². On the basis of soil erosion avoided from forests and sediment delivery rate of 30% derived from InVEST exercise for Periyar (used here due to similarity in topography), the total sediment load avoided in the Ramganga Reservoir by the forested regions of the CTR is approximately equal to 0.30 million tonnes year⁻¹. It may be noted that on account of lack of data, this only includes the sediment load avoided from forested regions and ignores the contribution of grasslands for arresting soil erosion.



To estimate the economic value of avoiding the estimated sediment load in the Ramganga Reservoir, the cost of alternative technological interventions is considered. Considering cost estimates of ₹ 58.31 / cum given by the Central Water Commission as the earth excavation costs⁷⁴ along with an assumed weight of soil as 1.2 tonne/cum⁴⁰, the economic value of sedimentation avoided is approximately equal to ₹ 14.58 million per year.

3.1.2.14 NUTRIENT CYCLING

The nutrient cycle in an undisturbed forest ecosystem is nearly closed, thereby preventing unnecessary loss of nutrients^{75,76}. Studies conducted in nearby agricultural fields have shown that while fields use fertilizers which are two to three orders of magnitude less than the national average, the productivity of these fields is only slightly less than the national average⁷⁷. Nutrient regulation has been estimated by several studies, mostly using the replacement cost of fertilizers³⁴⁻⁴¹. A similar approach has been used here to estimate the value of nutrient cycling functions of forests of CTR.

Due to soil erosion in the absence of forests, vital nutrients shall be lost along with sediments. The litter also has significant nutrient concentration and if these forests

would not have been there, nutrients would further leach from this litter nutrient pool. However, to keep estimates conservative, the nutrient leaching from litter is not considered in the study. On account of lack of local estimates for CTR, a study conducted for the Doon Valley has been used. The study site resembles CTR in terms of terrain, soil types, rainfall and forest vegetation⁷⁸.

As estimated earlier, the total sediment load avoided in the Ramganga Reservoir by the forested regions of the CTR is approximately equal to 0.30 million tonnes year⁻¹. Using this estimate and the concentration of N, P and K in soil from Table 11, the quantity of nitrogen, phosphorus and potassium that would leach out from the system is approximately equal to 696, 13 and 2475 tons annually. Valuing the quantity of nutrient lost in this process with the help of price of NPK fertilizers⁷⁹, the total value of CTR's forests in preventing nutrient loss is equal to ₹ 53.56 million annually and is demonstrated in Table 11 below.



600000 agricultural area irrigated
hectares

300 electricity generated
million KWH per year

190 drinking water supplied to the city of New Delhi
million cubic metre per year

0.3 sedimentation avoided
million cubic metre per year

Table 11

Avoided Nutrient Loss by Corbett Tiger Reserve

Nutrient	Soil Nutrient concentration I (g kg ⁻¹)	Total Nutrient Loss Avoided by CTR Forests (ton yr ⁻¹)	Fertilizer Used for Valuation	Price of fertilizer ^{iv} (₹ kg ⁻¹)	Economic Value of Nutrient Loss Avoided (₹ million yr ⁻¹)
Nitrogen (N)	2.320	696.0	Urea (46% N)	5.31	3.70
Phosphorus (P)	0.044	13.2	DAP (18-46-0-0)	20.10	0.27
Potassium (K)	8.25	2475	Muriate of Potash (60% K ₂ O)	20.00	49.50
TOTAL					53.56

3.1.2.15 BIOLOGICAL CONTROL

Using estimates of economic value of biological control for tropical forests (₹ 660 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1170 km² of forests of CTR is equal to ₹ 77.22 million / year.

3.1.2.16 MODERATION OF EXTREME EVENTS

The Ramganga reservoir provides protection to more than 60,000 hectares of flood-prone areas in downstream districts of Uttar Pradesh including Bijnaur, Moradabad, Bareilly, Rampur, Shahjahanpur and Farrukhabad⁸⁰. CTR has a location value in terms of providing an ideal location for building a dam to provide flood protection benefits. However, due to paucity of data to estimate the value attributable to CTR, the same has not been estimated here in terms of monetary value.

3.1.2.17 POLLINATION

Using estimates of economic value of pollination for tropical forests (₹ 1,800 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1170 km² of forests of CTR is equal to ₹ 210.60 million / year.

3.1.2.18 NURSERY FUNCTION

As mentioned earlier, river Mandal flowing into the Ramganga reservoir holds its significance as a vital breeding ground for endangered masheer fish. However on account of paucity of data regarding the same, the nursery function of CTR has not been estimated in monetary terms.

3.1.2.19 HABITAT / REFUGIA

Using estimates of the economic value of habitat / refugia for tropical forests (₹ 2,340 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1170 km² of forests of CTR is equal to ₹ 273.78 million per year.

River Mandal is a vital breeding ground for endangered **mahseer fish**



3.1.2.20 CULTURAL HERITAGE

CTR has a rich conservation history having the honour of being the first national park of the Asian mainland and third throughout the world after Yellowstone National Park and Kruger National Park. The reserve also represents one of the last surviving stretches of untouched sub-Himalayan wilderness and thus represents an irreplaceable cultural and natural heritage.

3.1.2.21 RECREATION

CTR is a very popular tourist destination. The scenic beauty of interplay of rivers, grasslands (*chaurs*) and Sal forests in the backdrop of the Shivalik hills and wildlife attract many tourists — both Indians and foreigners. The number of visitors to the reserve has been on the rise with more than 2 lakh tourists on an average visiting CTR in the last five years as shown in Table 6 above.

Recreational tourism brings significant revenues for the authorities of the CTR. For the last three years, this has been approximately equal to ₹ 70 million⁵⁶. In addition, about 200 hotels and resorts in Ramnagar and neighbouring towns directly benefit from the recreational opportunities offered at CTR.

While it is acknowledged that the revenue for Reserve Authorities as well as other establishments can be attributed largely to the scenic beauty and wildlife of the CTR, exact attribution is difficult. A recent study⁷⁷ has estimated the economic value of the recreational tourism of CTR which has been used here. The study found that the consumer surplus, which is the difference between the price which one is willing to pay and the price one actually pays for an average tourist visiting CTR is equal to ₹ 150 per visit*. Based on the average annual

visitation rates of 2 lakh tourists based on the last five years, the total estimated consumer surplus of recreation services from CTR is approximately equal to ₹ 30 million per year.

3.1.2.22 SPIRITUAL TOURISM

There are no major points of spiritual tourism within CTR and hence the economic value of this service from CTR has not been estimated here.

3.1.2.23 RESEARCH, EDUCATION AND NATURE INTERPRETATION

CTR is one of the sought-after places for conducting research on account of its wilderness and long history of relatively undisturbed natural processes. As a result, many research works have been carried out by the Wildlife Institute of India, Zoological Society of India, Kumaun University, and Pantnagar Agriculture University, among several others in the area of wildlife ecology, remote sensing, plant survey, eradication of invasive species, fire ecology, ornithology and tourism. The entire landscape of CTR provides unique opportunities for research, education and nature interpretation, not easily found in any other areas.

3.1.2.24 GAS REGULATION

Using estimates of economic value of gas regulation for tropical forests (₹ 720 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1170 km² of forests of CTR is equal to ₹ 84.24 million per year.

3.1.2.25 WASTE ASSIMILATION

Using estimates of economic value of waste assimilation for tropical forests (₹ 7,200 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1170 km² of forests of CTR is equal to ₹ 842.40 million per year.

* Assuming 1 US\$ = ₹ 60

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

3.1.2.26 SUMMARY OF ECOSYSTEM SERVICES BASED ON TEV FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Direct Use Value	106.96	₹ million / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce		
Indirect Use Value	3965.48	₹ million / year
carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation		
Option Value	10650.00	₹ million / year
gene-pool protection		

3.1.2.27 SUMMARY OF ECOSYSTEM SERVICES BASED ON MILLENNIUM ECOSYSTEM ASSESSMENT FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Provisioning Services	10756.96	₹ million / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection		
Regulating Services	3935.48	₹ million / year
carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, gas regulation, waste assimilation		
Cultural Services	30.00	₹ million / year
cultural heritage, recreation, spiritual tourism, research, education and nature interpretation		



3.1.2.28 SUMMARY OF ECOSYSTEM SERVICES BASED ON STOCK AND FLOW BENEFITS FRAMEWORK

Type of Value	Value	Unit
Flow Benefits	14.72	₹ billion / year
	1.14	₹ lakh / ha / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection, carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation		
Stock	261.75	₹ billion / year
standing timber, carbon storage		

3.1.2.29 SUMMARY OF ECOSYSTEM SERVICES BASED ON TANGIBLE AND INTANGIBLE BENEFITS FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Tangible Benefits	106.96	₹ million / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce		
Intangible Benefits	14615.48	₹ million / year
carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation, gene-pool protection		

3.1.2.30 DISTRIBUTION ACROSS STAKEHOLDERS (FLOW BENEFITS)

Based on assumptions made in Section 2.4.29, approximately 9 per cent of flow benefits accrue at the local level, 53 per cent at the national level and 39 per cent at the global level.

3.1.2.31 INVESTMENT MULTIPLIER

According to the last sanction from the National Tiger Conservation Authority, the annual management costs of Corbett Tiger Reserve for the year 2013-14 amounted to ₹ 36.74 million. Based on the flow benefits of ₹ 14.72 billion per year, for every rupee spent on management costs in CTR, flow benefits of ₹ 368 are realized within and outside the tiger reserve.

For every rupee spent on management costs currently, flow benefits of approximately

₹ 368

are realized within and outside the Corbett Tiger Reserve.



KANHA TIGER RESERVE



KEY MESSAGES

A typical geo-physiographical representative of the Central India Highlands, Kanha is internationally renowned for successful conservation of two endangered wildlife species, viz. the Royal Bengal Tiger and the Central Indian Barasingha.

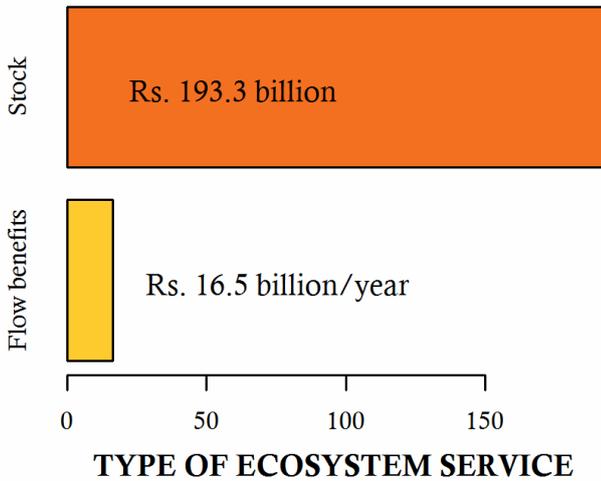
Important ecosystem services originating from Kanha include gene-pool protection (₹12.41 billion year⁻¹), provisioning of water to downstream regions (₹ 558 million year⁻¹) and provisioning of fodder in buffer areas (₹ 546 million year⁻¹).

Other important services emanating from Kanha include recreation value (₹ 384 million year⁻¹), provision of habitat and refugia for wildlife (₹ 319 million year⁻¹) and sequestration of carbon (₹ 219 million year⁻¹).

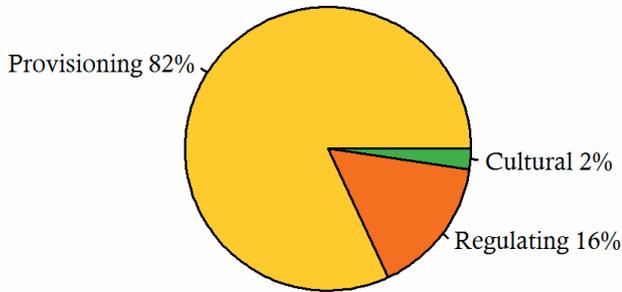
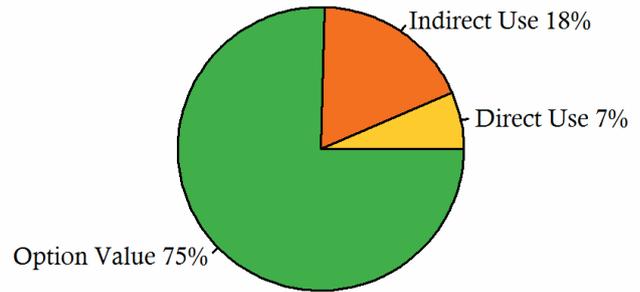
ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

3.2 KANHA TIGER RESERVE

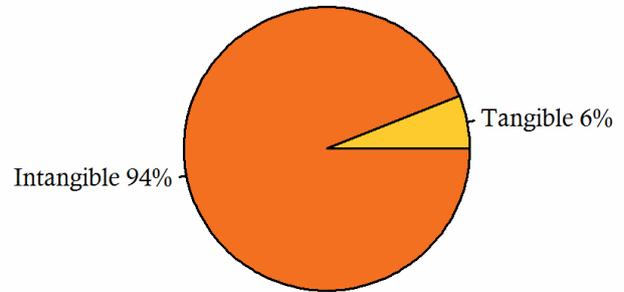
STOCK AND FLOW



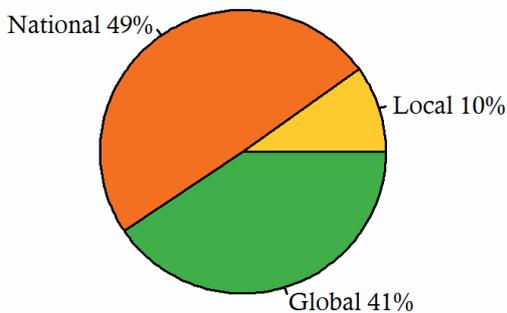
TYPE OF VALUE



TANGIBLES AND INTANGIBLES



DISTRIBUTION OF VALUE



Flow benefits per hectare per year
(Rs. lakh)

0.8

Flow benefits as a ratio of
management costs

273

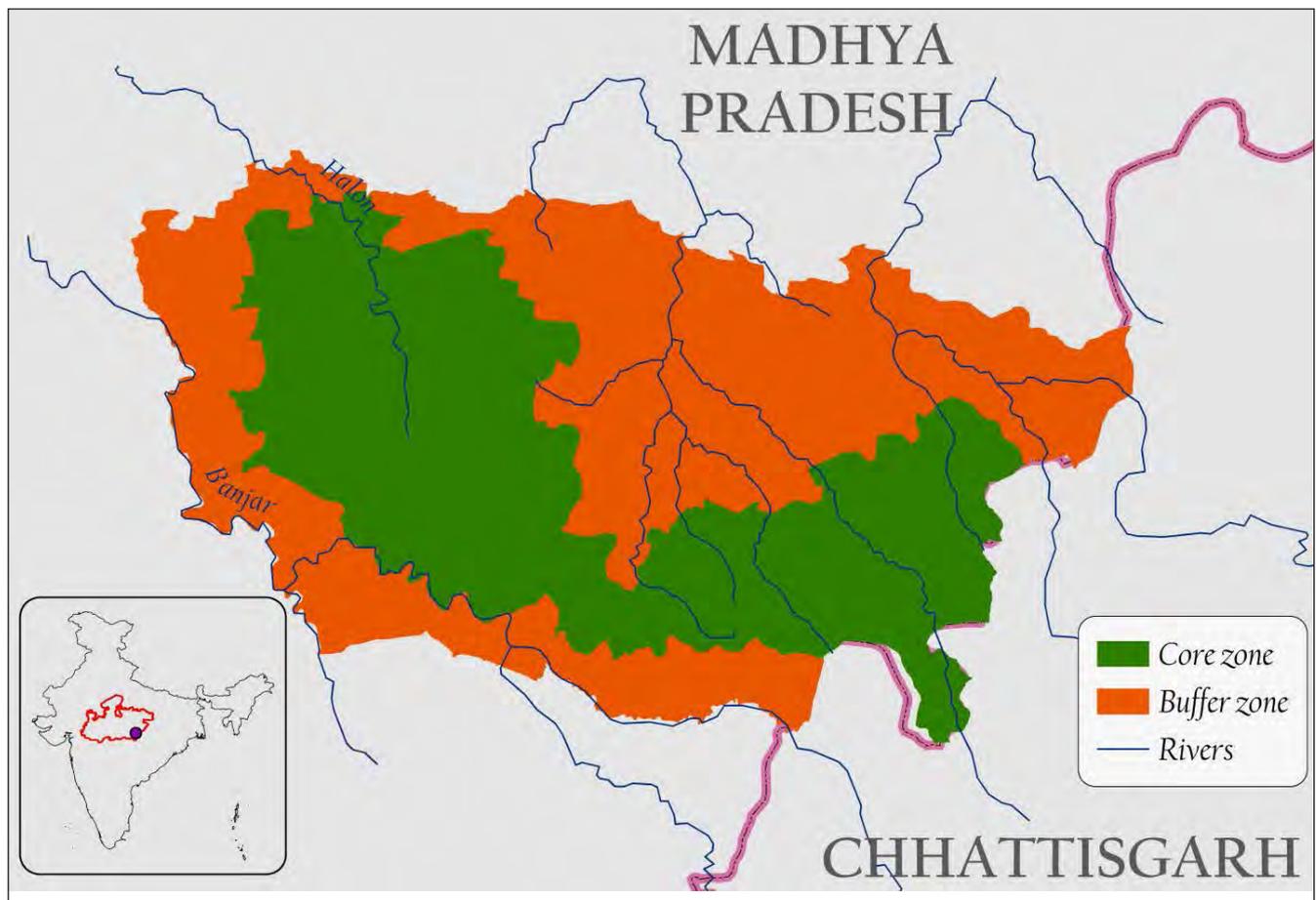
3.2.1 SITE SPECIFICATION

3.2.1.1 LOCATION AND LANDSCAPE

A typical geo-physiographical representative of the Central India Highlands, Kanha Tiger Reserve (KTR) situated in Madhya Pradesh is internationally renowned for successful conservation of two endangered wildlife species, viz. the Royal Bengal Tiger and the Central Indian Barasingha. Spread over districts of Mandla, Balaghat and Dindori, KTR covers an area of 2051 km² (917 km² of core zone and 1134 km² of buffer zone)⁸¹.

Figure 9

Kanha Tiger Reserve



Broadly, the forests of KTR can be classified into Sal and Mixed Deciduous Forests (mainly includes saja, tinsa, dhawara, lendia, tendu, achar, khair, mahua, bija, harra and aonla). The data of different vegetation and age class-wise areas suggests dominance of middle-aged miscellaneous crops (54% of land area) in the core zone followed by middle aged sal forests (38%)⁸¹. Grasslands occupy nearly 8% area of KTR's core zone and are a significant feature of this dynamic ecosystem. The grassland meadows of the core zone are regularly invaded by woodland species, requiring the arrest of this ecological succession for maintaining meadows to foster ungulate population in the tiger reserve.

44%

covered with very dense forest

88%

area with slope of less than 10 degrees

60

square kilometres

area of relocated villages reclaimed for wildlife

475

population of Hardground Barasingha

According to the assessment carried out on forest cover in tiger reserves of India by the Forest Survey of India⁶⁰, about 44 per cent of the tiger reserve area (including both core and buffer) is covered with Very Dense Forest (canopy cover density greater than 70 per cent), 16 per cent with Moderately Dense Forest (canopy cover density between 40 and 70 per cent), and 6 per cent with Open Forest (canopy cover density between 10 and 40 per cent). The remaining area, i.e. 34 per cent of the tiger reserve is non-forest.

The buffer zone of KTR consists of forest land (mainly reserve forests), revenue land and private holdings. Revenue land occupies roughly half of the buffer zone. Except for some of the eastern region, the buffer in KTR almost completely surrounds the core zone and exemplifies the 'core-buffer' strategy for biodiversity conservation.

3.2.1.2 TOPOGRAPHY AND CLIMATE

The topographical data of the core zone suggests that the area is almost flat with 88% of land having a slope of less than 10 degrees. The eastern and the western part of the core zone is divided by a narrow ridge known as the "chicken's neck". These topographical attributes foster pockets of high and low prey density areas within the tiger reserve, resulting in unequal concentrations of tigers and co-predators in different portions of the habitat. Natural fires are very rare occurrences here.

3.2.1.3 RIVERS

Geographically, the Maikal range is the most important terrain feature, running along the eastern boundary of the core zone, forming the watershed between the rivers Narmada and the Mahanadi. This hill-range continues to the west within the core zone as the Bhaisanghat ridge, dissecting the Narmada catchment between the River Banjar, to the south-west and west, and the River Halon, to the east and the north-east. The Bhaisanghat ridge

bifurcates near Bamhnidadar, with the main spur running to the north, while its branch running west sub-divides the Banjar River catchment between the Banjar itself and its tributary, the Sulkum (also known as the Surpan in the lower reaches).

The River Halon originates in the state of Chhatisgarh just outside the Supkhar range, and flowing through this range in the eastern part enters the buffer zone. The river remains perennial within the park. The River Banjar, forming the core zone's south-western boundary, though not perennial, retains small and large pools of water. Due to erratic rainfall, only some of the major tributaries of these rivers have perennial stretches in the upper reaches of the tiger reserve.

3.2.1.4 BIODIVERSITY

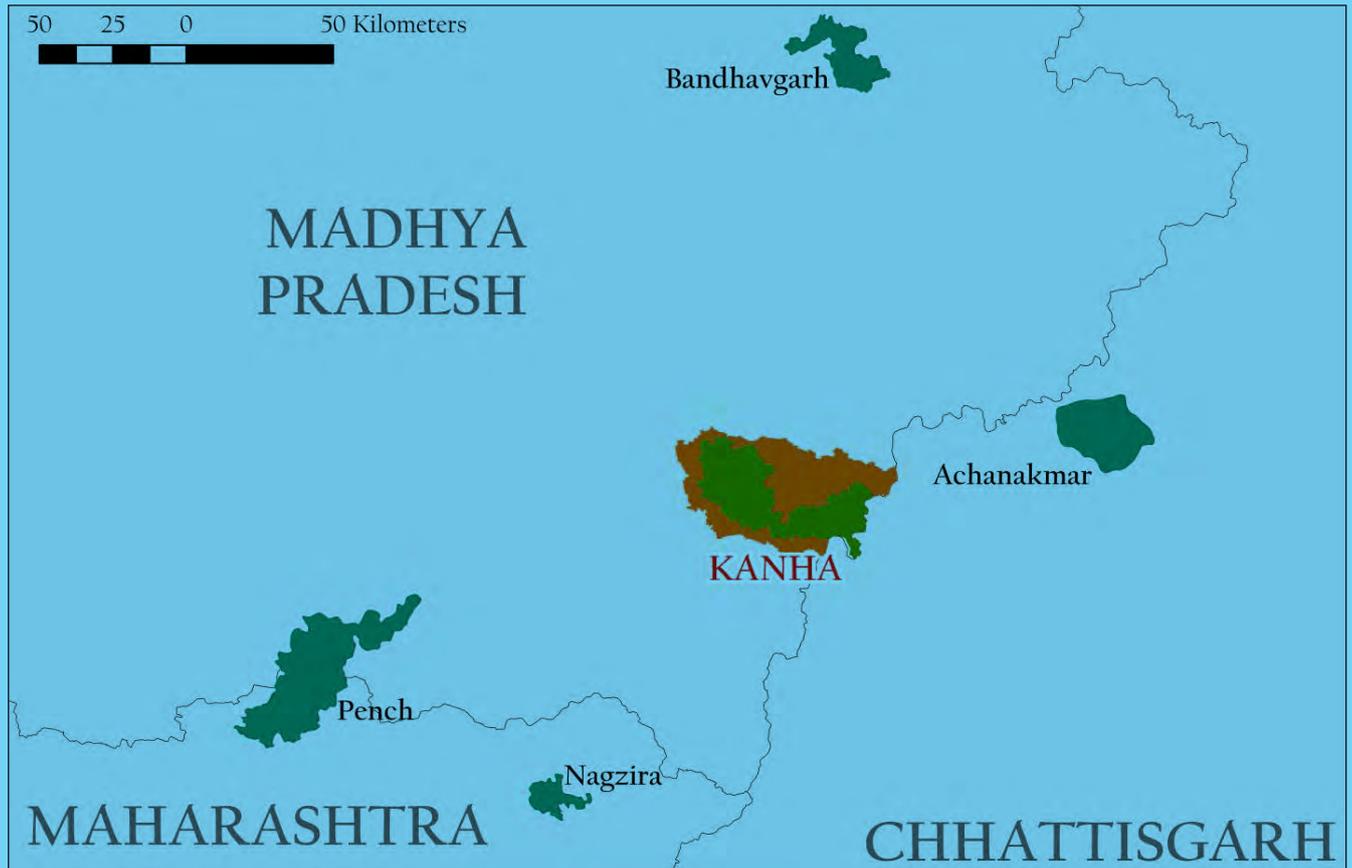
While there are broadly two habitat types, namely forests and grasslands, in the core zone of KTR, finer classification of habitats suggest the existing presence of a range of habitat complexes such as sal forests, miscellaneous forests, miscellaneous forests with bamboo, grasslands, grassland with groves, forest-grassland edges and riparian. In addition, about 60 km² of large clearings of already relocated villages have been reclaimed for wildlife habitat.

KTR supports the tiger as the main predator, and the leopard and wild dog as co-predators. These predators rank as such in the predation hierarchy, and have a distinct niche of their own. The prey population includes the chital, wild boar and other ungulates. A recent animal biomass assessment has shown that almost one-fifth of the total prey biomass in KTR is available to predators annually. Roughly, 90% of the food of predators is derived from the prey biomass available in KTR⁸¹. The balance requirement is met by livestock from peripheral villages.

The core zone of KTR enjoys considerable ecological connectivity with other wildlife protected areas in and around the tiger

reserve. These include the Achanakmar Tiger Reserve in Chhattisgarh, Bandhavgarh and Pench Tiger Reserves in Madhya Pradesh, and Nagzira and Pench Tiger Reserves in Maharashtra (See Figure 10). The Kanha-Pench corridor on the western side is arguably the most promising connectivity reported to be frequently used by tigers. Lying in the middle of an extensive forest belt, the significance of KTR as a conservation nucleus for ensuring gene flow cannot be overstated.

Figure 10
Kanha Tiger Reserve as a Conservation Nucleus



The tiger reserve is an excellent example of how tiger serves as an umbrella species and ensures adequate protection measures for all forms of wildlife. KTR is the last world population of the endangered sub-species Hard Ground Barasingha. Once found in several districts of Madhya Pradesh, Maharashtra, Orissa and Andhra Pradesh, the Hard Ground Barasingha has been revived from the brink of extinction and is now endemic only to the core zone of KTR in the world. Its current population is about 475⁸¹. In the recent past, the Park Management has successfully translocated a few gaurs, a tiger and two tigresses to other protected areas and more projects are proposed under active wildlife management.



3.2.1.5 TOURISM

Presently, an area of about 350 km² is designated as the tourism zone with the core area of KTR⁸¹. The entire tourism zone has been divided into three sub-zones, i.e. Kanha, Mukki and Sarhi.

3.2.1.6 SOCIO-ECONOMIC SITUATION

Since being notified as a National Park, 28 forest villages have been relocated from the reserve in a peaceful, transparent and problem-free manner, with the latest being Jami in 2010⁸¹. At present, there are 17 forest villages inside the core zone of KTR, out of which 7 have been proposed for relocation⁸². About 20 km² of additional area will be available for wildlife habitat in the core once the relocation programme of 1000 households in these 7 villages is finally implemented. The remaining 10 villages are situated along the outer regions of the critical zone, and hence it has been proposed to redraw the boundaries of the national park such that they are included in the buffer zone. Presently, an aggregate population of 8000 people and 7000 cattle units live within these 17 villages in the core zone of KTR⁸². The region still carries a touch of the aboriginal lifestyle and most of the local populations — especially those living in core and buffer areas — depend on forests for their day-to-day sustenance.

There are about 160 forest and revenue villages in the buffer zone of KTR⁸¹. The caste structure of communities living in the buffer zone includes the Gonds, Baigas, Ahirs, Panika, and Kurmis, besides Scheduled Castes (SCs) and Other Backward Classes (OBCs). Most of this population depends on a single rain-fed crop during a year. Apart from agriculture, Non-Wood Forest Produce (NWFP) collection and wages earned through manual labour constitute their main sources of income. Some of the other economic activities in the buffer zone include forestry-related activities (e.g. rehabilitation of degraded forests, small plantation, soil and moisture conservation, water development,

road repair, fire protection, boundary pillars and construction), agriculture (including private plantation, horticulture and vegetable farming), tourism (e.g. employment in hotels, resorts, restaurants and other related activities), and integrated development activities undertaken as part of the Eco-Development Committees (EDCs).

To supplement the income of local communities living inside KTR or along the fringe villages, various initiatives have been introduced through EDCs. Regular allocations received from the statement government as well as from the National Tiger Conservation Authority are spent on developmental activities in these villages such as drinking water facilities, irrigation facilities, nistari tank, approach road, gobar-gas plant, distribution of LPG gas connection, solar light system, distribution of pressure cookers, distribution of improved cattle, self-employment, bio-agriculture, and wormiculture. Through one such initiative, the Kanha Vikas Nidhi constituted in 1997, EDCs receive a share of revenues received from tourism which can be used for livelihood augmentation and developmental activities in the region. Funds from Kanha Vikas Nidhi are also diverted to relocated villages for providing hand-holding support during the transition phase. The local community also finds employment opportunities as daily labourers in various managerial and development works carried out in the core and buffer zone of the tiger reserve as well for panchayats to supplement their income.

A recent socio-economic survey conducted in 30 villages within the core zone, buffer zone and villages within a 5-kilometre periphery of the buffer zone boundary has found that most villagers live in kuccha houses and huts, and require bamboos, poles and timber in large quantities for the maintenance of their homes⁸¹. The demand of this *nistar* material is mostly met from the forests of KTR⁸¹. In addition, daily-wage labour and employment are essential for supplementing income earned

Presently,
an aggregate
population of

8000

people &

7000

cattle units live
within these

17

villages in
the core
zone of KTR



from agriculture. Further, as stall-feeding is not practised in the region, almost all cattle graze in the forest areas of KTR⁸¹. Important NTFPs extracted from the buffer zone of KTR include tendu leaves, achar, aonla, harra, baheda, mahua flower and seed, mahul leaves / bakkal, sal seed, chhind bahari, honey, chakoda seed, karlihari, satawar, bhilma, safed musli, kali musli, van tulsi, baichandi, kullu and dhawda, jack fruit and mango⁸¹. Except tendu leaves, these NTFP are collected by local communities individually and sold in the markets nearby. To ensure maximum income from NWFP harvesting, soft loans are also provided to EDCs for value addition.

3.2.2 VALUATION OF ECOSYSTEM SERVICES FROM THE KANHA TIGER RESERVE

3.2.2.1 EMPLOYMENT GENERATION

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.2.2.2 AGRICULTURE

On account of paucity of information that can objectively establish linkages between agricultural productivity and KTR, the

economic value of agriculture in KTR attributable to the tiger reserve has not been estimated in monetary terms.

3.2.2.3 FISHING

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.2.2.4 FUEL WOOD

As stated earlier, a number of households living in and around KTR have been given usufruct rights for fuel wood harvesting. According to an estimate, about 21,800 households are directly dependent on buffer areas of the tiger reserve for fuel wood requirements⁸² and the average annual consumption per household is approximately 5 tons^{83,84}. Thus, approximately 109 million kilograms of fuel wood are extracted annually from KTR. Using the local price of fuel wood as ₹ 1 / kilogram, the economic value of fuel wood extracted from KTR is equal to ₹ 109 million per year.

3.2.2.5 GRAZING

In addition to fuel wood, the local community in and around the tiger reserve are given usufruct rights for grazing their cattle in designated buffer areas. Currently, about 370 km² of forests within buffer



areas of KTR is available for grazing⁸¹. Approximately 85,000 Adult Cattle Units (ACUs) in 161 villages of the buffer area and 13 villages of the core area are largely dependent on these designated forests areas for provisioning of fodder⁸². About 20 per cent of fodder requirements for these livestock is met from agriculture while the rest is met by the forest areas. While various other sources indicate that about 50,000 additional cattle units in villages adjoining the tiger reserve are also dependent on KTR for grazing, the same has not been included on account of inability to verify the information.

Assuming an average daily forage quantity of 22 kilograms / cattle⁵⁸, the total annual quantity of fodder harvested from the forest areas of KTR is approximately equal to 546 million kilograms. Assuming an average price of ₹ 1 / kilogram of fodder based on the local market price, the economic value of grazing services provided by KTR is approximately equal to ₹ 546 million per year.

3.2.2.6 TIMBER

There are 128 forest compartments within the Selection-Cum-Improvement (SCI) Working Circle (WC) in the buffer areas of KTR aggregately occupying an area of approximately 255 km². Based on the forest resources survey conducted by tiger reserve authorities, the average stock of compartments included in the SCI is 76.90 cubic metres, comprising 42.98 cubic metres of Sal trees and the remaining 33.74 cubic metres of miscellaneous trees⁸².

Based on Von Mantel's formula, the annual maximum yield of SCI Working Circle will be 14546 cubic metres, comprising 6680 cubic metres of Sal trees and 7866 cubic metres of miscellaneous trees⁸². The calculations have been done assuming the rotation period for Sal at 150 years. Assuming the local market price of ₹ 35,000 and ₹ 25,000 per cubic metre of Sal and miscellaneous trees respectively, and considering 20 per cent of the market price as maintenance and transportation cost, the economic value of timber harvest from the SCI Working Circle in the buffer areas of KTR is approximately equal to ₹ 344.36 million per year.

3.2.2.6.1 STANDING STOCK

While the flow value of timber from KTR is approximately equal to ₹ 344.36 million annually, the standing stock of timber has a significant economic value. Using the growing stock estimates of Tropical Dry Deciduous Forests from the forest inventory database⁵⁹ of the Forest Survey of India and using area estimates for forests under different canopy cover densities⁶⁰, it is estimated that about 8.64 million cubic metres of standing stock of timber is contained in KTR. The economic value of this resource using an average price of timber at ₹ 25,000 / cubic metre and accounting for maintenance and transportation costs at 20 per cent of market price is approximately equal to ₹ 172.78 billion. The calculations for estimating the economic value of standing timber stock of KTR are as shown in Table 12 below.

Table 12
Standing Stock of Timber in KTR

Canopy Cover Density Class	Growing Stock (cum / ha)	Area (km ²)	Total Stock (million cum)	Economic Value (₹ billion)
VDF	74.03	910	6.74	134.73
MDF	50.78	328	1.67	33.31
OF	18.92	125	0.24	4.73
TOTAL		1363	8.64	172.78

3.2.2.7 NON-WOOD FOREST PRODUCE (NWFP)

Apart from fuel wood and fodder, a number of non-wood forest produce (NWFP) are also harvested by the local community from the buffer areas of KTR. These include tendu leaf, harra, gum, mohul leaf, mahua, cassia tora seeds, van tulsi seed, broomstick leaf, kosum lac and palas lac. Based on average annual harvested quantity and local market price (See Table 13), the aggregated economic value of all the NWFPs harvested from buffer areas of KTR is equal to ₹ 70.05 million per annum.

Table 13

NWFPs Harvested from Kanha Tiger Reserve⁸²

NWFP	Harvested Quantity	Unit	Unit Price (₹)	Economic Value (₹ million)
Tendu leaf	5500.00	Standard Bags	3000	16.50
Harra	20.00	Metric Ton	5000	0.10
Gum	5.00	Metric Ton	50000	0.25
Mohul leaf	500.00	Metric Ton	10000	5.00
Mahua	1400.00	Metric Ton	30000	42.00
Cassia tora seed	50.00	Metric Ton	10000	0.50
Van tulsi seed	50.00	Metric Ton	50000	2.50
Broomstick leaf	0.60	Million Number	5	3.00
Palas lac	1.60	Metric Ton	100000	0.16
Kosum lac	0.30	Metric Ton	120000	0.04
TOTAL				70.05

3.2.2.8 GENE-POOL PROTECTION

Using estimates of economic value of gene-pool protection for tropical forests (₹ 91,020 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1363 km² of forests of KTR is equal to ₹ 12.41 billion / year.

3.2.2.9 CARBON STORAGE

The carbon stock for Tropical Dry Deciduous Forests across various forest canopy cover densities has been worked out for the State of Madhya Pradesh in a recent study which has been used here to estimate the carbon storage of KTR.

Table 14

Carbon Stock in Tropical Dry Deciduous Forests of Madhya Pradesh²⁵

Density Class	Carbon Stock (tonnes C / hectare)					Total
	Above Ground Biomass (AGB)	Below Ground Biomass (BGB)	Dead Wood (DW)	Litter	Soil Organic Matter (SOM)	
VDF	60.30	23.68	0.46	7.33	62.58	154.35
MDF	57.08	22.41	0.15	0.40	57.45	137.50
OF	11.64	4.57	0.13	0.34	22.12	38.80

As stated earlier, Very Dense Forests, Moderately Dense Forests and Open Forests cover an area of approximately 910 km², 328 km² and 125 km² respectively in KTR. Using these estimates in conjunction with carbon stock in various carbon pools as indicated in Table 14, the total carbon stored in KTR is approximately equal to 19.04 million tonnes. Valued in terms of social cost of carbon for India by making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of carbon stored in KTR is estimated to be ₹ 20.50 billion.

3.2.2.10 CARBON SEQUESTRATION

Apart from storing 19.04 million tonnes of carbon, forests of KTR sequester carbon on an annual basis. As no primary study estimating carbon sequestration in KTR exists, the same has been estimated here based on the forest inventory database of the Forest Survey of India. The total biomass for Tropical Deciduous Forests in different canopy cover densities, i.e. Very Dense Forests, Moderately Dense Forests, Open Forests and Scrub has been taken from the forest inventory database⁵⁹. Based on total biomass per unit area, the mean annual increment (MAI) has been estimated using the Von Mantel Formula⁶¹ and the physical rotation period estimated in a recent study for Tropical Dry Deciduous Forests⁶². Assuming a biomass-to-carbon conversion ratio of 50%⁶³, the mean annual increment in above ground biomass has been converted to carbon sequestered in dry matter.

Using this methodology, the total carbon sequestered in the forests of KTR by aggregating across different canopy cover density classes is equal to 203.75 kilo tonnes annually. The derivation of the same is as shown below in Table 15.

Table 15
Carbon Sequestration in KTR

Canopy Cover Density	Total Biomass (t/ha)	MAI (t ha ⁻¹ yr ⁻¹)	Annual Carbon Sequestration (tC ha ⁻¹ yr ⁻¹)	Area (km ²)	Total Carbon Sequestration ('000 tC yr ⁻¹)
VDF	94.08	3.42	1.71	910.0	155.66
MDF	68.34	2.49	1.24	327.9	40.75
OF	32.2	1.17	0.59	125.5	7.35
				1363.4	203.75

Using the social cost of carbon for India and making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of carbon sequestered in KTR is estimated to be ₹ 219.41 million per year.

3.2.2.11 WATER PROVISIONING

Forested watershed ensures regular flow of water in the Halon and Banjar rivers, especially in dry seasons by acting as a sponge and releasing water slowly. This is essential for agriculture in and around the tiger reserve. A study done for the Green India State's Trust has estimated that forests in Eastern Madhya Pradesh contribute to 222 mm / hectare of additional water recharge considering all factors such as, inter-alia, precipitation, evapo-transpiration, saturation capacity of the soil and run-off vis-à-vis a non-forest area in the eastern region of the state³⁰.





Only accounting for Very Dense Forests, Moderately Dense Forests and Open Forests (with a combined area of 1363.5 km²), the total amount of additional water recharge attributable to KTR forests is equal to 30.27 million m³. Using the economic value of ₹ 18.43 / m³, the total economic value of annual water recharge by KTR is approximately equal to ₹ 557.86 million.

3.2.2.12 WATER PURIFICATION

No information is available on how the drinking water requirements of the local community are met in and around the tiger reserve. Thus, due to paucity of data, the ecosystem service of water purification has not been estimated in monetary terms for KTR.

3.2.2.13 SEDIMENT REGULATION

Deep tree roots of forests of KTR stabilize and provide mechanical support to the soils in this dry climate which can help to prevent shallow mass movements. In the absence of forests in KTR, the sediment load in the Halon and Banjar Rivers and other tributaries is likely to increase manifold. The increased sediment load will lead to decrease in the capacity of these rivers. Technological measures will then be needed to dredge the reservoir

and excavate the sediment load to ensure deriving maximum benefits from rivers. The forests of KTR play an important role of minimizing the sediment load and the avoided cost of dredging can be directly attributed as an economic value of the KTR⁷¹⁻⁷³.

According to a series of studies conducted by ICIMOD⁸⁵ and other organizations⁸⁶, forests near Kanha Tiger Reserve prevent soil loss in the magnitude of 12.29 tons ha⁻¹ year⁻¹. Using this estimate and assuming a sediment delivery rate of 20 per cent (lower compared to Corbett Tiger Reserve), 1363 km² of Very Dense Forests, Moderately Dense Forests and Open Forests of KTR aggregately prevent 0.34 million tonnes of soil erosion annually.

To estimate the economic value of avoiding this estimated sediment load by the forests of KTR, the cost of alternative technological interventions is considered. On account of lack of site-specific data, the cost estimate of ₹ 58.31 / cum given by the Central Water Commission as the earth excavation costs is used⁷⁴ along with an assumed weight of soil as 1.2 tonne/ cum⁴⁰ to arrive at the economic value of sedimentation avoided. The economic value so derived is approximately equal to ₹ 16.29 million per year.

222
mm / ha / year

additional water recharge

0.34
million tonnes

avoided soil erosion

3600
tonnes

avoided nutrient loss

3.2.2.14 NUTRIENT CYCLING

On account of the lack of local estimates for KTR, a study conducted by the Green Indian States Trust has been used for deriving the soil nutrient composition⁴¹. As estimated earlier, the total sediment load avoided by the forested regions of the KTR is equal to 0.34 million tonnes year⁻¹. Using this estimate and the concentration of N, P and K in soil from Table 16 below, the quantity of nitrogen, phosphorus and potassium that would leach out from the KTR system is approximately equal to 780, 15 and 2800 tons annually. Valuing the quantity of nutrients lost in this process with the help of the price of NPK fertilizers⁷⁹, the total value of KTR's forests in preventing nutrient loss is equal to ₹ 60.59 million annually and is derived in Table 16.

Table 16
Avoided Nutrient Loss by Kanha Tiger Reserve

Nutrient	Soil Nutrient Concentration ³ (g kg ⁻¹)	Total Nutrient Loss Avoided by KTR Forests (ton yr ⁻¹)	Fertilizer Used for Valuation	Price of Fertilizer ⁴ (₹ kg ⁻¹)	Economic Value of Nutrient Loss Avoided (₹ million yr ⁻¹)
Nitrogen (N)	2.320	788.80	Urea (46% N)	5.31	4.19
Phosphorus (P)	0.044	14.96	DAP (18-46-0-0)	20.10	0.30
Potassium (K)	8.250	2805.00	Muriate of Potash (60% K ₂ O)	20.00	56.10
TOTAL					60.59

3.2.2.15 BIOLOGICAL CONTROL

Using estimates of economic value of biological control for tropical forests (₹ 660 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1363 km² of forests of KTR is equal to ₹ 89.96 million per year.

3.2.2.16 MODERATION OF EXTREME EVENTS

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.2.2.17 POLLINATION

Using estimates of economic value of pollination for tropical forests (₹ 1,800 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1363 km² of forests of KTR is equal to ₹ 245.34 million per year.

3.2.2.18 NURSERY FUNCTION

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.



3.2.2.19 HABITAT / REFUGIA

Using estimates of economic value of habitat / refugia for tropical forests (₹ 2,340 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1363 km² of forests of KTR is equal to ₹ 318.94 million per year.

3.2.2.20 CULTURAL HERITAGE

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.2.2.21 RECREATION

KTR is one of the finest wildlife tourism destinations in the country and receives thousands of national and international tourists every tourism season. The information on average annual tourist influx of the past six years (2007-08 to 2012-13) is as shown in Table 17. Based on data for the last 10 years, around 10 per cent of the annual tourists visiting KTR are foreign tourists⁸¹.

Table 17

Annual Influx of Tourists in Kanha Tiger Reserve⁸²

Year	Annual Influx of Tourists
2012-13	130457
2011-12	182354
2010-11	174773
2009-10	154024
2008-09	137295
2007-08	132601

Recreational tourism brings significant revenues for the authorities of the KTR. In addition, many hotels and resorts in and around KTR with a combined capacity of approximately 1600 tourist beds directly benefit from the recreational opportunities offered at KTR.

A recent study⁸⁷ has estimated the economic value of recreational tourism of KTR which

has been used here. The study has found that the consumer surplus, which is the difference between the price which one is willing to pay and the price one actually pays for an average tourist visiting KTR is equal to ₹ 2,558 per visit. Based on the average annual visitation rates for the last six years (150,000 visits per year), the total estimated consumer surplus of recreation services from KTR is approximately equal to ₹ 383.70 million per year.

3.2.2.22 SPIRITUAL TOURISM

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.2.2.23 RESEARCH, EDUCATION AND NATURE INTERPRETATION

The tiger reserve has gradually progressed into a study centre for national and international wildlife researchers, and has 9 Ph.D. and 1 D.Sc. thesis to its credit on various aspects of wildlife science. Besides, over 100 research and technical papers relating to the wildlife biology and ecology of the Kanha ecosystem have been published in various national and international journals⁸¹.

In addition, a number of conservation education and awareness activities are carried out in the buffer zone. These include park excursions and lectures for students, outsourcing of resource persons for conducting activities in various villages of tiger reserve, conservation camps, road shows, film shows, and wildlife week celebration. Further, highly technical research papers and bulletins to entertaining information on the history, flora and fauna, and local tribes of the tiger reserve are available at the tourist education centre. In addition, scientific and technical information on prey base (skeleton exhibits), wildlife research, wildlife estimation, foods of tigers, grasses of Kanha, animals in action, satellite imageries, aerial photographs, tiger

In addition to 9 Ph.D. & 1 D.Sc. thesis, over **100 research and technical papers** relating to wildlife and ecology of Kanha have been published.

telemetry and its importance, a video film based on wildlife, and research papers have been exhibited through various panels and models at the tourist education centre. The entire landscape of KTR thus provides unique opportunities for research, education and nature interpretation, not easily found in any other areas.

3.2.2.24 GAS REGULATION

Using estimates of economic value of gas regulation for tropical forests (₹ 720 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1363 km² of forests of KTR is equal to ₹ 98.14 million per year.

3.2.2.25 WASTE ASSIMILATION

Using estimates of economic value of waste assimilation for tropical forests (₹ 7,200 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1363 km² of forests of KTR is equal to ₹ 981.36 million per year.



3.2.2.26 SUMMARY OF ECOSYSTEM SERVICES BASED ON TEV FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Direct Use Value	1069.41	₹ million / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce		
Indirect Use Value	2971.59	₹ million / year
carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation		
Option Value	12410.00	₹ million / year
gene-pool protection		



3.2.2.27 SUMMARY OF ECOSYSTEM SERVICES BASED ON MILLENNIUM ECOSYSTEM ASSESSMENT FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Provisioning Services employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection	13479.41	₹ million / year
Regulating Services carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, gas regulation, waste assimilation	2587.89	₹ million / year
Cultural Services cultural heritage, recreation, spiritual tourism, research, education and nature interpretation	383.70	₹ million / year

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

3.2.2.28 SUMMARY OF ECOSYSTEM SERVICES BASED ON STOCK AND FLOW BENEFITS FRAMEWORK

Type of Value	Value	Unit
Flow Benefits	16.45	₹ billion / year
	0.80	₹ lakh / ha / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection, carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation		
Stock	193.28	₹ billion / year
standing timber, carbon storage		

3.2.2.29 SUMMARY OF ECOSYSTEM SERVICES BASED ON TANGIBLE AND INTANGIBLE BENEFITS FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Tangible Benefits	999.36	₹ million / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce		
Intangible Benefits	15451.64	₹ million / year
carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation, gene-pool protection		

3.2.2.30 DISTRIBUTION ACROSS STAKEHOLDERS (FLOW BENEFITS)

Based on assumptions made in Section 2.4.29, approximately 10 per cent of flow benefits accrue at the local level, 49 per cent at the national level and 41 per cent at the global level.

3.2.2.31 INVESTMENT MULTIPLIER

According to the last sanction from the National Tiger Conservation Authority, the annual management costs of Kanha Tiger Reserve for the year 2014-15 amounted to ₹ 60.26 million. Based on the flow benefits of ₹ 16.45 billion per year, for every rupee spent on management costs in KTR, flow benefits of ₹ 273 are realized within and outside the tiger reserve.





KAZIRANGA TIGER RESERVE



KEY MESSAGES

Kaziranga is a World Heritage Site inhabited by the world's largest population of one-horned rhinoceroses. In addition, it also supports population of tigers and elephants.

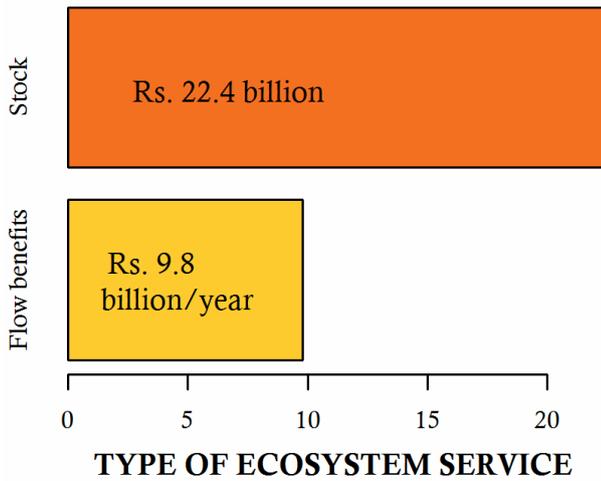
Important ecosystem services originating from Kaziranga include habitat and refugia for wildlife (₹ 5.73 billion year⁻¹) and gene-pool protection (₹ 3.49 billion year⁻¹).

Other important services emanating from Kaziranga include recreation value (₹ 21 million year⁻¹), biological control (₹ 150 million year⁻¹) and sequestration of carbon (₹ 17 million year⁻¹).

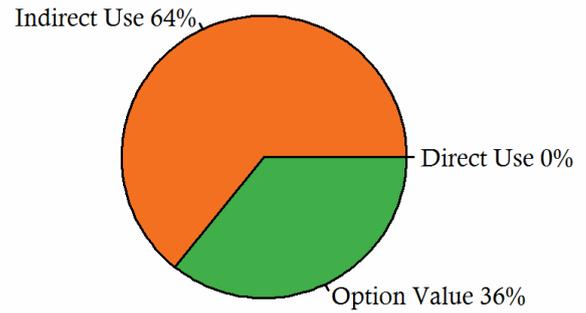
ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

3.3 KAZIRANGA TIGER RESERVE

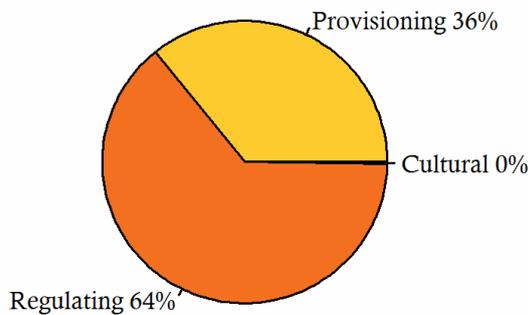
STOCK AND FLOW



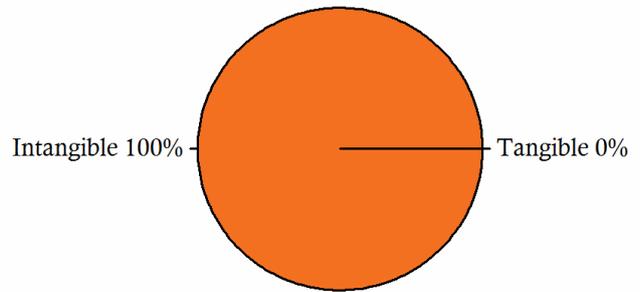
TYPE OF VALUE



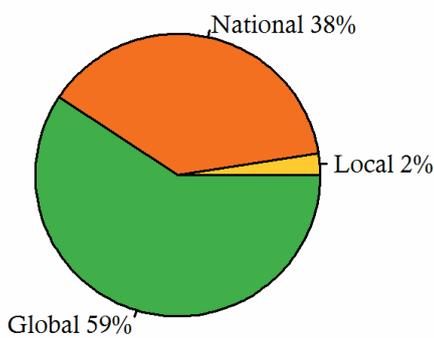
TYPE OF ECOSYSTEM SERVICE



TANGIBLES AND INTANGIBLES



DISTRIBUTION OF VALUE



Flow benefits per hectare per year
(Rs. lakh)

0.95

Flow benefits as a ratio of
management costs

200

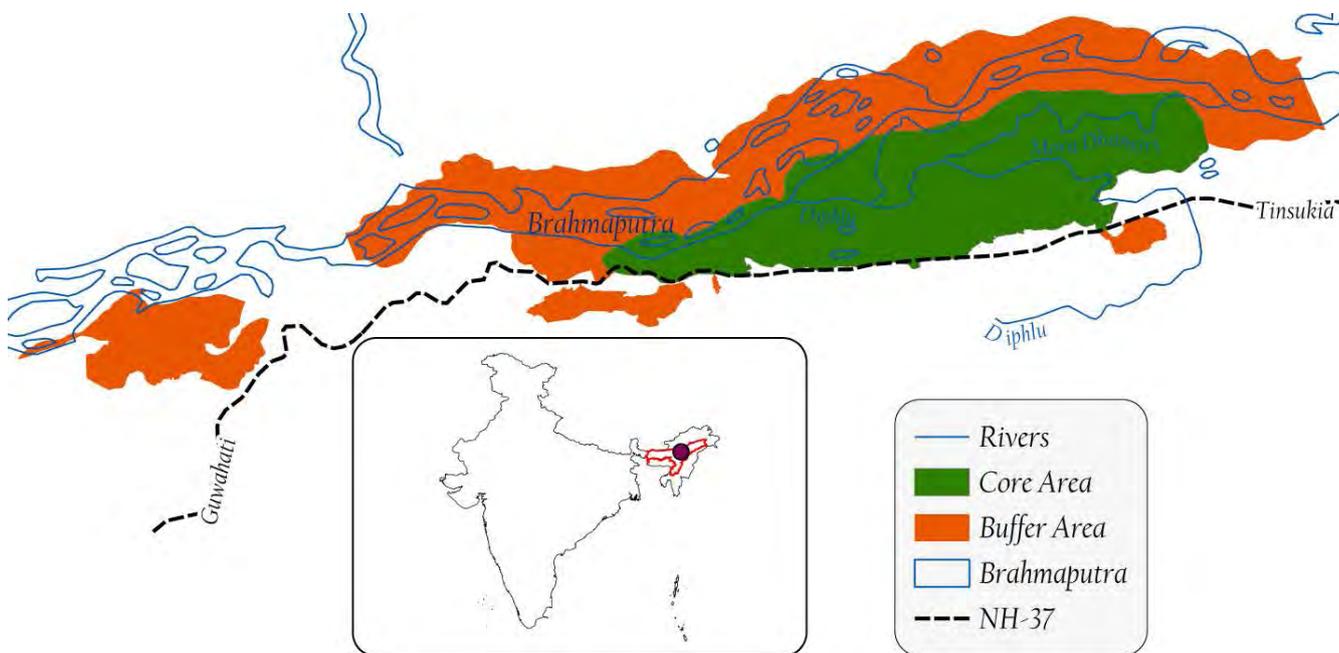
3.3.1 SITE SPECIFICATION

3.3.1.1 LOCATION AND LANDSCAPE

In the heart of Assam, Kaziranga Tiger Reserve (KZTR) is one of the last areas in eastern India undisturbed by a human presence. The tiger reserve is inhabited by the world's largest population of one-horned rhinoceroses, as well as many mammals, including tigers, elephants, panthers and bears, and thousands of birds. KZTR is a hallmark of conservation measures used to preserve biodiversity. Since protection, the estimated number of rhinoceros has increased from 40 in 1911 to more than 2000 in 2009. It is situated in the flood plains of the mighty Brahmaputra River with the entire area formed by erosion, accretion and silt deposition carried by the river systems flowing through or near it. Floods are regular annual feature of the tiger reserve which is spread over Nagaon, Golaghat & Sonitpur districts of Assam and covers an area of little more than a thousand square kilometres (482 km² of core zone and 548 km² of buffer zone). The tiger reserve derives its name from the Karbi language in which the word 'Kazi' means 'Goat' or 'Deer' and 'Rangai' means 'Red', thus meaning 'the land of red goats or deer'.



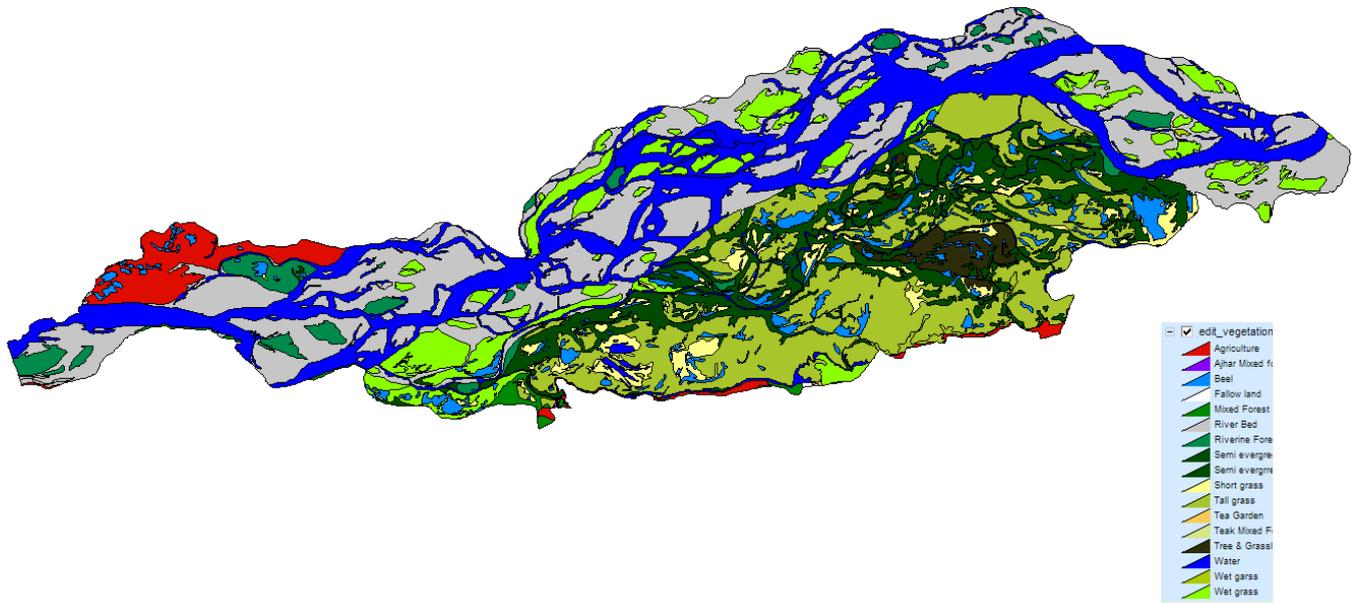
Figure 11
Kaziranga Tiger Reserve



There are several different types of habitat and habitat complexes in KZTR. These include short grassland in low lying areas, short grass patches with tall grasslands, short grass patches in open woodland, tall grasses in moist and wet areas, tall grasses (mostly imperata cylindrical) in comparatively drier areas, open woodlands (largely lagerostromia-bombax) with tall grasses, closed woodland with cane undergrowth, swampy aquatic habitat of permanent water bodies (locally known as 'beels'), aquatic habitat of Difalu and Mora Dhansiri rivers, aquatic habitat of the Brahmaputra River, newly formed landmasses in and near the Brahmaputra river and forested habitat of Kukurakata and Panbari Reserve Forests. These habitat complexes cannot be seen in isolation and are interdependent and complementary. In KZTR, the tree forests occupy a comparatively higher ground along the central and eastern portion of the tiger reserve.

Figure 12

Land Cover of Kaziranga Tiger Reserve



About three-fifth of the area of KZTR is tall grasslands. Short grasslands are mostly found in the open areas near the *beels* which remain inundated during the monsoon and dry up during winter comprising loamy soils. About 5% of the total area of KZTR is covered by *beels* and streams excluding the area of the Brahmaputra River during the dry months. The area under water increases drastically during the monsoon due to flooding.

The Kaziranga Tiger Reserve presents a unique ecosystem where prescribed burning is used to maintain the vegetation structure by arresting the seral stage of grassland and preventing invasion of tree forest. This is done to ensure adequate quantity and nutritional value of food supply (i.e. grass) to the large population of various herbivores. Though profuse regeneration occurs in the tiger reserve, the seedlings are destroyed annually by controlled fires, and thus further progress is arrested. Coupled with fire, the annual flood plays an important role in arresting the process of soil development by washing away the topsoil and by fresh silt depositions.

3.3.1.2 HISTORY

In view of the high density tiger presence in the area and reportedly the only viable population of tigers in any of the north east India tiger landscapes, the Government of India approved the constitution of KZTR in August 2006. The Government of Assam accordingly notified KZTR with the total area of 1030 km², involving Kaziranga National Park (KZNP), Additions to KZNP, adjoining Reserve Forests

and Laokhowa and Burachapori Wildlife Sanctuaries.

The width of the Brahmaputra River in the portion flowing along the northern boundary of the KZTR is about 8 kilometres and the river does not have a permanent well-defined bank all through. On account of the changing pattern, the left bank of the river erodes away considerable stretch of the land severely affecting the KZTR. Over the years the resident population of rhinoceros as well as other mega herbivores, i.e. elephants and wild buffaloes of KZNP had increased manifold while the geographical area of the national park was reduced considerably by erosion. With the overall goal of compensating for area lost due to erosion, the Government of Assam in the mid 1980s notified a number of proposed Additions to KZNP in order to secure corridors for migration of wild animals, and escape routes in case of high flooding and for extending the Park by inclusion of the chapories. Till date, there have been six Additions to KZNP.

3.3.1.3 TOPOGRAPHY AND CLIMATE

The elevation of the tiger reserve ranges from 40 msl to 80 msl. The reserve experiences three seasons: summer, monsoon, and winter. The winter season, between November and February, is mild and dry, with a mean high of 25 °C and low of 5 °C. During this season, *beels* and water channels dry up. The summer season between March and May is hot, with temperatures reaching a high of 37 °C. The rainy monsoon season lasts from June to September, and is responsible for most of Kaziranga's annual rainfall of 2,220 mm.

3.3.1.4 RIVERS AND FLOODING

Though the annual average rainfall in the entire upper catchment areas of the Brahmaputra River and its tributaries generally does not vary significantly, the intensity of floods in its basin varies due to the intensity of rain in concentrated spells. In the event of a flood, the floodwater from the Brahmaputra River enters the park from the northern boundary and through the Diphlu and the Mori Dhansiri rivers. While the water from the submerged high lands clears up fast, the low lying areas inside the tiger reserve form basins, especially around the *beels* of the southern boundary on the western part remain under water for a considerable period of time even after flood waters have receded from other places. There are about 60 rivers and small water channels and about 200 water-bodies in the core area of KZTR.

Flooding is an integral part of the ecological system of the tiger reserve. It not only helps in maintenance of vegetation status, flooding also contributes to the process of silt deposition and soil formation which replenishes the dry *beels* and adds fertility to soil. Flooding also ensures maintenance of water quality by catalyzing clearing of water hyacinth in stagnated waters. The *beels* and rivers of Kaziranga are the home of several freshwater fishes. Owing to annual flooding and stagnation of water in *beels* for the rest of the year, Kaziranga is regarded as breeding

ground for tropical freshwater fishes in India's northeastern region. While understudied, the function of Kaziranga acting as nursery for freshwater fishes is highly significant considering that fish is one of the primary sources of protein for the people living in this part of the world. Flooding in KZTR is however not without its undesirable impacts on wildlife with regard to shortage of fodder, malnutrition and animal casualty.

3.3.1.5 BIODIVERSITY

The Kaziranga Tiger Reserve (or the erstwhile Kaziranga National Park) is known for the charismatic 'BIG FIVE'. These include Great Indian One horned Rhinoceros (*Rhinoceros unicornis*), Asiatic Wild Buffalo (*Bubalus bubalis*), Asiatic Elephant (*Elephas maximus*), Swamp Deer (*Cervus duvauvelii ranjitsinghi*), and Royal Bengal Tiger (*Panthera tigris*).

The main trees species in the forests of KZTR include *Bombax ceiba*, *Albizia procera*, *Albizia odorotissima*, *Albizia lucida*, *Careya arborea*, *Premna latifolia*, *Lagerstroemia parviflora*, *Dillenia pentagyna*, *Zizyphus jujube*, while the major species of grasses and reeds are *Saccharum* spp. *Imperata cylindrica*, *Erianthus ravaneae*, *Arundo donax*, *Phragmites karka*, *Imperata arundinacea*, *Neyraudia reynaudiana*, *Typha elephantine*. Tiger is the major predator of the reserve. Other co-predators such as leopards, jackals and bears, though rare, are found in the reserve.

Flooding is an integral part of the Kaziranga ecological systems. It maintains vegetation status and contributes to silt deposition and formation which replenishes the dry *beels* and adds fertility to soil.

The Eastern Swamp Deer (*Rucervus duvauceli*) population of KZTR is one of the last surviving populations of the eastern subspecies, one of the three subspecies apart from Northern Swamp Deer and Central Swamp Deer classified based on morphological features. It is a medium size deer found in the open grasslands and marshes of a few pocket areas of the Indian subcontinent. The only other area where the Eastern Swamp Deer can be found is the Manas National Park.

Kaziranga is situated in the Indo-Australian mega fly way of birds and has at least 550 different avifauna species visiting the tiger reserve. The inventory contains 25 species of global importance of which 23 are critically endangered, endangered or vulnerable. The tiger reserve also acts as the roosting and nesting ground for these migratory and indigenous water birds. In the backdrop of drastic decline of vultures elsewhere, the population of vultures in KZTR which contains critically endangered long-billed and slender-billed vultures has been growing up in recent times⁸⁸.

3.3.1.6 TOURISM

Unlike other Tiger Reserves, tourism in KZTR is limited to small access by road along the southern boundary and is not tiger centric. The types of safari include vehicle (gypsy), elephant and boat safari. Visitors generally come to see prehistoric looking Greater One-horned Rhinoceros that are easily visible from vehicles immediately after entry to the Tiger Reserve. Other tourist attractions include an occasional view of the majestic Royal Bengal Tiger, sighting of critically endangered eastern swamp deer, and viewing of Asiatic wild elephant, apart from Asiatic wild buffalo, hog deer, wild boar and other mammals.

Annual Influx of Tourists and Tourism Revenues in Kaziranga Tiger Reserve⁸⁹

Year	Annual Influx of Tourists	Revenue from Gate Fees (₹ million)
2013-14	128435	26.86
2012-13	101165	20.57
2011-12	124932	14.94
2010-11	119839	13.67
2009-10	112844	12.16
2008-09	106151	11.22

As with other tiger reserves, Kaziranga significantly supports the economy of the neighbouring town Kohoro.

3.3.1.7 SOCIO-ECONOMIC SITUATION

There is no human habitation inside the core area of the tiger reserve⁸⁸. However, there is presence of human habitation in the 2nd and 3rd Addition; and camps and cattle camps in the 5th and 6th Addition. Further, there are about 150 revenue villages within 5 kilometres from the southern boundary of the tiger reserve. The main communities in these villages include Mishing, Karbi, Nepali, Tea Garden tribes and Muslims. The establishment of the Kaziranga Tiger Foundation has facilitated and supported initiatives to address the developmental needs of the fringe communities through establishment and operation of Eco-Development Committees (EDCs). The primary livelihood activity of people residing in buffer areas or zone of influence is agriculture, covering about 80% of the land area. There are about 14 large tea gardens and numerous small tea plantations in the area on the southern and south east side of the core zone of KZTR covering approximately 600 km² of the land along the fringe areas. Other than tea, paddy is cultivated in most of the other areas. Usually two crops of paddy, one in the rainy season and the other one in winter, are taken in the region. While livestock

40

population of rhinoceros
in 1911

2000

population of rhinoceros
in 2009

550

visiting avifauna species





rearing is prevalent in the region to supplement income, it is not very widespread.

A number of developmental activities are also carried out in and around KZTR for the local communities. In total, there are 33 EDCs consisting of more than 8,000 households through which such developmental activities are coordinated and carried out⁸⁹. More than 40,000 people are directly associated with these EDCs.

3.3.2 VALUATION OF ECOSYSTEM SERVICES FROM THE KAZIRANGA TIGER RESERVE

3.3.2.1 EMPLOYMENT GENERATION

Due to paucity of information, the economic value of employment generation from KZTR is not estimated here in monetary terms.

3.3.2.2 AGRICULTURE

On account of paucity of information that can objectively establish linkages between agricultural productivity and KZTR, the economic value of agriculture in KZTR attributable to the tiger reserve has not been estimated in monetary terms.

3.3.2.3 FISHING

Although large quantities of fish are found in the *beels* of KZTR, no fishing is allowed. Hence the economic value of this ecosystem service from KZTR is not estimated here in monetary terms.

3.3.2.4 FUEL WOOD

No harvesting of fuel wood is allowed in KZTR and hence the economic value of this ecosystem service from KZTR is not estimated here in monetary terms.

3.3.2.5 GRAZING

Grazing of livestock is not practised in KZTR and hence the economic value of this ecosystem service from KZTR is not estimated here in monetary terms.

3.3.2.6 TIMBER

No harvesting of timber is carried out in KZTR and hence the economic value of this ecosystem service from KZTR is not estimated here in monetary terms.

3.3.2.6.1 STANDING STOCK

While the flow value of timber from KZTR is not estimated in monetary terms, the standing stock of timber has a significant economic value. Using the growing stock estimates of Tropical Semi-Evergreen Forests (North East) from the forest inventory database⁵⁹ of the Forest Survey of India and assuming forests under the Moderately Dense Forest Category on account of paucity of data, it is estimated that about 1.07 million cubic metres of standing stock of timber is contained in KZTR. The economic value of this resource using an average price of timber at ₹ 25,000 / cubic metre and accounting for maintenance and transportation costs at 20 per cent of the market price is approximately equal to ₹ 21.40 billion. The calculations for estimating the economic value of standing timber stock of KZTR are as shown in Table 19 below.

Table 19
Standing Stock of Timber in KZTR

Canopy cover density class	Growing Stock (cum / ha)	Area (km ²)	Total Stock (million cum)	Economic Value (₹ billion)
MDF	93.88	114	1.07	21.40

3.3.2.7 NON-WOOD FOREST PRODUCE (NWFP)

Harvesting of NWFPs is not carried out in KZTR and hence the economic value of this ecosystem service from KZTR is not estimated here in monetary terms.

3.3.2.8 GENE-POOL PROTECTION

Using estimates of economic value of gene-pool protection for tropical forests (₹ 91,020 / hectare / year), grasslands (₹ 72,840 / hectare / year) and wetlands (₹ 14,580 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 145 km² of forests, 289 km² of grasslands and 48 km² of wetlands in the core of KZTR is equal to ₹ 3.49 billion per year.

3.3.2.9 CARBON STORAGE

Information on land cover classes, especially forests, in KZTR is only partly available. According to an estimate⁸⁹, Tropical Semi-Evergreen Forests occupy approximately 114 km² of core zone in KZTR. Further disaggregation according to canopy cover density classes is not available for the forests in the core zone. Additionally, information on forest cover in buffer areas is unavailable. Under these circumstances, the calculations on carbon storage have been conducted assuming that forests belong to the Moderately Dense Forest canopy cover category.

The carbon stock for Tropical Semi-Evergreen Forests (North East) for Moderately Dense Forests has been worked out for the state of Assam in a recent study which has been used here to estimate the carbon storage of KZTR.

Table 20

Carbon Stock for Tropical Semi-Evergreen Forests in Assam for Moderately Dense Forest²⁵

Canopy Cover Density Class	Carbon Stock (tonnes C / hectare)					Total
	Above Ground Biomass (AGB)	Below Ground Biomass (BGB)	Dead Wood (DW)	Litter	Soil Organic Matter (SOM)	
MDF	19.58	4.03	0.37	1.81	54.97	80.76

As stated earlier, forests cover an area of approximately 114 km² in the core zone of KZTR. Using these estimates in conjunction with carbon stock in various carbon pools as shown in Table 20, the total carbon stored in KZTR is





approximately equal to 0.92 million tonnes. Valued in terms of the social cost of carbon for India by making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of carbon stored in KZTR is estimated to be ₹ 0.99 billion.

3.3.2.10 CARBON SEQUESTRATION

Apart from storing 0.92 million tonnes of carbon, forests of KZTR sequester carbon on an annual basis. As no primary study estimating carbon sequestration in KZTR exists, the same has been estimated here based on the forest inventory database of the Forest Survey of India. The total biomass for Tropical Semi-Evergreen Forests (North East) in the Moderately Dense Forest Category has been taken from the forest inventory database⁵⁹. Based on total biomass per unit area, the mean annual increment (MAI) has been estimated using the Von Mantel Formula⁶¹ and the physical rotation period estimated in a recent study for Tropical Semi-Evergreen Forests (North East)⁶². Assuming a biomass-to-carbon conversion ratio of 50%⁶³, the mean annual increment in above ground biomass has been converted to carbon sequestered in dry matter.

Using this methodology, the total carbon sequestered in the forests of KZTR is approximately equal to 16.13 kilo tonnes annually. The derivation of the same is as shown below in Table 21.

Table 21
Carbon Sequestration in KZTR

Canopy Cover Density	Total Biomass (t/ha)	MAI (t ha ⁻¹ yr ⁻¹)	Annual Carbon Sequestration (tC ha ⁻¹ yr ⁻¹)	Area (km ²)	Total Carbon Sequestration ('000 tC yr ⁻¹)
MDF	90.54	2.83	1.41	114.0	16.13

Using the social cost of carbon for India and making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of carbon sequestered in KZTR is estimated to be ₹ 17.37 million per year.



Based on the average annual visitation rates for the last 6 Years apprx.

115000

visits per year, the total estimate consumer surplus of recreation services from KZTR is approximately equal to

₹ 21.50

million

3.3.2.11 WATER PROVISIONING

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.3.2.12 WATER PURIFICATION

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.3.2.13 SEDIMENT REGULATION

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.3.2.14 NUTRIENT CYCLING

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.3.2.15 BIOLOGICAL CONTROL

Using estimates of economic value of biological control for tropical forests (₹ 660 / hectare / year), grasslands (₹ 1,860 / hectare / year) and wetlands (₹ 18,000 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 145 km² of forests, 289 km² of grasslands and 48 km² of wetlands in the core of KZTR is equal to ₹ 149.72 million per year.

3.3.2.16 MODERATION OF EXTREME EVENTS

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.3.2.17 POLLINATION

Using estimates of economic value of pollination for tropical forests (₹ 1,800 / hectare / year) and grasslands (₹ 2,100 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 145 km² of forests and 289 km² of grasslands in the core of KZTR is equal to ₹ 86.79 million / year.

3.3.2.18 NURSERY FUNCTION

The tiger reserve is bestowed with unique wetland ecosystems which serve as important nurseries for numerous fish population including Indian Major Carps⁹⁰⁻⁹². Various streams and *beels* of the tiger reserve serve the purpose of ideal breeding grounds for large fish population. As soon as the floodwater enters the reserve, a vast area gets submerged and the fishes found in the numerous *beels* and *nallahs* come out to lay eggs in the current of the floodwater. Many fishes go into the Brahmaputra river along with the receding flood and recharge the fish stock in the Brahmaputra and its tributaries.

However, these linkages have not been studied and their estimates are not available. Thus, owing to paucity of information,

this ecosystem service is not estimated here in monetary terms but is significant for economic benefits accruing downstream in the Brahmaputra river in terms of fish catch.

3.3.2.19 HABITAT / REFUGIA

Using estimates of economic value of habitat / refugia for tropical forests (₹ 2,340 / hectare / year), grasslands (₹ 72,840 / hectare / year) and wetlands (₹ 747,120 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 145 km² of forests, 289 km² of grasslands and 48 km² of wetlands in the core of KZTR is equal to ₹ 5.73 billion per year.

3.3.2.20 CULTURAL HERITAGE

As mentioned earlier, KZTR is a World Heritage Site designated by UNESCO since 1985 in recognition of the following:

- to be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; and
- to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

3.3.2.21 RECREATION

KZTR is one of the finest wildlife tourism destinations in the country and receives thousands of national and international tourists every tourism season. The information on the average annual tourist influx of the past six years (2008-09 to 2013-14) is as shown in Table 18. Based on data for the last decade, around 6 per cent of the annual tourists visiting KZTR are foreign tourists⁸⁹.

Recreational tourism brings significant

revenues for the authorities of the KZTR. The revenue to tiger reserve authorities from gate receipts and miscellaneous charges for the last financial year of 2013-14 was approximately ₹ 27 million. In addition, many hotels and resorts in and around KZTR with a combined capacity of approximately 500 tourist beds directly benefit from the recreational opportunities offered at KZTR. In 2006-07, it was estimated that the total amount of money that flowed through the tourism sector in Kaziranga National Park was approximately ₹ 300 million per annum, out of which different stakeholders (excluding government) received approximately ₹ 200 million per annum⁹⁵. The balance of income flowed as leakage for purchase of supplies and logistics outside the tourism zone.

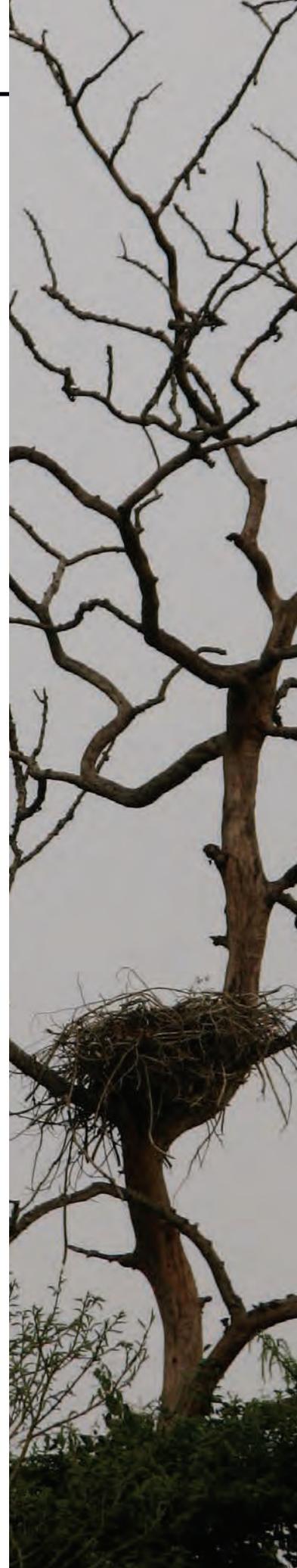
A recent study⁹⁴ has estimated the economic value of recreational tourism of KZTR which has been used here. The study has found that the consumer surplus, which is the difference between the price which one is willing to pay and the price one actually pays for an average tourist visiting KZTR is equal to ₹ 187 per visit. Based on the average annual visitation rates for the last six years (approximately 115,000 visits per year), the total estimate consumer surplus of recreation services from KZTR is approximately equal to ₹ 21.50 million.

3.3.2.22 SPIRITUAL TOURISM

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.3.2.23 RESEARCH, EDUCATION AND NATURE INTERPRETATION

KZTR provides a unique opportunity for research, education and nature interpretation since it preserves large tracts of pristine forests and wilderness and provides an interesting “outdoor laboratory” on many conservation practices and ecological processes. Such advancement of knowledge in the natural





laws may ultimately be used for the benefit of mankind. Several research studies have been carried out in KZTR⁸⁸, including doctoral⁹⁵ and M.Sc.^{96,97} dissertations. The areas of research not only include ecology and wildlife, but also socio-economic aspects and flood dynamics.

3.3.2.24 GAS REGULATION

Using estimates of economic value of gas regulation for tropical forests (₹ 720 / hectare / year) and grasslands (₹ 540 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 145 km² of forests and 289 km² of grasslands in the core of KZTR is equal to ₹ 26.05 million per year.

3.3.2.25 WASTE ASSIMILATION

Using estimates of economic value of waste assimilation for tropical forests (₹ 7,200 / hectare / year) and grasslands (₹ 4,500 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 145 km² of forests and 289 km² of grasslands in the core of KZTR is equal to ₹ 234.45 million per year.

3.3.2.26 SUMMARY OF ECOSYSTEM SERVICES BASED ON TEV FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Direct Use Value	0.00	₹ million / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce		
Indirect Use Value	6265.88	₹ million / year
carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation		
Option Value	3490.00	₹ million / year
gene-pool protection		

3.3.2.27 SUMMARY OF ECOSYSTEM SERVICES BASED ON MILLENNIUM ECOSYSTEM ASSESSMENT FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Provisioning Services employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection	3490.00	₹ million / year
Regulating Services carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, gas regulation, waste assimilation	6244.38	₹ million / year
Cultural Services cultural heritage, recreation, spiritual tourism, research, education and nature interpretation	21.50	₹ million / year

3.3.2.28 SUMMARY OF ECOSYSTEM SERVICES BASED ON STOCK AND FLOW BENEFITS FRAMEWORK

Type of Value	Value	Unit
Flow Benefits employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection, carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation	9.76 0.95	₹ billion / year ₹ lakh / ha / year
Stock standing timber, carbon storage	22.39	₹ billion / year

3.3.2.29 SUMMARY OF ECOSYSTEM SERVICES BASED ON TANGIBLE AND INTANGIBLE BENEFITS FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Tangible Benefits employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce	0.00	₹ million / year
Intangible Benefits carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation, gene-pool protection	9755.88	₹ million / year

3.3.2.30 DISTRIBUTION ACROSS STAKEHOLDERS (FLOW BENEFITS)

Based on assumptions made in Section 2.4.29, approximately 2 per cent of flow benefits accrue at the local level, 38 per cent at the national level and 59 per cent at the global level.

3.3.2.31 INVESTMENT MULTIPLIER

According to the last sanction from the National Tiger Conservation Authority, the annual management costs of Kaziranga Tiger Reserve for the year 2014-15 amounted to ₹ 48.88 million. Based on the flow benefits of ₹ 9.76 billion per year, for every rupee spent on management costs in KZTR, flow benefits of ₹ 200 are realized within and outside the tiger reserve.



PERIYAR TIGER RESERVE



KEY MESSAGES

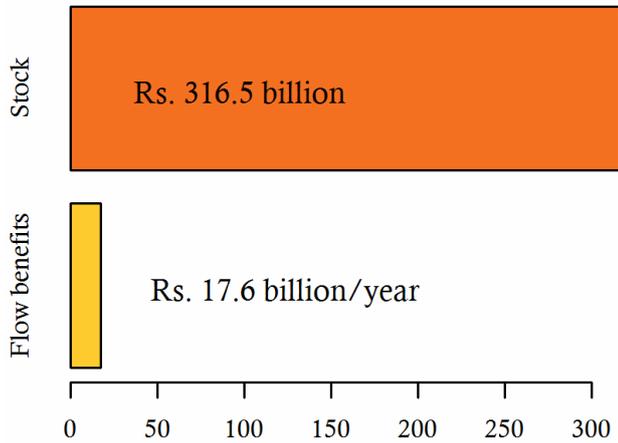
Periyar Tiger Reserve is a representative of the Southern Western Ghats with high endemism.

Important ecosystem services originating from Periyar include gene-pool protection (₹ 7.86 billion year⁻¹), provisioning of water to districts of Tamil Nadu (₹ 4.05 billion year⁻¹) and provision of habitat and refugia for wildlife (₹ 3.55 billion year⁻¹).

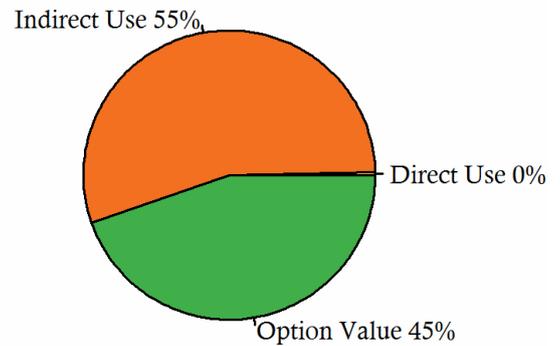
Other important services emanating from Corbett include generation of employment for local communities (₹ 25 million year⁻¹), water purification services to neighbouring towns and districts (₹ 483 million year⁻¹) and recreation value (₹ 425 million year⁻¹).

3.4 PERIYAR TIGER RESERVE

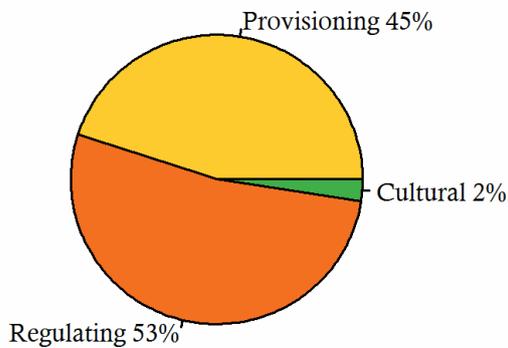
STOCK AND FLOW



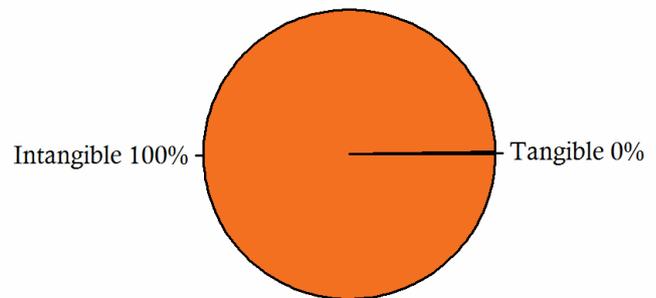
TYPE OF VALUE



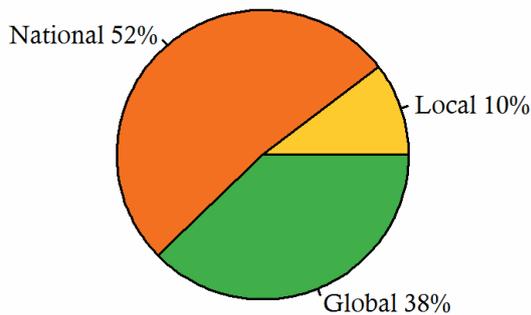
TYPE OF ECOSYSTEM SERVICE



TANGIBLES AND INTANGIBLES



DISTRIBUTION OF VALUE



Flow benefits per hectare per year
(Rs. lakh)

1.9

Flow benefits as a ratio of
management costs

459

3.4.1 SITE SPECIFICATION

3.4.1.1 LOCATION AND LANDSCAPE

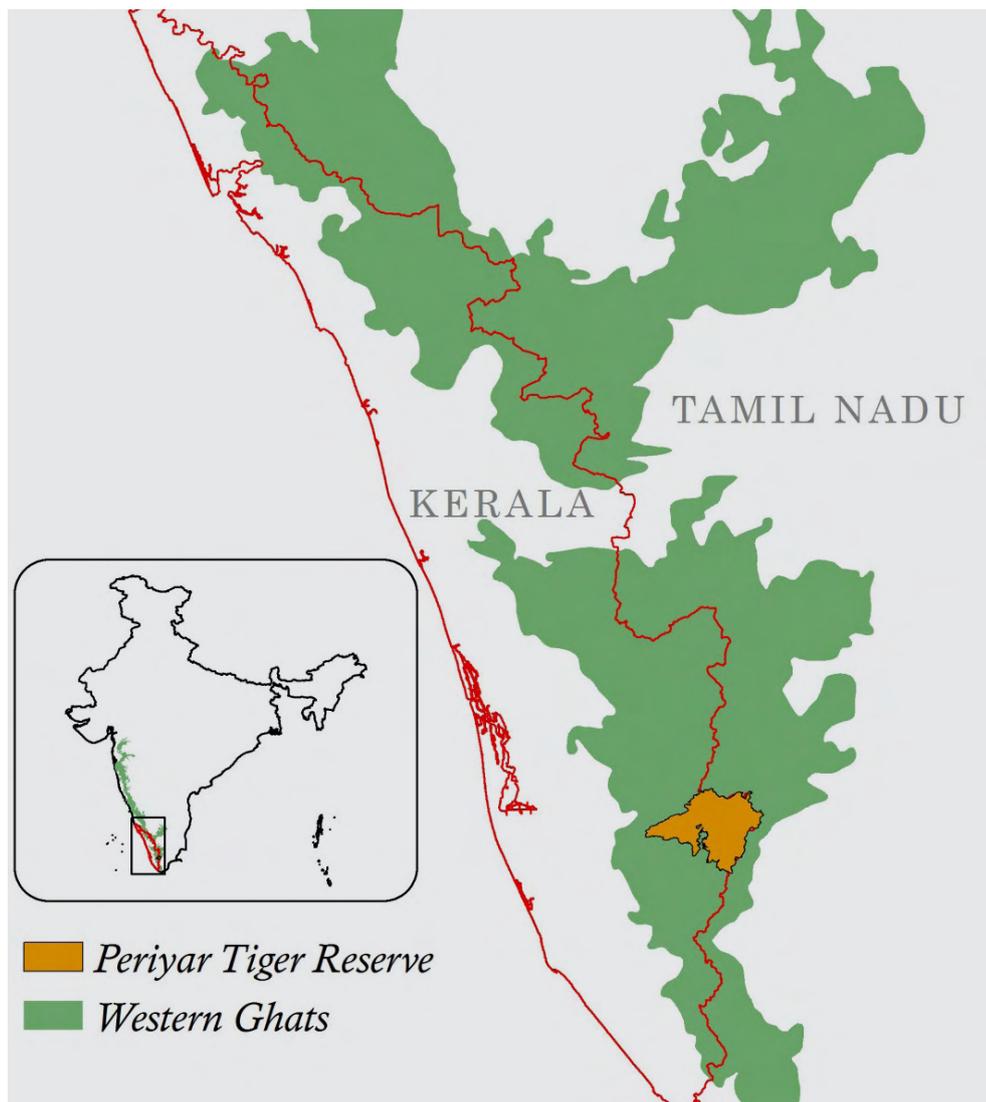
Periyar Tiger Reserve (PTR) is situated in southern India and is a representative area of the Southern Western Ghats. Located in the Idukki district of Kerala, PTR extends over an area of 925 km² (881 km² of core zone and 44 km² of buffer zone), including the 26 km² water spread area of the Periyar Lake created by construction of Mullaperiyar dam. The eastern side of the tiger reserve shares a common boundary with the state of Tamil Nadu.

3.4.1.2 HISTORY

The historical origin of PTR is linked to the establishment of the Nellikkampetti Reserve formed along with the construction of the Mansory dam across Periyar river in 1895. In 1899, the forest around the artificial lake (Periyar Lake) created as a result of the dam was declared as reserve forest. After constituting it as a sanctuary in 1933, the Maharaja of Travancore State proclaimed it as Nellikkampetti Reserve in 1934, one of the first reserves in India⁹⁸. In 1950, the adjacent forests near Periyar Lake and Sabarimala were also declared reserve forests before the sanctuary was officially designated as a tiger reserve in 1978.

Figure 13

Periyar Tiger Reserve

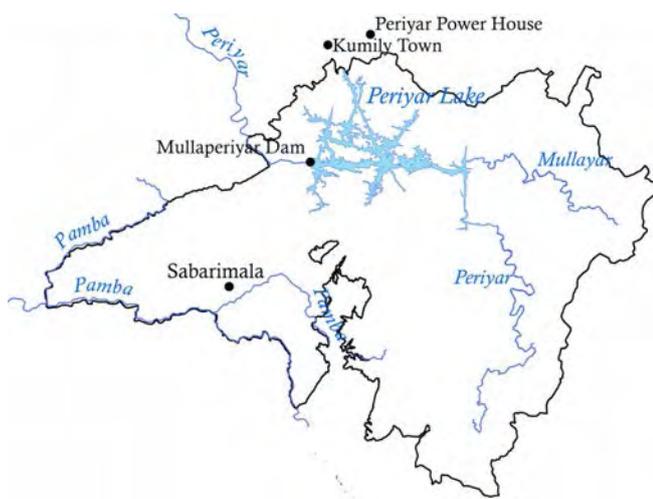


3.4.1.3 TOPOGRAPHY AND CLIMATE

The terrain of PTR is highly undulating with altitude varying from 100 msl in the west at Pamba Valley (confluence of Pamba and its tributary Azhutha) to 2000 msl in the east at Kottamala peak. The annual precipitation across 10 monitoring stations in PTR ranges from 1400 mm (Thannikudy) to 4500 mm (Pachakanam). Roughly two-thirds of the total rainfall occurs during the south-west monsoon between June and September. The north-east monsoon, though less predictable, normally occurs during October to December. The wettest month is July and the driest January. In contrast, the area on the eastern side of PTR in the state of Tamil Nadu is a rain shadow region and receives scanty rainfall. The temperature in PTR generally varies from 11°C to 27 °C with April-May being the hottest time and December-January being the coldest. Lowest humidity prevails during the dry months of February to April. The dew formulation during the cooler season, December-January, keeps the vegetation of PTR, especially grass, green and wet. The wind velocity at PTR is at its maximum during the onset of the south-west monsoon.



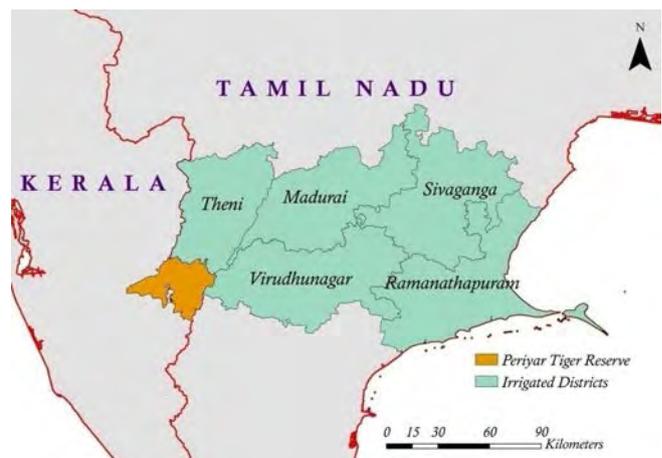
Figure 14
Rivers of Periyar Tiger Reserve



3.4.1.4 RIVERS

Periyar, the longest river of Kerala, originates inside PTR. Mullayar, a tributary of Periyar, also originates inside PTR. From their place of origins, Mullayar running west meets Periyar running north at the Periyar Lake. The lake is the reservoir of the Mullaperiyar dam; a masonry gravity dam constructed in 1895 and operated by Tamil Nadu. While the dam has a capacity of 443 million m³, the live storage of the dam has been currently restricted to approximately 300 million m³ for safety concerns⁹⁹. The entire watershed of the lake lies within PTR. In addition to meeting the drinking water demand of nearby Kumily town as well as that of Theni and Madurai districts in Tamil Nadu without the need of any water purification plant, the water from the reservoir is diverted eastwards through a tunnel to Tamil Nadu. After utilization of water at the Periyar Power Station for hydroelectricity (140 MW capacity), the water is released into Suruliyar river which serves for irrigation of an extent of 92,963 hectares (during 1994-95) in the rain-shadow districts of Theni, Madurai, Sivaganga, Ramanathapuram and Virudhunagar in Tamil Nadu¹⁰⁰. A five-judge Constitution Bench of the Supreme Court of India has recently given Tamil Nadu the rights to increase the water level in the dam up to 142 feet, 6 feet up from the previous level¹⁰¹. The judgment is likely to result in greater agricultural area being brought under irrigation in the state of Tamil Nadu.

Figure 15
Irrigation from Periyar Reservoir



River Pamba, also known as *Dakshina Ganga*, is the third longest river of Kerala and also originates inside PTR. From its origin, Pamba runs west and forms the lower boundary of PTR. Bathing in the river, believed to absolve one's sins, is a requirement before commencing the trek through the forest to the Ayyappan Temple atop Sabarimala shrine also situated in PTR. In addition to being impounded for generation of hydroelectricity at Kakki dam outside PTR, the river irrigates many important rice cultivating areas in Kerala.

3.4.1.5 SOCIO-ECONOMIC SITUATION

There is no human inhabitation inside the core area of PTR. There are 5 tribal and non-tribal settlements covering an area of 729 hectares in the buffer region of PTR. Approximately 857 families of tribal communities reside in these settlements including the Mannan, Paliyan, Urali, Mala Arayan, and Malampandaram. Agriculture is one of the main sources of income for these communities with pepper, coffee, cardamom, and rubber being the major crops. About 100 tons of organic green pepper is produced in tribal settlements which is currently exported to Germany at premium prices¹⁰². As a result of the India Eco-Development Project (IEDP), the dependency on forests for collection of fuel wood, honey and fishing has considerably reduced. Approximately 6000 households, including those residing in the fringe areas of PTR, are involved in a total of 76 Eco-Development Committees (EDCs) at PTR. Extraction of fuel wood and non-wood forest produce (NWFP), fishing as well as grazing in PTR is regulated through these EDCs.

PTR is a world-acclaimed example of participation of the local community in management of tge protected area. With restrictions being put in place as a result of it being a tiger reserve in terms of extraction of timber, fuel wood, fodder and others, the park authorities have been engaging with local communities in diversifying their livelihood options. Many community-based eco-tourism (CBET) activities are being conducted at PTR which generate employment and revenue for the local community. This form of responsible tourism not only regenerates the environment, but also provides a livelihood for local people and tribes. Originally funded by IEDP, the CBET activities in PTR produce benefits for the environment while generating revenues for the local economy that funds improvements to local infrastructure such as roads and schools.

3.4.1.6 TOURISM

PTR is an internationally renowned recreation destination because of its pleasant climate, scenic beauty and visual splendour. An annual tourist inflow of approximately 8 lakh, and increasing every year, provides sizeable revenue to the State of Kerala, and particularly to the flourishing hotel and tourism industry in the town of Kumily. About 8 per cent of tourists visiting PTR are foreigners. Tourism is currently only allowed in the buffer area of PTR. A survey conducted in 2011 found that there are approximately 2,750 tourist beds available in the town of Kumily and approximately 5,000 locals have been working in these hotels, homestays and resorts for housekeeping in Kumily¹⁰⁰. In addition, there are three hotels operated by Kerala Tourism Development Corporate (KTDC) – Lake Palace, Aranya Nivas and Periyar House with a combined capacity of 80 rooms – as well as a Holiday Home operated by the Labour Welfare Fund Board with a capacity of 23 rooms inside PTR. Boat cruise is a major tourist attraction at PTR to see wildlife at Lakeshore and is operated both by KTDC and PTR and is an important source of revenue. It has been estimated that about 20,000 to 30,000 people living inside and within a 2-kilometre radius of PTR are substantially dependent on tourism at PTR for their livelihood.

3.4.1.7 PILGRIMAGE

Two important Hindu shrines, Sabarimala and Mangaladevi-Kannagi Temple, are also located inside PTR. Sabarimala, one of the largest annual pilgrimages in the world draws about 10 million devotees ever year during the two-month period it is opened. Mangaladevi-Kannagi Temple is opened only one day a year and draws about 20,000 devotees. A large majority of devotees trek through the forests to reach these shrines. Apart from recreation tourism, pilgrimages also contribute significantly to the local economy, especially the tribal communities which are involved in petty-sectors along the route during the pilgrimage season. Rich biodiversity and endemism of flora and fauna, diverse habitats and the relation of tribal communities with nature in PTR offer unique opportunities for research, education and nature interpretation.

3.4.1.8 BIODIVERSITY

The forests of PTR can be broadly classified into evergreen forests, semi-evergreen forests, moist deciduous forests, dry deciduous forests and eucalyptus plantations^{103,104}. Other major land cover classes include grasslands and water bodies. The area under each of these land cover classes in PTR is as shown in Table 22 below.

Table 22

Land Cover Classification of Periyar Tiger Reserve

Land Cover / Vegetation Class	Core Area (km ²)	Buffer Area (km ²)	Total Area (km ²)
Evergreen forests	339.70	2.42	342.12
Semi-evergreen forests	223.20	0.00	223.20
Moist deciduous forests	14.70	23.78	38.48
Dry deciduous forests	41.00	0.00	41.00
Plantations	55.00	0.00	55.00
Grassland - savannah	197.40	1.80	199.20
Waterbody	10.00	16.00	26.00
Total	881.00	44.00	925.00

76

Active Eco-Development Committees

8

lakh

tourists visiting Periyar annually

10

million

devotees visiting the Sabarimala temple annually

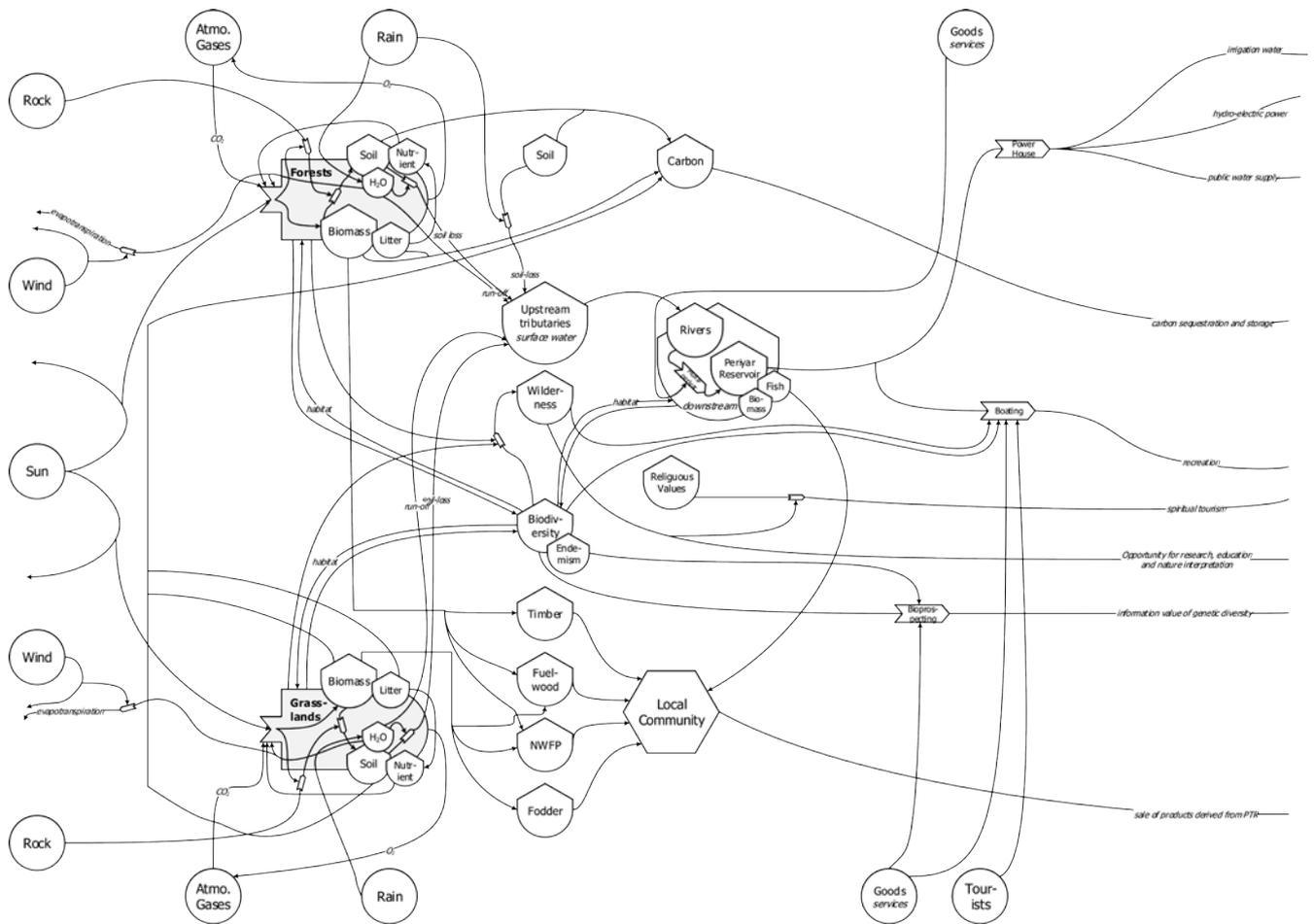
Various studies have reported large stocks of carbon stored in the biomass and soil content in the Western Ghats²⁵. Protection measures ensure that the likelihood of this stored carbon getting released into the atmosphere and exacerbating the effects of climate change is greatly reduced. The large tracts of forested landscapes of PTR are not only storehouses of carbon but add to this stock annually. While the carbon sequestration in old growth forests of PTR is unlikely to be as high as that in other relatively young forests¹⁰⁵, it is nevertheless significant.

The major habitat types within PTR include vayals/marshes, grasslands, moist deciduous forests, evergreen forests, streams and reservoirs. Limited studies have shown that herbivores intensively use the grasslands and vayals/marshy area as a result of which carnivores are also frequently sighted in these habitats. Evergreen forests are being used by arboreal animals such as the lion-tailed macaque, Nilgiri langur and Malabar giant squirrel. The artificial Periyar Lake covering an area of 26 km² is also a major aquatic ecosystem of PTR. Many dead trees standing out owing to inundation offer an ideal habitat to otters, water birds and pond terrapin. Different habitats within PTR satisfy the needs of individual plant and animals species including food, water and shelter.

PTR falls under the Anamalai-High Range centre of endemism. Twenty-five of the 94 species endemic to this range are reported to be in found in PTR¹⁰⁶. The fauna of the reserve is represented by 66 species of mammals (11 Orders, 25 Families, 50 Genera, and 10 Endemic Species)^{100,107}, 323 species of birds including 21 species of raptors, 23 aquatic including 7 winter visitors and 14 endemic to Western Ghats¹⁰⁸, 48 species of reptiles (12 Families, 33 Genera, and 17 Endemic Species including 13 snake species endemic to Western Ghats)¹⁰⁰, 29 species of amphibians (9 Families, 17 Genus, and 12 species endemic to Western Ghats)^{100,109}, 45 species of fishes including three new records (6 Orders, 11 Families, 23 Genus, 16 endemic to Western Ghats, 5 endemic to PTR and 2 Exotic Species)^{100,110}, and 180 species of butterflies (19 endemic to Western Ghats)¹¹¹. PTR contains only 10% of the total forest area in Kerala but contains about 41% (1985 species) of flowering plants found in the state. Out of those flowering plants found in PTR, 519 species (26%) are endemic to southern western Ghats¹⁰⁰ and 149 species are under various threat categories¹¹².



3.4.2 SYSTEM'S DIAGRAM



3.4.3 VALUATION OF ECOSYSTEM SERVICES FROM THE PERIYAR TIGER RESERVE

3.4.3.1 EMPLOYMENT GENERATION

3.4.3.1.1 EMPLOYMENT IN MANAGEMENT OF PTR

The Community-based Eco-Tourism programmes conducted at PTR are so designed that there is a component of protection like joint patrolling in all EDC activities. The cost of patrolling is covered by the revenue generated by guests participating in these activities, and thus the protection cost to the government is greatly reduced. This avoided cost is indeed an economic benefit generated from PTR. In 2009, 36,438 additional man-days were generated due to joint patrolling in programmes such as Tiger Trail, Bamboo Rafting, Jungle Patrol, Border Hiking, Nature Walk and Jungle Inn¹⁰⁰. The economic value of these additional man-days generated at the rate of ₹ 400 per man-day is estimated to be approximately ₹ 14.58 million per year.

3.4.3.1.2 EMPLOYMENT IN COMMUNITY-BASED ECO-TOURISM (CBET)

Several people in various EDCs such as Tribal Trekkers, Tribal Heritage, Vidiyal and PETS are directly involved and gain from their employment through these CBET programmes. The total income earned through these CBET activities for 2012-13 was approximately equal to ₹ 21.26 million¹¹³. For 2012-13, more than 27,600 man-days were generated for the local community through these CBET activities and approximately ₹ 10 million was paid as wages to the local communities.

3.4.3.2 AGRICULTURE

Pepper is the principal crop cultivated by the communities living in the buffer area of PTR. Pepper cultivated in the Vanchivayal Tribal Settlement is certified as organic pepper and fetches a premium price of ₹ 220 / kilogram. The pepper cultivated in Mannakudy and Paliyakudy Tribal Settlements, although organic, is not certified and hence fetches a lower price of ₹ 180 / kilogram. The annual production in these settlements is approximately 25 tons and 72.5 tons respectively¹¹³. The total economic value of pepper cultivated in these settlements in PTR is thus approximately equal to ₹ 18.55 million.

3.4.3.3 FISHING

Fishing in Periyar Lake by Mannan and Paliyan tribes is regulated through EDCs. In 2011-12, approximately 19.65 tons of fish was harvested from Periyar Lake through these EDCs (6.40 tons for self-use and 13.25 tons for sale)¹¹⁴. Assuming an average rate of ₹ 150 / kilogram of harvested fish, the economic value of annual fish harvested from Periyar Lake inside PTR is approximately equal to ₹ 2.95 million.

3.4.3.4 FUEL WOOD

The EDCs in PTR involved in harvest of fuel wood for sale include the Paliyakudy EDC and the Firewood and Thatching Grass EDC. In 2011-12, these EDCs

together harvested approximately 504 ton of fuel wood from PTR¹¹⁴. Further, the Pilgrim EDC is also involved in harvesting of fuel wood from PTR for sale during the Sabarimala pilgrimage. In 2011-12, the quantity of fuel wood harvested for sale by the Pilgrim EDC was approximately equal to 825 ton¹¹⁴. In addition, harvest of fuel wood for self-use is regulated through a number of EDCs and the total quantity of fuel wood harvested from PTR for self-use in 2011-12 was approximately equal to 2185 ton¹¹⁴. Thus, the total quantity of fuel wood harvested for various purposes from PTR was approximately equal to 3,500 ton in 2011-12¹¹⁴. Assuming an average price of ₹ 2 / kilogram of fuel wood, the economic value of annual fuel wood harvested from PTR is approximately equal to ₹ 7.03 million.

3.4.3.5 GRAZING

Although there are 841 cattle inside PTR, only 382 cattle owned by the Grazier EDC graze in the forests of PTR near Thekkady¹¹⁴. Assuming an average daily forage quantity of 22 kilograms / cattle⁵⁸, the total annual quantity of fodder harvested is approximately equal to 3,060 ton. Assuming an average price of ₹ 1 / kilogram of fodder, the economic value of annual grazing services provided by PTR is approximately equal to ₹ 3.06 million.

3.4.3.6 TIMBER

No timber harvesting takes place in PTR and hence the economic value of flow benefits from timber in PTR is zero. However, EDC members collect eucalyptus and bamboo poles to construct houses and cattle sheds. The total number of poles collected annually for all EDCs in PTR is approximately equal to 5,000 poles¹¹⁴. Conservatively assuming an average price of pole as ₹ 100, the total economic value of poles collected by EDC members from PTR is equal to ₹ 0.50 million.

3.4.3.6.1 STANDING STOCK

While the flow value of timber from



PTR is approximately equal to ₹ 0.50 million annually, the standing stock of timber has a significant economic value. Using the growing stock estimates of Tropical Evergreen Forests (TEF), Tropical Semi Evergreen Forests (TSEF), Tropical Moist Deciduous Forests (TMDF) and Tropical Dry Deciduous Forests (TDDF) from the forest inventory database⁵⁹ of the Forest Survey of India and assuming forests under Very Dense Canopy Cover, it is estimated that about 14.99 million cubic metres of standing stock of timber is contained in PTR. The economic value of this resource using an average price of timber at ₹ 25,000 / cubic metre and accounting for maintenance and transportation costs at 20 per cent of the market price is approximately equal to ₹ 299.74 billion. The calculations for estimating the economic value of standing timber stock of PTR are as shown in Table 23 below.

Table 23
Standing Stock of Timber in PTR

Forest Type Group	Canopy Cover Density Class	Growing Stock (cum / ha)	Area (km ²)	Total Stock (million cum)	Economic Value (₹ billion)
TEF	VDF	277.05	342.12	9.48	189.57
TSEF	VDF	202.95	223.20	4.53	90.60
TMDF	VDF	175.52	38.48	0.68	13.51
TDDF	VDF	74.03	41.00	0.30	6.07
TOTAL			644.80	14.99	299.74

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

64000 local employment
generated annually
man-days

15 standing timber
stock protected
million cubic meters

15.57 carbon stored
million tonnes

168 carbon sequestered
annually
kilo tonnes



3.4.3.7 NON-WOOD FOREST PRODUCE (NWFP)

Honey and thatching grass are the most significant NWFPs harvested from PTR¹³. The details of quantity harvested for each and their local market price is given below in Table 24.

Table 24

Non-Wood Forest Produce from Periyar Tiger Reserve

Sr. No.	NWFP	Quantity (ton)	Rate (₹ / kg)	Total value (₹ million)
1	Honey	2.8	200	0.56
2	Thatching grass (dried)	80	6.5	0.52
3	Thatching grass (green)	418	2.1	0.88
TOTAL				1.98

The total economic value of annual NWFP harvested from PTR is thus approximately equal to ₹ 1.98 million.

3.4.3.8 GENE-POOL PROTECTION

Using estimates of economic value of gene-pool protection for tropical forests (₹ 91,020 / hectare / year), grasslands (₹ 72,840 / hectare / year) and wetlands (₹ 14,580 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 700 km² of forests, 199 km² of grasslands and 26 km² of wetlands of PTR is equal to ₹ 7.86 billion per year.

3.4.3.9 CARBON STORAGE

No study exists on the quantity of carbon stored in various pools for PTR. As a result, estimates derived for the State of Kerala by a recent study from the Forest Survey of India have been used²⁵. The estimated carbon stored in five major carbon pools – above ground biomass (AGB), below ground biomass (BGB), dead wood (DW), litter and soil organic matter (SOM) for major forest types of Kerala is shown in Table 25. It may be noted that the estimates below for Forests and Plantations pertain to Very Dense Forests (canopy density greater than 70%). Considering the long conservation history of PTR and on account of lack of estimates on forest canopy density classes for PTR, all the forests of PTR are treated to belonging to the Very Dense Forests category⁶⁰.



Table 25

Carbon Stock in Periyar Tiger Reserve

Land Cover / Vegetation Class	Carbon Stock in Various Pools (tonnes C / hectare) ⁵					Total Carbon Stock (tC/ha)	Total Area (km ²) ⁶	Total Carbon Stock (million tC)
	AGB	BGB	DW	Litter	SOM			
Evergreen forests	78.54	27.17	4.10	9.21	97.19	216.21	342.12	7.40
Semi evergreen forests	62.91	12.94	4.10	5.94	85.19	171.08	223.20	3.82
Moist deciduous forests	72.58	14.92	1.17	4.84	79.19	172.70	38.48	0.66
Dry deciduous forests	62.27	24.55	0.45	6.36	111.82	205.45	41.00	0.84
Plantations	46.47	9.41	0.00	7.06	114.71	177.65	55.00	0.98
Grassland - savannah	6.29	10.35	0.00	0.00	68.15	84.80	199.20	1.69
Waterbody	0.00	0.00	0.00	0.00	68.15	68.15	26.00	0.18
TOTAL							925.00	15.57

On account of lack of site-specific estimates for Grassland and Waterbody and as these together constitute less than 1/4th of the land cover of the tiger reserve, broad assumptions have been made to estimate carbon storage for these two land cover classes based on discussions with local experts. Care was taken to reduce errors on the side of underestimation than otherwise. For grassland, it has been assumed that 10% of above ground biomass of semi-evergreen forests and 80% of below ground biomass and soil organic matter of semi-evergreen forests is found in grasslands. Carbon stored in the other two pools – dead wood and litter – is assumed to be zero for grasslands, a reasonably safe assumption. For waterbody, it has been assumed that 80% of carbon in soil organic matter of semi-evergreen forests is found in the sediments of the waterbody. Carbon stored in all other pools for waterbody is assumed to be zero.

As shown in Table 25 above, carbon stock of more than 15 million tonnes is stored in PTR. The stock has immense economic value in terms of avoiding the perilous effects of climate change. Based on a recent study by Yale University that has estimated the social cost of carbon for India and making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of carbon stored in PTR is estimated to be ₹ 16.76 billion.

3.4.3.10 CARBON SEQUESTRATION

The large tracts of forested landscapes of PTR are not only storehouses of carbon but add to this stock annually. While the carbon sequestration in old growth forests of PTR is unlikely to be as high as that in other relatively young forests, it is nevertheless significant¹⁰⁵. No studies on the carbon sequestration rates in the forests of PTR were available and hence

annual carbon sequestration was derived from the biomass (growing) stock estimates⁵⁹. Conservatively assuming a rotation period of 75 years for all forest types of PTR²⁹ and using the biomass stock estimates, the annual carbon sequestration in the above ground biomass in these forest types have been derived. On account of lack of reliable data, it is assumed that carbon sequestration in all other pools for forests — Below Ground Biomass, Dead Wood, Litter and Soil Organic Matter — and all pools for grasslands and waterbody is zero; but this is highly unlikely. Based on these assumptions, the estimates so derived are in the Table below

Forest Type	Total Vegetation Biomass (ton/ha)	Rotation Period (years)	Carbon Sequestration (ton/ha/year)	Area (km ²)	Annual Carbon Sequestration ('000 ton)
Evergreen forests	105.71	75	2.82	342.12	96.44
Semi-evergreen forests	75.85	75	2.02	223.20	45.15
Moist deciduous forests	87.5	75	2.33	38.48	8.98
Dry deciduous forests	86.82	75	2.32	41.00	9.49
Plantations	55.88	75	1.49	55.00	8.20
TOTAL				699.80	168.25

Once again using the social cost of carbon for India and making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of annual carbon sequestered in PTR is estimated to be ₹ 181.18 million.

3.4.3.11 WATER PROVISIONING

The dense and deep root system of forest soils, dense under-storey and the high porosity of its essentially organic horizons in PTR make for excellent water infiltration and retention capacity. Surface runoff is minimal and groundwater recharge more efficient, resulting in regular stream flow to the Periyar reservoir during the year. The role of such cloud forests as those found in PTR on water inputs to dams has been extensively documented in Sáenz and Mulligan (2013). The water from the Periyar reservoir irrigates 92,963 hectares in Theni, Madurai, Sivaganga, Ramanathapuram and Virudhunagar districts of Tamil Nadu. Being a rain-shadow region, these districts are heavily dependent on irrigation for agricultural production. Assuming that it would be possible to carry out rainfed agriculture in these areas even without getting water from Periyar Lake and the water from the lake is used to take second (*Rabi*) crop in these agricultural areas, the economic value of water from PTR is estimated using the production function approach. Such an approach has been used globally to value forests for the water catchment benefits⁶⁴. To avoid over-complexity, it is assumed that the major crops of these districts, i.e. rice and sugarcane, is cultivated in these areas in the same proportion as it is currently done in these 5 districts, i.e. 94% and 6% respectively¹¹⁶. Assuming an average yield of 3.9 tonnes / hectare for paddy and 112.5 tonnes / hectare for sugarcane¹¹⁶ and Minimum Support Prices of ₹ 13,100 / ton and ₹ 2,100 / ton respectively¹¹⁷, the estimates of total value of agricultural production attributable to irrigation from PTR are derived as shown in Table 26.

Periyar reservoir irrigates
92963
hectares in Theni, Madurai, Sivaganga, Ramanathapuram & Virudhunagar districts of Tamil Nadu.

Table 26

Additional Agricultural Production Due to Irrigation from PTR

Crop	Area (ha)	Productivity (ton / ha)	Total Production ('000 tonnes)	MSP (₹ / ton)	Value of Production (₹ million)
Rice	87131	3.92	341.36	13100	4471.86
Sugarcane	5832	112.53	656.30	2100	1378.23
TOTAL	92963				5850.09

Assuming that 50% of the value of this agricultural production can be attributed to irrigation⁶⁷, the total economic value of irrigation water from PTR estimated through the production function approach for agricultural production is thus approximately equal to ₹ 2925 million.

In addition, the water from Periyar Lake is first used for production of hydro-electricity before being released into the Suruliar River that carries the water for irrigation. The current capacity of the hydropower unit is 140 MW (4 x 35 MW) and average annual electricity production through the unit is approximately equal to 450 million KWH¹¹⁸. Conservatively assuming an average unit price of ₹ 2.5 / KWH, the economic value of annual electricity produced through the water from PTR is approximately equal to ₹ 1125 million.

The economic value of agricultural production and hydropower electricity generated in Tamil Nadu through the water from PTR is approximately equal to ₹ 4,050 million.

3.4.3.12 WATER PURIFICATION

Periyar Lake is a major source of domestic water for Theni and Madurai districts of Tamil Nadu as well as for the Kumily Panchayat. Due to natural filtration processes, the water derived from the catchment of PTR does not need any artificial treatment before supply. This service of natural water purification is a benefit in terms of water purification costs avoided^{2,34,68,69}.

While no exact estimates of the proportion of domestic water requirement of Theni and Madurai districts satisfied by Periyar Lake exist, it is documented as a primary source. Based on recent court cases, it can be safely assumed that half the domestic water requirements in these two districts is satisfied by Periyar Lake¹¹⁹. This assumption is conservative considering that Periyar Lake also satisfies domestic water requirements of other districts of Tamil Nadu such as Sivaganga, Ramanathapuram and Virudhunagar, but on account of unavailability of reliable data for the same, these districts have not been considered here. The Kumily Panchayat (consisting of Kumily and Periyar villages) are completely dependent on Periyar Lake for domestic water supply¹⁰⁰. The National Commission on Urbanization, Government of India, has suggested that even in the worst drought conditions and even in the poorest colonies, at least 70 liters per capita per day (LCPD) of water must be delivered per day to sustain human life at a minimum standard of hygiene. The optimal supply recommended by the World Health Organization is 100 to 200 lpcd to lead a hygienic existence. The conservative figure of the total quantity of domestic water thus supplied to the districts of Theni and Madurai as well as Kumily Panchayat from Periyar Lake according to the National Commission on Urbanization and that does not require prior artificial treatment is estimated as shown in Table 27.

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

Table 27

Drinking Water Requirement Satisfied by Periyar Tiger Reserve

Place	Population (2011 Census)	Minimum Domestic Water Requirement (lpcd ⁷)	Assumed % of Domestic Water Requirement met by Periyar Lake	Total Water Requirement (million m ³)
Theni District	1093950	70	50%	13.98
Madurai District	2578201	70	50%	32.94
Kumily Village	30276	70	100%	0.77
Periyar Village	22978	70	100%	0.59
TOTAL				48.27

Assuming an average cost of treating water for domestic supply at ₹ 10/m³ based on estimates for different municipalities in India³², the avoided cost of purifying 48.27 million m³ of water annually is approximately equal to ₹ 482.70 million per year.

3.4.3.13 SEDIMENT REGULATION

As stated earlier, Periyar Lake, the reservoir of the Mullaperiyar dam, is a lifeline for the neighbouring districts of the state of Tamil Nadu for irrigation and drinking water. Vegetation of PTR, especially forests, protects soil and reduces erosion rates. Deep tree roots stabilize slopes of this undulating terrain and give the soil mechanical support which can help to prevent shallow mass movements. In the absence of forests in the catchment of the Periyar Lake, the sediment load in the rivers and streams draining into the lake is likely to increase manifold. The increased sediment load will lead to decrease in the capacity of the reservoir. Technological measures will then be needed to dredge the reservoir and excavate the sediment load in it to ensure deriving maximum benefits from the reservoir. The forests of PTR, and even the grasslands surrounding the reservoir to an extent, play this important role of minimizing the sediment load in the streams that eventually flow into Periyar Lake. The avoided cost of dredging the reservoir can be directly attributed as an economic value of the PTR⁷¹⁻⁷³.

A recent study has estimated soil erosion rates in non-forested regions using the Revised Universal Soil Loss Equation (RUSLE) around the PTR in the range of 17.73 tonne ha⁻¹ yr⁻¹¹²⁰. Assuming that the soil erosion in forested regions of PTR is negligible, the soil erosion rates in non-forested regions can be directly used as avoided soil erosion from the forested areas of PTR. Digital Elevation Data (resolution of 90 metres) was obtained from the Shuttle Radar Topography Mission for the region to delineate the watershed of river Periyar and its tributaries that directly drain into Periyar Lake. The land cover map prepared by the French Institute of Pondicherry was used to extract land cover information in the delineated watershed which is presented in Table 28.



Table 28

Land Cover Classification in Periyar Lake Watershed within Periyar Tiger Reserve

Land cover	Type	Area (km ²)
Evergreen Forests	Forest	391.34
Moist Deciduous Forests	Forest	155.27
Semi-Evergreen Forests	Forest	3.47
Dry Deciduous Forests	Forest	0.01
Grasslands	Grassland	64.75
Waterbody	Water	24.93
Others	Non-Forest	2.72
TOTAL		642.49



The total forested area of the PTR in the watershed draining into Periyar Lake is approximately 550 km². On the basis of soil erosion avoided from forests and sediment delivery rate of 30% derived from InVEST exercise for Periyar (discussed later in Section 4.4.3), the total sediment load avoided in the Periyar Lake by the forested regions of the PTR is thus equal to 0.292 million tonnes year⁻¹. It may be noted that on account of lack of data, this only includes the sediment load avoided from forested regions and ignores the contribution of grasslands for arresting soil erosion. In addition, this also ignores the contribution of PTR in reducing the sediment load to another reservoir of Pampa dam just outside the PTR. The figure derived can thus be regarded as an underestimate.

To estimate the economic value of avoiding the estimated sediment load in the Periyar Lake, the cost of alternative technological interventions is considered. On account of lack of site-specific data, the cost estimates of ₹ 58.31 / cum given by the Central Water Commission as the earth excavation costs is used⁷⁴ along with an assumed weight of soil as 1.2 tonne/cum⁴⁰ to arrive at the economic value of sedimentation avoided. The economic value so derived is approximately equal to ₹ 14.21 million per year.

3.4.3.14 NUTRIENT CYCLING

On account of lack of local estimates for PTR, a study done by the Kerala Forest Research Institute for tropical rainforests in northern Kerala has been used. The study site resembles PTR in terms of terrain, soil types, rainfall and forest vegetation¹²¹.

As estimated earlier, the total sediment load avoided in the Periyar Lake by the forested regions of the PTR is approximately equal to 0.29 million tonnes year⁻¹. Using this estimate and the concentration of N, P and K in soil from the Table below, the quantity of nitrogen, phosphorus and potassium that would leach out from the system is approximately equal to 803, 219 and 1168 tons annually. Valuing the quantity of nutrient lost in this process with the help of the price of NPK fertilizers⁷⁹, the total value of PTR's forests in preventing nutrient loss is approximately equal to ₹ 38 million annually and is demonstrated in Table 29 below.



Table 29

Avoided Nutrient Loss by Periyar Tiger Reserve

Nutrient	Soil Nutrient Concentration ⁸ (mg kg ⁻¹)	Total Nutrient Loss Avoided by PTR Forests (ton yr ⁻¹)	Fertilizer Used for Valuation	Price of Fertilizer ⁹ (₹ kg ⁻¹)	Economic Value of Nutrient Loss Avoided (₹ million yr ⁻¹)
Nitrogen (N)	2,750	803	Urea (46% N)	5.31	4.27
Phosphorus (P)	750	219	DAP (18-46-0-0)	20.10	4.41
Potassium (K)	4,000	1168	Muriate of Potash (60% K ₂ O)	20.00	23.4
TOTAL					38.08

3.4.3.15 BIOLOGICAL CONTROL

Using estimates of economic value of biological control for tropical forests (₹ 660 / hectare / year), grasslands (₹ 1,860 / hectare / year) and wetlands (₹ 18,000 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 700 km² of forests, 199 km² of grasslands and 26 km² of wetlands of PTR is equal to ₹ 130 million per year.

3.4.3.16 MODERATION OF EXTREME EVENTS

Moderation of extreme events, especially floods, is not a significant service provided by PTR due to the presence of the dam and hence has not been estimated.

3.4.3.17 POLLINATION

Using estimates of economic value of pollination for tropical forests (₹ 1,800 / hectare / year) and grasslands (₹ 2,100 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 700 km² of forests and 199 km² of grasslands of PTR is equal to ₹ 167.79 million per year.

3.4.3.18 NURSERY FUNCTION

This is not a significant service in the context of PTR and hence has not been estimated.

3.4.3.19 HABITAT / REFUGIA

Using estimates of economic value of habitat / refugia for tropical forests (₹ 2,340 / hectare / year), grasslands (₹ 72,840 / hectare / year) and wetlands (₹ 747,120 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 700 km² of forests, 199 km² of grasslands and 26 km² of wetlands of PTR is equal to ₹ 3.56 billion per year.

3.4.3.20 CULTURAL HERITAGE

The indigenous tribes living inside PTR represent a cultural heritage whose economic value may although be impossible to estimate, but its cultural significance is enormous. PTR has, over several generations, provided a natural environment for these tribes to survive, adapt and make a living. Their cultures have thus evolved within this natural environment and PTR thus has great significance for preserving this cultural heritage.

450
million KWH

electricity generated
annually

0.29
million tonnes

annual sedimentation
avoided in Periyar
reservoir

3.4.3.21 RECREATION

PTR is a popular tourist destination. The scenic beauty of evergreen forests and wildlife attract a large number of tourists – both Indians and foreigners. The number of visitors to the reserve has been on the rise with approximately 8 lakh tourists visiting the PTR in 2012-13 as shown in Table 30 below¹¹³. It may be noted that the numbers below do not include those visiting PTR for Sabarimala and Mangaladevi-Kannagi pilgrimages.

Table 30
Tourists Visiting Periyar Tiger Reserve for Recreation

Financial Year	Number of Tourists to Thekkady		
	Domestic	Foreigners	Total
2008-09	590950	53985	644935
2009-10	491623	42940	534553
2010-11	499001	44730	543731
2011-12	628214	48476	676690
2012-13	666371	40611	780853

Recreational tourism brings significant revenues for the authorities of the PTR. For 2012-13, this was approximately equal to ₹ 46.98 million¹²². Further, the turn-over of establishments of the Kerala Tourism Development Corporation (KTDC) in PTR was approximately equal to ₹ 33.1 million in 2012-13¹¹³. In addition, various hotels, resorts and home stays (combined capacity is roughly more than 2,750 tourist beds) in Kumily directly benefit from the recreational opportunities offered at PTR.

While it is acknowledged that the revenue for Reserve Authorities as well as other establishments such as KTDC can be attributed largely to the scenic beauty and wildlife of the PTR, exact attribution is difficult. Two studies have estimated the economic value of recreational tourism of PTR. The first one conducted by Manoharan, Muraleedharan, and Anitha (1998) has estimated the economic value

of ecotourism via two commonly used methods — travel cost method (TCM) and contingent valuation method (CVM). The other study conducted by Bulov and Lundgren (2007) as a part of their dissertation thesis has used TCM to estimate the economic value of recreation services offered by PTR. Manoharan et al. (1998) provide a more conservative estimate and is used here to estimate the economic value of recreation services from PTR.

According to the study, the average consumer surplus per visitor from Kerala according to the travel cost method ranged from ₹ 147.38 to ₹ 161.32¹²³. Considering that a significant proportion of tourists are expected from other states of India as well as abroad (foreign tourists constitute more than 5% of total tourists visiting PTR), the study has used the higher estimate of average consumer surplus, i.e. ₹ 161.32 and has adjusted it according to the current prices using the Wholesale Price Index¹²⁵. The average consumer surplus per visitor so derived is approximately equal to ₹ 544.47 per visitor. Using the visitation rate of 780,853 tourists in 2012-13, the total consumer surplus of recreation tourism from PTR is approximately equal to ₹ 425.15 million per year.

3.4.3.22 SPIRITUAL TOURISM

The annual pilgrimages provide a significant source of livelihoods to the communities in the fringe area of the tiger reserve. A study conducted in Pandalam rural locality near PTR found that the average monthly income of a household involved in activities such as petty trading, accommodation/dormitory facilities, food and tea shops, and transportation facilities rose by ₹ 16,110 during the Sabarimala pilgrimage season compared to the non-pilgrimage season¹²⁶.

While attribution of the economic benefits generated from pilgrimage to the PTR is difficult, it must be acknowledged that the forested landscapes and wilderness

Annual pilgrimages of Sabarimala and Mangaladevi provide a significant source of livelihoods to the communities in the fringe area of the tiger reserve.

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

of PTR that pilgrims must track through to reach the shrines contributes to the overall cultural experience of the pilgrimage. The sounds of nature, remote landscapes and hardships undertaken to tread through difficult forest path is an important factor that adds to the spiritual experience of the pilgrimage.

3.4.3.23 RESEARCH, EDUCATION AND NATURE INTERPRETATION

PTR provides a unique opportunity for research, education and nature interpretation since it preserves large tracts of pristine forests and wilderness and provides an interesting “live” laboratory on many conservation practices and ecological processes. With more than one hundred and eighty research publications¹⁰⁰, PTR is one of the best studied areas in the country. The areas of research not only include ecology and wildlife, but also socio-economic aspects. In the backdrop of climate change and associated adaptations required by human and especially ecological systems, PTR also has high option value for providing

a suitable environment for research and thereby gain important insights that may be critical for the well-being of humankind¹²⁷.

3.4.3.24 GAS REGULATION

Using estimates of economic value of gas regulation for tropical forests (₹ 720 / hectare / year) and grasslands (₹ 540 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 700 km² of forests and 199 km² of grasslands of PTR is equal to ₹ 61.15 million per year.

3.4.3.25 WASTE ASSIMILATION

Using estimates of economic value of waste assimilation for tropical forests (₹ 7,200 / hectare / year) and grasslands (₹ 4,500 / hectare / year) from a global meta-analysis study²⁴, the economic value of approximately 700 km² of forests and 199 km² of grasslands of PTR is equal to ₹ 593.55 million per year.



3.4.3.26 SUMMARY OF ECOSYSTEM SERVICES BASED ON TEV FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Direct Use Value employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce	58.65	₹ million / year
Indirect Use Value carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation	9699.65	₹ million / year
Option Value gene-pool protection	7860.00	₹ million / year

3.4.3.27 SUMMARY OF ECOSYSTEM SERVICES BASED ON MILLENNIUM ECOSYSTEM ASSESSMENT FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Provisioning Services employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection	7918.65	₹ million / year
Regulating Services carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, gas regulation, waste assimilation	9274.50	₹ million / year
Cultural Services cultural heritage, recreation, spiritual tourism, research, education and nature interpretation	425.15	₹ million / year

3.4.3.28 SUMMARY OF ECOSYSTEM SERVICES BASED ON STOCK AND FLOW BENEFITS FRAMEWORK

Type of Value	Value	Unit
Flow Benefits employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection, carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation	17.62 1.90	₹ billion / year ₹ lakh / ha / year
Stock standing timber, carbon storage	316.50	₹ billion / year







3.4.3.29 SUMMARY OF ECOSYSTEM SERVICES BASED ON TANGIBLE AND INTANGIBLE BENEFITS FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Tangible Benefits	56.67	₹ million / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce		
Intangible Benefits	17561.63	₹ million / year
carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation, gene-pool protection		

3.4.3.30 DISTRIBUTION ACROSS STAKEHOLDERS (FLOW BENEFITS)

Based on assumptions made in Section 2.4.29, approximately 10 per cent of flow benefits accrue at the local level, 52 per cent at the national level and 38 per cent at the global level.

3.4.3.31 INVESTMENT MULTIPLIER

According to the last sanction from the National Tiger Conservation Authority, the annual management costs of Periyar Tiger Reserve for the year 2014-15 amounted to ₹ 38.36 million. Based on the flow benefits of ₹ 17.62 billion per year, for every rupee spent on management costs in PTR, flow benefits of ₹ 459 are realized within and outside the tiger reserve.



RANTHAMBORE TIGER RESERVE



KEY MESSAGES

Ranthambore is arguably the most popular tiger reserve and marks the transition zone between the true desert and seasonally wet peninsular India.

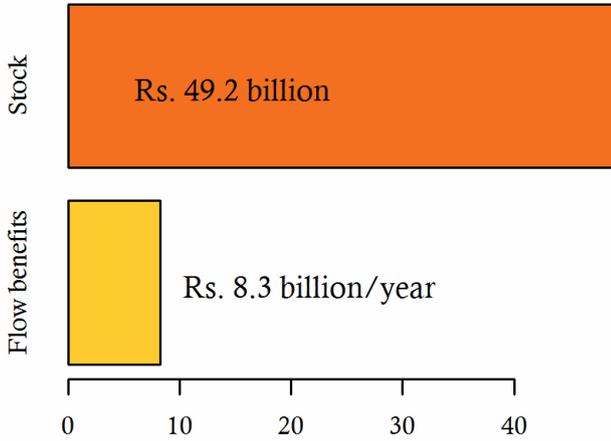
Important ecosystem services originating from Ranthambore include gene-pool protection (₹ 7.11 billion year⁻¹), provisioning of water to neighbouring regions (₹ 115 million year⁻¹) and provisioning of habitat and refugia for wildlife (₹ 182 million year⁻¹).

Other important services emanating from Ranthambore include generation of cycling of nutrients (₹ 34 million year⁻¹) and sequestration of carbon (₹ 69 million year⁻¹), apart from housing the Ganesh Temple visited by about 10 lakh pilgrims every year.

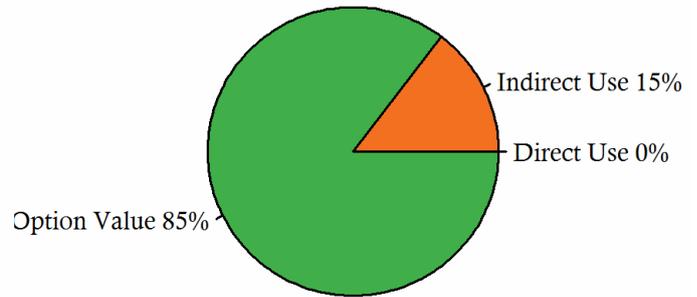
ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

3.5 RANTHAMBORE TIGER RESERVE

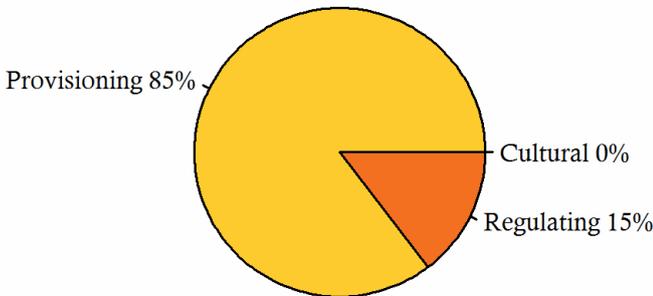
STOCK AND FLOW



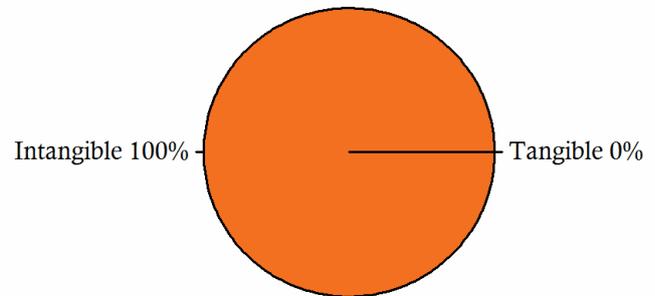
TYPE OF VALUE



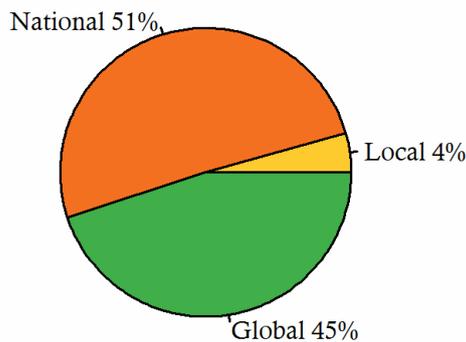
TYPE OF ECOSYSTEM SERVICE



TANGIBLES AND INTANGIBLES



DISTRIBUTION OF VALUE



Flow benefits per hectare per year
(Rs. lakh)

0.56

Flow benefits as a ratio of
management costs

273

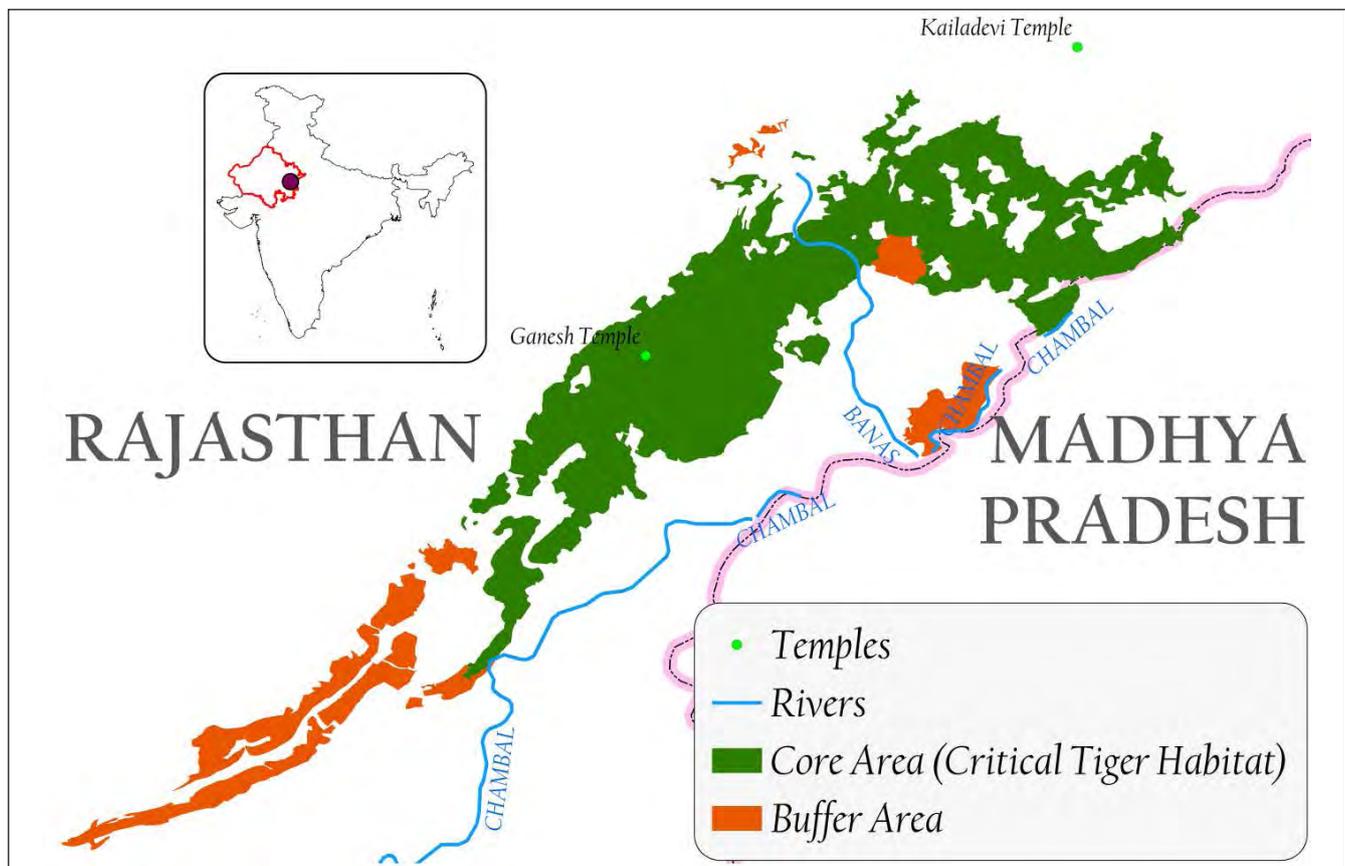
3.5.1 SITE SPECIFICATION

3.5.1.1 LOCATION AND LANDSCAPE

Arguably the most popular tiger reserve in India, Ranthambore Tiger Reserve (RTR) is situated in the south-eastern part of Rajasthan. The tiger reserve spans 1473 km² (1113 km² of core zone or critical tiger habitat and 360 km² of buffer zone)¹²⁸. The core zone of RTR is spread over 2 districts, viz. Sawai Madhopur and Karauli. The buffer zone does not circumscribe the core area in RTR but adjoins it in places and consists of available forest land outside the core zone. The buffer zone falls is spread over 3 districts, viz. Sawai Madhopur, Bundi and Tonk. The tiger reserve marks the transition zone between the true desert and seasonally wet peninsular India.

Figure 16

Ranthambore Tiger Reserve



The forests of RTR are mainly of edaphic climax and belong to the forest sub-type of Tropical Dry Deciduous Forests. *Anogeissus pendula* (common names: dhok, kardhai, chakwa) is the dominant species and constitutes about 80 per cent of the vegetation cover in RTR¹²⁸. Generally found in the hilly areas, *Anogeissus pendula* maintains luxuriant growth on gentle slope of hills owing to better soil formation and water holding capacity. The forests of RTR are also one of the last intact *Acacia pendula* forests of climax type in the state of Rajasthan. According to the assessment carried out on forest cover in the tiger reserves of India by the Forest Survey of India⁶⁰, about 16 per cent of the tiger reserve area is covered with Moderately Dense Forest (canopy cover density between 40 and 70 per cent), 38 per cent is covered with Open Forest (canopy cover density between 10 and 40 per cent) and 8 per cent is covered with scrub (canopy cover density less than 10 per cent). The remaining, area i.e. 39 per cent of the tiger reserve is not covered with forests.

3.5.1.2 HISTORY

In 1989, the Ranthambore National Park was notified out of the erstwhile Sawai Madhopur Wildlife Sanctuary. In 1983 and 1984, adjoining areas were also elevated to the status of sanctuaries whereby two sanctuaries were notified as the Sawai Mansingh Sanctuary and Keladevi Sanctuary respectively. RTR was among the first established tiger reserves in the country in 1973 and included the Keladevi Sanctuary Sawai Mansingh Sanctuary and other adjoining areas like Qualji. Following the disappearance of tigers from the Sariska Tiger Reserve, 2 tigers from the Ranthambore Tiger Reserve were relocated to Sariska in 2008¹²⁸.

3.5.1.3 TOPOGRAPHY AND CLIMATE

The terrain of RTR is hilly and there is hardly any plain area of considerable size available for cultivation inside the tiger reserve. As a result, the land use of RTR is mainly forest land with very good to poor tree or grass cover and isolated blank areas. The terrain, topography and geology of the tiger reserve influence the water regime by contributing towards runoff and recharging the ground water. The water holding capacity of the region is very poor because of the geological formations.



The rainfall in RTR is erratic and varies significantly from year to year. The average rainfall in the reserve is 750 to 800 millimetres, with over 90% of it occurring during June to September. In addition, droughts are common occurrences in the region. During droughts, there is acute shortage of fodder in the core and buffer areas of the tiger reserve and water becomes a limiting factor. The forest tracts of RTR are also vulnerable to incidents of fires during the summer season. However, there has not been any major fire incident in the last decade.

3.5.1.4 RIVERS

There is no entry of water in RTR from outside. All the water flows from RTR to the surrounding areas. Two major rivers — Chambal and Banas — flow out of RTR. The mighty river Chambal flows along the eastern side of the tiger reserve. The other river, Banas, divides the tiger reserve in two parts and flows from the west before it confluences with Chambal. RTR acts as multiple catchments of the low land plains adjoining the area of the tiger reserve. Small streams originating from the catchments supply water to all the wells in the plains and augment the water table. Without these catchments capability, the productivity of low land plains is likely to be greatly reduced. The tiger reserve thus has immense value in conserving water and acts as a lifeline for the survival of the local community living in and around RTR. A few water reservoirs have been constructed to harness the rain water flowing out of the reserve. These reservoirs maintain the water table of the region throughout the year and are important sources of irrigation. A few such reservoirs are Padam talab, Pacholas, Surwal, Rajbagh talab, Lahpur talab, Gilai Sagar, Mansarovar, Devpura and Amarapura¹²⁸.

Streams flowing in the northern tract form the catchment of the Banas river while the streams flowing in the southern tract drain directly into the Chambal. Streams facing

sharp ridges contain water almost throughout the year as folded impervious rocky strata beneath do not permit the water to percolate.

3.5.1.5 BIODIVERSITY

RTR is an area of water scarcity and availability of water governs the movements of ungulates inside the tiger reserve, along with other factors. However, different types of habitat found in RTR contribute to rich biodiversity of the reserve. Major habitats include *dang* (dry and plain plateaus with little soil), *koob* (deep wide nallas cut into rocks), riparian areas, valleys and wetlands. The availability of water increases from Dang to ravines, valleys, khohs, riparian area and wet lands.

RTR is home to six species of cats, four species of dog family (including wild dog), three species of mongoose and marsh crocodile¹²⁸. With an estimated 38 species of mammals, 315 species of both resident and migratory birds, 14 species of reptiles, about 10 species of fish besides arthropods and over 400 species of plants, RTR has rich biodiversity¹²⁸. Specifically, the tiger reserve is home to about 730 angiosperms and 383 species of bird species¹²⁸. RTR is also recognized having exceptional medicinal plant diversity.

While tigers, leopards, caracals, and jungle cats are the major carnivorous mammals found in RTR, wolves, jackals and hyenas can be spotted in the peripheral open areas. The ungulates are represented by sambar, chital, rojhara, chinkara and wild boar. Despite the high abundance of prey population in RTR, domestic livestock accounts for nearly 10-12% of the tiger's diet in the reserve¹²⁸. Further, wetland areas of RTR not only support diverse aquatic flora and fauna including crocodiles¹²⁹, but are also the favourite grounds of many bird species including migratory birds. These wetland areas mainly include Padam talao, Rajbagh, Malik talao, Gilaisagar and Mansarovar.

3.5.1.6 TOURISM

More than 3 lakh tourists visited RTR during 2013-14¹³⁰. The famous fort of Ranthambore built in 994 A.D. is situated at the top of a hill of the Vindhyan system in the heart of RTR. Apart from the fort, a chain of forts are also located inside and in the vicinity of the tiger reserve.

Table 31

Tourist Visitation Rates and Revenues from Tourism in RTR130

Year	Total Tourist Visitation				Total Revenue (In ₹ Million)			
	Foreigners	Indian	Student	Total (in lakh)	From tourism	From Eco-Development Surcharge	Others	Total Income
2009-10	88949	101750	12718	2.03	1.62	20.92	5.84	5.84
2010-11	124307	103790	11172	2.39	2.01	48.63	13.94	13.94
2011-12	125084	157289	6155	2.89	2.36	58.98	16.65	16.65
2012-13	107932	136579	2255	2.47	17.30	52.03	0.03	0.03
2013-14	114099	205543	4683	3.24	18.39	56.17	0.26	0.26
TOTAL	560371	704951	36983	13.02	41.69	236.72	36.74	36.74

The neighbouring town of Sawai Madhopur is known the world over as the tiger destination and wildlife tourism is the most important economic industry in the district¹³¹. The current hotel capacity of the town is approximately 3000 tourist beds¹²⁸. Apart from the tourism industry in the Sawai Madhopur town, many people from local communities are involved in eco-tourism activities in RTR. For example, more than 100 people from the local community have been selected and trained as Nature Guides and earn their livelihood from tourism in RTR.

3.5.1.7 PLACES OF RELIGIOUS IMPORTANCE

There are several large and small temples inside RTR. Mainly, these include the Ganesh temple in Ranthambhore fort, Keladevi mata temple, Soleshwar Mahadev, Amareshwar Mahadev temple, Khatola Mahadev temple, and Kamaldhar Mahadev temple. The estimated visitation rates of Ganesh temple are 7 to 8 lakh annually, while the same for Keladevi temple is 15 to 20 lakh¹²⁸.

3.5.1.8 SOCIO-ECONOMIC SITUATION

Most of the villages, 12 out of 16, present inside the Ranthambore National Park were relocated with the launch of The Project Tiger in 1975-76. In total, there are 70 villages currently existing in the core area of RTR with a total of approximately 8000 households¹²⁸. The relocation plan for many of them is currently underway. With the existing villages, the main communities in villages located inside the core zone include Meena, Gujjars, Mogiyas, Jat, Muslims and Bairwas. While Meenas are agriculturist and Gujjars pastoralists, Mogiyas are a landless, nomadic community comprising professional hunters.

Major crops grown in villages inside the core zone include bajra, wheat, sorghum, wheat, rice, millet and maize depending on season and water availability. Major crops grown outside RTR include millet, wheat, mustard, gram, maize and vegetables, with horticulture of guava gaining momentum in the recent past.

There are about 110 villages inside the 2-kilometre periphery of the tiger reserve and is classified as the eco-development zone where livelihood activities to augment incomes of local communities are carried out. Cattle rearing being one of the major occupations of local people in the region, it has been estimated that there are over one lakh domestic cattle in the area of 5-kilometre radius from the boundary of the tiger reserve¹²⁸. To reduce the risk of communicable diseases from livestock to

wildlife, a systematic approach to get the domestic cattle immunized in adjoining villages is an ongoing operation of the tiger reserve carried out in the pre-monsoon season. Nearly 250,000 heads of cattle are seasonally dependent on the resources of RTR, mostly from outside the tiger reserve¹²⁸. In total, there are about 440 villages inside the 10-kilometre periphery of the tiger reserve which exert varying degrees of influence on RTR.

3.5.2 VALUATION OF ECOSYSTEM SERVICES FROM THE RANTHAMBORE TIGER RESERVE

3.5.2.1 EMPLOYMENT GENERATION

Due to paucity of information, the economic value of employment generation from RTR has not been estimated in monetary terms.

3.5.2.2 AGRICULTURE

On account of paucity of information that can objectively establish linkages between agricultural productivity and RTR, the economic value of agriculture in RTR attributable to the tiger reserve has not been estimated in monetary terms.

3.5.2.3 FISHING

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.5.2.4 FUEL WOOD

While in the past a high proportion of local population were dependent on RTR for satisfying their fuel wood requirements, more than 11000 LPG gas connections have been provided to these local communities under the India Eco Development Programme¹²⁸. As a result, several villages have seen a complete shift in the fuel wood consumption to the LPG.

Fuel wood harvesting is not allowed in RTR, either in the core or buffer, and hence the economic value of the fuel wood

7-8
lakh

pilgrims visiting the
Ganesh temple annually

70
villages

inside the core area

8000
households

inside the core area

provisioning service has not been estimated here in monetary terms.

3.5.2.5 GRAZING

Grazing of livestock is not permitted in the core and buffer areas of RTR. Hence the economic value of fodder provisioning service has not been estimated here in monetary terms.

3.5.2.6 TIMBER

No timber harvesting is carried out in RTR, either in core or buffer, and hence the economic value of timber provisioning services from RTR has not been estimated here in monetary terms.

3.5.2.6.1 STANDING STOCK

While the flow value of timber from RTR is not estimated here in monetary terms, the standing stock of timber has a significant economic value. Using the growing stock estimates of Tropical Dry Deciduous Forests from the forest inventory database⁵⁹ of the Forest Survey of India and using area estimates for forests under different canopy cover densities⁶⁰, it is estimated that about 2.21 million cubic metres of standing stock of timber are contained in RTR. The economic value of this resource using an average price of timber at ₹ 25,000 / cubic metre and accounting for maintenance and transportation costs at 20 per cent of the market price is approximately equal to ₹ 44.19 billion. The calculations for estimating the economic value of standing timber stock of RTR are as shown in Table 32 below.

Table 32

Standing Stock of Timber in RTR

Canopy Cover Density Class	Growing Stock (cum / ha)	Area (km ²)	Total Stock (million cum)	Economic Value (₹ billion)
MDF	50.78	229.3	1.16	23.29
OF	18.92	552.6	1.05	20.90
Scrub	2.10	123.6	0.03	0.52
TOTAL		905.5	2.21	44.19

3.5.2.7 NON-WOOD FOREST PRODUCE (NWFP)

No non-wood forest produces are harvested in RTR, either in core or buffer, and hence the economic value of NWFP provisioning services from RTR has not been estimated here in monetary terms.

3.5.2.8 GENE-POOL PROTECTION

Using estimates of economic value of gene-pool protection for tropical forests (₹ 91,020 / hectare / year) from a global meta-analysis study²⁴, the economic value of 780 km² of forests of RTR is equal to ₹ 7.10 billion / year.

3.5.2.9 CARBON STORAGE

The carbon stock for Tropical Dry Deciduous Forests across various forest canopy cover densities has been worked out for the state of Rajasthan in a recent study which has been used here to estimate the carbon storage of RTR.

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

Table 33

Carbon Stock for Tropical Dry Deciduous Forests of Rajasthan in Different Forest Canopy Cover Classes²⁵

Canopy Cover Density Class	Carbon Stock (tonnes C / hectare)					
	Above Ground Biomass (AGB)	Below Ground Biomass (BGB)	Dead Wood (DW)	Litter	Soil Organic Matter (SOM)	Total
MDF	50.83	19.96	0.15	0.40	42.28	113.61
OF	10.41	4.09	0.13	0.37	22.12	37.13

As stated earlier, Moderately Dense Forest and Open Forests cover an area of approximately 230 km² and 550 km² respectively in RTR. Using these estimates in conjunction with carbon stock in various carbon pools as shown in Table 33, the total carbon stored in RTR is approximately equal to 4.66 million tonnes. Valued in terms of the social cost of carbon for India by making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of carbon stored in RTR is estimated to be ₹ 5.01 billion.

3.5.2.10 CARBON SEQUESTRATION

Apart from storing 4.66 million tonnes of carbon, forests of RTR sequester carbon on an annual basis. As no primary study estimating carbon sequestration in RTR exists, the same has been estimated here based on the forest inventory database of the Forest Survey of India. The total biomass for Tropical Deciduous Forests in different canopy cover densities i.e. Very Dense Forests, Moderately Dense Forests, Open Forests and Scrub have been taken from the forest inventory database⁵⁹. Based on total biomass per unit area, the mean annual increment (MAI) has been estimated using the Von Mantel Formula⁶¹ and the physical rotation period estimated in a recent study for Tropical Dry Deciduous Forests⁶². Assuming a biomass-to-carbon conversion ratio of 50%⁶³, the mean annual increment in above ground biomass has been converted to carbon sequestered in dry matter.

Using this methodology, the total carbon sequestered in the forests of RTR by aggregating across different canopy cover density classes is approximately equal to 63.92 kilo tonnes annually. The derivation of the same is as shown below in Table 34.

Table 34

Carbon Sequestration in RTR

Canopy Cover Density	Total Biomass (t/ha)	MAI (t ha ⁻¹ yr ⁻¹)	Annual Carbon Sequestration (tC ha ⁻¹ yr ⁻¹)	Area (km ²)	Total Carbon Sequestration ('000 tC yr ⁻¹)
VDF	94.08	3.42	1.71	0	0.00
MDF	68.34	2.49	1.24	229.3	28.49
OF	32.2	1.17	0.59	552.6	32.35
Scrub	13.66	0.50	0.25	123.6	3.07
					63.92

Using the social cost of carbon for India and making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of annual carbon sequestered in RTR is estimated to be ₹ 68.83 million per year.

3.5.2.11 WATER PROVISIONING

As stated earlier, there are a few water reservoirs constructed to harness the rain water flowing out of the reserve. These reservoirs maintain the water table of the region throughout the year and are important sources of irrigation. The forested watershed ensures regular flow of water in the streams, especially in dry seasons by acting as a sponge and releasing water



slowly. A study done for the Green India State's Trust has estimated that forests in Western Rajasthan contribute to 80 mm / hectare of additional water recharge considering all factors such as, inter-alia, precipitation, evapo-transpiration, saturation capacity of the soil and run-off vis-à-vis a non-forest area in the western region of the state³⁰.

Only accounting for Moderately Dense Forests and Open Forests (with a combined area of approximately 780 km²), the differential water recharge from forests of RTR (80 mm ha⁻¹ year⁻¹), the total amount of additional water recharge attributable to RTR is approximately equal to 6.24 million m³. Using the economic value of ₹ 18.43 / m³, the total economic value of annual water recharge by RTR is approximately equal to ₹ 115 million per year.

3.5.2.12 WATER PURIFICATION

While the reservoirs do cater to drinking water requirements of the local communities, due to paucity of data regarding the same, the ecosystem service of water purification has not been estimated in monetary terms for RTR.

3.5.2.13 SEDIMENT REGULATION

Deep tree roots of forests of RTR stabilize and provide mechanical support to the soils in this dry climate which can help to prevent shallow mass movements. In the absence of forests in RTR, the sediment load in the Chambal and Banas rivers and other smaller reservoirs is likely to increase manifold. The increased sediment load will lead to decrease in the capacity of these rivers and reservoirs. Technological measures will then be needed to dredge the reservoir and excavate the sediment load to ensure deriving maximum benefits from rivers and reservoirs. The forests of RTR play this important role of minimizing the sediment load and this avoided cost of dredging can be directly attributed as an economic value of the RTR⁷¹⁻⁷³.

According to a study⁴¹, forests in Rajasthan prevent soil loss in the magnitude of 12.29 tons ha⁻¹ yr⁻¹. Using this estimate and assuming a sediment delivery rate of 20 per cent (lower compared to Corbett Tiger Reserve), 780 km² of Moderately Dense Forests and Open Forests aggregated prevent approximately 0.19 million tonnes of soil erosion annually.

To estimate the economic value of avoiding this estimated sediment load by forests of RTR, the cost of alternative technological interventions is considered. On account of lack of site-specific data, the cost estimates of ₹ 58.31 / cum given by the Central Water Commission as the earth excavation costs is used⁷⁴ along with an assumed weight of soil as 1.2 tonne/cum⁴⁰ to arrive at the economic value of sedimentation avoided. The economic value so derived is approximately equal to ₹ 9.32 million per year.

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

3.5.2.14 NUTRIENT CYCLING

As both the major rivers, Chambal and Banas, flow outward, what soil is eroded is washed away from the protected area with run-off along with soil nutrients lost forever. The natural ecosystems of RTR however ensure that the nutrients are regulated and their loss is avoided. In the scientific literature, this ecosystem services is mostly estimated using the replacement cost of fertilizers³⁴⁻⁴¹, and a similar approach has been used here.

Owing to soil erosion in the absence of forests, the nutrients will be lost along with sediments. The litter also has significant nutrient concentration and if these forests had not been there, the nutrients would further leach from this litter nutrient pool. However, due to paucity of data on the nutrient composition of litter, the same has not been considered in the study. On account of lack of local estimates for RTR, a study conducted by the Green Indian States Trust has been used for deriving the soil nutrient composition⁴¹. These estimates are in consonance with the qualitative description of soil nutrient composition of the Sawai Madhopur district¹³².

As estimated earlier, the total sediment load avoided by the forested regions of the RTR is approximately equal to 0.19 million tonnes year⁻¹. Using this estimate and the concentration of N, P and K in soil from the Table below, the quantity of nitrogen, phosphorus and potassium that would leach out from the RTR system is approximately equal to 440, 8 and 1567 tons annually. Valuing the quantity of nutrient lost in this process with the help of the price of NPK fertilizers⁷⁹, the total value of RTR's forests in preventing nutrient loss is approximately equal to ₹ 33.86 million annually and is demonstrated in Table 35.

Table 35
Avoided Nutrient Loss by Ranthambore Tiger Reserve

Nutrient	Soil Nutrient Concentration ¹⁰ (g kg ⁻¹)	Total Nutrient Loss Avoided by RTR Forests (ton yr ⁻¹)	Fertilizer Used for Valuation	Price of Fertilizer ¹¹ (₹ kg ⁻¹)	Economic Value of Nutrient Loss Avoided (₹ million yr ⁻¹)
Nitrogen (N)	2.320	440.80	Urea (46% N)	5.31	2.34
Phosphorus (P)	0.044	8.36	DAP (18-46-0-0)	20.10	0.17
Potassium (K)	8.25	1567.50	Muriate of Potash (60% K ₂ O)	20.00	31.25
TOTAL					33.86



3.5.2.15 BIOLOGICAL CONTROL

Using estimates of economic value of biological control for tropical forests (₹ 660 / hectare / year) from a global meta-analysis study²⁴, the economic value of 780 km² of forests of RTR is equal to ₹ 51.48 million / year.

3.5.2.16 MODERATION OF EXTREME EVENTS

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.5.2.17 POLLINATION

Using estimates of economic value of pollination for tropical forests (₹ 1,800 / hectare / year) from a global meta-analysis study²⁴, the economic value of 780 km² of forests of RTR is equal to ₹ 140.40 million / year.

3.5.2.18 NURSERY FUNCTION

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.5.2.19 HABITAT / REFUGIA

Using estimates of economic value of habitat / refugia for tropical forests (₹ 2,340 / hectare / year) from a global meta-analysis study²⁴, the economic value of 780 km² of forests of RTR is equal to ₹ 182.52 million / year.

3.5.2.20 CULTURAL HERITAGE

Due to paucity of information, this ecosystem service has not been estimated in monetary terms. However, there are many old temple sites within RTR which have a special cultural significance and are discussed later in Section 3.5.2.22.

3.5.2.21 RECREATION

The number of tiger reserves to be studied in the study made it difficult to conduct extensive primary data collection and the study relied on secondary peer-reviewed literature for each tiger reserve to provide the necessary information. As no study for RTR estimating consumer surplus of tourists was found, the economic value of recreation from RTR has not been estimated here in monetary terms.

3.5.2.22 SPIRITUAL TOURISM

RTR attracts numerous pilgrims due to the presence of several temple sites inside the tiger reserve. The most famous temple, the Ganesh Temple is situated in the Ranthambore fort inside the core area and attracts 15 to 20 lakh pilgrims every year and 7 to 8 lakh during the



mela (fair) from within and outside the state of Rajasthan. Apart from the Ganesh Temple, there are also other temples which attract a large number of pilgrims such as the Keladevi mata temple, Soleshwar Mahadev Temple, Amareshwar Mahadev temple, Khatola Mahadev temple and Kamaldhar Mahadev temple. Apart from conserving biodiversity, RTR plays a significant role in conservation of this cultural heritage.

3.5.2.23 RESEARCH, EDUCATION AND NATURE INTERPRETATION

RTR is one of the sought-after places for conducting research owing to the long history of interaction between social, cultural and natural dynamics. As a result, many of research works have been carried out by the Wildlife Institute of India, Zoological Society of India and Botanical Survey of India among several others in the area of documentation of traditional knowledge, wildlife ecology, floral and faunal survey, remote sensing, fire ecology, and tourism. The entire landscape of RTR provides unique opportunities for research, education and nature interpretation, not easily found in any other areas.

3.5.2.24 GAS REGULATION

Using estimates of economic value of gas regulation for tropical forests (₹ 720 / hectare / year) from a global meta-analysis study²⁴, the economic value of 780 km² of forests of RTR is equal to ₹ 56.16 million / year.

3.5.2.25 WASTE ASSIMILATION

Using estimates of economic value of waste assimilation for tropical forests (₹ 7,200 / hectare / year) from a global meta-analysis study²⁴, the economic value of 780 km² of forests of RTR is equal to ₹ 561.60 million / year.

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

3.5.2.26 SUMMARY OF ECOSYSTEM SERVICES BASED ON TEV FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Direct Use Value employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce	0.00	₹ million / year
Indirect Use Value carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation	1219.17	₹ million / year
Option Value gene-pool protection	7100.00	₹ million / year

3.5.2.27 SUMMARY OF ECOSYSTEM SERVICES BASED ON MILLENNIUM ECOSYSTEM ASSESSMENT FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Provisioning Services employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection	7100.00	₹ million / year
Regulating Services carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, gas regulation, waste assimilation	1219.17	₹ million / year
Cultural Services cultural heritage, recreation, spiritual tourism, research, education and nature interpretation	0.00	₹ million / year

3.5.2.28 SUMMARY OF ECOSYSTEM SERVICES BASED ON STOCK AND FLOW BENEFITS FRAMEWORK

Type of Value	Value	Unit
Flow Benefits employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection, carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation	8.32	₹ billion / year
Stock standing timber, carbon storage	49.20	₹ billion / year



3.5.2.29 SUMMARY OF ECOSYSTEM SERVICES BASED ON TANGIBLE AND INTANGIBLE BENEFITS FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Tangible Benefits	0.00	₹ million / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce		
Intangible Benefits	8319.17	₹ million / year
carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation, gene-pool protection		

3.5.2.30 DISTRIBUTION ACROSS STAKEHOLDERS (FLOW BENEFITS)

Based on assumptions made in Section 2.4.29, approximately 4 per cent of flow benefits accrue at the local level, 51 per cent at the national level and 45 per cent at the global level.

3.5.2.31 INVESTMENT MULTIPLIER

According to the last sanction from the National Tiger Conservation Authority, the annual management costs of the Ranthambore Tiger Reserve for the year 2013-14 amounted to ₹ 30.45 million. Based on the flow benefits of ₹ 8.32 billion per year, for every rupee spent on management costs in RTR, flow benefits of ₹ 273 are realized within and outside the tiger reserve.



SUNDARBANS TIGER RESERVE



KEY MESSAGES

Sundarbans forms the largest contiguous track of mangrove forest found anywhere in the world and is the only mangrove forest inhabited by tigers.

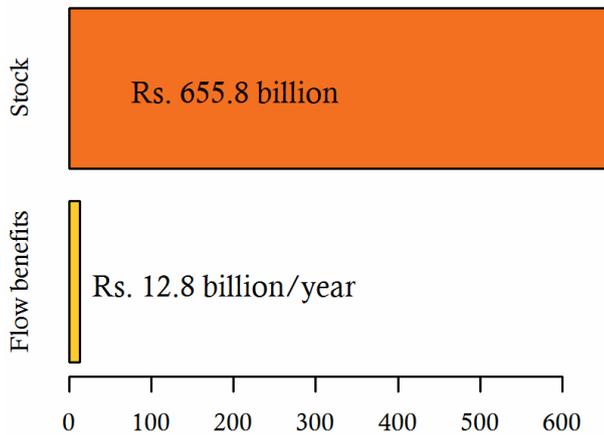
Important ecosystem services originating from Sundarbans include nursery function (₹ 5.17 billion year⁻¹), gene-pool protection (₹ 2.87 billion year⁻¹), provisioning of fish (₹ 1.6 billion year⁻¹) and waste assimilation services (₹ 1.5 billion year⁻¹).

Other important services emanating from Sundarbans include generation of employment for local communities (₹ 36 million year⁻¹), moderation of cyclonic storms (₹ 275 million year⁻¹), provision of habitat and refugia for wildlife (₹ 360 million year⁻¹) and sequestration of carbon (₹ 462 million year⁻¹).

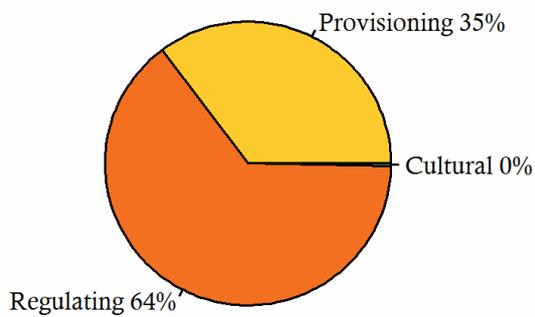
ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

3.6 SUNDARBANS TIGER RESERVE

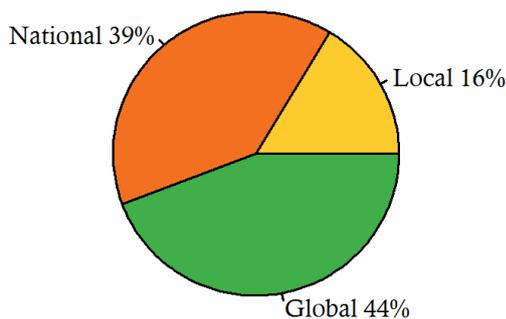
STOCK AND FLOW



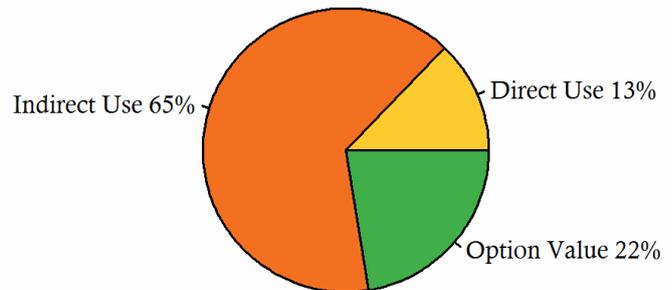
TYPE OF ECOSYSTEM SERVICE



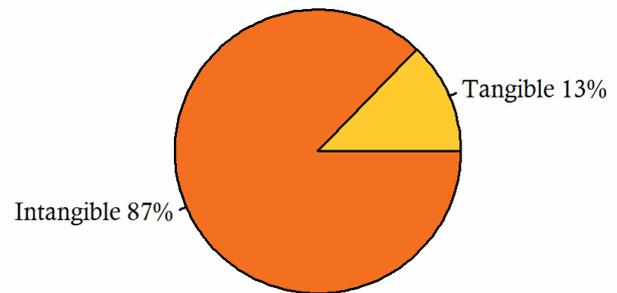
DISTRIBUTION OF VALUE



TYPE OF VALUE



TANGIBLES AND INTANGIBLES



Flow benefits per hectare per year
(Rs. lakh)

0.5

Flow benefits as a ratio of
management costs

530

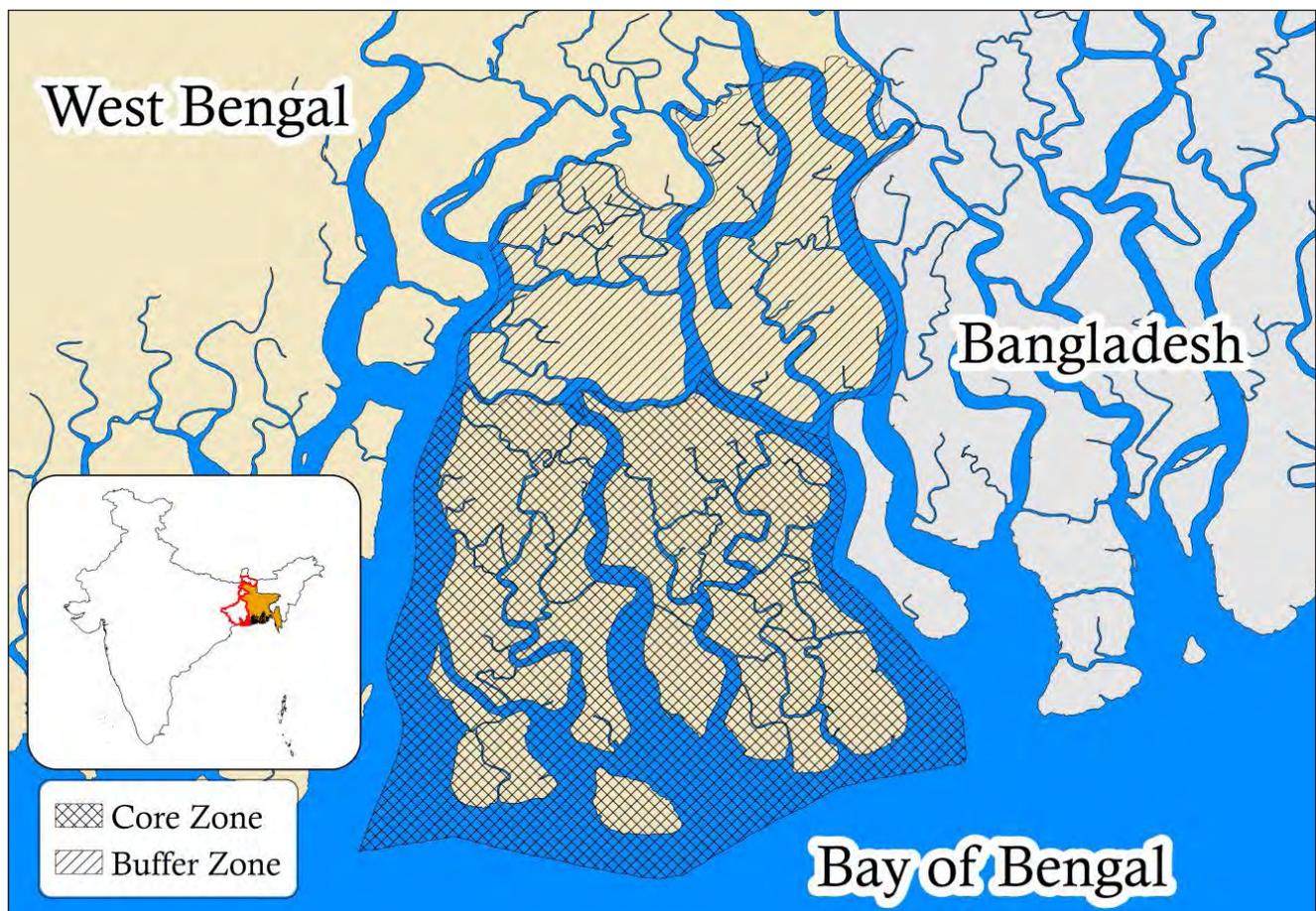
3.6.1 SITE SPECIFICATION

3.6.1.1 LOCATION AND LANDSCAPE

Sundarbans Tiger Reserve (STR) is situated in the coastal districts of South 24-Parganas and North 24-Parganas districts of West Bengal, about 100 kilometres from Kolkata. Lying at the southern-most extremity of the lower Gangetic delta¹ bordering the Bay of Bengal, STR can be described as a maze of estuaries, river channels and creeks encompassing more than 100 islands. STR extends over an area of 2585 km² (1700 km² of core zone and 885 km² of buffer zone) and forms the largest contiguous track of mangrove forest (together with Bangladesh Sundarbans) found anywhere in the world¹³³. STR is bounded by fringe villages along the northern boundary, the Bay of Bengal on the south, and Bangladesh on the east separated by Raimangal, Kalindi and Harinbhanga rivers.

Figure 17

Sundarbans Tiger Reserve



The entire stretch of forests in STR are classified under Mangrove forests (Littoral and Swamp Forests) according to the Champion and Seth Classification¹⁰³. Forests (mangroves) occupy about 60% of the total area of STR and the rest is

¹ The Sundarbans delta is part of the delta of the rivers Ganges, Brahmaputra and Meghna, spanning about 350 kilometres where seawater and freshwater mix.

occupied by water. The information on forest cover of STR including area under different forest density classes is as shown in Table 36 below.

Table 36
Forest Cover of Sundarban Tiger Reserve⁶⁰

Land Cover / Vegetation Class	Total Area (km ²)
Forest (Mangrove)	1538
Very Dense Forest	730
Moderately Dense Forest	663
Open Forest	145
Non-Forest (Waterbody)	1047
Total	2585

3.6.1.2 HISTORY

STR is one of the first nine tiger reserves declared under Project Tiger in the year 1973. The protection for conservation was further reinforced with the establishment of Sajnekhali Wildlife Sanctuary (now within STR) in 1976. Subsequently, a larger area was declared as a National Park under the Wildlife (Protection) Act, 1972 in 1984. Acknowledging the significance of the biogeographic region, the National Park area of the STR was included in the World Heritage Property in 1985 by United Nations Educational, Scientific and Cultural Organization (UNESCO). With the broad objective of conservation of the ecosystem and genetic diversities, inter alia, the entire area of Sundarbans including STR has also been declared as a Biosphere Reserve since 1989.

3.6.1.3 SIGNIFICANCE

STR exhibits very rich faunal and floral diversity^{134,135}. STR (along with Bangladesh Sundarbans) is the only mangrove forest in the world that is inhabited by the tiger. The land area in the Sundarbans is constantly being changed, moulded and shaped by the action of the tides, with erosion processes more prominent along estuaries and deposition processes along the banks of inner estuarine waterways influenced by the accelerated discharge of silt from sea water. The mangrove ecosystem of the STR is considered to be unique because of its immensely rich mangrove flora and mangrove-associated fauna. STR constitutes over 60 per cent of the total mangrove forest area in the entire country and has 90% of the total Indian mangrove species. About 78 species of mangroves have been recorded in the area making it the richest mangrove

forest in the world. It is also unique as the mangroves are not only dominant as fringing mangroves along the creeks and backwaters, but also grow along the sides of rivers in muddy as well as in flat, sandy areas.

3.6.1.4 BIODIVERSITY

STR supports a wealth of animal species including the single largest population of tiger and a number of other threatened aquatic mammals such as the Irrawaddy and Ganges river dolphins. The tiger reserve also contains an exceptional number of threatened reptiles including the king cobra and significant populations of the endemic river terrapin which was once believed to be extinct. The heritage site provides nesting grounds for marine turtles including the olive riley, green and hawksbill. Two of the four species of highly primitive horseshoe crab (*Tachypleus gigas* and *Carcinoscorpius rotundicauda*) are found here. It is also called the kingfishers' paradise as out of 12 species found in India, 8 are found here. The Sajnekhali area, listed as an Important Bird Area, contains a wealth of waterfowl and is of high importance for migratory birds.

At least a total of 1586 species of Protista (Protozoa) and Animalia have been reported from the Sundarban mangrove ecosystem¹³⁴. In the mangrove forest of Indian Sundarban, a total of 69 floral species belonging to 29 families and 50 genera have been recorded, out of which 34 species are of true mangrove type¹³⁶. Apart from higher plants, Sundarbans shelters rich microbial community including a wide range of bacteria, cyanobacteria and phytoplankton of the ambient aquatic phase. A total of 64 phytoplankton species have been recognized in the Indian Sundarbans¹³⁷.

3.6.1.5 CLIMATE

STR experiences tropical humid coastal climate characterized by moderate rainfall, temperature and high humidity with fierce cyclonic storms and depressions during pre-monsoon, monsoon as well as post-monsoon months. The tiger reserves an average annual rainfall of 1920 mm with average relative humidity over 80 per cent¹³³.

Cyclonic storms are regular characteristics of the region. Cyclones bring strong winds, heavy rainfall and flooding resulting in large-scale damage of lives and property. Further, severe cyclonic storms over the Bay of Bengal have registered an increase in frequency and intensity over the last decades¹³⁸. Table 37 below lists some of the major cyclones over the northern Bay of Bengal since 1999.

Table 37

List of Major Cyclones Over Northern Bay of Bengal Since 1999

Name of the Cyclone	Date of Occurrence	Speed (knots)	Category
	28-10-99	>140	Super Cyclonic Storm
	28-10-00	<40	Cyclonic Storm
	19-05-03	<60	Severe Cyclonic Storm
	17-04-03	<60	Severe Cyclonic Storm
	02-10-05	<40	Cyclonic Storm
Mala	24-04-06	>120	Super Cyclonic Storm
	13-05-07	<60	Severe Cyclonic Storm
Sidr	15-11-07	>120	Super Cyclonic Storm
	28-06-07	>120	Super Cyclonic Storm
Rashmi	26-10-08	>40	Cyclonic Storm
Nargis	27-04-08	<120	Very Severe Cyclonic Storm
Bijli	16-04-09	<60	Severe Cyclonic Storm
Aila	24-05-09	<60	Sever Cyclonic Storm

3.6.1.6 SOCIO-ECONOMIC SITUATION

There is no human inhabitation inside the core as well as buffer area of STR¹³³. However, the forest on the northern and western fringes is surrounded by human habitations with very high population density (excess of 700 people per km²) and have been historically underprivileged (more than 40% belong to Scheduled Castes and Scheduled Tribes). The poor socio-economic condition of the people with low literacy levels, absence of proper skill sets, and lack of employment opportunities in the absence of any industries leads to a high degree of natural resource dependency for both sustenance and livelihood¹³⁹. About 270,000 people live in the 46 fringe village surrounding STR.

Most of the human inhabited islands around STR were reclaimed from the river before the completion of the siltation process and hence are at a much lower level than the river water. Consequently frequent inundation is common leading to the land and sweet water bodies turning saline and therefore unfit for agriculture and human use respectively. To protect the villages from the river waters, earthen embankments have been built all around the islands. There are 3500 kilometres of earthen embankment which protect villages in 52 non-forested islands around STR against flooding during the high tide which occurs twice daily¹³³. However, the recent catastrophic cyclone AILA exposed weakness in the existing structures, which were breached because of strong waves leading to massive flooding in these villages. Flooding leads to loss of agricultural land and thereby affects the livelihood of most people as agriculture is one of the mainstays of the economy in the region.

Apart from agriculture, other occupations of people living in the fringe villages include agricultural labour, household work, fishing, and others. Most of the farmers in the villages are small and marginal who cultivate only one purely rain-fed crop. Infrastructural facilities in terms of electricity, roads, markets, hospitals and education services in the villages are extremely limited.

Cyclonic storms are a regular feature of this region resulting in large-scale damage of lives and property.

About **270,000** people live in the **46 fringe villages** surrounding the tiger reserve

157600
man-days

local employment
generated annually

₹ 1.6
billion per year

value of fish catch from
Sundarbans Tiger Reserve

31
million cubic metres
standing timber stock
protected

22.38
million tonnes
carbon stored

430
kilo tonnes
carbon sequestered
annually

Natural resource extraction in terms of fishing and honey collection is permitted from the buffer area only¹³³. Fishing is allowed against valid permits known as Boat License Certificate (BLCs). In addition, honey collection is also allowed for a certain period against permits issued by the Tiger Reserve Authority. This however is not without incidents of human-wildlife conflict. Encounters of villagers venturing into forest areas for fishing and honey collection with tigers, crocodiles and snakes are common.

3.6.2 VALUATION OF ECOSYSTEM SERVICES FROM THE SUNDARBANS TIGER RESERVE

3.6.2.1 EMPLOYMENT GENERATION

3.6.2.1.1 EMPLOYMENT IN MANAGEMENT OF STR

STR is a source of regular employment for the local communities living in the vicinity of the tiger reserve. In 2013-14, a total of 157,600 man-days were generated by the tiger reserve for various management activities in which local communities were involved¹⁴⁰. Conservatively using the wage rate for unskilled labour of ₹ 206 per man-day prevalent in the area¹⁴¹, the economic value of employment generated by STR is estimated to be ₹ 32.47 million per annum.

3.6.2.1.2 REVENUES FROM ECO-DEVELOPMENT COMMITTEES

There are currently 14 Eco-Development Committees (EDCs) and 11 Forest Protection Committees (FPCs) functioning in the adjoining areas of the tiger reserve. A portion of revenues accrued to the forest department through tourism is flowed back to these committees for implementing developmental activities in neighbouring villages. In 2013-14, the annual revenue of these EDCs and FPCs was approximately equal to ₹ 1.50 lakh¹⁴⁰. Thus, the total revenue of all such institutions around STR in 2013-14 is estimated to be ₹ 3.75 million.

3.6.2.2 AGRICULTURE

There are no inhabitants inside the tiger reserve (both core and buffer)¹³³ and hence the economic value of agriculture is not relevant in the case of STR.

3.6.2.3 FISHING

The buffer zone of STR except the Sajnekhali Wildlife Sanctuary is open for fishing for registered permit-holders for a period of 9 months. Presently there are about 923 Boat License Certificates or the Fishing Permits, out of which approximately 700 are active^{133,142,141}. While there are no reliable estimates on the quantity of fish, crab and prawns harvested from STR, a forthcoming study from WWF has estimated the quantity of fish auctioned at an average Aarat (auction centre) in Canning, the nearest fish market which receives catch only from Sundarbans. Based on the fact that there are 149 such Aarats in Canning and each Aarat auctions approximately 90 metric tonnes of fish annual¹⁴¹, the quantity of fish caught from STR (which occupies about 60% of Indian Sundarbans) is estimated to be 8,000 tonnes per year. This is in congruence with the discussions held with local fishermen wherein it was found that approximately 5 tonnes of fish are caught per month when fishing is allowed in STR. Assuming a conservative price of fish at ₹ 200 per kilogram based on local market price^{142,143}, the economic value of fish caught from STR is approximately equal to ₹ 1.6 billion per year. It may be noted that this estimate is still conservative on account of the following reasons:

- Does not account for quantity of crabs and prawns caught from STR which are sold at premium to fish.
- Does not include the quantity of fish caught for self-consumption.
- Does not account for the inputs that shrimp farms received from STR as seeds.

Considering that fish is the main source of protein for the underprivileged communities living around Sundarbans, the economic value of STR for fishing is very significant — economically and culturally.

3.6.2.4 FUEL WOOD

No extraction of fuel wood from STR is allowed¹³³ and hence the economic value of fuel wood provisioning is not relevant in this case.

3.6.2.5 GRAZING / FODDER

Since there is no human habitation inside the core and buffer areas of STR and as the tiger reserve is surrounded by water, provisioning of fodder for livestock owned by adjoining villages is not applicable in the case of STR¹³³. Hence, its economic value has not been estimated.

3.6.2.6 TIMBER

Timber harvesting in STR has been discounted since 2001¹³³ and thus provisioning of timber from STR is no longer relevant. As a result, the economic value of timber from STR has not been estimated.

3.6.2.6.1 STANDING STOCK

While the flow value of timber from STR is not estimated here in monetary terms, the standing stock of timber has a significant economic value. Using the growing stock estimates of Littoral and Swamp Forests from the forest inventory database⁵⁹ of the Forest Survey of India and using area estimates for forests under different canopy cover densities⁶⁰, it is estimated that about 31.43 million cubic metres of standing stock of timber is contained in STR. The economic value of this resource using an average price of timber at ₹ 25,000 / cubic metre and accounting for maintenance and transportation costs at 20 per cent of the market price is approximately equal to ₹ 628.70 billion. The calculations for estimating the economic value of standing timber stock of STR are as shown in Table 38 below.



Table 38

Standing Stock of Timber in STR

Canopy Cover Density Class	Growing Stock (cum / ha)	Area (km ²)	Total Stock (million cum)	Economic Value (₹ billion)
VDF	281.09	730	20.52	410.39
MDF	154.64	663	10.25	205.05
OF	45.70	145	0.66	13.25
TOTAL		1538	31.43	628.70

Mangroves are amongst the most **highly productive ecosystems** and produce large amounts of carbon in the form of leaf litter, and therefore have a high potential for storage & export.

3.6.2.7 NON-WOOD FOREST PRODUCE (NWFP)

While other NWFPs such as Golpata and Hental were earlier allowed to be extracted from STR, only honey is permitted for extraction from the buffer area of STR presently¹³³. Mangrove honey — with its subtle sweetness and tinge of saltiness — is a valuable commodity in Sundarbans. Permits are given to collect honey at a price fixed in consultation with the buyer of the collected honey, i.e. the West Bengal Forest Development Corporation Ltd. Each permit allows 6 to 10 people called ‘*Moulis*’ to enter the buffer area for collection of honey during the three-month period when fishing in STR is not permitted. The quantity of honey collection during 2014-15 was approximately equal to 47 metric tonnes and the revenues received from the sale of honey were approximately equal to ₹ 5.50 million¹⁴⁰.

3.6.2.8 GENE-POOL PROTECTION

Using estimates of economic value of gene-pool protection for mangroves (₹ 18,660 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1538 km² of forests of STR is equal to ₹ 2.87 billion / year.

3.6.2.9 CARBON STORAGE

Mangroves are amongst the most highly productive ecosystems and produce large amounts of carbon in the form of leaf litter, and therefore have a high potential for storage and export¹⁴⁴. While there have been few studies conducted on carbon storage (or sequestration) functions of Sundarbans¹⁴⁵⁻¹⁴⁸ these have either estimated carbon only for specific carbon pools or have estimated all carbon pools only for specific species / region in Sundarbans. As a result, estimates derived for the State of West Bengal by a recent study from the Forest Survey of India for mangrove forests have been used²⁵. The estimated carbon stored in five major carbon pools — above ground biomass (AGB), below ground biomass (BGB), dead wood (DW), litter and soil organic matter (SOM) for different canopy density classes of mangrove forests (called Littoral and Swamp Forests in the cited report) of West Bengal is shown in Table 39. It may be noted that the estimates below do not include carbon stock the in non-forest area, a large majority of which is waterbody. Although the carbon stock in the waterbody around mangrove forests is known to be significant^{149,150}, this has not been included here due to paucity of site-specific data.

Table 39
Carbon Stock in Sundarbans Tiger Reserve

Land cover	Density Class	Carbon Stock in Individual Pools (tonnes C /hectare) ¹²					C Stock (tC / ha)	Area in STR (km ²) ¹³	Total Carbon Stock (million tC)
		AGB	BGB	DW	Litter	SOM			
Mangrove forests	VDF	75.62	26.16	0.02	1.27	86.48	189.55	730	13.84
	MDF	44.47	15.38	0.02	0.67	56.80	117.36	663	7.78
	OF	14.31	4.95	0.02	0.38	33.02	52.68	145	0.76
Non-Forest	-	-	-	-	-	-	0	1047	0
TOTAL								2585	22.38

As indicated in Table 39, carbon stock of more than 22.38 million tonnes is stored in STR. The stock has immense economic value in terms of avoiding the perilous effects of climate change. Based on a recent study by Yale University that has estimated the social cost of carbon for India and making necessary adjustments for Purchasing Power Parity and inflation, the total economic value of carbon stored in STR is estimated to be ₹ 24.10 billion.

3.6.2.10 CARBON SEQUESTRATION

Apart from carbon storage, mangrove forests play a unique role in sequestering carbon. It has been concluded that the average rate of carbon sequestration in tropical mangrove forests is 4-5 times greater than the corresponding rate in tropical forests^{151,152} largely attributed to litter fall dynamics in mangroves. The net biosphere-atmosphere exchange of carbon in Sundarban forests has been estimated at 2.79 tonnes per hectare per annum¹⁵¹. Assuming this rate of carbon sequestration across the entire forest area⁶⁰ (1538 km²) of STR, the annual quantity of carbon sequestered in STR is approximately equal to 0.43 million tonnes.

Using the social cost of carbon for India and making necessary adjustments for Purchasing Power Parity and inflation as done for carbon storage, the total economic value of carbon sequestered in STR is estimated to be ₹ 462.08 million per annum.

3.6.2.11 WATER PROVISIONING

Lying at the southern-most extremity of the lower Gangetic delta, the ecosystem service of water provisioning is not relevant for STR and hence excluded from estimation.

3.6.2.12 WATER PURIFICATION

As in the case with water provisioning, the ecosystem service of water purification is not particularly relevant for STR. However, a related ecosystem service of Sundarbans – waste assimilation – is discussed later in Section 3.6.2.25.

3.6.2.13 SOIL CONSERVATION

Due to paucity of information, this ecosystem service has not been estimated in monetary terms.

3.6.2.14 NUTRIENT RETENTION

A study comparing concentration of nutrients in mangroves and non-mangroves areas in the nearby state of Odisha found that the available nitrogen, phosphorus and potassium in one hectare of mangrove soil exceeded that in non-mangrove soil by 849 kilograms, 8 kilograms and 342 kilograms respectively¹⁵³. The economic value of these nutrients using the market price of chemical fertilizers is approximately equal to ₹ 5.31, ₹ 20.10 and ₹ 20.00 per kilogram respectively for nitrogen, phosphorus and potassium respectively¹⁵⁴. Using these estimates, the additional NPK stored in mangrove soils is estimated to have an economic value of ₹ 11,509 per hectare. For the total area of STR, the economic value of nutrient retention function in terms of additional NPK available compared to non-mangrove soil is estimated to be ₹ 2.97 billion. It may be noted that on account of paucity of information on annual nutrient dynamics in soil, the annual value of this ecosystem service cannot be estimated for STR.

3.6.2.15 BIOLOGICAL CONTROL

Using estimates of economic value of biological control for forests (₹ 660 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1538 km² of forests of STR is equal to ₹ 101.51 million / year.

3.6.2.16 MODERATION OF EXTREME EVENTS

Undisturbed and natural mangroves forests act as seaward barrier and significantly check the coastal erosion and minimize tidal thrusts or storm hits arising from the sea¹⁵⁵⁻¹⁵⁹, with the degree of protection as a function of mangrove width. In the light of rising sea levels and changes in storm frequency and intensity, mangroves may offer low-cost

ECONOMIC VALUE OF ECOSYSTEM SERVICES FROM TIGER RESERVES

natural approaches to disaster risk mitigation¹⁶⁰. In recent decades, the cyclones originating in the Bay of Bengal as listed in Table 37 have caused considerable damage to crops, building infrastructure and settlements, power and communication systems, resulting in heavy loss of life and property¹⁶¹. Based on replacement cost approach for constructing dykes to replace the function of wind break and shore stabilizer¹⁶², the economic value of a hectare of mangroves is estimated to be ₹ 0.18 million.

In the neighbouring state of Odisha, a study has estimated that there would have been 1.72 additional deaths per village within 10 kilometres of the coast during the 1999 Indian Super Cyclone if the mangrove width had been reduced to zero¹⁶³. Extrapolating it to STR, mangroves can be attributed to saving about 79 lives in the 46 fringe villages of Indian Sundarbans during the 1999 Indian Super Cyclone. Considering similar socio-economic conditions but twice the population density in STR, this figure for STR is likely to be an underestimate. On the basis of statistical value of life of ₹ 11.66 million per life saved as used in the quoted study, the economic value of STR in terms of avoiding additional deaths due to the 1999 Indian Super Cyclone is estimated to be ₹ 921.14 million.

Another study has estimated the damage-cost avoided to property and agriculture owing to the presence of mangrove forests during the same cyclone at ₹ 7,260 per household^{153,164}. Village embankments near the mangrove forests were not breached while those further away were breached many places, suggesting the role of mangroves in protecting these defences. Extrapolating this estimate to

62,478 households living in the fringe villages of Indian Sundarbans¹⁶⁵, the damage-cost avoided due to the presence of mangroves during a cyclone of similar intensity is approximately equal to ₹ 453 million.

The total economic value of mangroves for moderating the impact of the 1999 Indian Super Cyclone due to saving of lives and damage-cost avoided for STR is thus approximately equal to ₹ 1.37 billion. Assuming that a cyclone in 'Super Cyclonic Storm' category hits the region every 5 years on the basis of short-term average indicated in Table 37, the annual economic value of STR from moderation of extreme events is approximately equal to ₹ 274.83 million. It is estimated that in the absence of Sundarbans, the impacts of such storms may be felt even up to the city of Kolkata. While the intensity of storms would be significantly reduced after the landfall to have considerable impact on lives or property in and around Kolkata, the impact on agricultural productivity can nevertheless be significant.

3.6.2.17 POLLINATION

Using estimates of economic value of pollination for forests (₹ 1,800 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1538 km² of forests of STR is equal to ₹ 276.84 million / year.

3.6.2.18 NURSERY FUNCTION

Mangroves are of vital importance in sustaining the productivity of onshore and offshore fisheries¹⁶⁶⁻¹⁶⁸. Many commercially important fishes, crabs, and shrimps not only use mangroves as nursery grounds but also for shelter



during their juvenile stages where the trees and root networks provide food and shelter from predation¹⁶⁹. These species help to replenish offshore fish populations when they reach their adult size and swim out to sea¹⁷⁰. Linkage scenarios show 20 to 100 per cent decrease in fish harvest (both on-shore and off-shore) if mangroves are destroyed¹⁷¹.

According to a model developed for Mekong Delta which is consistent with numerous previous studies quoted by the study using the model, 1 hectare of mangrove supports a marine (ocean) catch of 450 kilograms per annum, ranging between 100 to 1000 kilograms per annum of fish and shrimp catch¹⁷². Using the lower-bound estimate of 100 kilograms per hectare per annum and price of fish at ₹ 200 per kilogram as used earlier in Section 3.6.2.3 based on the local market^{142,143}, the economic value of the nursery function of STR is approximately equal to ₹ 5.17 billion per year.

3.6.2.19 HABITAT FOR SPECIES

Using estimates of economic value of habitat / refugia for forests (₹ 2,340 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1538 km² of forests of STR is equal to ₹ 359.89 million / year.

3.6.2.20 CULTURAL HERITAGE

As mentioned earlier, STR is a World Heritage Site designated by UNESCO since 1985 in recognition of the following:

- outstanding example representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; and
- contains the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

3.6.2.21 RECREATION

STR is a popular tourist destination. Being one of the country's most important conservation areas and home to the Royal Bengal Tiger, several domestic and international tourists visit STR annually. The number of visitors to the reserve has been on the rise with more than 1.5 lakh tourists visiting the STR in 2013-14 as shown in Table 40 below¹⁴⁰.

Table 40

Tourists Visiting Sundarbans Tiger Reserve for Recreation

Financial Year	Number of Tourists to Sundarbans		
	Domestic	Foreigners	Total
2011-12	124146	3418	127564
2012-13	139532	3461	142993
2013-14	154119	3638	157757

Recreational tourism brings significant revenues for the authorities of the STR. For 2013-14, the revenue from tourism was approximately equal to ₹ 14 million¹⁴⁰. Moreover, an eco-tourism cottage has been recently developed at Jhingekhali which will increase the revenues from STR further.

While it is acknowledged that the revenue for Reserve Authorities as well as other establishments such as the Eco-Tourism Cottage can be attributed largely to the unique natural heritage, an opportunity to see a tiger in the wild and mangrove forests of the STR, exact attribution is difficult. A recent study¹⁷³ has estimated the willingness to pay of Indians to get a glimpse of this magnificent animal. Based on the zonal travel cost method, the study estimates that the annual recreation value of the Indian Sundarban is approximately equal to ₹ 15 million. Adjusting the estimate to account for increase in tourist visitation to STR, the economic value of recreational services provided by STR is approximately equal to ₹ 37 million per year.

3.6.2.22 SPIRITUAL TOURISM

This ecosystem service is not applicable in the context of STR.

3.6.2.23 RESEARCH, EDUCATION AND NATURE INTERPRETATION

Mangroves are the focus for ecological research and hydrographic studies¹⁷⁴. STR is a living laboratory that has vast potential to contribute to our knowledge about marine ecosystems, connections between marine, freshwater and terrestrial ecosystems as well as linkages between ecosystem health and human well-being.

3.6.2.24 GAS REGULATION

Using estimates of economic value of gas regulation for forests (₹ 720 / hectare / year) from a global meta-analysis study²⁴, the economic value of 1538 km² of forests of STR is equal to ₹ 110.74 million per year.

Mangroves act as **nursery grounds** for various fish, crabs and shrimps and are thus of vital importance in sustainable the productivity of **onshore and offshore fisheries.**



3.6.2.25 WASTE ASSIMILATION

The city of Kolkata does not have a sewage treatment plant and the Sundarbans provide waste assimilation service to the city of Kolkata and nearby settlements. Assuming the population of Kolkata city governed by the Municipal Corporation as 4.5 million in 2011 according to the latest census¹⁶⁵, minimum per capita consumption of 70 lpcd* and the rate of return of 80% for water in the sewage disposal system, the city of Kolkata alone would require a sewage treatment plant of 250 MLD (million litres a day). A preliminary analysis of projects executed under the JNNURM (Jawaharlal Nehru National Urban Renewal Mission) in various municipalities across India suggest an average cost of sewage treatment plant as ₹ 10 million per MLD per annum¹⁷⁵. STR covers approximately 60% of the Sundarbans area in India¹⁶¹, and hence the economic value of waste assimilation services attributable to STR for Kolkata city alone is approximately equal to ₹ 1.5 billion per year

3.6.2.26 SUMMARY OF ECOSYSTEM SERVICES BASED ON TEV FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Direct Use Value	1641.72	₹ million / year
employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce		
Indirect Use Value	8292.89	₹ million / year
carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation		
Option Value	2870.00	₹ million / year
gene-pool protection		

* As suggested by the National Commission on Urbanization, Government of India



3.6.2.27 SUMMARY OF ECOSYSTEM SERVICES BASED ON MILLENNIUM ECOSYSTEM ASSESSMENT FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Provisioning Services employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection	4511.72	₹ million / year
Regulating Services carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, gas regulation, waste assimilation	8255.89	₹ million / year
Cultural Services cultural heritage, recreation, spiritual tourism, research, education and nature interpretation	37.00	₹ million / year

3.6.2.28 SUMMARY OF ECOSYSTEM SERVICES BASED ON STOCK AND FLOW BENEFITS FRAMEWORK

Type of Value	Value	Unit
Flow Benefits employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce, gene-pool protection, carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation	12.80 0.50	₹ billion / year ₹ lakh / ha / year
Stock standing timber, carbon storage	655.77	₹ billion / year

3.6.2.29 SUMMARY OF ECOSYSTEM SERVICES BASED ON TANGIBLE AND INTANGIBLE BENEFITS FRAMEWORK (FLOW BENEFITS)

Type of Value	Value	Unit
Tangible Benefits employment generation, agriculture, fishing, fuel wood, grazing / fodder, timber, non-wood forest produce	1641.72	₹ million / year
Intangible Benefits carbon sequestration, water provisioning, water purification, sediment regulation / retention, nutrient cycling / retention, biological control, moderation of extreme events, pollination, nursery function, habitat / refugia, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation, waste assimilation, gene-pool protection	11162.89	₹ million / year

3.6.2.30 DISTRIBUTION ACROSS STAKEHOLDERS (FLOW BENEFITS)

Based on assumptions made in Section 2.4.29, approximately 16 per cent of flow benefits accrue at the local level, 39 per cent at the national level and 44 per cent at the global level.

3.6.2.31 INVESTMENT MULTIPLIER

According to the last sanction from the National Tiger Conservation Authority, the annual management costs of Sundarbans Tiger Reserve for the year 2014-15 amounted to ₹ 24.18 million. Based on the flow benefits of ₹ 12.80 billion per year, for every rupee spent on management costs in STR, flow benefits of ₹ 530 are realized within and outside the tiger reserve.







04

APPLICATION OF SPATIAL MAPPING TOOL TO UNDERSTAND FLOW OF ECOSYSTEM SERVICES: A PILOT STUDY AT KANHA AND PERIYAR TIGER RESERVE USING “INVEST” MAPPING PACKAGE



KEY MESSAGES

In the last few years, the ecosystem valuation process has evolved from analytical models to GIS-based spatial simulation models. These simulation models are able to comprehend the local ecosystem characteristics in a better way; thus enriching the overall valuation. Such a mapping of ecosystem services can provide very useful management prescriptions for tiger reserve managements to optimize benefits from the tiger reserve. The current study applies one of the most widely used tools for mapping ecosystem services, Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) developed by the Natural Capital Project at Stanford University.

InVEST is a data-hungry tool. On account of paucity of time for collecting the required information, InVEST could only be applied at two of the selected tiger reserves: Kanha and Periyar. Further, 3 of the 17 models in the InVEST 3.0 package were applied at these two tiger reserves. These include the Carbon Storage and Sequestration: Climate Regulation Model, the Water Yield: Reservoir Hydropower Production Model and the Sediment Retention: Avoided Dredging and Water Purification Model.

The results of the InVEST exercise are envisaged to assist in identification of ecosystem service hotspots within tiger reserves and thus better equip tiger reserve managers in conservation and management of such areas. Its application in all tiger reserves across the country is thus highly recommended but will require standardized collection of specific input data necessary for InVEST models.

InVEST is a modelling software spanning **terrestrial, freshwater and marine environments** which use production functions to estimate changes in biodiversity & ecosystem services under different demographic, land-use and climate scenarios.

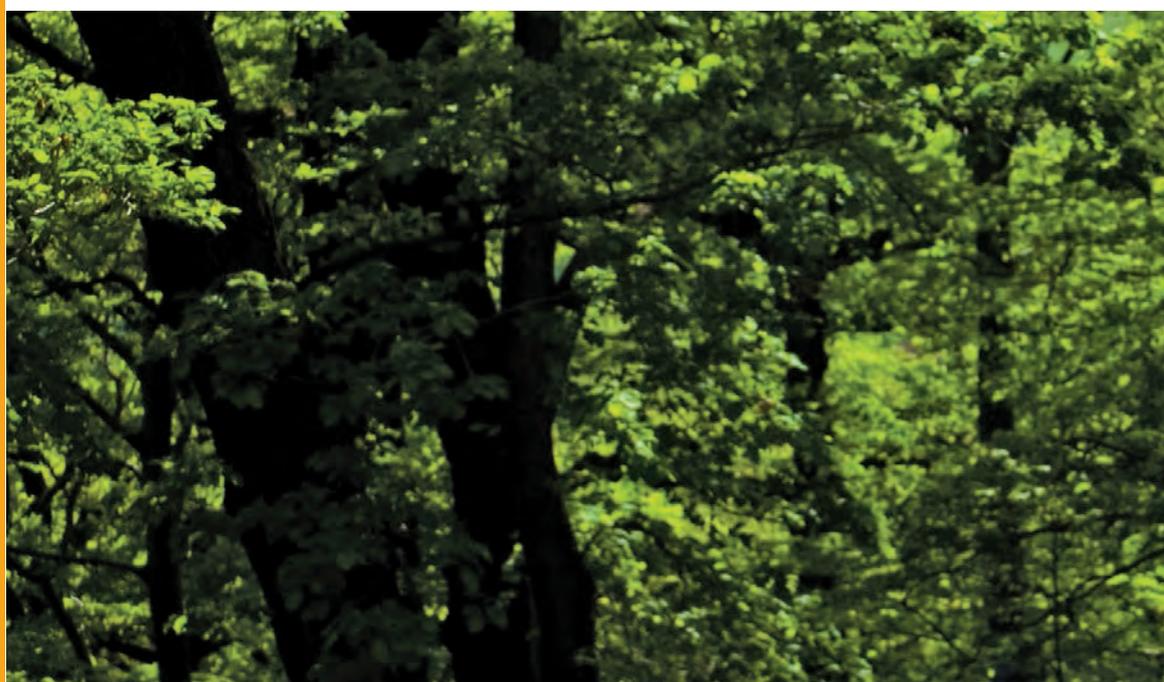
In the last few years, the ecosystem valuation process has evolved from analytical models to GIS based spatial simulation models. These simulation models are able to comprehend the local ecosystem characteristics in a better way; thus enriching the overall valuation. The current chapter talks about one such tool, known as “InVEST” which was developed by Stanford University for the Natural Capital Project at Woods Institute for the Environment.

4.1 INTRODUCTION TO NATCAP, INVEST AND PAST APPLICATIONS

The Natural Capital Project (NatCap) was formed in 2006 under the premise that biodiversity and ecosystem service (BES) information can be used to make informed decisions and thus improving the well-being of people and nature collectively. NatCap’s primary goal was to transform decisions affecting the environment and human well-being by providing clear and credible ecosystem service information which can be most useful for the decision makers. To support this work, various open source BES assessment tools are

being tested and developed and are available in a software platform known as InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs).

InVEST is a modelling software that has been developed for analysis of multiple services and objectives for the Natural Capital Project at Woods Institute for the Environment. The Natural Capital Project is a partnership of Stanford University, the Nature Conservancy, the World Wildlife Fund, and the University of Minnesota with an objective of developing and providing practical concepts and tools of ecosystem services. Applying these tools in select areas around the world along with engaging influential leaders would help advance changes in policy and practice through mainstreaming the approaches. It contains a set of models spanning terrestrial, freshwater, and marine environments which use production functions to estimate changes in biodiversity and ecosystem services under different demographic, land-use, and climate scenarios. While InVEST provides a basic template that is designed to be used globally, the approach in specific cases is to co-develop applications with decision-makers to ensure that inputs are tailored to local needs and



data availability and that output metrics and knowledge production processes are deemed credible, relevant and legitimate by stakeholders.

InVEST is designed to make informed decisions on natural resource management. It provides information about how changes in ecosystems are likely to influence the flows of benefits to people. Decision-makers, can then evaluate trade-offs among those using InVEST. It employs production function approach for quantifying and valuing ecosystem services. A production function specifies the output of ecosystem services provided by an ecosystem given its condition and processes. Once an ecological production function is defined, it can quantify the impacts on land or water owing to changes in the level of ecosystem services.

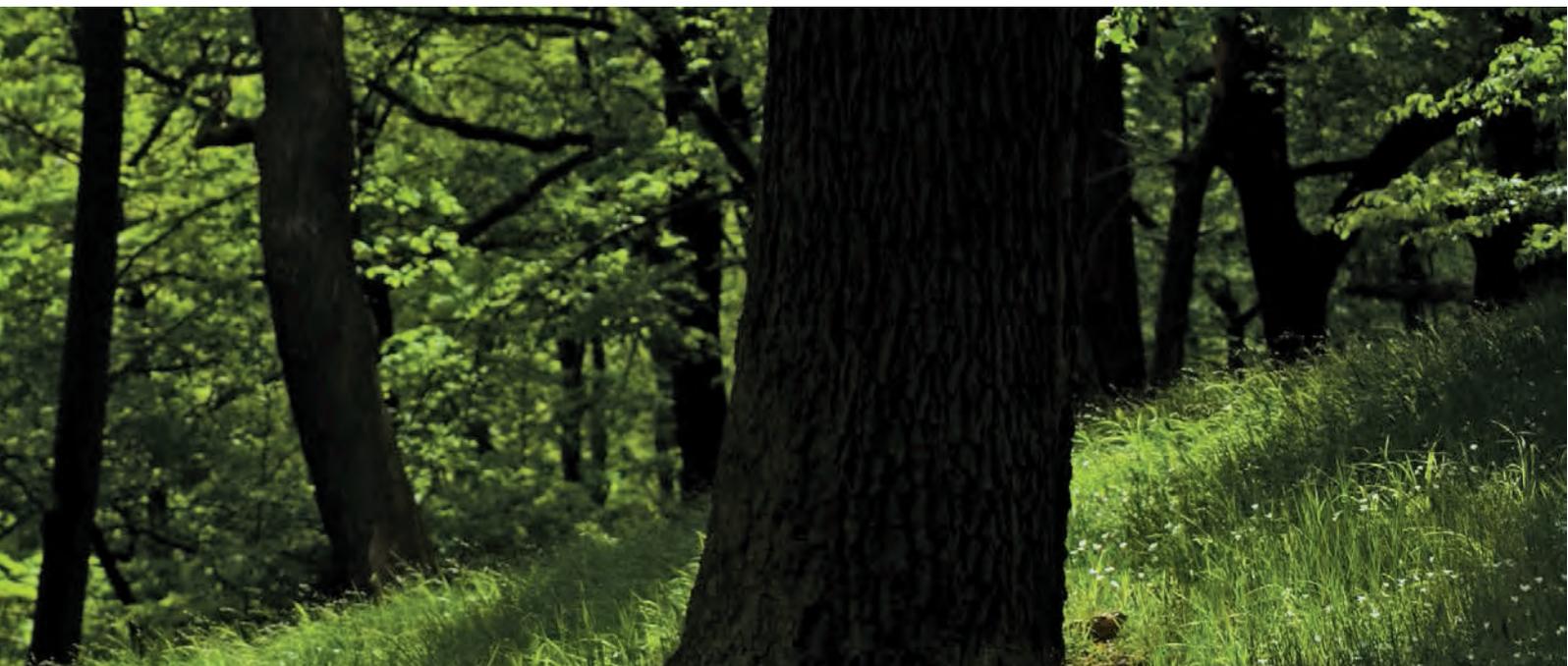
InVEST uses a simple framework by delineating “supply, service, and value” thus linking ecological production functions with ecosystem services provided to people. “Supply” represents which benefits are potentially available from the ecosystem (i.e. what the ecosystem structure and functions can provide). “Service” reflects demand and thus uses information about beneficiaries of that service (e.g. where people live, important cultural sites, infrastructure, etc.). “Value” includes social preference and allows for the calculation of economic and social metrics (e.g. avoided damages from erosion and flooding, numbers of people affected).

InVEST can help answer questions like:

- Where do ecosystem services originate and where are they consumed?
- How does a proposed forestry management plan affect timber yields, biodiversity, water quality and recreation?
- What kinds of coastal management and fishery policies will yield the best returns for sustainable fisheries, shoreline protection and recreation?
- Which parts of a watershed provide the greatest carbon sequestration, biodiversity, and tourism values?
- Where would reforestation achieve the greatest downstream water quality benefits while maintaining or minimizing losses in water flows?
- How will climate change and population growth impact ecosystem services and biodiversity?
- What benefits does marine spatial planning provide to society in addition to food from fishing and aquaculture and secure locations for renewable energy facilities?

The InVEST 3.0 package has models for quantifying, mapping, and valuing the benefits provided by terrestrial, freshwater and marine systems. In the current study three terrestrial models have been used, namely –

1. Carbon Storage and Sequestration: Climate Regulation
2. Water Yield: Reservoir Hydropower Production
3. Sediment Retention: Avoided Dredging and Water Purification

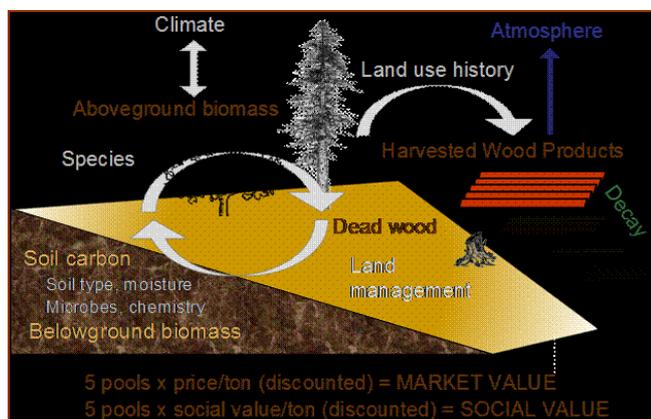


4.2 CARBON STORAGE AND SEQUESTRATION: CLIMATE REGULATION

Terrestrial ecosystems, which store more carbon than the atmosphere, are vital in influencing carbon dioxide-driven climate change. The InVEST model uses Land Use and Land Cover Maps (LULC) types and data on the rate of wood harvesting, degradation rates of harvested products, and stocks in four carbon pools (above ground biomass, below ground biomass, soil, dead organic matter) to estimate the amount of carbon stored in a landscape or the amount of carbon sequestered over time. Additional data on market or social value of sequestered carbon and its annual rate of change, and a discount rate can be used in an optional model that estimates the value of this ecosystem service to society. Limitations of the model include an oversimplified carbon cycle, an assumed linear change in carbon sequestration over time, and potentially inaccurate discounting rates.

Carbon storage on a land parcel largely depends on the sizes of four carbon pools: above ground biomass, below ground biomass, soil, and dead organic matter (Figure 18). The InVEST Carbon Storage and Sequestration model aggregates the amount of carbon stored in these pools according to the land use maps and the classifications produced by users. Above ground biomass comprises all living plant material above the soil (e.g. bark, trunks, branches, leaves). Below ground biomass encompasses the living root systems of above ground biomass. Soil organic matter is the organic component of soil, and represents the largest terrestrial carbon pool. Dead organic matter includes litter as well as lying and standing dead wood.

Figure 18
The InVEST Carbon Model¹⁷⁶



The model runs on a grid map of cells called raster format in GIS. Each cell in the raster is assigned a land use and land cover (LULC) type such as forest, pasture, or agricultural land. After running the model in raster format, results can be summarized to practical land units such as individual properties, political units, or watersheds.

For each LULC type, the model requires an estimate of the amount of carbon in at least one of the four fundamental pools described above. If the user has data for more than one pool, the modelled results will be more complete. The model simply applies these estimates to the LULC map to produce a map of carbon storage in the carbon pools included.

If, maps of both current and future LULC are provided, then the net change in carbon storage over time (sequestration and loss) and its social value can be calculated. To estimate this change in carbon sequestration over time, the model is simply applied to the current landscape and a projected future landscape, and the difference in storage is calculated, map unit by map unit.

Outputs of the model are expressed as Mg of carbon per grid cell, or if desired, the value of sequestration in dollars per grid cell. The developers recommend using social value of carbon sequestration for expressing sequestration in monetary units as it is the social value of a sequestered ton of carbon which actually reflects the social damage avoided by not releasing the ton of carbon into the atmosphere.

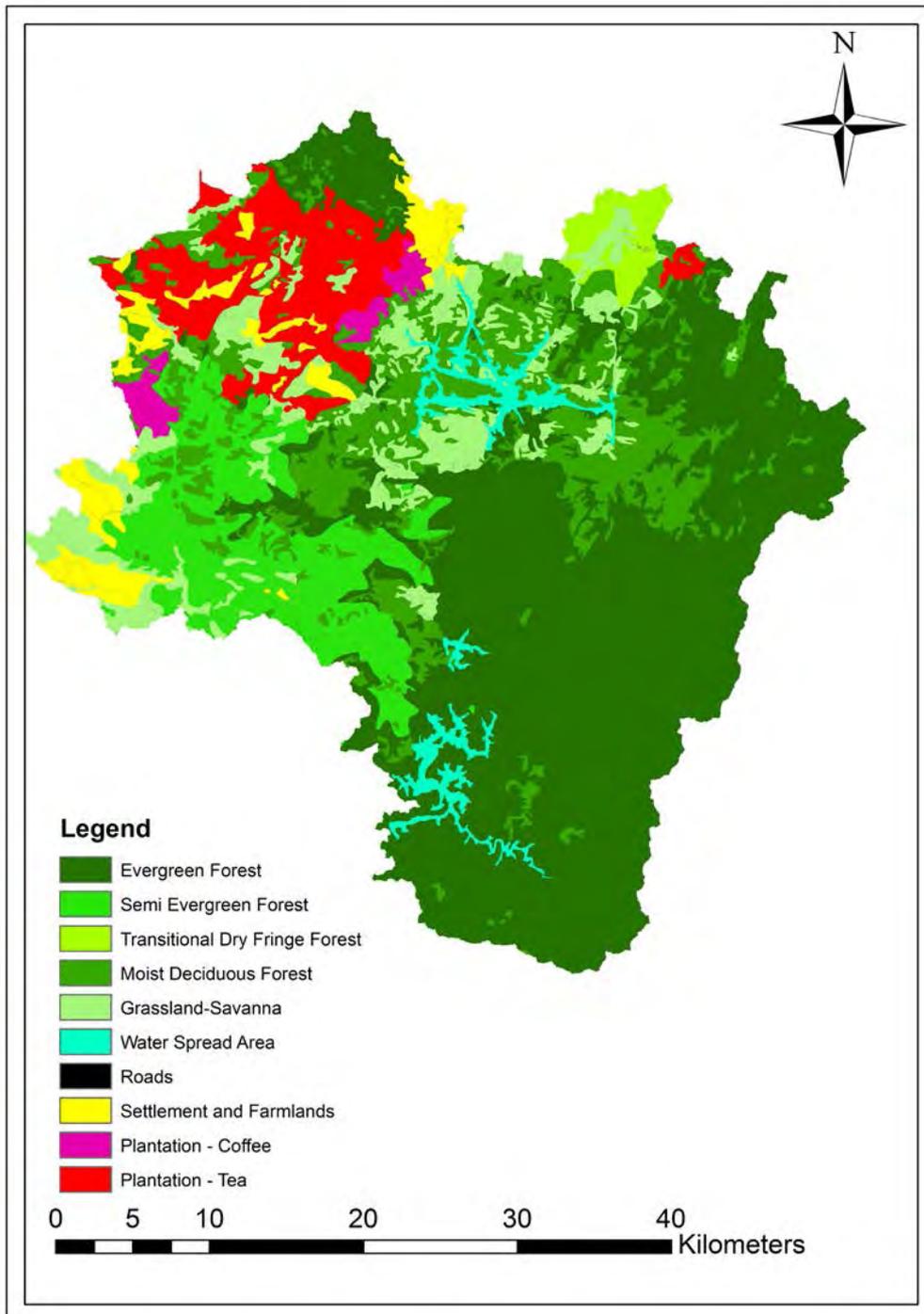
The valuation model estimates the economic value of sequestration (not storage) as a function of the amount of carbon sequestered, the monetary value of each unit of carbon, a monetary discount rate, and the change in the value of carbon sequestration over time. Thus, valuation can only be done in the carbon model if you have a future scenario. Valuation is applied to sequestration, not storage, because current market prices relate only to carbon sequestration.

4.2.1 APPLICATION OF CARBON MODEL AT PERIYAR TIGER RESERVE

4.2.1.1 INPUTS

This section outlines the map and data tables used to execute the Carbon Storage and Sequestration: Climate Regulation Model for Periyar Tiger Reserve.

Figure 19
Land Use Map of PTR



1. Current Land Use Land Cover (LULC) Map: It is a GIS raster dataset, with an integer LULC code for each cell. The map provided by the Periyar Foundation was from a research work undertaken by the French Institute of Pondicherry in 1995. As the whole park had been under a strict conservation regime during the map generation and as 15 years is a small timeline for natural systems to change, it was decided to use the same

The InVEST Carbon Storage and Sequestration model aggregates the amount of carbon stored in these pools according to the land use maps and the classifications produced by users.

map (Figure 19). The map provided by the Periyar Foundation was appended with data of roads, water bodies and farmlands. The appended map was converted in a raster format of seven metre resolution so as to reflect roads clearly in the map. The land use classes were also modified based on the carbon pool data used from the Forest Survey of India (FSI) study.

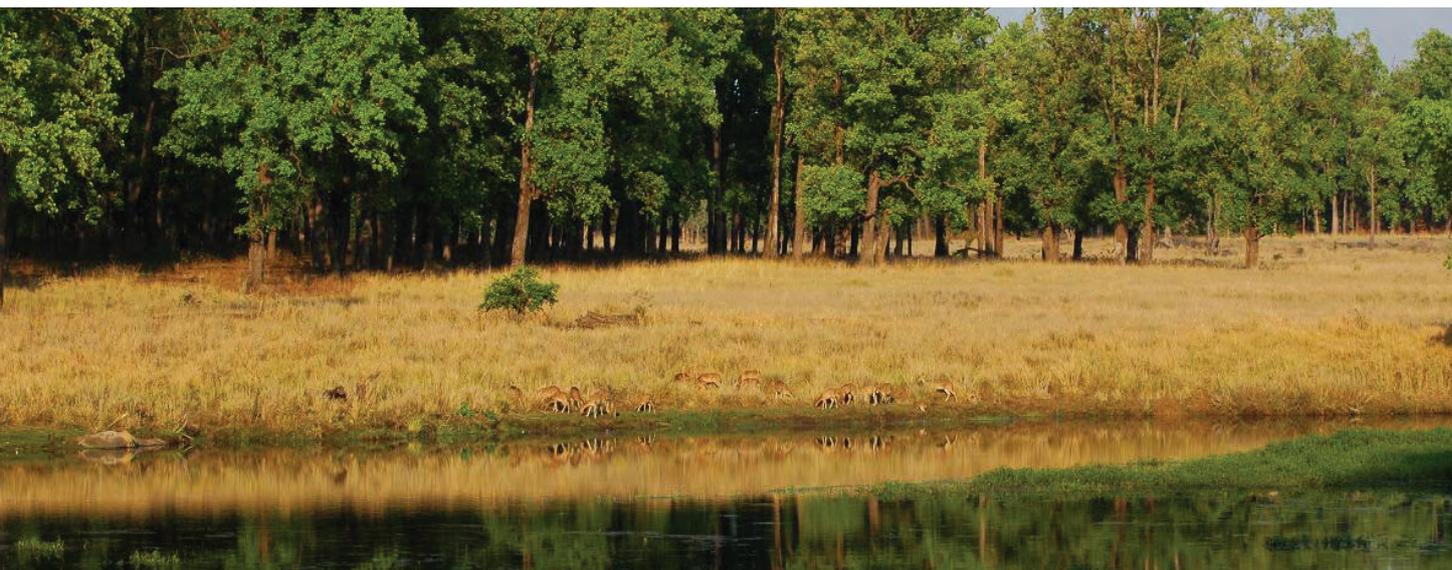
- Carbon pool table: It is a .csv format file, containing table of land use/land cover (LULC) classes with corresponding data on the four fundamental carbon pools namely, above ground biomass, below ground biomass, soil and dead organic matter. The carbon storage data for different forest types and plantation in PTR was derived from the Forest Survey of India report titled *Carbon Stock in India's Forests* published in 2011. For other land uses values were decided based on expert knowledge. The values used in calculation are as mentioned in Table 49.

Table 41

Biophysical Table for Carbon Calculation

lucode	LULC_name	C_above	C_below	C_soil	C_dead
1	Evergreen Forest	78.54	27.17	97.19	13.31
2	Semi Evergreen Forest	62.91	12.94	85.19	10.04
3	Transitional Dry Fringe Forest	62.27	24.55	111.82	6.82
4	Moist Deciduous Forest	72.58	14.92	79.19	6.01
5	Plantations	46.47	9.41	114.71	7.06
6	Grassland-Savanna	72.58	14.92	79.19	6.01
7	Water Spread Area	0	0	0	0
8	Roads	14.516	2.984	15.838	0
9	Settlement	62.91	12.94	85.19	10.04

Here lucode corresponds to the code given to relevant land use in the LULC map. C_above refers to above ground carbon, C_below to below ground carbon, C_soil to carbon stored in soil and C_dead refers to carbon stored in dead and decaying biomass. All the above values are in Mg ha⁻¹. For water spread area in the map all values were assumed to be zero because of lack of relevant data.

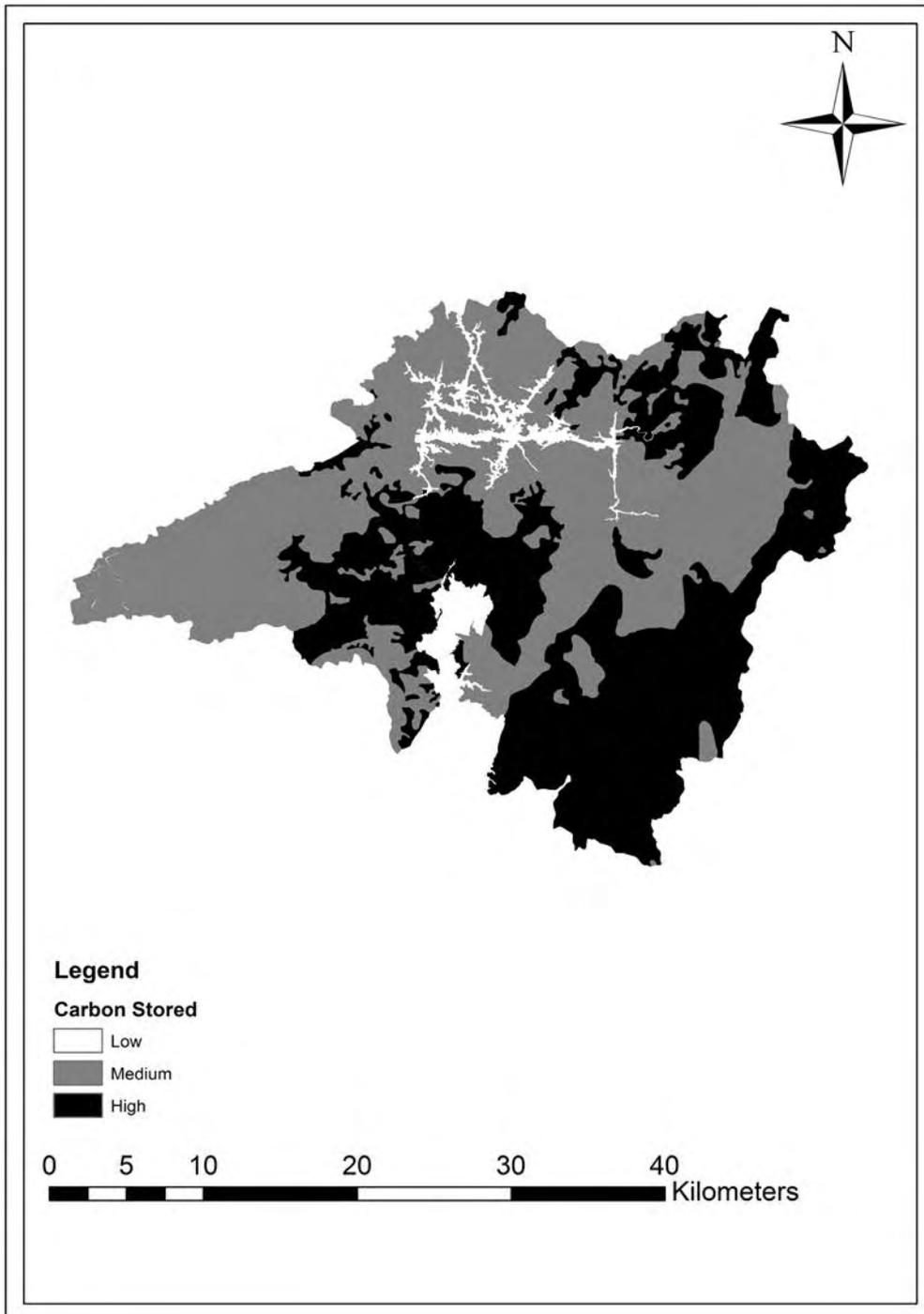


4.2.1.2 OUTPUT

The InVEST model gave outputs in the form of a carbon spread map and a summary table. According to the model Periyar Tiger Reserve stores approximately **172 thousand tons** of carbon. The second output received is in the form of a map where the stored carbon values are mapped spatially across the landscape (Figure 20).

Figure 20

Carbon Storage Map of PTR



The Carbon Sequestration model could not be executed for valuation purposes due to various data and model limitations. The model calculates sequestration only when a different land use map is provided. For PTR, as it legally cannot have any other land use apart from the existing one, the team decided not to use the sequestration model of InVEST. As for valuation, InVEST does valuation only for Sequestered Carbon and since the sequestration model was not executed, the valuation model could not be executed.

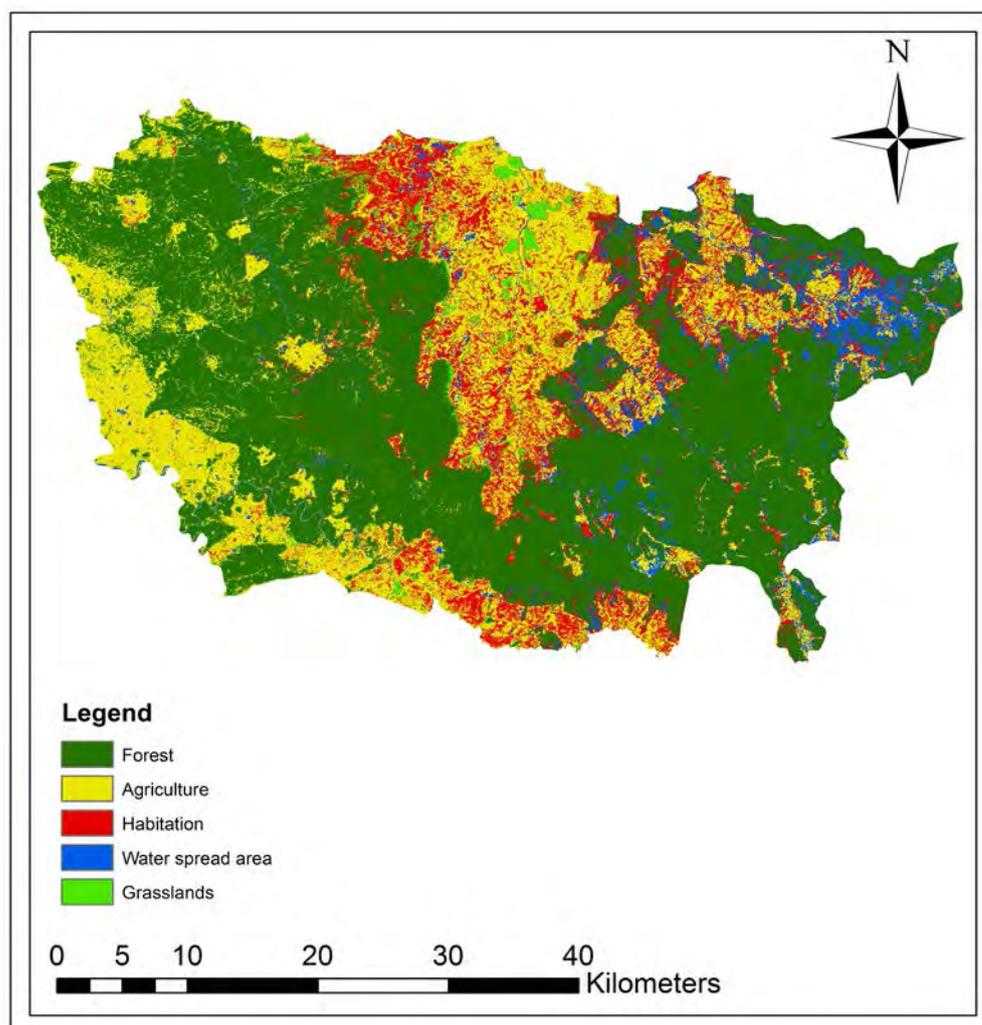
4.2.2 APPLICATION OF CARBON MODEL AT KANHA TIGER RESERVE

This section outlines the map and data tables used to execute the Carbon Storage and Sequestration: Climate Regulation Model for Kanha Tiger Reserve.

4.2.2.1 INPUTS

1. Current Land Use Land Cover (LULC) Map: It is a GIS raster dataset, with an integer LULC code for each cell. The map was prepared using Landsat-8 imagery downloaded from the United States Geological Survey website. Supervised classification was done to make the land use map as shown in Figure 21. The map was prepared to have five land use types namely; Forest, Agriculture/Fallow Land, Habitation, Waterlogged Areas and Grasslands.

Figure 21
Land Use Map of Kanha Tiger Reserve



According to the model, about **172 thousand tons & 192 thousand tons** of carbon is stored in Periyar Tiger Reserve and Kanha Tiger Reserve respectively.



2. Carbon Pool Table: It is a .csv format file, containing table of land use/land cover (LULC) classes with corresponding data on the four fundamental carbon pools namely, above ground biomass, below ground biomass, soil and dead organic matter. The carbon storage data for forest and grasslands in KTR was derived from the Forest Survey of India report titled Carbon Stock in India's Forests published in 2011. For other land uses, carbon values were decided based on expert knowledge. The carbon values used in the model are as mentioned in Table 42.

Table 42

Biophysical Table for Carbon Calculation

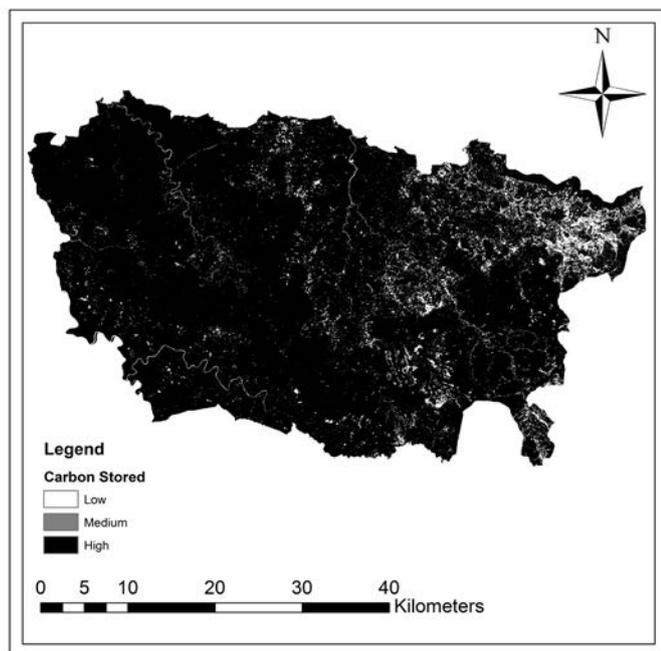
lucode	LULC_name	C_above	C_below	C_soil	C_dead
1	Forest	60.30334	23.67872	62.57683	7.787446
2	Agriculture/Fallow Land	11.64187	4.571287	22.12217	0.466671
3	Habitation	11.64187	4.571287	22.12217	0.466671
4	Waterlogged Area	0	0	0	0
5	Grasslands	11.64187	4.571287	22.12217	0.466671

Here lucode corresponds to the code given to relevant land use in the LULC map. C_above refers to above ground carbon, C_below to below ground carbon, C_soil to carbon stored in soil and C_dead refers to carbon stored in dead and decaying biomass. All the above values are in Mg ha⁻¹. For water spread area in the map all values were assumed to be zero because of lack of relevant data.

4.2.2.2 OUTPUT

With the available data the model outputs have been obtained. First was a summary tab which communicated the biophysical results. The model provided that approximately **192 thousand tons** of carbon are stored in KTR.

Figure 22
Carbon Storage in KTR



4.2.3 LIMITATIONS AND SIMPLIFICATIONS

The model greatly oversimplifies the carbon cycle which allows it to run with relatively little information, but also

leads to important limitations. A major limitation in the model is that of using the same carbon values across similar land use classes. Since the model relies on carbon storage estimates for each LULC type, the results are only as detailed and reliable as the LULC classification used. Carbon storage clearly differs among LULC types (e.g. tropical forest vs. open woodland), but often there can also be significant variation within a LULC type. For example, carbon storage within a “tropical moist forest” is affected by temperature, elevation, rainfall, and the number of years since a major disturbance (e.g. clear-cut or forest fire). The variety of carbon storage values within coarsely defined LULC types can be partly recovered by using a LULC classification system and related carbon pool table which stratifies coarsely defined LULC types with relevant environmental and management variables. For example, forest LULC types can be stratified by elevation, climate bands or time intervals since a major disturbance. Of course, this more detailed approach requires data describing the amount of carbon stored in each of the carbon pools for each of the finer LULC classes.

Another limitation of the model is that it does not capture carbon that moves from one pool to another. For example, if trees in a forest die due to disease, much of the carbon stored in aboveground biomass becomes carbon stored in other (dead) organic material. Also, when trees are harvested from a forest, branches, stems, bark, etc. are left as slash on the ground. The model assumes that the carbon in wood slash “instantly” enters the atmosphere.

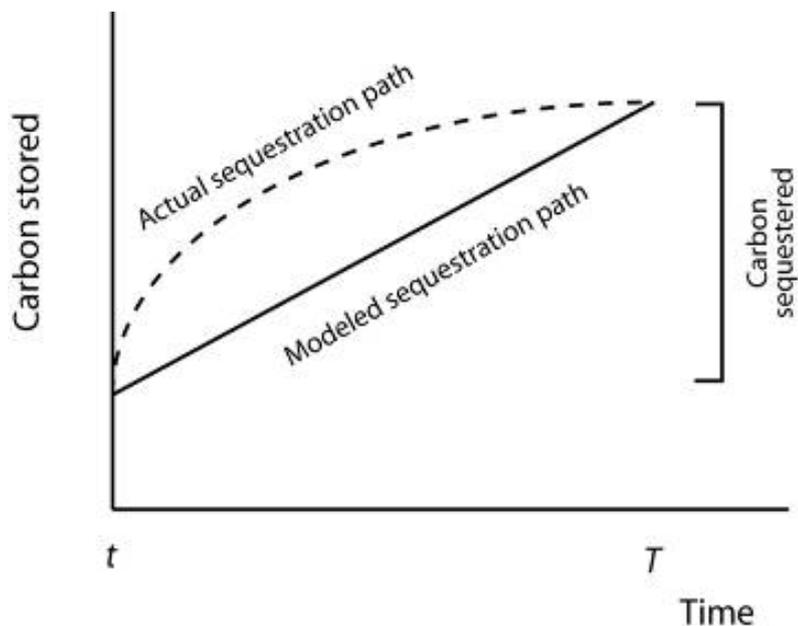
Finally, while most sequestration follows a non-linear path such that carbon is sequestered at a higher rate in the first few years and a lower rate in sequestration assumes a linear change in carbon storage over time. The assumption of



a constant rate of change will tend to undervalue the carbon sequestered, as a non-linear path of carbon sequestration is more socially valuable due to discounting than a linear path (Figure 23).

Figure 23

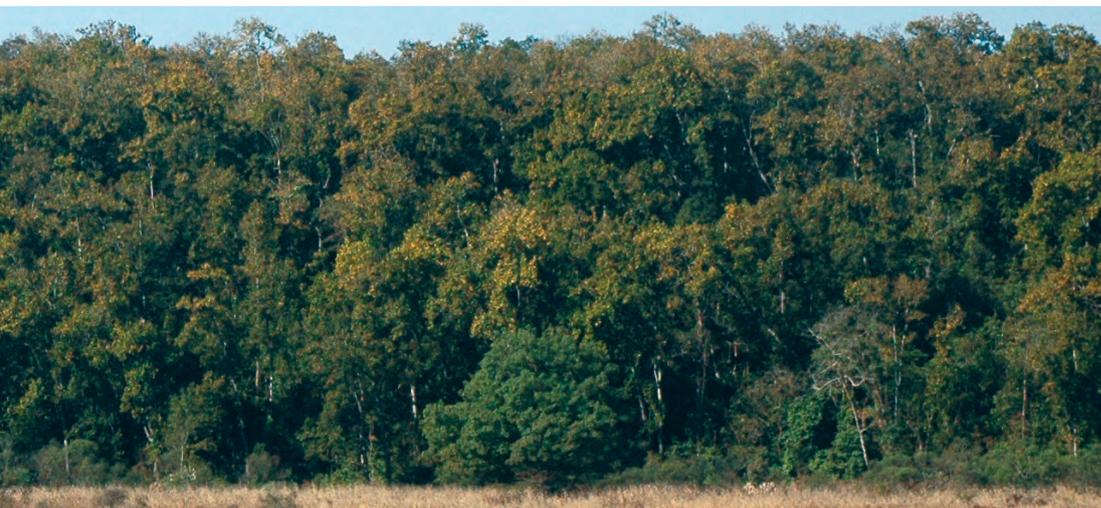
Difference Between Actual Sequestration and InVEST Approach¹⁷⁶



4.3 WATER YIELD: RESERVOIR HYDROPOWER PRODUCTION

4.3.1 THE MODEL

The “*Water Yield: Reservoir Hydropower Production*” model of InVEST estimates the water yield or value for each part of the landscape and its annual contribution towards hydropower production. In the current study this model has been used to assess the water provisioning service being rendered by the watersheds of PTR. The provision of fresh



The **Water Yield model** estimates the relative contributions of water from different parts of a landscape, offering insight into how changes in land use patterns affect annual surface water yield.

water is an ecosystem service that contributes to the welfare of society and is necessary for survival. The systems are designed to account for annual variability in water volume, given the likely levels for a given watershed, but are vulnerable to extreme variation caused by land use and land cover (LULC) changes. LULC changes can alter hydrologic cycles, affecting patterns of evapo-transpiration, infiltration and water retention, and changing the timing and volume of water that is available for use^{177,178}.

The InVEST Reservoir Hydropower model estimates the relative contributions of water from different parts of a landscape, offering insight into how changes in land use patterns affect annual surface water yield. With the model identifying areas of high water yield in PTR, concentrated efforts can be made by the park management in sustaining the areas with high water yield and also improve upon areas facing degradation.

The model runs on a gridded map. It estimates the quantity and value of water used for hydropower production from each subwatershed in the area of interest. It has three components, which run sequentially. First, it determines the amount of water running off each pixel as the precipitation reduces the fraction of the water that undergoes evapo-transpiration. The model does not differentiate between surface, subsurface and base flow, but assumes that all water yield from a pixel reaches the point of interest via one of these pathways. This model then sums and averages water yield to the subwatershed level. The pixel-scale calculations allows representation of the heterogeneity of key driving factors in water yield such as soil type, precipitation, vegetation type, etc. These values are then extrapolated from subwatershed to watershed scale. Second, beyond annual average runoff, it calculates the proportion of surface water that is used for hydropower production by subtracting the surface water that is consumed for other uses.

4.3.1.1 WATER YIELD MODEL

The water yield model is based on the Budyko curve and annual average precipitation. First, we determine annual water yield $Y(x)$ for each pixel on the landscape x as follows:

$$Y(x) = \left(1 - \frac{AET(x)}{P(x)}\right) * P(x)$$

where $AET(x)$ is the annual actual evapo-transpiration for pixel x and $P(x)$ is the annual precipitation on pixel x .

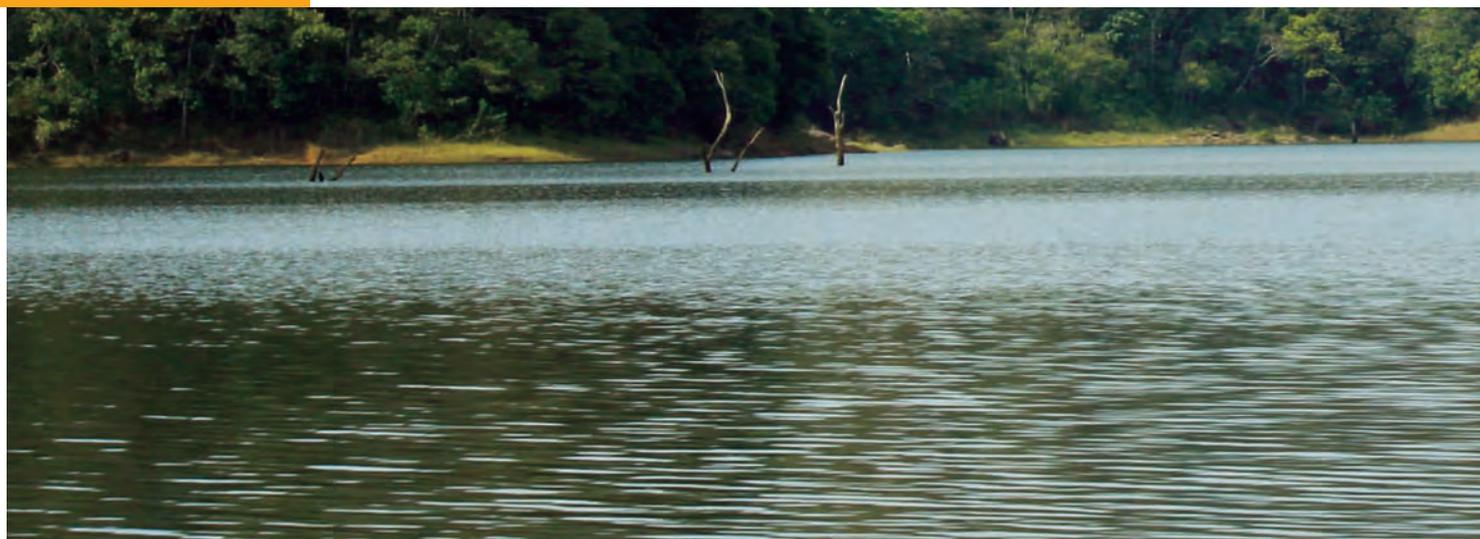
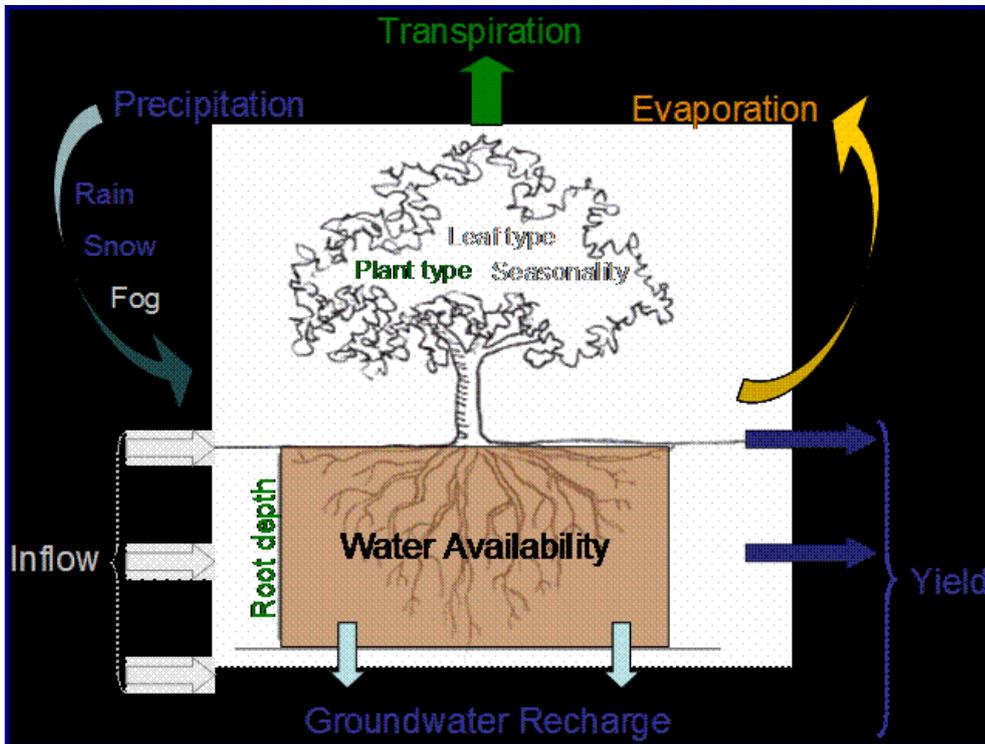


Figure 24
 Conceptual Diagram of Water Balance Model Used in InVEST¹⁷⁶

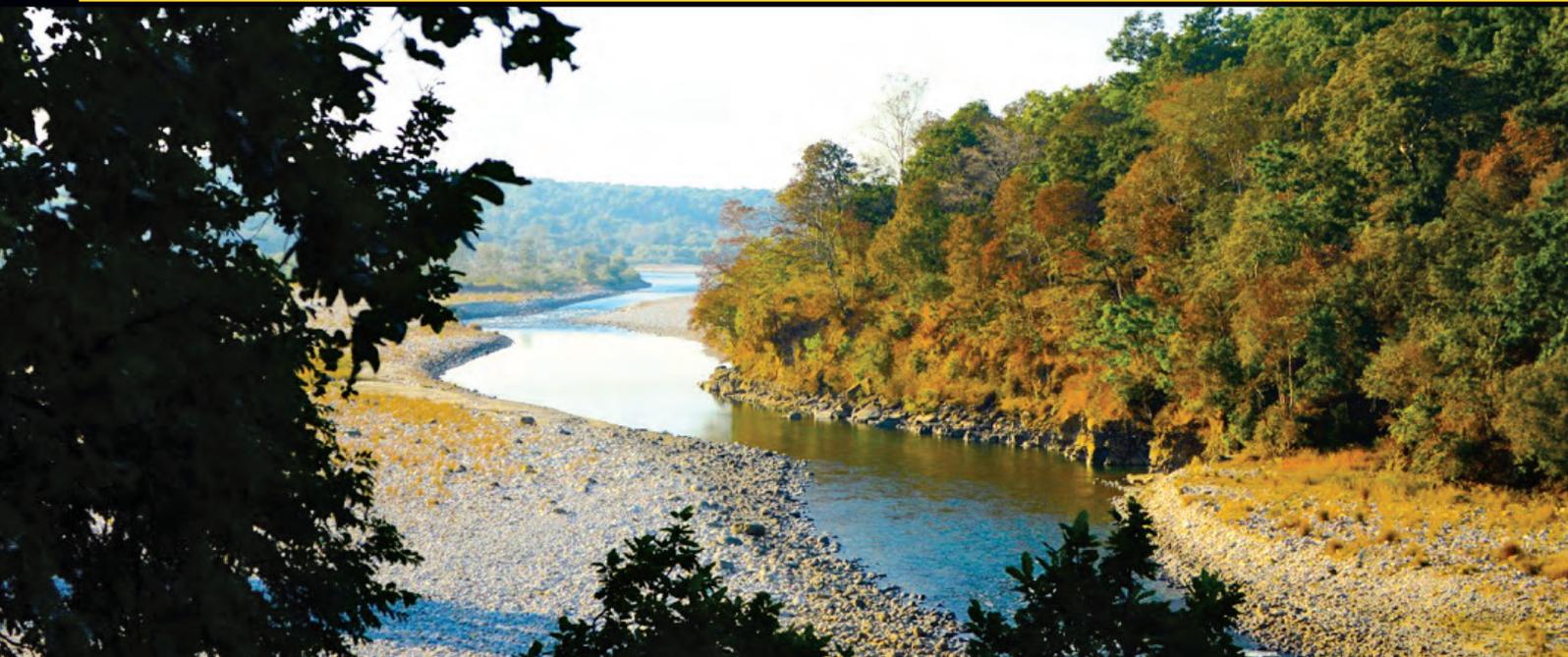


The conceptual diagram of the water balance model is used in the hydropower production model. The water cycle is simplified, including only the parameters shown in colour, and ignoring the parameters shown in grey (Figure 24).

For vegetated LULC, the evapo-transpiration portion of the water balance, $\frac{AET(x)}{P(x)}$ based on an expression of the Budyko curve^{179,180}:

$$\frac{AET(x)}{P(x)} = 1 + \frac{PET(x)}{P(x)} - \left[1 + \left(\frac{PET(x)}{P(x)} \right)^\omega \right]^{\frac{1}{\omega}}$$





where $PET(x)$ is the potential evapo-transpiration and $\omega(x)$ is a non-physical parameter that characterizes the natural climatic-soil properties, both detailed below.

Potential evapo-transpiration $PET(x)$ is defined as:

$$PET(x) = K_c(lx) * ET_o(x)$$

where, $ET_o(x)$ is the reference evapo-transpiration from pixel x and $K_c(lx)$ is the plant (vegetation) evapo-transpiration coefficient associated with the LULC on pixel x . $ET_o(x)$ reflects local climatic conditions, based on the evapo-transpiration of a reference vegetation such as grass of alfalfa grown at that location. $K_c(lx)$ is largely determined by the vegetative characteristics of the land use/land cover found on that pixel¹⁸¹. K_c adjusts the ET_o values to the crop or vegetation type in each pixel of the land use/land cover map.

$\omega(x)$ is an empirical parameter that can be expressed as linear function of $\frac{AWC \cdot N}{P}$, where N is the number of events per year, and AWC is the volumetric plant available water content (see below for additional details). While further research is being conducted to determine the function that best describe global data, we use the expression proposed by Donohue¹⁸² in the InVEST model, and thus define:

$$\omega(x) = Z \frac{AWC(x)}{P(x)} + 1.25$$

where:

$AWC(x)$ is the volumetric (mm) plant available water content. The soil texture and effective rooting depth define $AWC(x)$, which establishes the amount of water

that can be held and released in the soil for use by a plant. It is estimated as the product of the plant available water capacity and the minimum of root restricting layer depth and vegetation rooting depth:

$$AWC(x) = \text{Min}(\text{Root:layer:depth}; \text{root:depth}) \cdot PAWC$$

Root restricting layer depth is the soil depth at which root penetration is inhibited because of physical or chemical characteristics. Vegetation rooting depth is often given as the depth at which 95% of a vegetation types root biomass occurs. $PAWC$ is the plant available water capacity, i.e. the difference between field capacity and wilting point.

Z is an empirical constant, sometimes referred to as “seasonality factor”, which captures the local precipitation pattern and additional hydrogeological characteristics. It is positively correlated with N , the number of rain events per year. The 1.25 term is the minimum value of $\omega(x)$, which can be seen as a value for bare soil (when root depth is 0), as explained by Donohue¹⁸². Following the literature^{182,183}, values of $\omega(x)$ are capped to a value of 5.

For other LULC (open water, urban, wetland), actual evapo-transpiration is directly computed from the reference evapo-transpiration $ET_o(x)$ and has an upper limit defined by the precipitation:

$$AET(x) = \text{Min}(K_c(lx) * ET_o(x), P(x))$$

where $ET_o(x)$ is the reference evapo-transpiration, $K_c(lx)$ and is the evaporation factor for each LULC. Guidance for estimating the K_c factor is provided in the “Data sources” section.

Table 43

Summary of Model Calculations

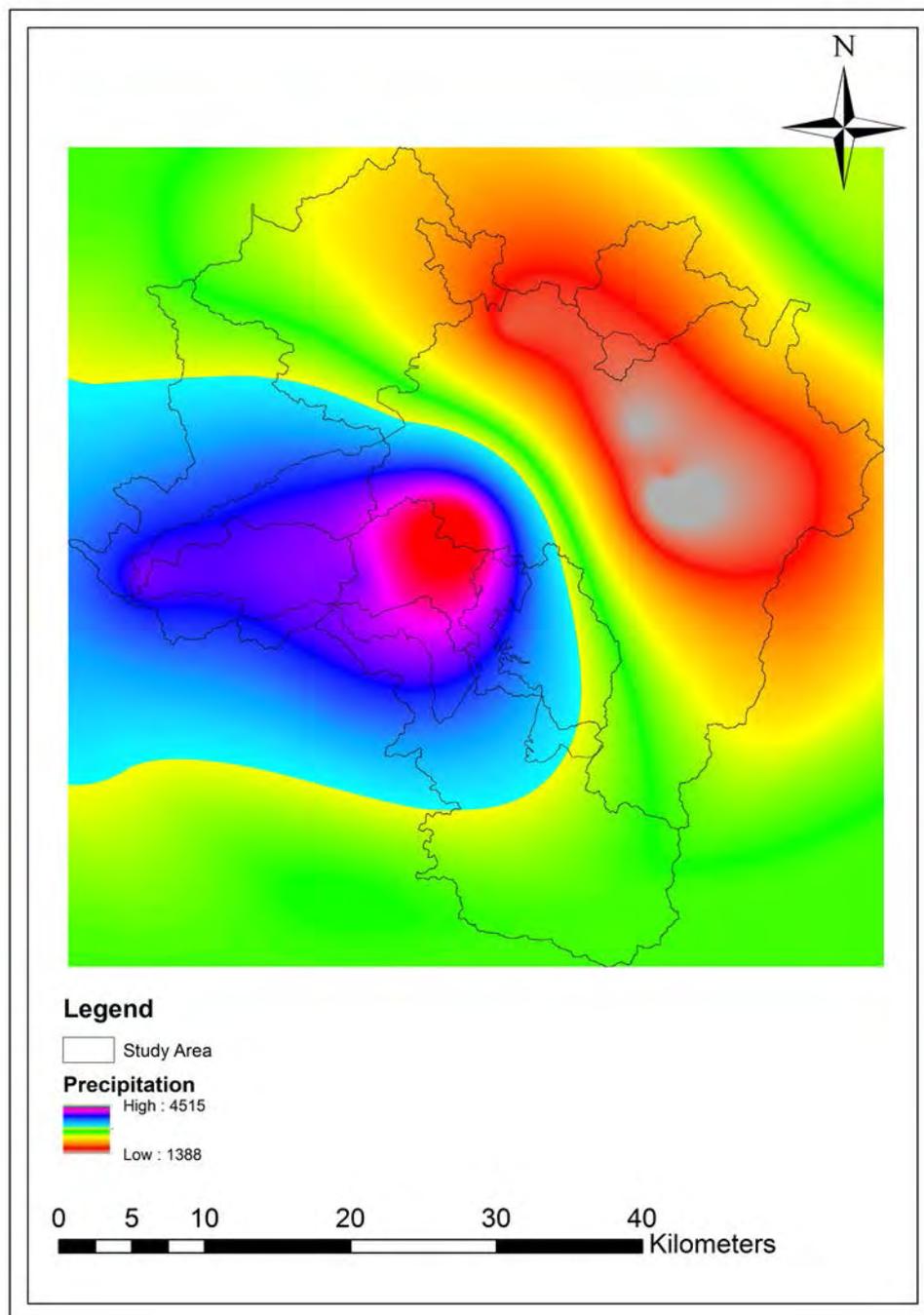
Step No.	Calculation	Variables Used
1	Calculation of AWC(x), volumetric (mm) plant available water content. $AWC(x) = \text{Min}(\text{Rest:layer:depth}; \text{root:depth}).PAWC$	Root Restricting Layer Depth Vegetation Rooting Depth Plant Available Water Content
2	Actual Evapo-transpiration (AET(x)) $AET(x) = \text{Min}(Kc(lx) * ET_o(x), P(x))$	Reference Evapo-transpiration ($ET_o(x)$) Evaporation Factor ($Kc(lx)$) Annual Precipitation ($P(x)$)
3	Calculation of Empirical Parametre $\omega(x) = Z \frac{AWC(x)}{P(x)} + 1.25$	Volumetric Plant Available Water Content (AWC(x)) Seasonality Factor (Z) Annual Precipitation ($P(x)$)
4	Potential Evapo-transpiration $PET(x)$ $PET(x) = Kc(lx) * ET_o(x)$	Evaporation Factor ($Kc(lx)$) Reference Evapo-transpiration ($ET_o(x)$)
5	Water Balance $\frac{AET(x)}{P(x)}$ $\frac{AET(x)}{P(x)} = 1 + \frac{PET(x)}{P(x)} - \left[1 + \left(\frac{PET(x)}{P(x)} \right)^{\omega} \right]^{\frac{1}{\omega}}$	Potential Evapo-transpiration $PET(x)$ Actual Evapo-transpiration (AET(x)) Empirical Parametre $\omega(x)$ Annual Precipitation ($P(x)$)
6	Water Yield Y(x) $Y(x) = \left(1 - \frac{AET(x)}{P(x)} \right) * P(x)$	Water Balance $\frac{AET(x)}{P(x)}$ Annual Precipitation ($P(x)$)

4.3.2 APPLICATION OF MODEL AT PERIYAR TIGER RESERVE**4.3.2.1 INPUTS**

This section outlines the map and data tables used to execute the Water Yield: Reservoir Hydropower Production Model for Periyar Tiger Reserve.

1. Root restricting layer depth: This is a GIS raster dataset with an average root restricting layer depth value for each cell. Root restricting layer depth is the soil depth at which root penetration is strongly inhibited because of physical or chemical characteristics. The root restricting layer depth values should be in millimetres. For PTR this layer was derived using Soil Survey of India datasets which were found to be 5000 for the entire area.
2. Precipitation: This is the average annual precipitation for each cell in a GIS raster format with all non-zero values in millimetres. The Periyar Tiger Foundation provided precipitation data in a tabular format from 10 weather stations within PTR for the time period 2007 to 2010. The data include monthly total rainfall and minimum and maximum temperature.

Figure 25
Precipitation Map of PTR

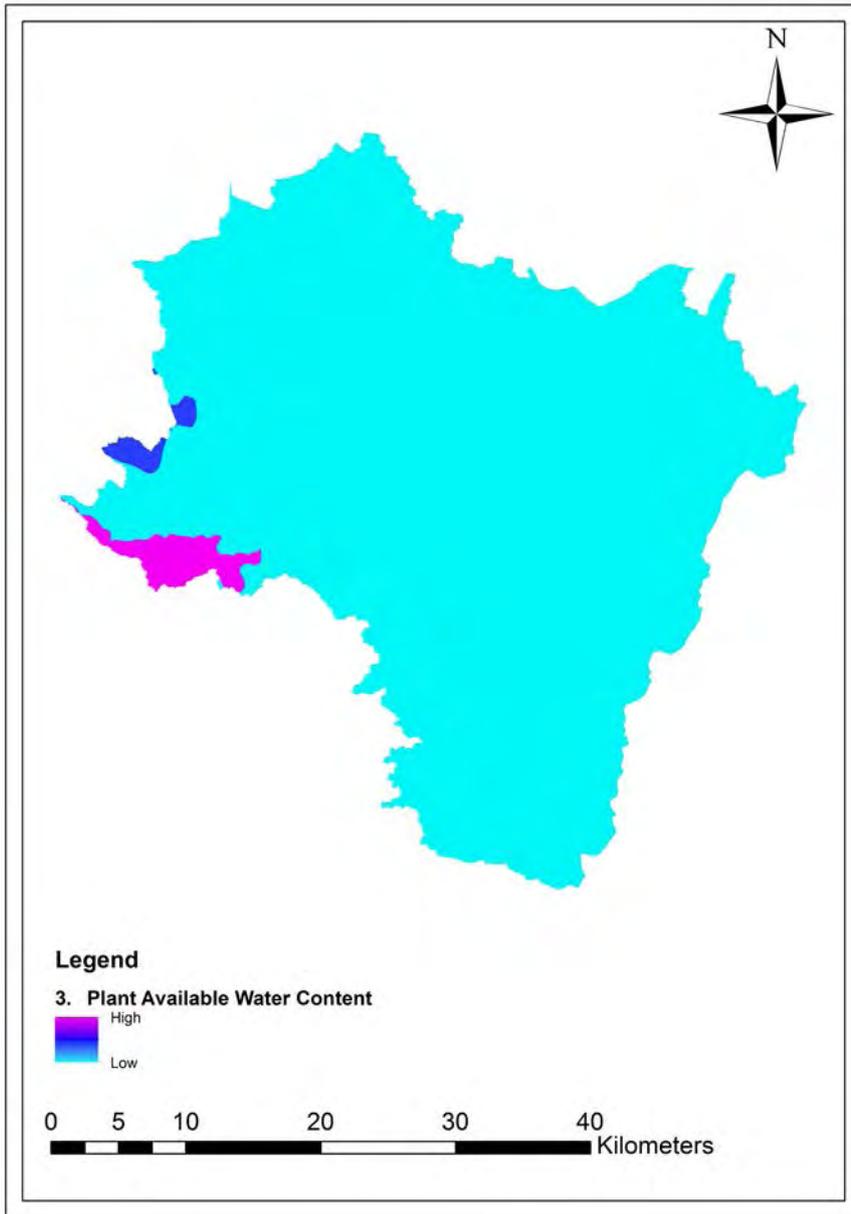


To form the necessary annual precipitation raster database, we totalled the rainfall for each year and took the 4-year average. This average for each station was interpolated to create a raster at 30m resolution. Interpolation was done using Kriging tools available in ArcGIS software (Figure 25).

3. Plant Available Water Content: This is a GIS raster dataset with a plant available water content value for each cell. Plant Available Water Content fraction (PAWC) is the fraction of water that can be stored in the soil profile that is available for plants use. For

Periyar this was calculated using data from Soil Survey of India and SPAW Hydrology and Water Budgeting software downloaded from the United States Department of Agriculture. (Figure 26)

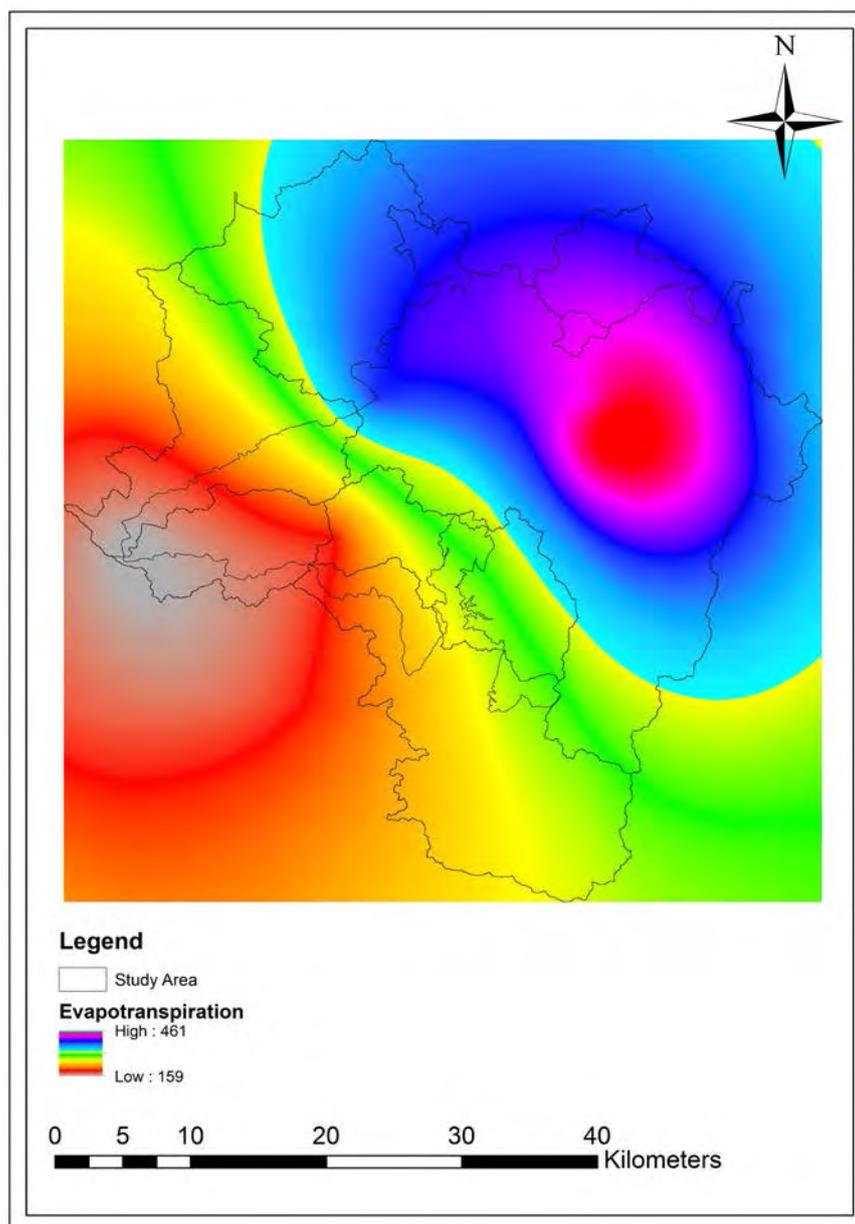
Figure 26
Available Water Content



4. Average Annual Reference Evapo-transpiration: This is a GIS raster dataset, with an annual average evapo-transpiration value for each cell. Reference is the potential loss of water from soil by both evaporation from the soil and transpiration by healthy alfalfa (or grass) if sufficient water is available. This was calculated using the metrological data from the 10 weather stations within PTR. The data include monthly total rainfall, minimum (Tmin) and maximum (Tmax) temperature for 2007 to 2010. A few missing values

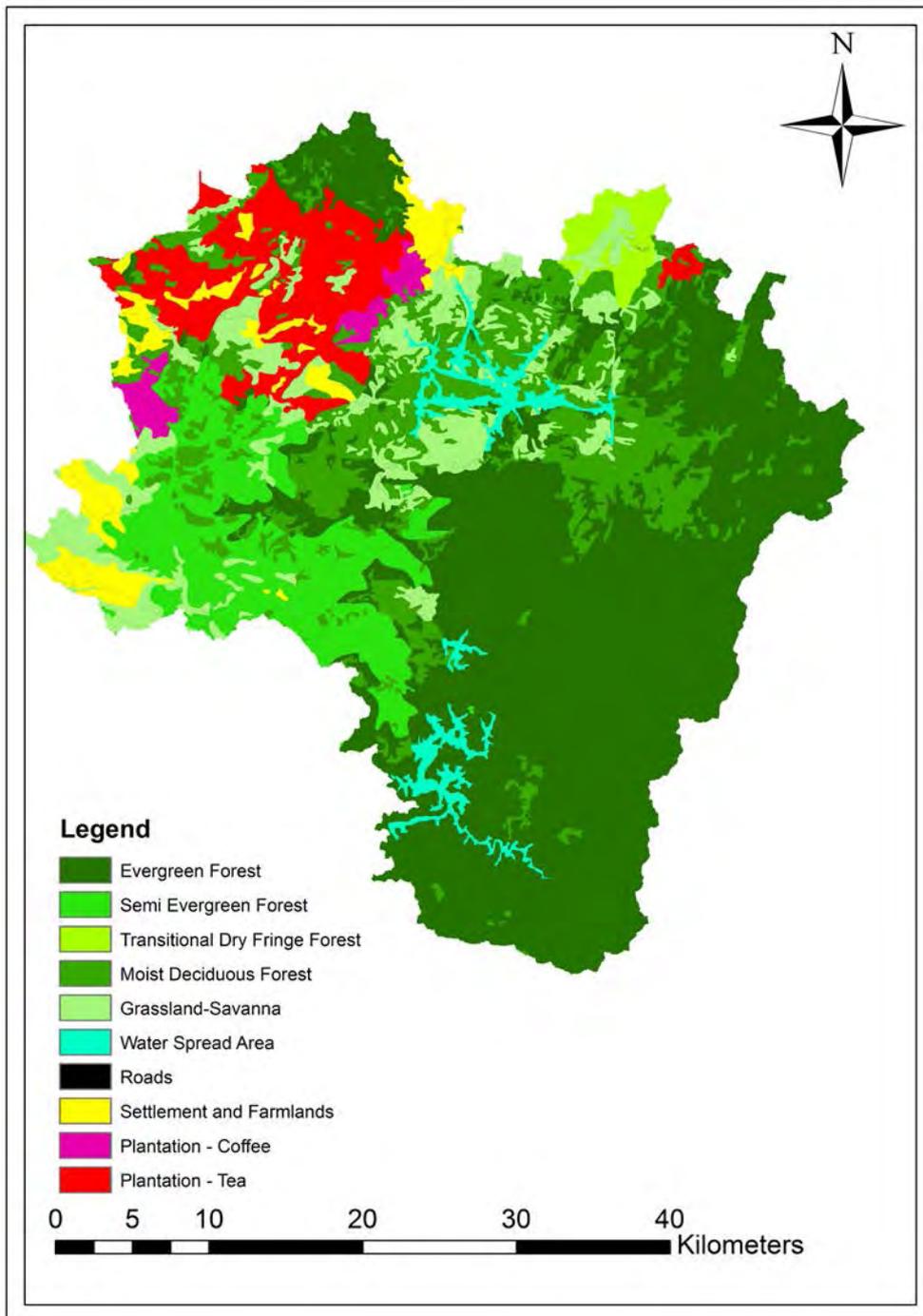
for T_{min} and T_{max} were filled using values from the year following the missing data. To calculate evapo-transpiration raster, the tabular data was interpolated for monthly precipitation, minimum and maximum temperature using the same Kriging tool described above for annual precipitation. Next, we used an ArcGIS script from NatCap (Stacie Wolny) to calculate annual evapo-transpiration (Figure 27).

Figure 27
Average Evapo-transpiration



5. Land Use / Land Cover: This is a GIS raster dataset, with an LULC code for each cell. This was the same map as used in the carbon model with some more land area included in the map. This land area, which was outside PTR was added to complete the watersheds lying within the boundary of PTR (Figure 28).

Figure 28
Land Use for the Entire Study Area



6. Watersheds: This is a shapefile, with one polygon per watershed. The layer was derived using the DEM raster in the Global Mapper software using its Generate Watershed tool. To generate the watersheds 50m stream length was taken as the default parameter. From the output, those watersheds were selected that contribute to rivers in Periyar or receive water from the Periyar Tiger Reserve.

7. Subwatersheds: Owing to data constraints subwatersheds for the watersheds could not be calculated. To execute the model the watershed shape file was also used as the subwatershed shape file.
8. Biophysical Table: It is a table of land use/land cover (LULC) classes, containing data on biophysical coefficients used in the model (Table 44). For the water yield model the table had the following values –
 - a. locode (Land use code): Unique integer for each LULC class
 - b. LULC_desc: Descriptive name of land use/land cover class
 - c. LULC_veg: Contains the information on which AET equation to use (Eq. 1 or 2).
 - d. root_depth: The maximum root depth for vegetated land use classes, given in integer millimetres
 - e. Kc: The plant evapo-transpiration coefficient for each LULC class.

Table 44

Biophysical Table for Water Yield Model

LULC_desc	locode	LULC_veg	root_depth	Kc
Evergreen Forest	1	1	2000	0.95
Semi Evergreen Forest	2	1	2000	0.92
Transitional Dry Fringe Forest	3	1	2500	0.9
Moist Deciduous Forest	4	1	2000	0.66
Plantations	5	1	1500	0.9
Grassland-Savanna	6	1	500	0.7
Water Spread Area	7	0	200	0.5
Roads	8	0	1	0.1
Settlement and Farmlands	9	1	500	0.25
Plantation – Coffee	10	1	1200	0.9
Plantation – Tea	11	1	1500	0.9

9. Seasonality Factor (Z): This factor conveys the seasonal distribution of precipitation to the model. It was calculated using expert knowledge and calculation recommended in InVEST documentation.

$$Z = \text{estimate of number of rainfall days in a year} * 0.2$$

$$Z = 180 * 0.2 = 36$$



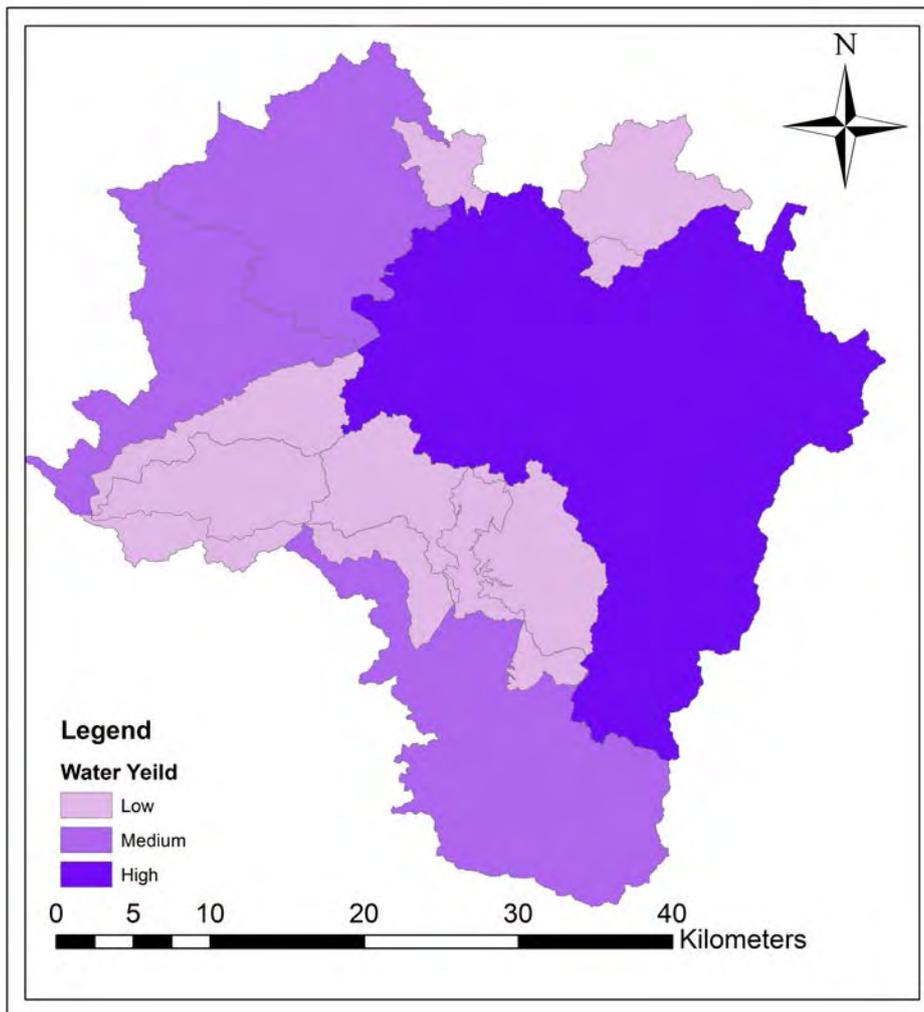
4.3.2.2 OUTPUT

The output of the model is very exhaustive. It provides with a shape file where various outputs can be spatially studied. It provides the modelled values of Mean Actual Evapo-transpiration, Mean Potential Evapo-transpiration, water yield volume, etc. Figure 29 displays the water yield output of the model.

The total water yeild from PTR as well as its fringe areas amounts to **4366 million KL** per annum. With Periyar dam in function all this water flows down to the reservoir, from where it is consumed for various needs across Kerala and Tamil Nadu. These outputs are validated by the usage pattern that is observed in the study area. This water is stored in the Periyar dam and is used for electricity generation, irrigation (at least 6 districts are completely dependent on this water), drinking water, etc.

Figure 29

Water Yield Output for Periyar Tiger Reserve



4.3.3 APPLICATION OF MODEL AT KANHA TIGER RESERVE

4.3.3.1 INPUTS

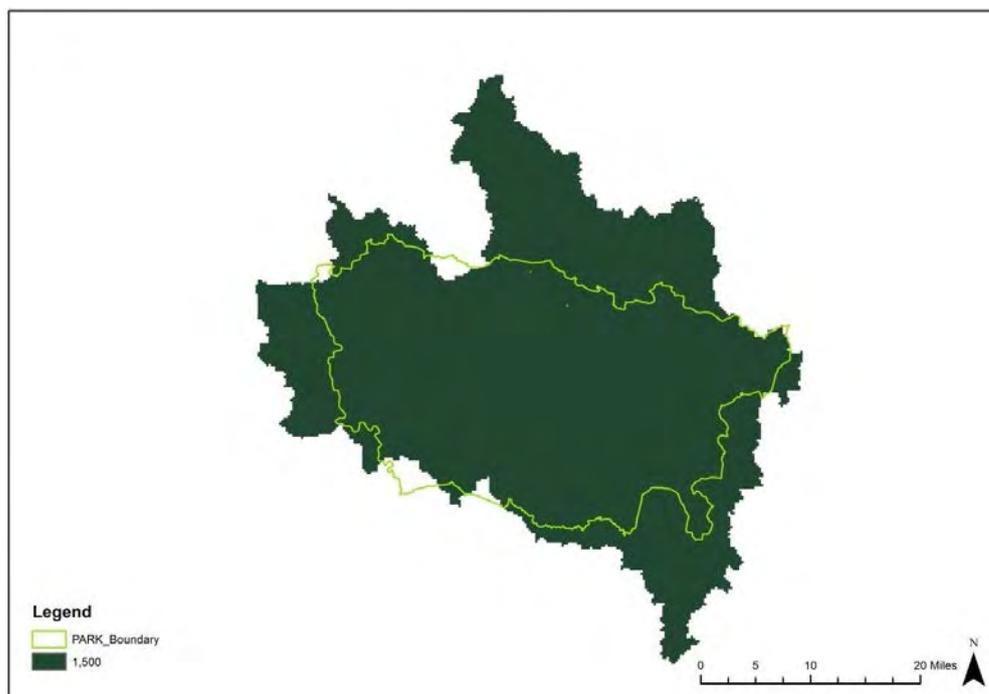
This section outlines the map and data tables used to execute the Water Yield: Reservoir Hydropower Production Model for Kanha Tiger Reserve.



1. Root Restricting Layer Depth: Root restricting layer depth is the soil depth at which root penetration is strongly inhibited because of physical or chemical characteristics. The root restricting layer depth values is taken in millimetres. For KTR the value was derived to be 1500mm for the entire study area. The same value had to be extrapolated for the entire study area on account of unavailability of reliable site specific data.

Figure 30

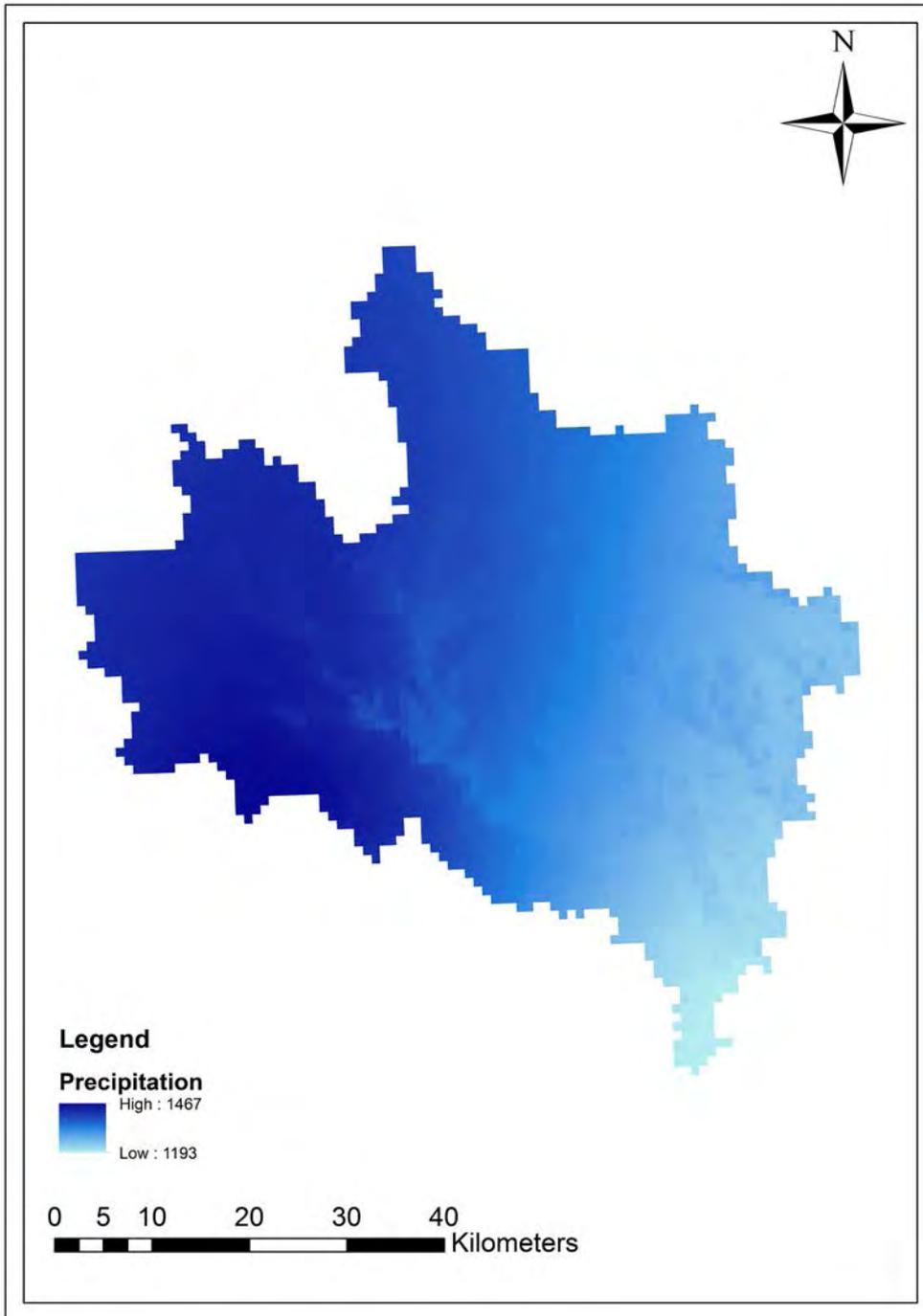
Root Restricting Layer for KTR



2. Precipitation: This is the average annual precipitation for each cell in a GIS raster format with all non-zero values in millimetres. For KTR the available datasets at the ground level were not in the desired shape making them unusable. Thus Worldclim data downloaded from <http://www.worldclim.org/> was used. Raster data of 30 second resolution was downloaded from the web database. Data for the study area was masked

from the original raster using the study area boundary shape file. Figure 31 shows the precipitation map for the study area.

Figure 31
Precipitation at KTR



3. Plant Available Water Content: This is a GIS raster dataset with a plant available water content value for each cell. Plant Available Water Content fraction (PAWC) is the

fraction of water that can be stored in the soil profile that is available for plants use. For Kanha this was calculated using data from FAO soil type data and SPAW Hydrology and Water Budgeting software downloaded from the United States Department of Agriculture (Figure 32).

4. Average Annual Reference Evapo-transpiration: This is a GIS raster dataset, with an annual average evapo-transpiration value for each cell. Reference is the potential loss of water from soil by both evaporation from the soil and transpiration by healthy alfalfa (or grass) if sufficient water is available. For Kanha this layer was derived from the global Evapo-transpiration layer as provided by FAO at their geodatabase website Figure 33.
5. Land Use / Land Cover: This is a GIS raster dataset, with an LULC code for each cell. This was the same map as used in the carbon model with some more land area included in the map in order to complete the watershed areas, as desired by the current model. In order to complete the watersheds some area of the KTR had to be excluded (Figure 34).

Figure 32
Available Water Fraction in KTR

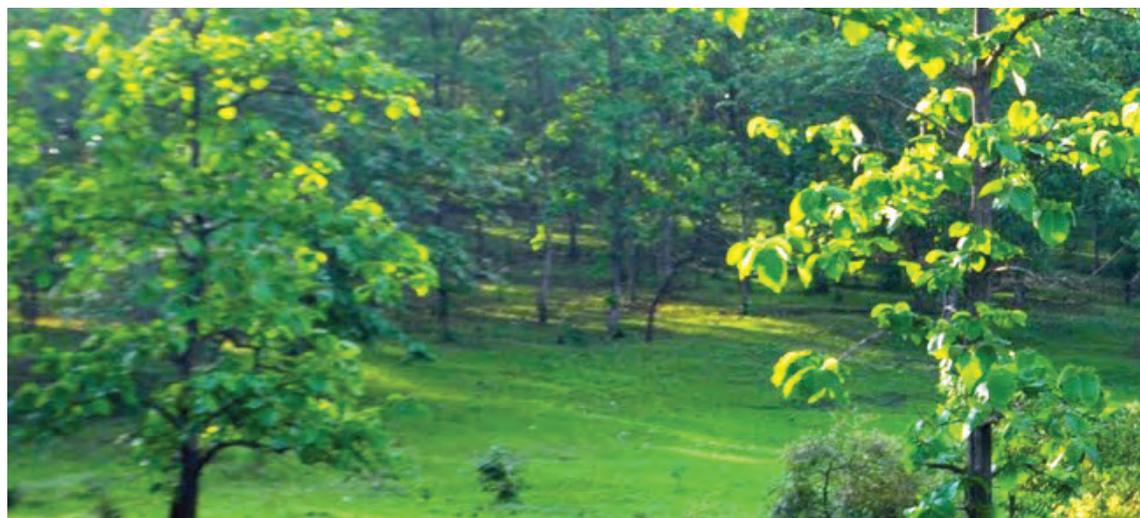
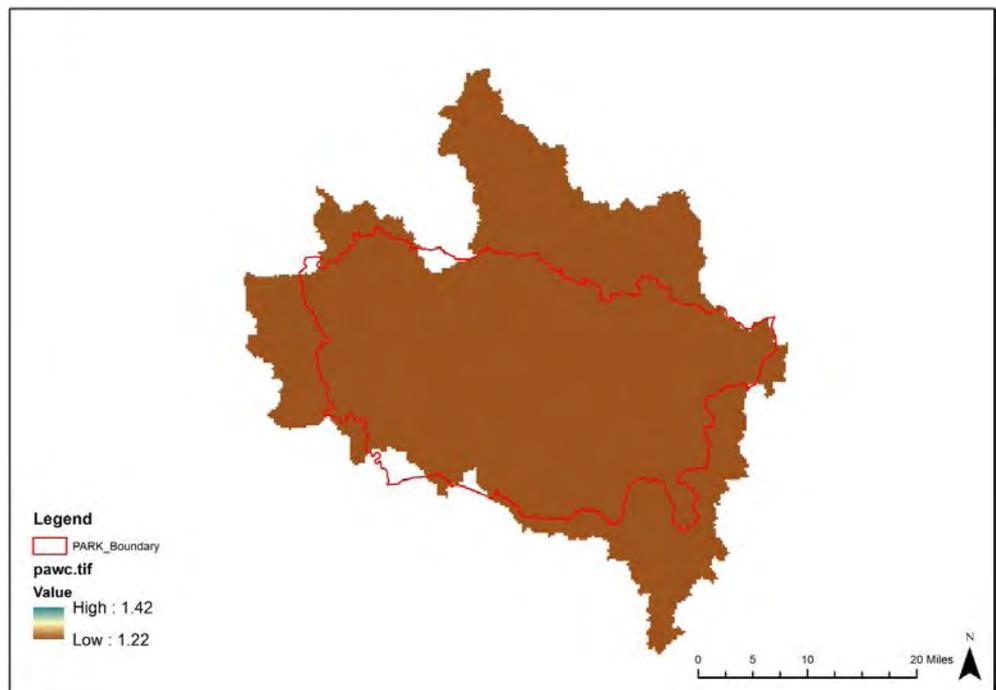


Figure 33
Average Evapo-transpiration at KTR

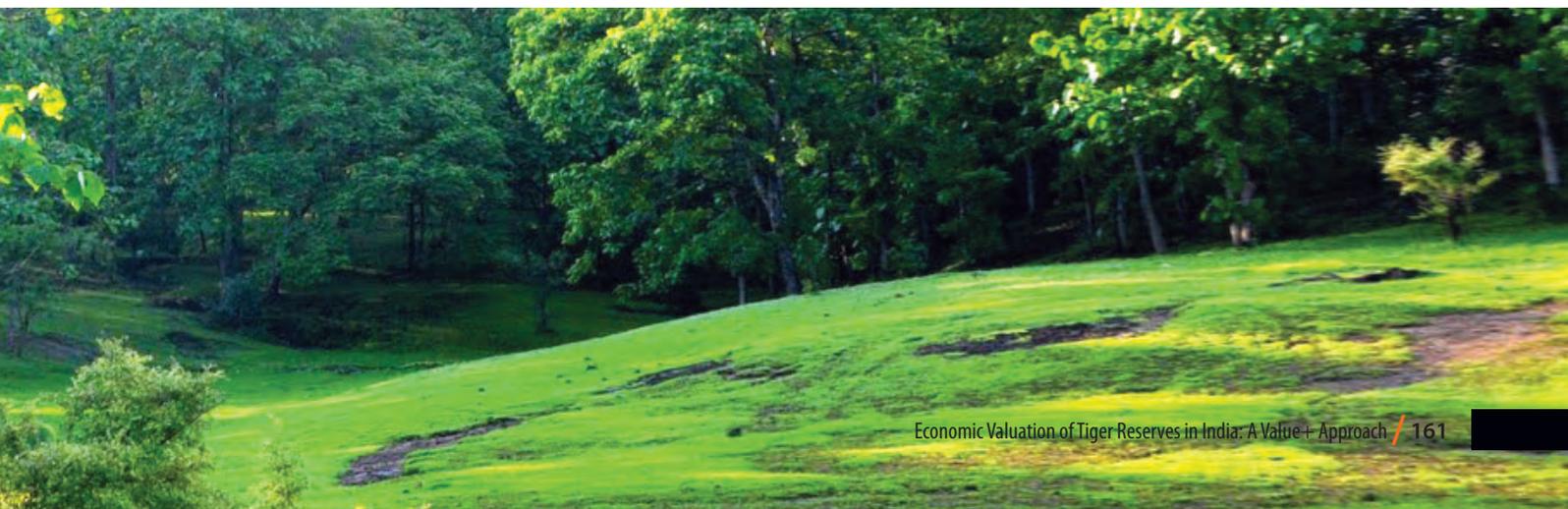
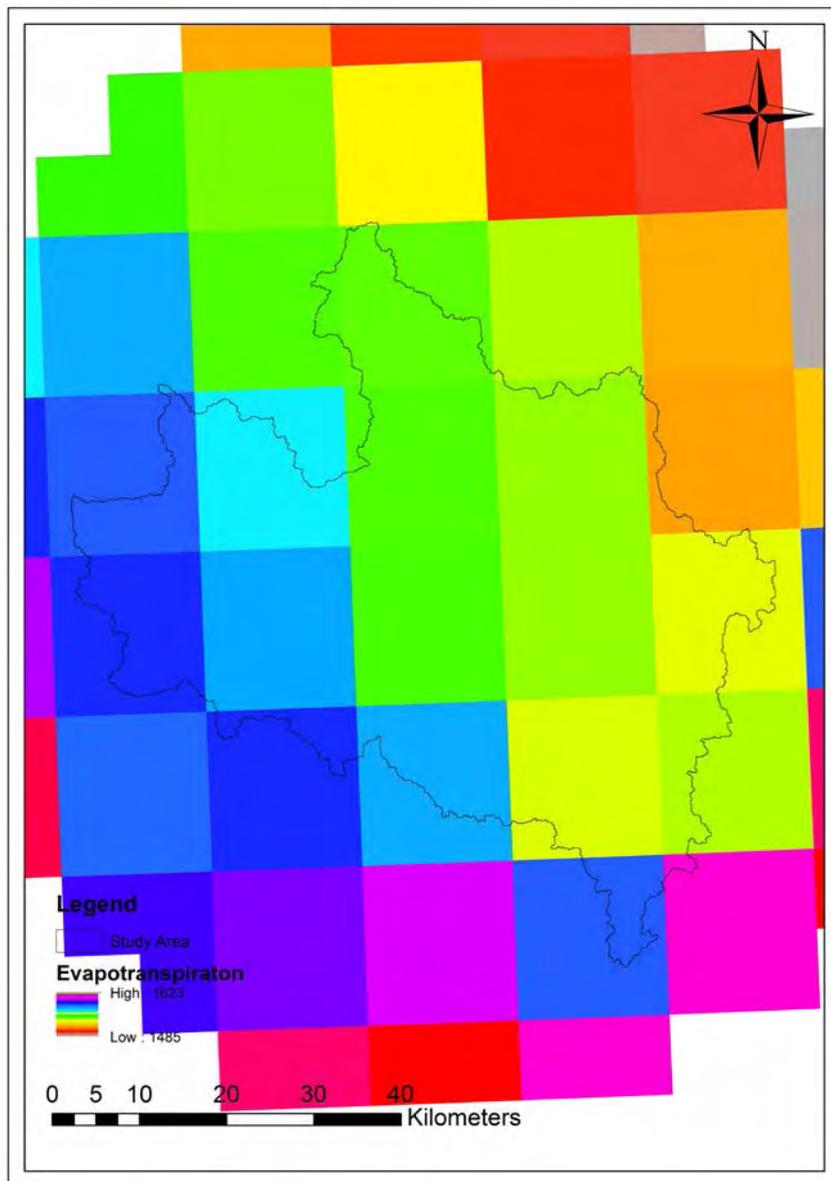
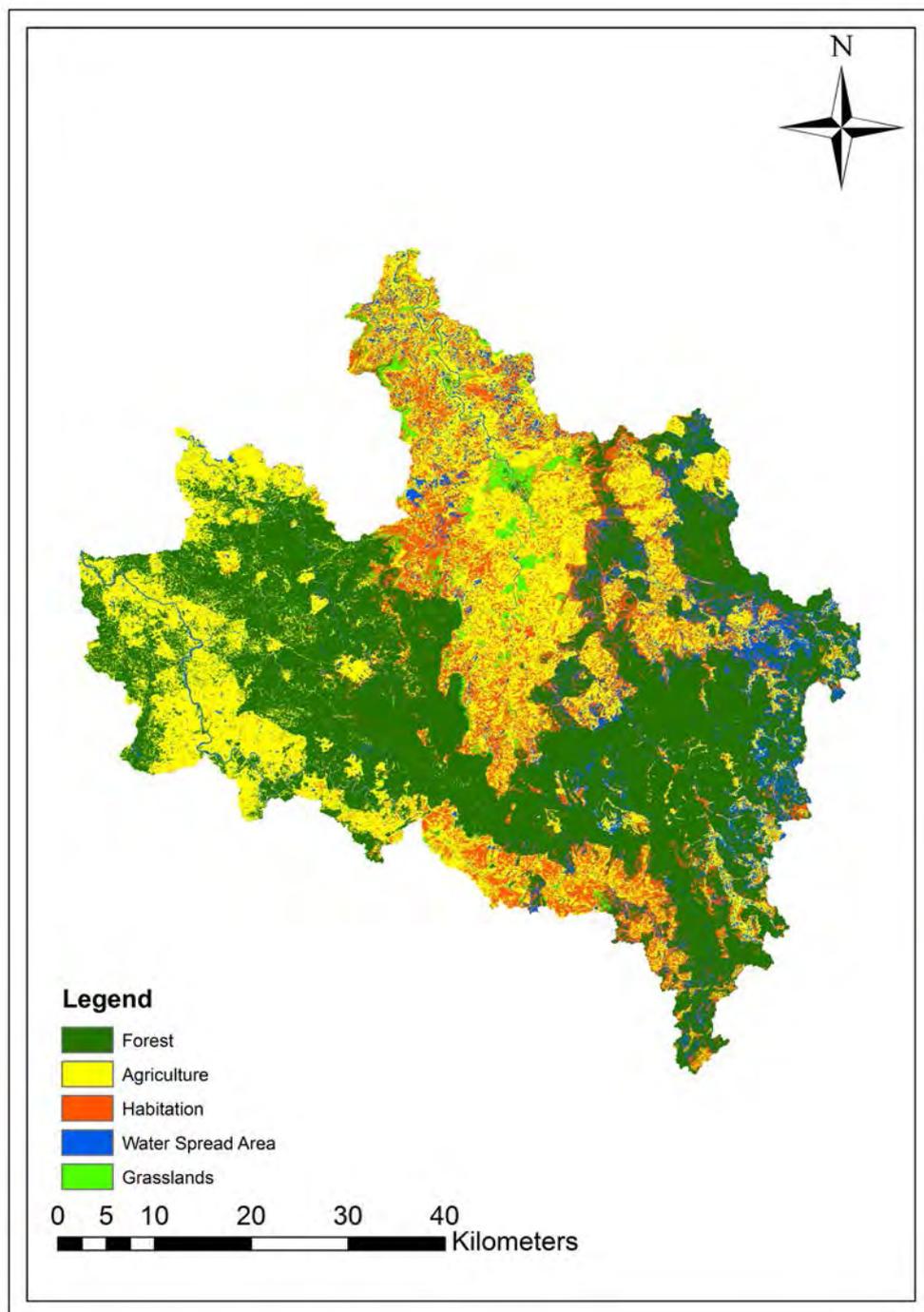


Figure 34
Land Use Map of KTR Study Area



6. Watersheds: This is a shapefile, with one polygon per watershed. The layer was derived using the DEM raster downloaded from the USGS website, in ARC-GIS software using its hydrology tool present in the spatial analyst toolbox. All those watersheds which had more than 10% of their area lying within the KTR were selected to be part of the study area. Figure 35 shows all the watersheds selected to be included in the study area.

7. Subwatersheds: Owing to data constraints subwatersheds for the watersheds could not be calculated. To execute the model the watershed shape file was used as the subwatershed shape file.
8. Biophysical Table: It is a table of land use/land cover (LULC) classes, containing data on biophysical coefficients used in the model (Table 45). For the water yield model the table had the following values –
 - a. lrcode (Land use code): Unique integer for each LULC class
 - b. LULC_desc: Descriptive name of land use/land cover class
 - c. LULC_veg: Contains the information on which AET equation to use (Eq. 1 or 2)
 - d. root_depth: The maximum root depth for vegetated land use classes, given in integer millimetres
 - e. Kc: The plant evapo-transpiration coefficient for each LULC class

Figure 35

Watershed Map of the Study Area

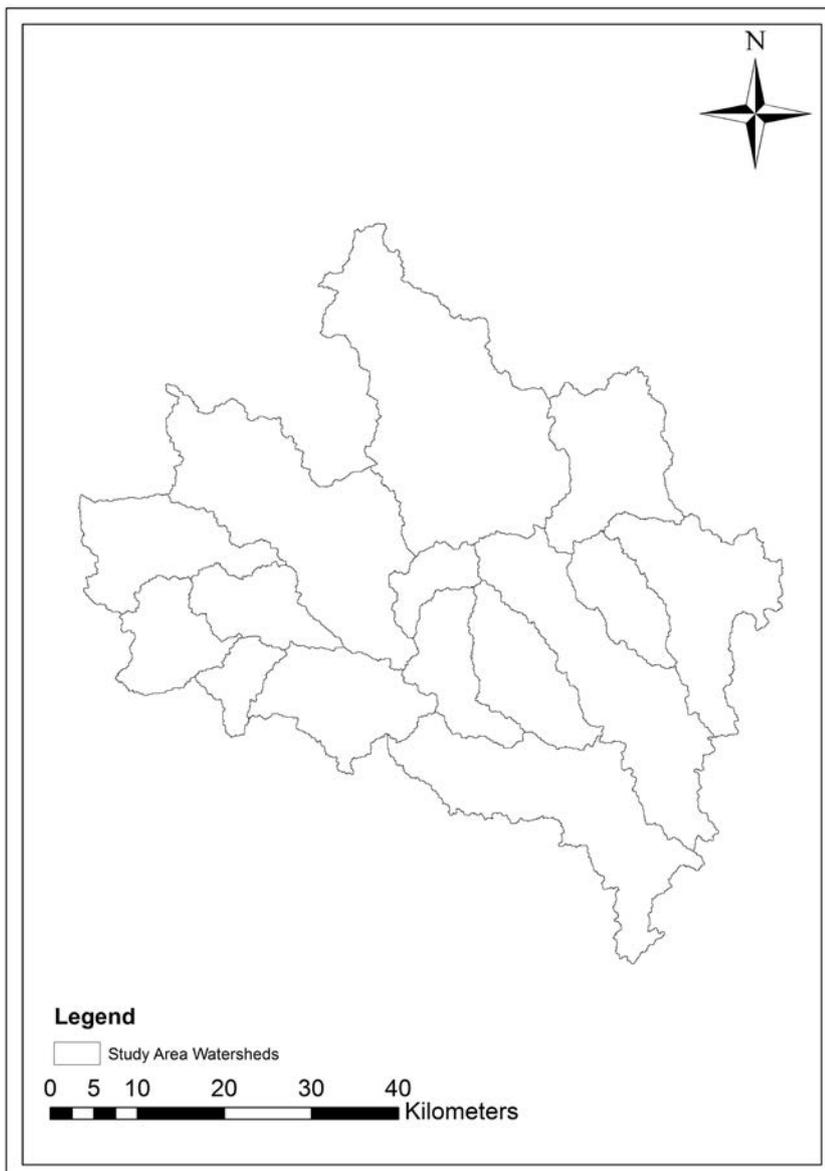


Table 45

Biophysical Table for Water Yield Model

LULC_desc	lucode	LULC_veg	root_depth	Kc
Forest	1	1	1500	0.9
Agriculture / Fallow Land	2	1	1000	0.25
Habitation	3	0	700	0.4
Waterlogged Areas	4	0	500	0.5
Grasslands	5	1	800	0.7

9. Seasonality Factor (Z) – This factor conveys the seasonal distribution of precipitation to the model. It was calculated using expert knowledge and calculation recommended in InVEST documentation.

$$Z = \text{estimate of number of rainfall days in a year} * 0.2$$

$$Z = 100 * 0.2 = 20$$

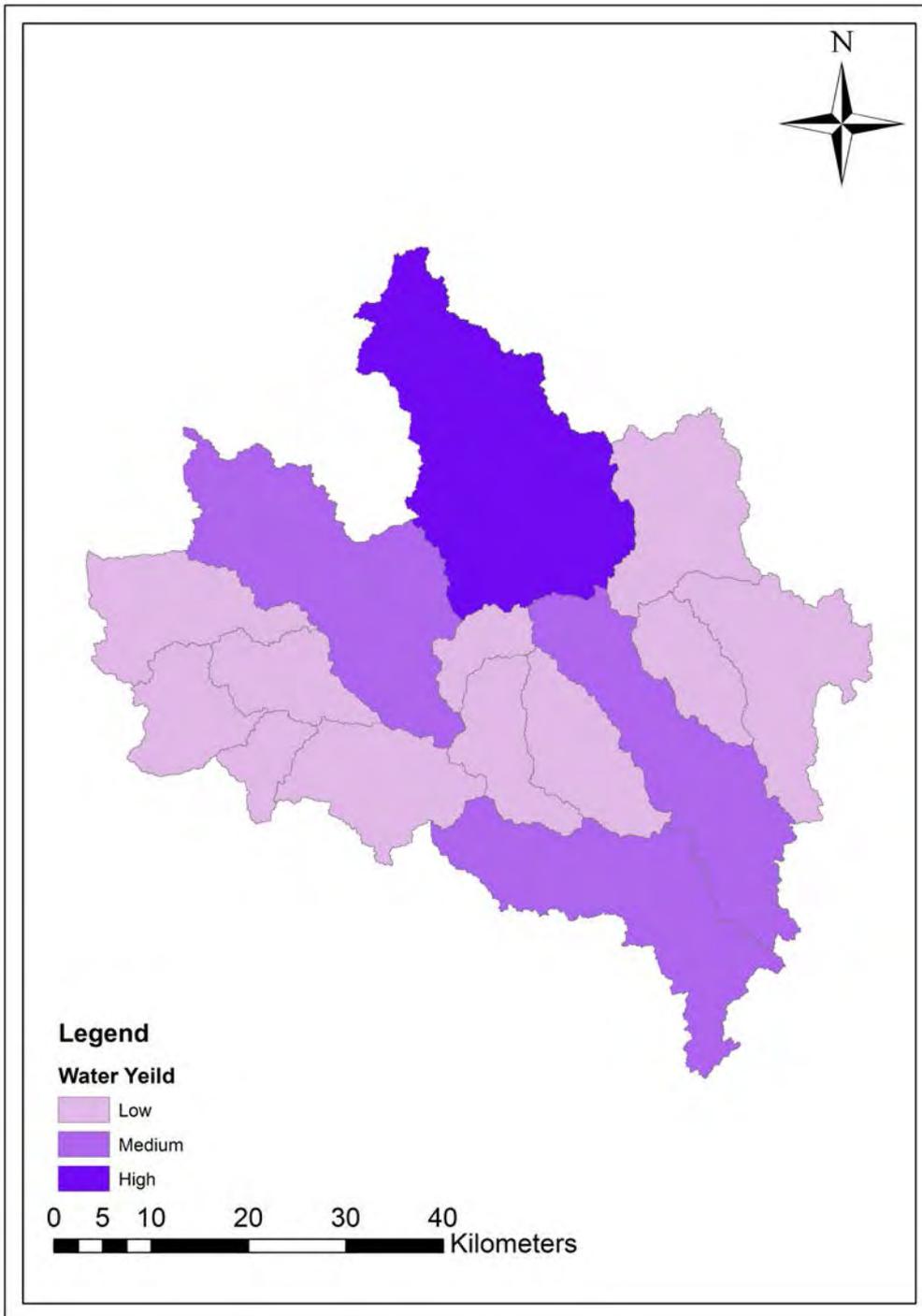
4.3.3.2 OUTPUT

The model provides various outputs like modelled values of Mean Actual Evapo-transpiration, Mean Potential Evapo-transpiration, water yield volume etc. Figure 36 displays the water yield output of the model.

The net water yield of the study area is around 1804 million KL per annum. This value is validated by the river flow data available with KTR.



Figure 36
Water Yield for KTR



4.3.4 LIMITATIONS

The model has a number of limitations as listed below –

1. It is not intended for devising detailed water plans, but rather for evaluating how and where changes in a watershed may affect water yield for reservoir systems. It is based on

annual averages, which neglect extremes and do not consider the temporal dimensions of water supply.

2. The model assumes that all water produced in a watershed in excess of evapotranspiration arrives at the watershed outlet, without considering water capture by means other than primary human consumptive uses. Surface water–ground water interactions are entirely neglected, which may be a cause for error especially in areas of karst geology. The relative contribution of yield from various parts of the watershed should still be valid.
3. The model does not consider sub-annual patterns of water delivery timing. Water yield is a provisioning function and its benefits are affected by flow regulation. The timing of peak flows and delivery of minimum operational flows throughout the year determines the utility towards irrigation and other uses. Changes in landscape scenarios are more likely to affect the timing of flows than the annual water yield, and are greater a concern when considering drivers such as climate change. Modelling the temporal patterns of overland flow requires detailed data that are not appropriate for current approach. Still, this model provides a useful initial assessment of how landscape scenarios may affect the annual delivery of water to hydropower production.
4. The model describes consumptive demand by LULC type. In reality, water demand may differ greatly between parcels of the same LULC class. Much of the water demand may also come from large point source intakes, which are not represented by the LULC class. The model simplifies water demand by distributing it over the landscape.
5. Fifth, a single variable (d) is used to represent multiple aspects of water resource allocation, which may misrepresent the complex distribution of water among uses and over time.

4.4 SEDIMENT RETENTION: AVOIDED DREDGING AND WATER PURIFICATION

Erosion and sedimentation are natural processes that contribute to a healthy ecosystem, but too much may have severe consequences. Excessive erosion can reduce agricultural productivity, increase flooding and pollutant transport, and threaten bridges, railroads and power infrastructure. Erosion can lead to sediment build-up, which strains water infrastructure, such as reservoirs and flood control systems, and increases water treatment costs. Sedimentation is particularly problematic for reservoirs, which are designed to retain sediment as water is released. Regular sediment removal can avoid some of these issues, but this incurs substantial maintenance costs.

The magnitude of sediment transport in a watershed is determined by several factors. Natural variation in soil properties, precipitation patterns, and slope influence patterns of erosion and sediment runoff. Vegetation holds soil in place and captures sediment moving overland. Accordingly, changes in land management practices that alter vegetation can change the sediment retention capacity of land.

To reduce the damages and costs associated with sedimentation, land, water and reservoir managers require information regarding the extent to which different parts of a landscape contribute to sediment retention, and how land use changes may affect this retention. Such information can support decisions by government agencies, businesses, and NGOs.

Using InVEST one can model and predict the change in sedimentation with change in



land use. It estimates the capacity of a land parcel to retain sediment using data on geomorphology, climate, vegetation and management practices.

4.4.1 THE MODEL

The Sediment Retention calculates the average annual soil loss from each parcel of land, determining how much of that soil may arrive at a particular point of interest, estimating the ability of each parcel to retain sediment, and assessing the cost of removing the accumulated sediment on an annual basis. An important determinant of soil retention capacity is land use and land cover.

To identify a land parcel, the InVEST Avoided Reservoir Sedimentation model uses the Universal Soil Loss Equation (USLE)¹⁸⁴ at the pixel scale, which integrates information on LULC patterns and soil properties, as well as a digital elevation model, rainfall and climate data. The pixel-scale calculations allows representation of the heterogeneity of key driving factors in water yield such as soil type, precipitation, vegetation type, etc.

4.4.2 MODEL FUNCTIONS

The InVEST sediment retention model employs the Universal Soil Loss Equation (USLE)¹⁸⁴ at a grid cell scale, together with a grid cell scale sediment retention approach for sediment deposition. The basic grid cell-scale export calculation integrates information on land-use/land-cover (LULC) patterns, soil properties, elevation, rainfall and climate data to estimate soil erosion (USLE) from a grid cell i :

$$USLE_i = (R \cdot K \cdot L \cdot C \cdot P)_i$$

where R is the rainfall erosivity, K is the soil erodibility factor, LS is the slope length-gradient factor, C is the crop management factor and P is the support practice factor.

For calculation of Potential Soil Loss the InVEST model uses raster layers to represent erosivity and erodibility, and a raster layer of land cover to map C and P factors. The values for crop/vegetation and support practice are assumed equal for all grid cells of identical LULC class, and are held in the LULC parameters table. Other assumptions in the model include:

- Steady state conditions
- Sediment that enters the channel network leaves the basin during the same year (no carry-over the years).

The L and S factors are considered to be the most critical

parameters of the USLE equation and several researchers have made modifications to the original LS factor developed by Foster and Wischmeier (1974). In the model the method developed by Desmet and Govers¹⁸⁵ for two-dimension surface has been used:

$$Li \cdot Si = Si \frac{(Ai + D^2) - Ai^{m+1}}{D^{m+2} \cdot Xi^m \cdot 22.13^m}$$

Where

- Si = the slope factor for grid cell calculated as function of slope degree as follows:

$$Si = 10:8 \cdot \sin() + 0:03; \text{ where slope is } \leq 9\%$$

$$Si = 16:8 \cdot \sin() - 0:50; \text{ where slope is } \geq 9\%$$

- Ai = the contributing area (m^2) at the inlet of grid cell i that is calculated from the D -infinity flow accumulation algorithm.
- D = the grid cell linear dimension (m)
- Xi is a factor for adjusting the flow length across a cell it is equal to $j \sin(\alpha_i) + j \cos(\alpha_i)$ where α_i is the aspect direction for the grid cell.

For calculating upstream soil retention the model assumes that the estimated soil loss from USLE is transported to the downstream grid cell if the retention capacity of the receiving cell is zero. This retention is an outcome of physical filtration and slowing down of overland flow by vegetation, allowing sediment particles to deposit. Factors such as slope, soil permeability and area also play an important role in sediment transportation and deposition processes. For the InVEST sediment model this parameter is summarized into a per cell retention efficiency factor defined as a function of a landcover code in the biophysical table input.

The mass balance equation which governs the transport of sediment in the InVEST sediment retention model is:

$$Si = \left(\sum_{j \in \{i \text{ neighbors}\}} Sj \right) (1 - Ei) + USLE_i$$

The total retained sediment ($sret_j$) is equal to the sum of the sediment retained on the pixel itself due to the C and P factors as well as the sediment removed through routing filtration.

Table 46
Summary of Model Calculations



Step No.	Calculation	Variables Used
1	Slope length gradient factor (LS)	S_i = the slope factor for grid cell A_i = contributing area (m ²) D = the grid cell linear dimension (m) X_i is a factor for adjusting the flow length across a cell
2	Soil Erosion (USLE)	R is the rainfall erosivity K is the soil erodibility factor LS is the slope length-gradient factor C is the crop management factor P is the support practice factor

4.4.3 SEDIMENT RETENTION MODEL FOR PERIYAR TIGER RESERVE

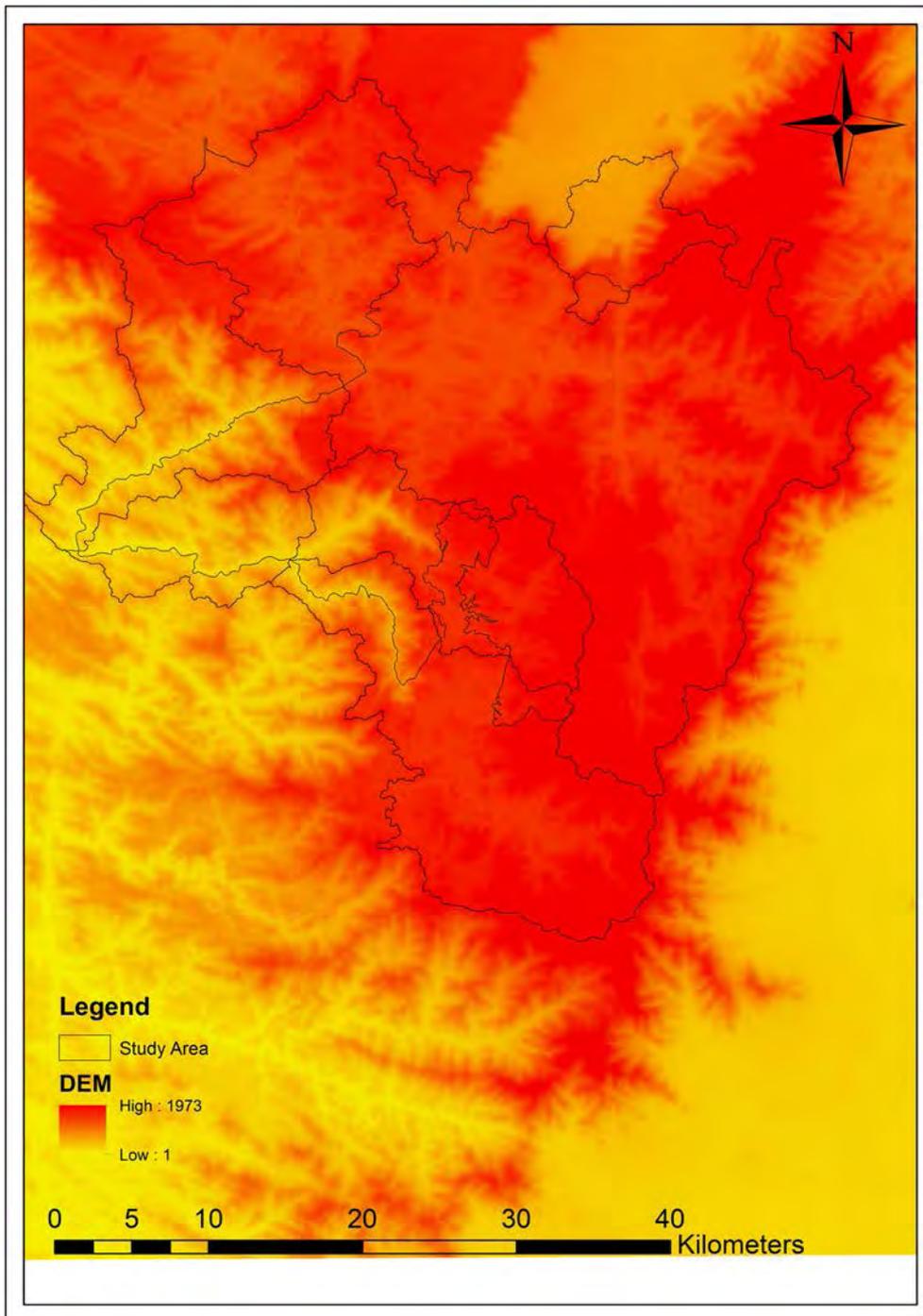
4.4.3.1 INPUTS

This section outlines the map and data tables used to execute the Sediment Retention: Avoided Dredging and Water Purification Model for Periyar Tiger Reserve.

- Digital Elevation Model (DEM): It is a GIS raster dataset with an elevation value for each cell. For the sediment model Aster DEM at 30m resolution was used. The raster layer was clipped to cover the entire study area (Figure 37).
- Rainfall Erosivity Index (R): R is a GIS raster dataset, with an erosivity index value for each cell. The precipitation layer generated earlier for the water yield model was used to calculate R. R was then calculated using Singh et al.1981 equation for the country.

$$\text{Avg erosivity} = 79 + (0.363 * \text{avg_annual_P})$$
 The map generated using the above equation is as shown in Figure 38.
- Soil Erodibility (K): K is a GIS raster dataset, with a soil erodibility value for each cell. Soil erodibility, K, is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. For PTR this was derived from soil texture information provided in the Soil Survey of India data and user table as provided in the InVEST User Guide.
- Land Use / Land Cover (LULC): Same as used in Water Yield model.
- Watersheds: Same as used in Water Yield model.
- Biophysical Table: A .csv table containing model information corresponding to each of the land use classes (Table 47).
 - lucode (Land use code): Unique integer for each LULC class
 - LULC_desc: Descriptive name of land use/land cover class
 - usle_c: Cover-management factor for the USLE, a floating point value between 0 and 1.
 - usle_p: Support practice factor for the USLE, a floating point value between 0 and 1.
 - sedret_eff: The sediment retention value for each LULC class, as a floating point value 0 and 1.

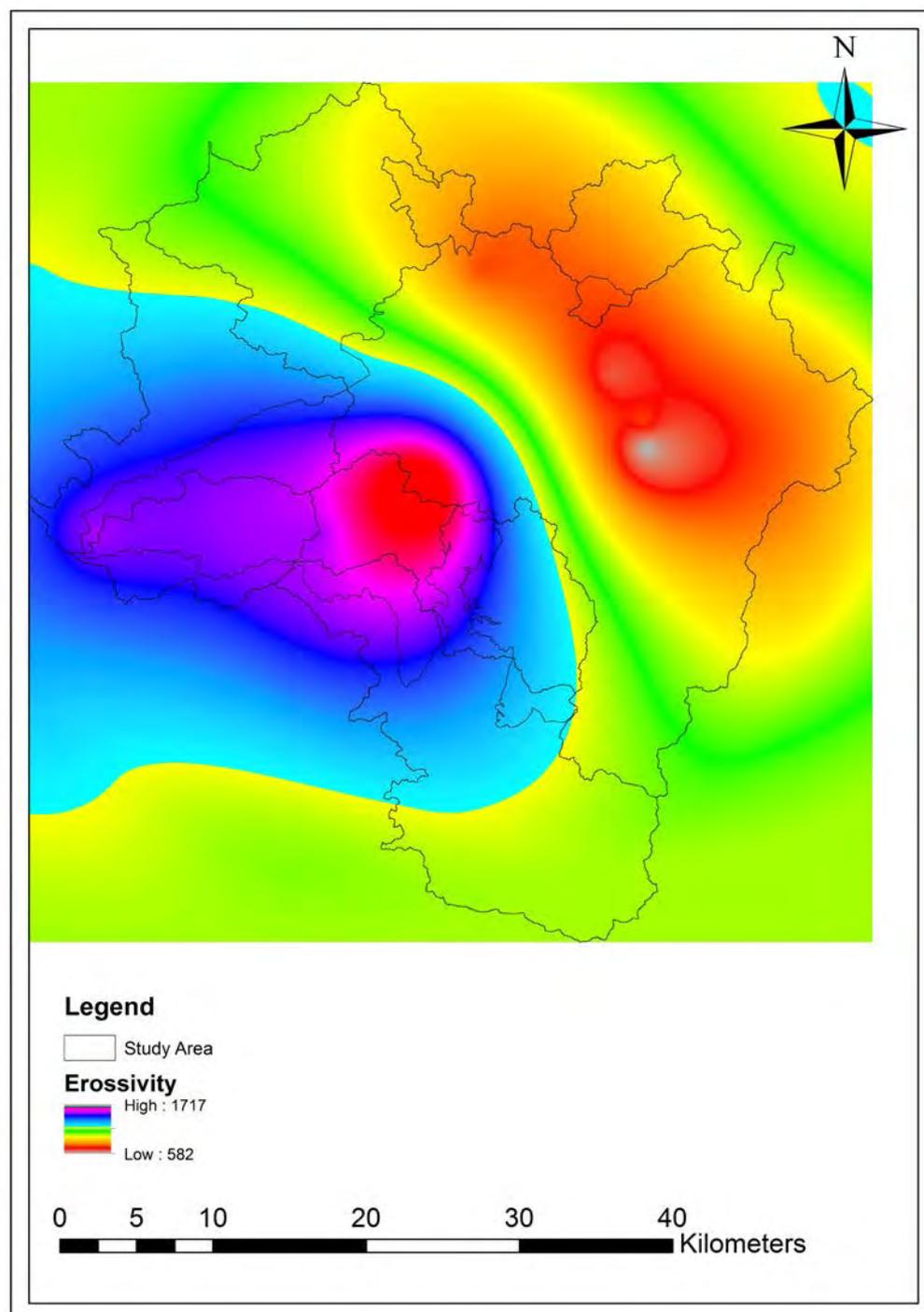
Figure 37
DEM for PTR



The **Sediment Retention Model** calculates the average annual soil loss from each parcel of land and estimates the avoidability of each parcel to retain sediment.

7. Threshold flow accumulation: The number of upstream cells that must flow into a cell before it is considered part of a stream, which is used to classify streams in the DEM. For PTR this was determined by doing different iterations and comparing the results with the perennial stream map provided by PTR. A value of 2000 was found suitable in executing the model.

Figure 38
Erosivity Map of PTR



8. Sediment Threshold Table: A .csv table containing annual sediment load threshold information for each of the reservoirs.
 - a. ws_id: Unique integer value for each reservoir, which must correspond to values in the watersheds layer.
 - b. dr_time: Integer time period corresponding to the remaining designed lifetime of the

reservoir (if assessing avoided sedimentation) or the expected time period over which the land use will remain relatively constant. For PTR this was taken as 60 years.

- c. dr_deadvol: It is a design dimension below which water is not available for any use and it is designed to store (deposit) sediment without hindering turbine and reservoir hydropower functions. For PTR this value was taken as 0 as the dead volume is unknown, and all sediment retained should be counted as an ecosystem service.
- d. q_annload: Allowed annual sediment loading, used for valuing sediment retention for water quality.

Table 47

Biophysical Table Used in Sediment Model

Description	lucode	usle_c	usle_p	sedret_eff
Evergreen Forest	1	0.003	1	0.8
Semi Evergreen Forest	2	0.004	1	0.8
Transitional Dry Fringe Forest	3	0.004	1	0.75
Moist Deciduous Forest	4	0.003	1	0.8
Plantations	5	0.06	0.8	0.6
Grassland-Savanna	6	0.054	1	0.7
Water Spread Area	7	0.001	1	0.95
Roads	8	0.8	0.75	0.3
Settlement and farmlands	9	0.06	0.75	0.3
Plantation - Coffee	10	0.06	0.9	0.6
Plantation - Tea	11	0.08	0.8	0.6

4.4.3.2 OUTPUT

The model provides various outputs for spatial analysis of the area. Figure 39 provides the values for the total amount of potential soil loss in each watershed calculated using the USLE equation. The output suggests that the potential for the highest soil loss is from the areas lying outside the park boundary, which are under agriculture, urban development and various other land uses.

Figure 40 provides spatial detail of the total sediment exported to the stream per watershed in the study area. Here also the model suggests high sediment load being generated from the areas lying outside the boundary of PTR.





Figure 39
Soil Loss Using USLE Equation

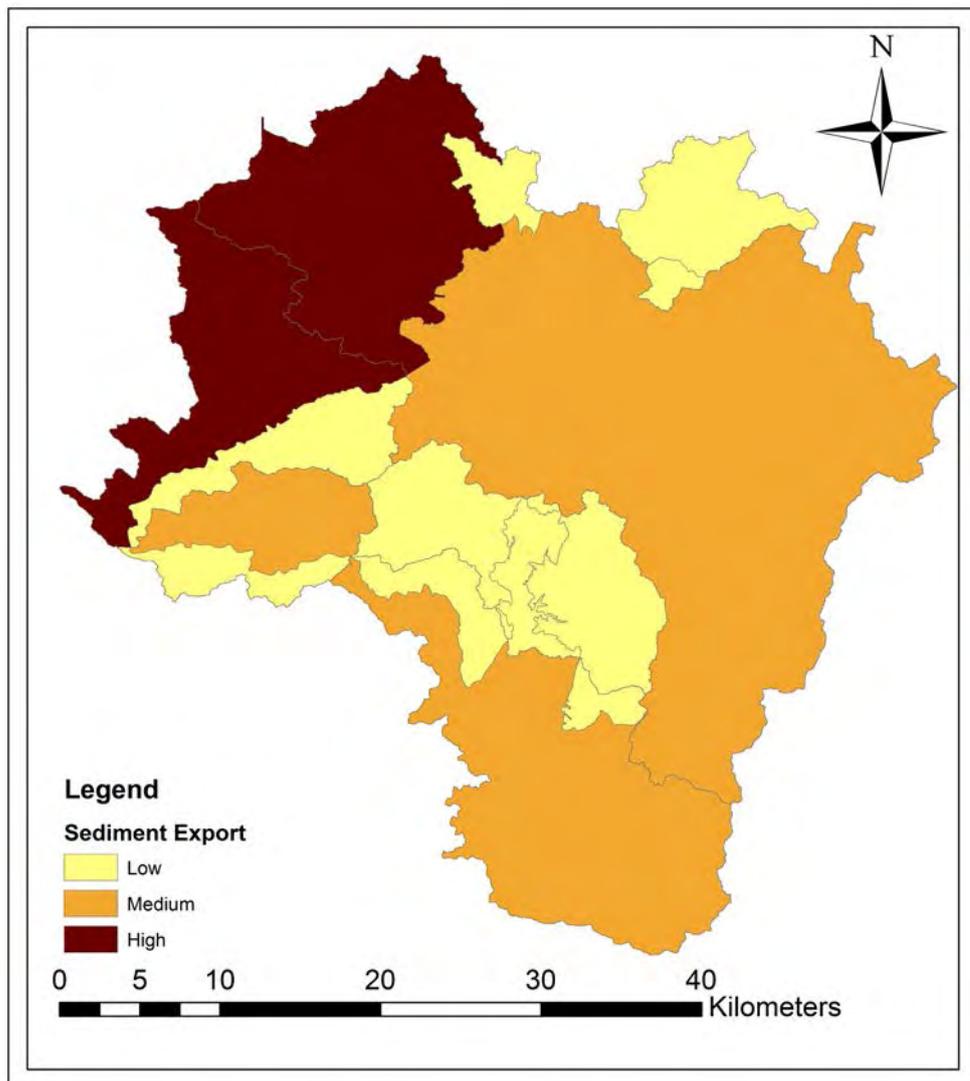
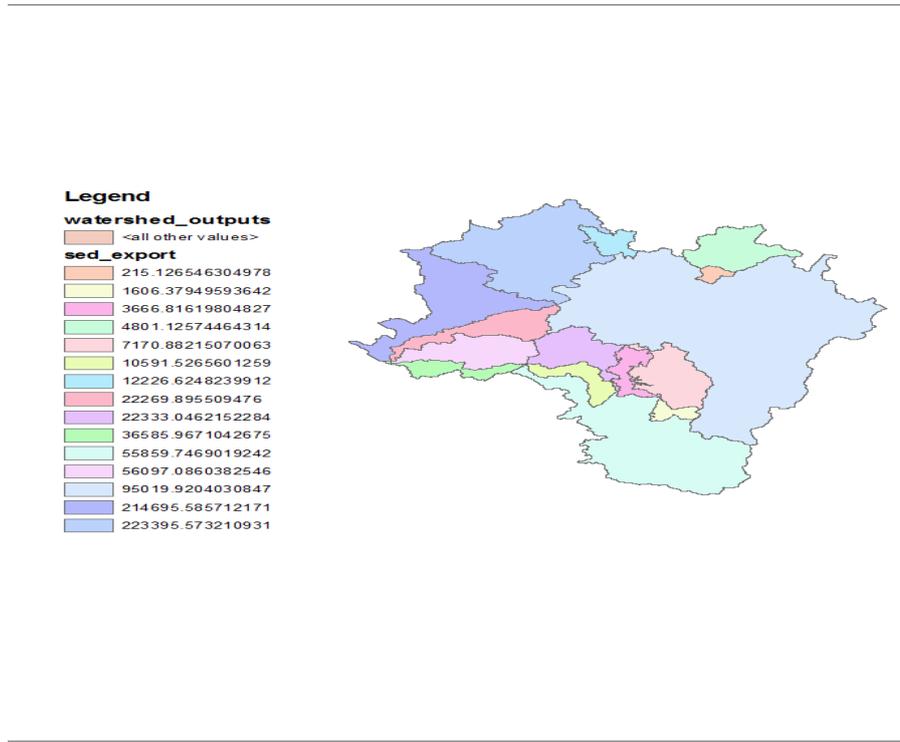


Figure 40

Sediment Export from the Study Area



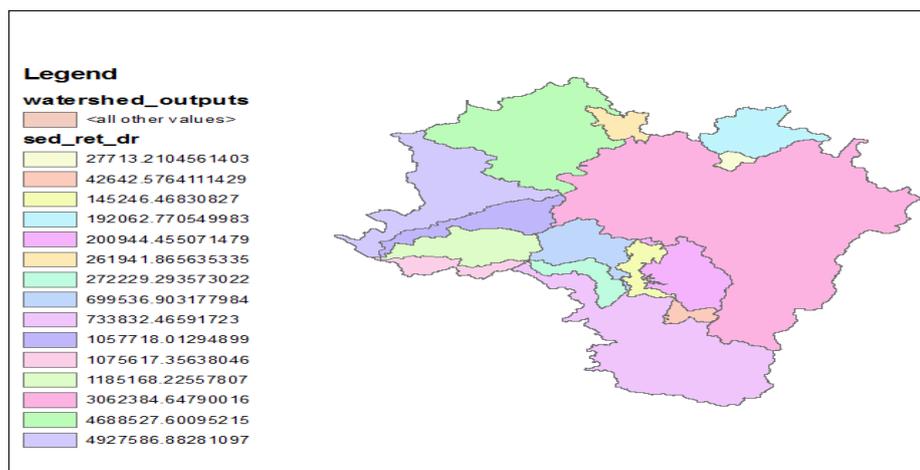
The Sediment Retention output of the model supports the theory that forested areas help in controlling sediment flow in an area. As shown in Figure 41 the sediment retention in the PTR landscape is high across all the watersheds. This is high because of the high amount of vegetation that exists in this region.

The model also validates the statement, that the existence of Periyar Reservoir is dependent on its surrounding forests. As it has been the case that in more than 100 years of the dam's existence, no dredging activity has been undertaken; all because of the sediment retention service provided by PTR.





Figure 41
Sediment Retention in PTR



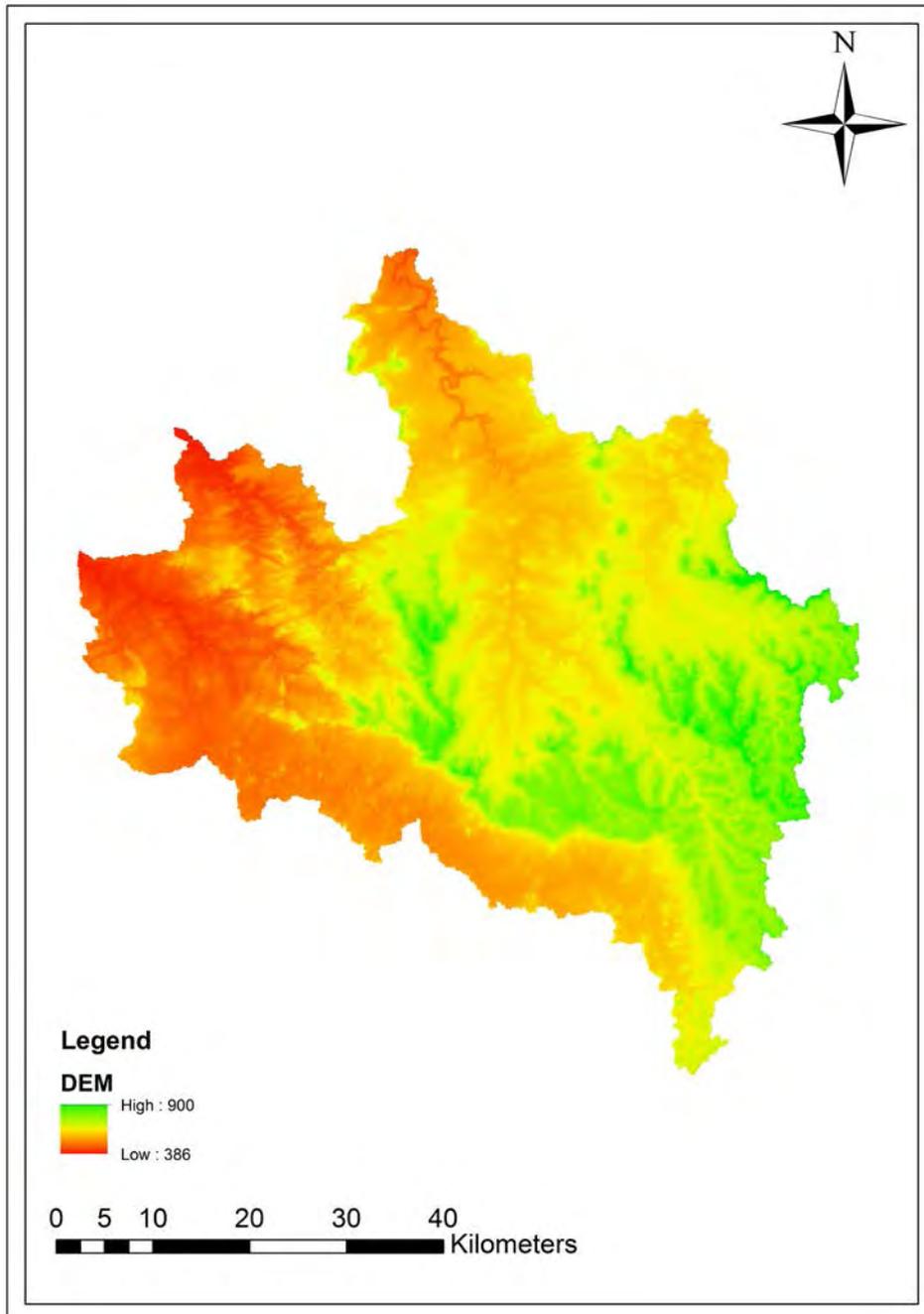
4.4.4 SEDIMENT RETENTION MODEL FOR KANHA TIGER RESERVE

4.4.4.1 INPUTS

This section outlines the map and data tables used to execute the Sediment Retention: Avoided Dredging and Water Purification Model for Kanha Tiger Reserve.

1. Digital Elevation Model (DEM): It is a GIS raster dataset with an elevation value for each cell. For the sediment model Aster DEM at 90m resolution downloaded from USGS was used (Figure 42).

Figure 42
DEM for KTR



As evident from maps, areas inside the tiger reserve are much more effective in avoiding soil erosion compared to areas outside the tiger reserve.

2. Rainfall Erosivity Index (R): R is a GIS raster dataset, with an erosivity index value for each cell. The precipitation layer generated earlier for the water yield model was used to calculate R. R was then calculated using Singh et al., 1981 equation for the country.

$$\text{Avg erosivity} = 79 + (0.363 * \text{avg_annual_P})$$

The map generated using the above equation is as shown in Figure 43.

3. Soil Erodibility (K): K is a GIS raster dataset, with a soil erodibility value for each cell. Soil erodibility, K, is a measure of the susceptibility of soil particles to detachment and

transport by rainfall and runoff. For PTR this was derived from soil texture information provided in the Soil Survey of India data and user table as provided in the InVEST User Guide.

4. Land Use / Land Cover (LULC): Same as used in the Water Yield model.
5. Watersheds: Same as used in the Water Yield model.
6. Biophysical Table: A .csv table containing model information corresponding to each of the land use classes (Table 48).
 - a. lrcode (Land use code): Unique integer for each LULC class
 - b. LULC_desc: Descriptive name of land use/land cover class
 - c. usle_c: Cover-management factor for the USLE, a floating point value between 0 and 1.
 - d. usle_p: Support practice factor for the USLE, a floating point value between 0 and 1.
 - e. sedret_eff: The sediment retention value for each LULC class, as a floating point value 0 and 1.

Figure 43

Erosivity Map of KTR

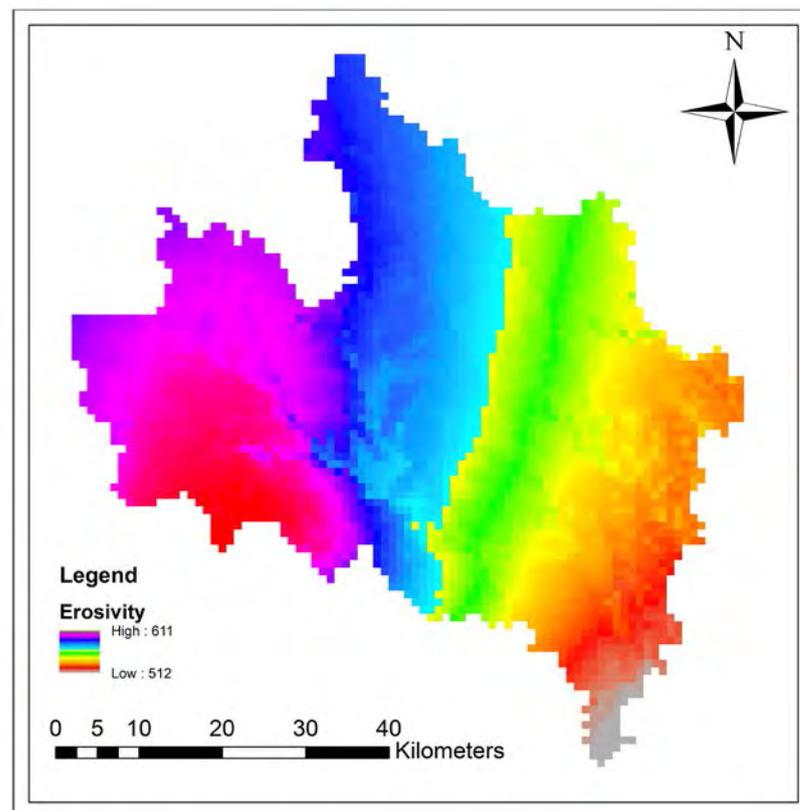




Table 48

Biophysical Table Used in the Sediment Model for KTR

Description	lucode	usle_c	usle_p	sedret_eff
Forest	1	0.004	1	0.8
Agriculture / Fallow Land	2	0.1	0.6	0.8
Habitation	3	0.001	0.9	0.5
Waterlogged Areas	4	0.001	1	0.5
Grasslands	5	0.007	1	0.9

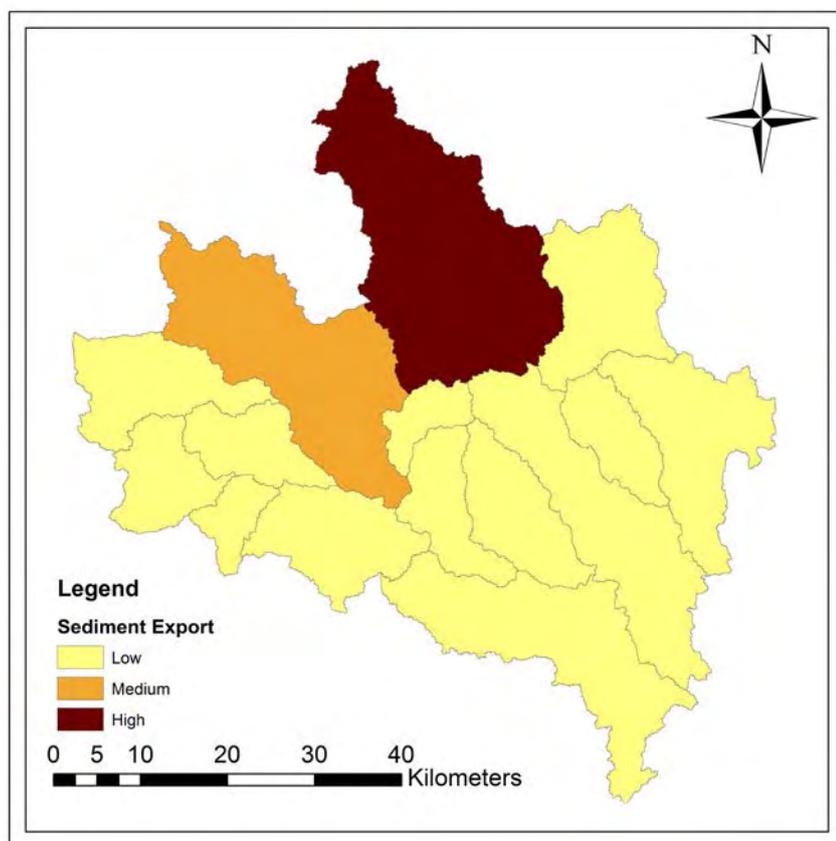
7. Threshold Flow Accumulation: The number of upstream cells that must flow into a cell before it is considered part of a stream, which is used to classify streams in the DEM. For KTR this was determined by doing different iterations and comparing the results with the perennial stream. A value of 200 was found suitable in executing the model.
8. Sediment Threshold Table: A .csv table containing annual sediment load threshold information for each of the reservoirs.
 - a. ws_id: Unique integer value for each reservoir, which must correspond to values in the watersheds layer.
 - b. dr_time: Integer time period corresponding to the remaining designed lifetime of the reservoir (if assessing avoided sedimentation) or the expected time period over which the land use will remain relatively constant. For KTR this was taken as 100 years.
 - c. dr_deadvol: It is a design dimension below which water is not available for any use and it is designed to store (deposit) sediment without hindering turbine and reservoir hydropower functions. For PTR this value was taken as 0 as the dead volume is unknown, and all sediment retained should be counted as an ecosystem service.
 - d. q_annload: Allowed annual sediment loading, used for valuing sediment retention for water quality.

4.4.4.2 OUTPUT

The model provides various outputs for spatial analysis of the area. Figure 44 provides spatial detail of the total sediment exported to the stream per watershed in the study area. The model suggests negligible sediment export from the study area. This is supported by the fact that the silt flow is less in the rivers originating from the reserve.

Figure 44

Sediment Export from the Study Area



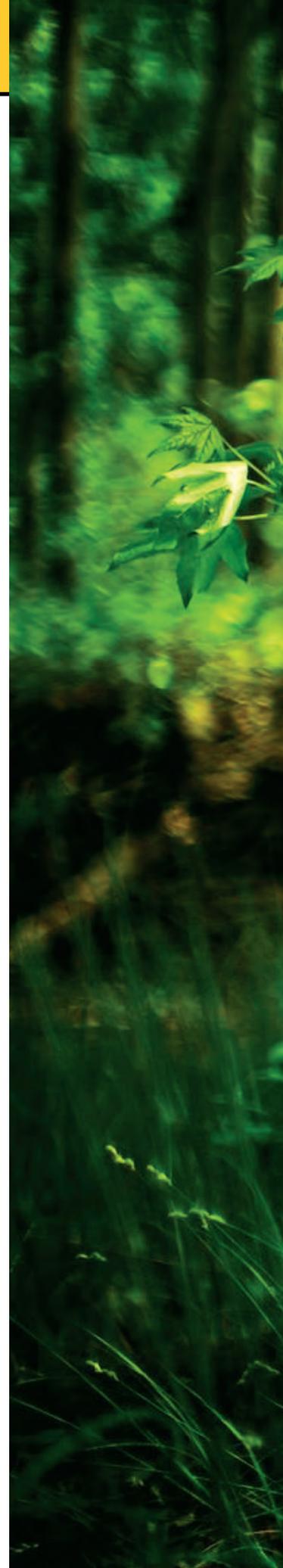
4.4.4 LIMITATIONS AND SIMPLIFICATIONS

The accuracy of the sediment retention value is limited by the quality of information and the user’s ability to calibrate it with actual sedimentation data. The model allows for a calibration constant to be applied and adjusted via the Sediment Delivered output. This can improve the model, but only if the user has access to reliable sedimentation data for the watershed(s) of interest. The USLE method is a standard method to calculate soil loss, but it has several limitations:

- USLE predicts erosion from sheet wash alone (erosion from plains in gentle slopes).
- Rill, gullies and/or stream-bank erosion/deposition processes are not included in this model. Moreover, the relationship between rainfall intensity and kinetic

energy may not hold in mountainous areas because it has only been tested in the American Great Plains. Finally, the equation considers only the individual effect of each variable.

- The model relies on retention or filtration efficiency values for each LULC type. However, there are often few data available locally for filtration rates associated with local LULC types. Data from other regions may be applied in these cases, but may misrepresent filtration by local LULC types.
- The model may not accurately depict the sedimentation process in the watershed of interest since the model is based on parametrization of several different equations and each parametre describes a stochastic process. Owing to the uncertainty inherent in the processes being modelled, it is not recommended to make large-scale area decisions based on a single run of the model.







05

**COST OF INACTION:
RE-CREATING A
TIGER RESERVE**



KEY MESSAGES

While natural landscapes such as tiger reserves in all practicality can never be recreated, the study has made an attempt to estimate the cost of inaction if inadequate protection to existing tiger reserves necessitate establishment of new ones. Based on the objective of maximum conservation gain and minimum human distress, a patch of 1069 km² in the Pilbhit-Dudhwa landscape was identified for a hypothetical exercise and basic minimum costs for establishing a tiger reserve on the patch were estimated.

The major costs involved include land acquisition, rehabilitation, resettlement and habitat development. The conservative cost estimate based on categories of costs included is approximately equal to ₹ 491,800 million, which translates to approximately ₹ 4.62 million hectare⁻¹. It is important to note that the estimate only includes a handful of costs and does not account for many other costs due to paucity of required information. Further, even after incurring such an astronomical cost, it cannot be guaranteed that the new area would be able to conserve genetic repository comparable to any existing tiger reserve.

Further, an online survey to assess the willingness to pay for tiger conservation was also carried out in the study. While this was an attempt to provide an indication of non-use values associated with tiger conservation, limitations in seeking responses from a representative sample and low response rate to the survey meant that the results cannot be extrapolated to draw any meaningful conclusions at the national level. Considering the fact that a large proportion of respondents were willing to pay for tiger conservation, a dedicated study may be required to objectively estimate the same.

Some things in this world, when lost, are lost forever. The human is curious specie and this curiosity of him trying to know everything around him has been the reason science has evolved so much. Things which once looked like a remote possibility have now been turned into a reality. Though this has made life much easier for man without a doubt but it has raised questions on man's own existence on this planet. Moreover it has resulted in making man think of him as the most superior as well as most knowledgeable living entity that ever existed on this planet. For him, he knows everything that happens on this planet, every phenomenon and every process. But the reality is exactly the opposite. He may know a lot about what exists around him, but claiming that he knows everything would be unwise from at least the wisest animal on this planet.

Man has been able to re-create many things but has he really been able to re-create something living? Something that existed once on this planet but has now ceased to exist. Can man bring the dinosaurs or the Giant Mammoth back to life? Probably not! This shows that evolution is one thing on which man still doesn't have a control over and probably won't ever have. But can the brightest minds on the planet ever replicate the process of natural evolution in any possible way? This is one question which only the future may have an answer on. Evolution is such a complex mechanism that understanding it completely is impossible, at least at this point of time. We don't even know about the complete set of entities involved in the evolution process, let alone the way they interact in the ecosystem. Creating an ecosystem again requires the thorough understanding of all these principles. The question again is – are we at all ready to do it?

Similarly re-creating a tiger reserve has been proposed on several occasions. The reason behind this, maybe, is that for people it is just a forest land where tigers live. So probably planting trees, creating

varied canopy density areas, grasslands and a tiger habitat would be done. Next is just probably dropping a few tigers in this area, releasing some herbivores and then tigers would no longer need to fast. This may seem too easy a probability on paper, but a tiger reserve, just like evolution is one complex mechanism, which is not only impossible to create, it would take ages for that area to start becoming one. It is essential for people to see it like as an ecosystem and not just a collection on pieces of a jigsaw. Replication of an ecosystem is not just tough, it is impractical. Though, it is evident from the past experiences that the tiger is a highly robust specie but it still cannot be adjudged that the tiger can survive just anywhere. If this was the case then the 3 species namely Javan, Caspian and Bali Tigers would not have become extinct. Though this fierce, brave and charismatic animal has shown signs of finding a habitat in almost any kind of area in India, sparing very few, it cannot be concluded that it will survive in any habitat man tries to create for it. Proper habitat conditions, sustainable prey population and a composite of good management and protection are just a few of the essential conditions to name, for the tiger to survive and sustain itself.

It is often seen that the areas around tiger reserves in the country boast great productivity in terms of agriculture and horticulture. The reason for this may be seen as the benefits flowing out from these tiger reserves which are impacting the productivity. The ecological services provided by the tiger reserves have a high impact on the surrounding areas. This chapter will discuss on what is needed if a tiger reserve has to be built from scratch. Though it is practically impossible to re-create a new tiger reserve anywhere as the complexity involved in doing so is too high for humans to deal with, but this chapter still tries to derive an approximate and major cost that would be involved in this exercise. Tiger reserves we see in the country today

Would man be able to revive a specie gone extinct?

Probably not!



are forests which have evolved for centuries. Considering the time frame it would require to build a new tiger reserve today, it again seems highly impossible to do this. Moreover there would be man factors which are active in such an area which humans are still unaware of. Science has unfolded a lot about forests but claiming that we know it hundred per cent would not be right.

5.1 NEED FOR THIS TYPE OF ASSESSMENT

This exercise has been carried out to estimate the costs involved in just the establishment of a new tiger reserve. The time factor of the same has not been considered, primarily because we still do not know how much time it would require to raise a tiger habitat from scratch which would evolve like other tiger reserves in India. Another factor that has not been considered in this exercise is the operational cost. It is assumed that once the tiger reserve is established, the operational cost would be borne by the central and state governments, just like the other tiger reserves. It is undisputed that creating new patches of such forest would, in the real world, be ideal on the aspect of conservation only if the existing ones are preserved as well. But the idea of clearing one forest and attempting to re-create the same elsewhere is a far-fetched plan.

Imagine a contiguous patch of forest running more than 68676.47 sq.kms (combining all the tiger reserves in the country)¹⁸⁶. But this is neither practically possible nor ecologically good for the country. In the last few chapters we have been reading about the human services provided by tiger reserves. If all such services were centred at just one part of the country, only the areas in the vicinity would benefit from it. Right now the tiger reserves are scattered throughout the country and rationing their services would involve almost the entire country.

COSTS CONSIDERED

- Land Acquisition
- Rehabilitation & Resettlement
- Habitat Development
- Park Fencing
- Infrastructure
- Tourism-related

5.2 ASSESSMENT OF COSTS

The major cost heads corresponding to the establishment of a tiger reserve from scratch can be the following.

5.2.1 LAND ACQUISITION

Land is a scarce commodity everywhere. In this scenario too acquiring land would be the most complicated as well as most expensive process. Census 2011 data for villages has been used for the calculation of land value to be acquired. The primary land use in the targeted area is agriculture for which the collector approved district land rates have been obtained from the respective district's website. The minimum land rates at each village have then been multiplied by the total area under revenue land including irrigated, non-irrigated and wastelands. Forest area under each village has been excluded as the forests in the region are exclusively owned by the government. Land under canals, rivers and other common properties have also been excluded from being calculated in the total revenue land. The projected land value (minimum) in each sub-district is as shown in Table 49 below.

Table 49

Cost of Land Acquisition in Re-Creating a Tiger Reserve

Sr. No.	District	Sub-District	Number of Villages	Cost (₹ million)
1	Kheri	Palia	140	284,690
2	Pilibhit	Puranpur	53	100,640
Total			193	385,330

The total cost that would be required for the land acquisition is hence projected at ₹ 385,330 million.

5.2.2 REHABILITATION AND RESETTLEMENT

Rehabilitation and Resettlement is one of the most important features of any project. Every project has its own socio-economic impacts. In the case of this exercise, a number of people / families / households will be rendered homeless and would lose their livelihood option which in this case is mainly agriculture. There were a total of 251 villages in the area for which total households were accounted, using the data from the Census 2011. It is assumed that each household would comprise 3.2 families approximately¹⁸⁷. It was assumed that each household would have at least one married couple and the effective “families” (considering the number of adults in a household as one family) would then be 2.2. Hence the numbers of households were multiplied by a factor of 2.2 to get the number of families entitled for compensation.

The compensation that was calculated for relocation is based on the Land Acquisition, Rehabilitation and Resettlement (R&R) Act (2013). The relevant heads of the R&R Act which are applicable in this scenario are indicated in the Table below.

Table 50

Estimation of Compensation Per Family for Re-Creating a Tiger Reserve

Sr. No.	Heads	Cost Per Family (₹)
1	Construction of Houses ¹⁸⁸	25,000
2	Choice of Employment	5,00,000
3	Subsistence Grant for Displaced Families	35,000
4	Transportation Cost	50,000
5	Cattle Shed	25,000
6	One Time Resettlement Allowance	50,000
7	3 rd Schedule Cost (Aggregated)	50,000
Total		7,35,000

Total compensation cost per family is thus estimated to be
₹ 7,35,000

Total compensation per family is thus estimated to be ₹ 7,35,000. Total Compensation for the two sub-districts is as follows:



Table 51

Total Cost of Compensation for Re-Creating a Tiger Reserve

Sr. No.	District	Sub-district	Households	Cost (₹ million)
1	Kheri	Palia	46668	75,450
2	Pilibhit	Puranpur	15811	25,570
Total				101,020

5.2.3 HABITAT DEVELOPMENT

After the land targeted to be the new tiger reserve is finalized, it would need to be converted to a tiger habitat. Converting an agricultural land to forest would have many parameters. Some part of it would need to be afforested with forests with varied canopy density. Other parts would include the creation of grasslands. Grasslands would form an essential part of the reserve as they play a critical role in the sustenance of prey population including the most important ungulates for tigers and other predators. Maintaining a healthy ratio of woodlands and grasslands is an important factor in creating a tiger habitat. The main cost heads in habitat development are as shown below.

Table 52

Assessment of Habitat Development Costs for Re-Creating a Tiger Reserve

Sr. No.	Head	Suggested Ratio	Cost (₹ ha ⁻¹)	Total Area (ha)	Total Cost Required (₹ million)
1	Afforestation	88.2%	48610	93840	4561.5
2	Grassland Development ¹⁸⁹	11.8%	31554	12554	396.1
3	Grassland Fencing ¹⁹⁰ 20% under controlled grazing		20260	250	5.1
4	Creation of Water Holes				10.0
5	Creation of Salt Licks				10.0
Total					4982.7

Approximations for the land use have been taken from the Mapping of National Parks and Wildlife Sanctuaries, Dudhwa Tiger Reserve¹⁹¹.

5.2.4 PARK FENCING

Man-animal conflict is one of the major issues of this area. Currently Pilibhit and Dudhwa Tiger Reserves are facing numerous cases where man-animal conflicts have been reported. It is thus recommended for the tiger reserve area to be fenced so as to reduce such incidents. Added to this are the suggested site runs along the national boundary. Fencing the park would directly mean fencing along the border between Nepal and India which would reduce the infiltration and trespassing. This might also play a significant role in strengthening the national security. Park fencing will allow the movement of animals from the two reserves.

Total cost involved in park fencing would be:

Table 53

Assessment of Fencing Costs for Re-Creating a Tiger Reserve

Sr. No.	Zone	Length (km)	Cost (₹ km ⁻¹)	Cost (₹ million)
1	Along International Boundary	48	50,000	2.4
2	Others	38	50,000	1.9
Total		86		4.3

5.2.5 INFRASTRUCTURE

Re-creating a tiger reserve would involve the establishment of basic infrastructure as well. These might be building for offices and residence or equipment and other assets required for initiating the working of a tiger reserve and its management.

5.2.5.1 BUILDINGS

Buildings are required for the management of a tiger reserve. It should be strategically planned, where to build an office and other establishment so that the entire tiger reserve may be efficiently managed and monitored. Every tiger reserve in the country has a central office with a number of range offices scattered inside the park along with check posts and other posts for forest guards. Other building requirements would comprise animal clinics, residence for forest officials and staff, monitoring stations, laboratories and barracks.

Projected total Cost of Buildings: ₹ 408.0 million.

5.2.5.2 VEHICLES

The uneven terrain of tiger reserves would require specialized vehicles that can run in different terrain types. Ideally vehicles having four wheel drive mechanisms are suited for such a requirement. In India, Gypsies are used extensively at every tiger reserve, be it by officials for forest management or safaris for tourists.

Projected Cost for Vehicles: ₹ 18.5 million.

5.2.5.3 EQUIPMENT

Equipment is a pre-requisite for any forest management. If the forest contains species that need to be conserved, the equipment requirement becomes even more. This equipment would meet the IT requirement for office use like computers, fax, phones, etc as well as forest monitoring equipment including radio units, walkie-talkies, GPS, camera traps and binoculars.

Projected Cost of Equipment: ₹ 12.5 million.

5.2.5.4 ARMS AND AMMUNITION:

Securing the tiger reserve is one of the foremost requirements for the management. The history of India shows it clear and wide that tigers have always been under a high threat from humans. Tiger reserves are still under a huge threat of poaching activities not just for tigers but also other animals like leopard, black-buck, rhinoceros and others. Arms and Ammunition are thus essential to ensure the safety of these reserves.

Projected Cost of Arms and Ammunition: ₹22.1 million.

5.2.6 TOURISM

Tiger is one specie which attracts tourism from all over the world. India is fortunate to have 47 tiger reserves which promote extensive tourism revenue for the country. It has been debated that tourisms at tiger reserves may have negative implications on animal behaviour and increased tourism pressure leads to many other issues. But it cannot be challenged that tourism at these reserves is a major source of revenue which can actually make these parks sustainable. Moreover the guidelines from NTCA allows only 20% of a tiger reserve to be exposed to tourism safeguards natural animal movements and ensures the stability of the forest ecosystem. Tiger reserves in India where the tiger sightings are high for tourists like Bandhavgarh and Ranthambore, the tourism pressure is immense. But the high tourist pressure ensures stable and high revenues to the tiger reserves, which are further invested in the maintenance of the reserve in an efficient manner. To enhance tourism activities, the tiger reserve would need to set up tourism facilities as well. This would include the establishment of lodges, restaurants, tourism vehicles, guides, drivers, and most importantly, tourism plans. The cost units out of these would only be the

building cost such as lodge and restaurant construction, setting and establishing ticket counters etc. The other elements of tourism like vehicles, drivers and guides would not be borne by the government entirely. Approximately 10 vehicles may be bought by the tiger reserve to initiate tourism, which would require 10 drivers and 10 guides. The rest, like the operations of other tiger reserves, private vehicles, fulfilling the criteria set by the park management, may be registered annually having their own drivers and guides (1 for each vehicle). The revenue may be shared by the park for the same based on the trips done by each vehicle. Any other vehicle (non-registered) would not be allowed to enter the park area. The cost of buildings has been included in the infrastructure head, but this has been explained separately to highlight the importance of tourism as a separate entity.

Cost of Tourism Facilities (Buildings): ₹ 52.5 million (included in infrastructure head).

Cost of Vehicles (10 Gypsies): ₹ 6.0 million.

Salaries of Drivers and Guides (annually): ₹ 0.96 million.



5.3 SUMMARY OF COSTS

Table 54

Summary of Costs for Re-Creating a Tiger Reserve

Sr. No.	Head	Total Estimated Cost (₹ million)
1	Land Acquisition	385,330.0
2	Rehabilitation and Resettlement	101,020.0
3	Habitat Development	4982.7
4	Park Fencing	4.3
5	Infrastructure	461.1
6	Tourism (Excluding Buildings)	7.0
Total		491,805.1

The total estimated cost of approximately ₹ 491,800 million for re-creating a tiger reserve with an area of 1064 km² translates to approximately ₹4.62 million ha⁻¹.

5.4 WILLINGNESS TO PAY FOR TIGER CONSERVATION

According to the methodology discussed earlier in Section 2.5.2, the average willingness to pay towards the fund is estimated to be ₹ 141 per month for a period of 5 years, to be included in their monthly electricity bill. The survey output supports the belief that people in the country are willing to contribute towards tiger conservation in the country.

While this was an attempt to provide an indication of non-use values associated with tiger conservation, limitations in seeking responses from a representative sample and low response rate to the survey meant that the results cannot be extrapolated to draw any meaningful conclusions at the national level. Considering the fact that a large proportion of respondents were willing to pay for tiger conservation, a dedicated study may be required to objectively estimate the same.

The total estimated cost of re-creating a tiger reserve with an area of about 1000 square kilometer is estimated to be approximately

₹ 500 billion.

This translates to approximately

₹ 4.6 million

per hectare.



06

**SUMMARY AND
WAY FORWARD**





KEY MESSAGES

The study findings indicate that the monetary value of flow benefits emanating from selected tiger reserves range from ₹ 8.3 to 17.6 billion annually. In terms of unit area, this translates into ₹ 50,000 to 190,000 per hectare per year. In addition, selected tiger reserves protect and conserve stock valued in the range of ₹ 22 to 656 billion.

In the light of growing awareness of life-supporting functions of many ecosystem services and advanced technology to make use of genetic diversity, the economic value of this stock is likely to appreciate rapidly.

Study findings also indicate that a large proportion of flow benefits (as well as stock) are intangible, and hence often unaccounted for in market transaction. Economic valuation can help in recognizing these intangibles and hence have been considered in policy actions.

Further, adequate investment in natural capital contained in tiger reserves is essential to ensure the flow of ecosystem services in future, and is economically rational based on the study findings.

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. A proper understanding 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.

Where justified by broader benefit, economic valuation consequently can help in establishing effective policies and mechanisms for payment of ecosystem services to equitably share benefits and costs of conservation.

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.

Further, it is essential to integrate management of tiger reserves into the broader landscape and enhance / restore ecological connectivity among these tiger reserves and their wide 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.

While tiger reserves are aimed primarily at ensuring the continuity of natural evolutionary processes by protecting natural landscapes with untouched wilderness, they also provide a range of associated economic, social, cultural and spiritual benefits. Tiger reserves support human life by protecting fish nurseries and agricultural genetic material (wild cultivars) and providing cheap, clean drinking and irrigation water from forests. Tiger reserves not only help in mitigating natural disasters such as floods and cyclonic storms, but the genetic material is also a source of many medicines and drugs. Natural and cultural resources in tiger reserves are important driver of tourism, supporting local earnings and employment. In addition, these natural landscapes play an important role in ecosystem-based approaches to climate change adaptation and contribute to mitigation by storing and sequestering carbon. Forty-seven established tiger reserves occupy about 2 per cent of the country's geographical area, but their number and aggregate area have witnessed saturation in recent years.

The study findings indicate that the monetary value of flow benefits emanating from selected tiger reserves range from ₹ 8.3 to 17.6 billion

annually. In terms of unit area, this translates into ₹ 50,000 to 190,000 per hectare per year. In addition, selected tiger reserves protect and conserve stock valued in the range of ₹ 22 to 656 billion. In the light of growing awareness of life-supporting functions of many ecosystem services and advanced technology to make use of genetic diversity, the economic value of this stock is likely to appreciate rapidly. Study findings also indicate that a large proportion of flow benefits (as well as stock) are intangible, and hence often unaccounted for in market transactions. Economic valuation can help in recognizing these intangibles and hence have been considered in policy actions.

Apart from a wide array of provisioning and regulating services, tiger reserves also protect cultural and spiritual resources. While these values are poorly accounted for by markets and methodologies for valuing them have larger challenges as compared to other types of services, nonetheless are immensely important to society. Based on secondary studies, estimated consumer surplus from visiting selected tiger reserves ranges from ₹ 150 to ₹ 2,558

per visit. Religious places situated inside the tiger reserves offer large spiritual benefits. Further, indigenous groups and other traditional owners living in tiger reserves often have invaluable traditional knowledge of using and managing natural resources.

It is also important to bear in mind that selected tiger reserves vary greatly in terms of their ecological and socio-economic context. As a result, the type of ecosystem services emanating from

each tiger reserve and their significance varied greatly. Further, availability of data — both primary and secondary — influenced which ecosystem services were possible to estimate in terms of monetary value, and in some cases, which valuation methodologies were used to estimate these values. As a result, direct comparison of economic values across different tiger reserves is strongly inadvisable. The primary aim of valuation exercise is to recognize important ecosystem services from each tiger reserve, understand their significance in its specific context and hence identify required policy actions to ensure continued flow of benefits in future.

In addition to economic valuation of tiger reserves, the study has also made an attempt to map ecosystem services to two of the selected tiger reserves: Periyar Tiger Reserve and Kanha Tiger Reserve. The results of the exercise are envisaged to assist in identification of ecosystem service hotspots within tiger reserves and thus better equip protected area managers in conservation of such areas. It is proposed that such exercises be carried out for all tiger reserves in India for effective management of tiger reserves.

While natural landscapes such as tiger reserves in all practicality can never be recreated, the study has also made an attempt to estimate the cost of inaction if inadequate protection to existing tiger reserves necessitate establishment of new ones. Based on the objective of maximizing conservation gain and minimizing agricultural area to be acquired, a patch of 1069 km² in Pilbhit-Dudhwa landscape was identified for the exercise and basic minimum costs for establishing a tiger reserve on the patch were estimated. The major costs involved include land



KEY LEARNING

It is strongly suggested to look at economic values in specific context and **not make comparisons** across tiger reserves



POLICY QUESTION

Are Tiger reserves worth conserving?



acquisition, rehabilitation and resettlement and habitat development. The conservative cost estimate based on categories of costs included is approximately equal to ₹ 491,800 million, which translates to approximately ₹ 4.62 million ha⁻¹.

Further, an online survey to assess the willingness to pay for tiger conservation was also carried out in the study. While this was an attempt to provide an indication of non-use values associated with tiger conservation, limitations in seeking responses from a representative sample and low response rate to the survey meant that the results cannot be extrapolated to draw any meaningful conclusions at the national level. Considering the fact that a large proportion of respondents were willing to pay for tiger conservation, a dedicated study may be required to objectively estimate the same.

Tiger reserves are crucial if future generations are to have an opportunity to enjoy natural landscapes that exist today. Additionally, the rate at which society is now recognizing previously unappreciated ecosystem services suggests that unknown option values embedded in these tiger reserves are likely to be immense. These include potential for important new discoveries, e.g. in pharmaceuticals, crop resilience, biomimicry and other areas. Preservation of option values is a significant argument in its own right for managing and expanding network of tiger reserves.

Contrary to the common perception that protected areas are a burden to local populations, the study findings indicate that tiger reserves can be beneficial if the ecosystem services provided by them at the local level are considered. These include provisioning services from buffer areas, ecosystem services accruing at the local level such as pollination, and creation of employment for supporting



park management and tourism. However, where opportunity costs are high, there is a need to establish fair and equitable benefit-sharing mechanisms to offer such costs and provide adequate incentives and motivation for establishment and effective functioning of tiger reserves and thus enhance human well-being on the local, national and global scale.

In order to conserve biological diversity and ensure flow of a wide range of ecosystem services from tiger reserves, it is imperative to expand the network of tiger reserves so as to make them comprehensive and representative. Further, it is essential to integrate management of tiger reserves into the broader landscape

and enhance / restore ecological connectivity among these tiger reserves and their wide environment. Connectivity and exchange of gene-flow are critical for increasing ecosystem resilience, their ability to mitigate environmental risks, e.g. by supporting ecosystem-based adaptation to climate change.

A focus on ecosystem services is also essential 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. Local authorities, including tiger reserve managers, are intermediaries between actors with diverse social

and economic interests. A proper understanding 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 to address conflicts related to tiger reserves. Where justified by broader benefit, economic valuation consequently can help in establishing effective policies and mechanisms for payment of ecosystem services to equitably share benefits and costs of conservation.

Economic valuation can also help in securing stable financial resources to implement and manage tiger reserves by designing appropriate



and innovative funding instruments and ensuring adequate international funding. While there is paucity of information on the current financing gap in tiger reserves, the funding available per unit area is significantly lower than other parts of the globe. Adequate investment in natural capital contained in tiger reserves is essential to ensure flow of ecosystem services in future, and is economically rational based on the study findings.

It is however important to mention here that valuation is not a panacea. Some important values that these tiger reserve protect are difficult to capture through economic analysis, including sacred values of particular places to faith groups, health values of

living inside or near a healthy natural landscape and natural evolution.

The primary objective of the study was to provide initial estimates of the economic value of benefits derived from tiger reserves. Broad assumptions and secondary literature thus had to be used for covering six tiger reserves across the country. The study acknowledges the following major limitations which may be taken note of:

- Not all data required for benefits included in the study were available at all the selected tiger reserves. It was thus not possible to estimate such services in those tiger reserves.
- Further, lack of standardization

and consistency in data collection on various parameters across tiger reserves mean that the economic values derived from this data cannot be compared to other tiger reserves.

- Unavailability of site-specific data on specific input parameters (and constants) both for Valuation and the InVEST model. In such cases, secondary literature and global data has been used.
- Assumptions used and different sources of secondary literature for a particular ecosystem services across tiger reserves mean that the derived estimates for each tiger reserve are incomparable to other tiger reserves.



07

REFERENCES



1. Gutman, P. & Davidson, S. A review of innovative international financial mechanisms for biodiversity conservation with a special focus on the international financing of developing countries' protected areas. WWF-MPO Wash. DC Oct. (2007). at <http://sp10.conservation.org/global/gcf/Documents/rev_int_financial_mechanisms.pdf>
2. Pagiola, S., von Ritter, K. & Bishop, J. Assessing the economic value of ecosystem conservation. (The World Bank, The Nature Conservancy and IUCN - The World Conservation Union, 2004). at <<http://nbsapforum.net/uploads/299.pdf>>
3. Campbell, A., Miles, L., Lysenko, I., Hughes, A. & Gibbs, H. Carbon storage in protected areas: Technical report. U. N. Environ. Programme World Conserv. Monit. Cent. Camb. UK (2008).
4. Phillips, A. Economic values of protected areas: guidelines for protected area managers. (IUCN — The World Conservation Union, Ecosystems, 1998). at <http://cmsdata.iucn.org/downloads/pag_002.pdf>
5. Stolton, S., Mansourian, S. & Nigel Dudley. Valuing protected areas. (The World Bank, 2010).
6. EPA. Valuing the Protection of Ecological Systems and Services: A Report of the EPA Science Advisory Board. (2009). at <[http://yosemite.epa.gov/sab/sabproduct.nsf/WebBOARD/SAB-09-012-Letter/\\$File/Letter%20to%20Administrator.pdf](http://yosemite.epa.gov/sab/sabproduct.nsf/WebBOARD/SAB-09-012-Letter/$File/Letter%20to%20Administrator.pdf)>
7. Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis. (Island Press, 2005).
8. Shuirong, H. Y. W. Recent Progress on Theory & Method of Ecosystem Valuation and Rectification on the Related Concepts Popular in China [J]. *World For. Res.* 5, 003 (2008).
9. Pearce, D. W. The Economic Value of Forest Ecosystems. *Ecosyst. Health* 7, 284–296 (2001).
10. Mace, G. M., Norris, K. & Fitter, A. H. Biodiversity and ecosystem services: a multilayered relationship. *Trends Ecol. Evol.* 27, 19–26 (2012).
11. Simpson, D. Biodiversity prospecting - shopping the wilds is not the key to conservation. *Resources Winter*, 12–15 (1997).
12. Stolton, S., Macted, N., Ford-Lloyd, B., Kell, S. & Dudley, N. Food stores: using protected areas to secure crop genetic diversity. (World Wide Fund for Nature (WWF), 2006).
13. Tisdell, C. Economics and the debate about preservation of species, crop varieties and genetic diversity. *Ecol. Econ.* 2, 77 – 90 (1990).
14. Ehrlich, P. R. & Ehrlich, A. H. The Value of Biodiversity. *Ambio* 21, 219–226 (1992).
15. Gundimeda, H., Sanyal, S., Sinha, R. & Sukhdev, P. The value of biodiversity in India's forests. (Green Indian States Trust, 2006).
16. Holling, C., Schindler, D., Walker, D. & Roughgarden, J. in *Biological diversity: economic and ecological issues* (eds. Perrings, C., Folke, C., Holling, C., Janssen, B. & Maler, K.-G.) 44–83 (Cambridge University Press, 1994).
17. Perrings, C. Resilience in the Dynamics of Economy-Environment Systems. *Environ. Resour. Econ.* 11, 503–520 (1998).
18. Heal, G. M. Economics of biodiversity: an introduction. *Resour. Energy Econ.* 26, 105–114 (2004).
19. Swanson, T. *Global Action for Biodiversity: An International Framework for Implementing the Convention on Biological Diversity*. (Taylor & Francis, 2013). at <<http://books.google.co.in/books?id=lgwfAgAAQBAJ>>

20. Simpson, D. & Sedjo, R. Valuation of biodiversity for use in new product research in a model of sequential search. (RFF, 1996). at <<http://www.rff.org/documents/RFF-DP-96-27.pdf>>
21. Simpson, D. & Craft, A. The social value of using biodiversity in new pharmaceutical product research. (Resources for the Future, 1996). at <<https://www.cbd.int/financial/values/g-valuepharmace.pdf>>
22. Simpson, D., Sedjo, R. & Reid, J. W. Valuing biodiversity for use in pharmaceutical research. *J. Polit. Econ.* **104**, 163–185 (1996).
23. Rausser, G. C. & Small, A. A. Valuing Research Leads: Bioprospecting and the Conservation of Genetic Resources. *J. Polit. Econ.* **108**, 173 (2000).
24. Costanza, R. et al. Changes in the global value of ecosystem services. *Glob. Environ. Change* **26**, 152–158 (2014).
25. FSI. Carbon stock of India's forests. (Forest Survey of India, 2013).
26. Nordhaus, W. Estimates of the social cost of carbon: background and results from the RICE-2011 Model. (Yale University, 2011). at <<http://www.econ.yale.edu/~nordhaus/homepage/documents/CFDP1826.pdf>>
27. Johnson, L. & Hope, C. The social cost of carbon in U.S. regulatory impact analyses: an introduction and critique. *J. Environ. Stud. Sci.* **2**, 205–221 (2012).
28. World Health Organization. Purchasing Power Parity 2005. (2005). at <<http://www.who.int/choice/costs/ppp/en/>>
29. Verma, M., Negandhi, D., Wahal, A. K. & Kumar, R. Revision of rates of NPV applicable for different class/category of forests. (Indian Institute of Forest Management, 2013).
30. Kumar, P., Sanyal, S., Sinha, R. & Sukhdev, P. Accounting for the ecological services of India's forests: soil conservation, water augmentation and flood prevention. (Green Indian States Trust, 2006).
31. Bhatia, R., Kumar, R., Misra, S. & Robins, N. Full-cost pricing of water options and impacts: a case study of the impacts of moving to full-cost pricing on freshwater demand, recycling and conservation at the Tata Steel Company (TISCO), India. (The World Bank, 2000).
32. Mathur, O. P. & Thakur, S. Urban water pricing - setting the stage for reforms. 53 (National Institute of Public Finance and Policy, 2003). at <http://www.nipfp.org.in/media/medialibrary/2013/08/urban_water_pricing.pdf>
33. Pimentel, D. et al. Environmental and Economic Costs of Soil Erosion and Conservation Benefits. *Science* **267**, 1117–1123 (1995).
34. Perrot-Maitre, D. & Esq, P. D. Case studies of markets and innovative financial mechanisms for water services from forests. (Forest Trends, World Resources Institute and The Katoomba Group, 2001). at <http://www.forest-trends.org/documents/files/doc_134.pdf>
35. Johnson, N., White, A. & Perrot-Maitre, D. Developing markets for water services from forests: issues and lessons for innovators. (Forest Trends, World Resources Institute and The Katoomba Group, 2001). at <http://www.forest-trends.org/documents/files/doc_133.pdf>
36. Croitoru, L. How much are Mediterranean forests worth? *For. Policy Econ.* **9**, 536–545 (2007).
37. Verweij, P. et al. Keeping the Amazon forests standing: a matter of values. (WWF, 2009). at <<http://www.wwf.se/source.php/1229304/Keeping%20the%20Amazon%20forests%20standing.pdf>>
38. Ninan, K. N. & Inoue, M. Valuing forest ecosystem services: Case study of a forest reserve in Japan. *Ecosyst. Serv.* **5**, 78–87 (2013).

39. IIED. Valuing forests: a review of methods and applications in developing countries. (International Institute for Environment and Development, 2003). at <<http://pubs.iied.org/pdfs/8116IIED.pdf>>
40. Eshwara Reddy, N. V., Devakumar, A. S., Charan Kumar, M. E. & Madhusudana, M. K. Assessment of nutrient turnover and soil fertility of natural forests of Central Western Ghats. *Int. J. Sci. Nat.* **3**, 162–166 (2012).
41. Kumar, P., Sanyal, S., Sinha, R. & Sukhdev, P. Accounting for the ecological services of India's forests: soil conservation, water augmentation, and flood prevention. (Green Indian States Trust, 2006).
42. Patz, J. A., Graczyk, T. K., Geller, N. & Vittor, A. Y. Effects of environmental change on emerging parasitic diseases. *Int. J. Parasitol.* **30**, 1395–1405 (2000).
43. Vittor, A. Y. et al. The effect of deforestation on the human-biting rate of the anopheles darlingi, the primary vector of falciparum malaria in the Peruvian Amazon. *Am. J. Trop. Med. Hyg.* **74**, 3–11 (2006).
44. FAO. Forests and water: international momentum and action. (Food and Agriculture Organization of the United Nations, 2013).
45. Seth, P. N. Successful tourism management: fundamentals of tourism. **1**, (Sterling Publishers, 1997).
46. Srivastava, P. et al. Tourism Satellite Account for India. (National Council of Applied Economic Research, 2006).
47. Bennett, E. M., Peterson, G. D. & Gordon, L. J. Understanding relationships among multiple ecosystem services. *Ecol. Lett.* **12**, 1394–1404 (2009).
48. Wang, S. & Fu, B. Trade-offs between forest ecosystem services. *For. Policy Econ.* **26**, 145–146 (2013).
49. NTCA. Reserve wise Sanctions. National Tiger Conservation Authority / Project Tiger (2014). at <http://projecttiger.nic.in/content/187_6_ReservewisSanctions.aspx>
50. Qamar Qureshi et al. Evaluating Tiger Habitat: At the Tehsil Level. (Project Tiger Directorate and Wildlife Institute of India, 2006).
51. CTR. Tiger Conservation Plan - Corbett Tiger Reserve. (Corbett Tiger Reserve, 2011).
52. GEO. Ramganga (Kalagarh) Hydro Power Plant India. Global Energy Observatory (2014). at <<http://globalenergyobservatory.org/geoid/5003>>
53. UP Irrigation Department. Project: Ramganga Dam. (2008). at <<http://irrigation.up.nic.in/ptr/ramganga.htm>>
54. Status of the tigers, co-predators and prey in India. 302 (National Tiger Conservation Authority and Wildlife Institute of India, 2010).
55. Johnsingh, A. & Joshua, J. Conserving Rajaji and Corbett National Parks—the elephant as a flagship species. *Oryx* **28**, 135–140 (1994).
56. CTR. Office of the Field Director, Corbett Tiger Reserve. (Corbett Tiger Reserve (CTR), 2014).
57. Yang, W. Y. Methods of farm management investigation. (Food and Agriculture Organization of the United Nations, 1971).
58. Pandey, R. Consumption and valuation of livestock fodder under different forest types of Himalayas, India. *Silva Lusit.* **19**, 195–207 (2011).
59. FSI. Forest Inventory Database. (2013).
60. FSI & PTD. Forest Cover in Tiger Reserves of India - Status and Changes. (Forest Survey of India and Project Tiger Directorate (now called National Tiger Conservation Authority), 2006).

61. Armitage, I. Guidelines for forest management planning. (Food and Agriculture Organization of the United Nations, 1998). at <<http://www.fao.org/docrep/w8212e/w8212e07.htm>>
62. Verma, M., Negandhi, D., Wahal, A. K. & Kumar, R. Revision of rates of NPV applicable for different class/category of forests. (Indian Institute of Forest Management, 2013).
63. IPCC. Good Practice Guidance for Land Use, Land Use Change and Forestry. (Intergovernmental Panel on Climate Change, 2003).
64. Kumari, K. An environmental and economic assessment of forest management options: A case study in Malaysia. 56 (The World Bank, 1995). at <http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/1999/09/14/000178830_98101912360813/Rendered/PDF/multi_page.pdf>
65. GoUP. Perspective and Strategic Plan for Integrated Watershed Management Programme in Uttar Pradesh. (Department of Land Development and Water Resources, 2009).
66. Gol. MSP for kharif crops for 2013-14 season. (2013). at <<http://www.pib.nic.in/newsite/erelease.aspx?relid=96854>>
67. Jin, S., Yu, W., Jansen, H. & Muraoka, R. The impact of irrigation on agricultural productivity: evidence from India. in (IAAE, 2012).
68. Holmes, T. The offsite impact of soil erosion on the water treatment industry. *Land Econ.* **64**, 356–366 (1988).
69. Emerton, L. & Bos, E. Value: counting ecosystems as water infrastructure. 88 (IUCN — The World Conservation Union, Ecosystems, 2004). at <<http://earthmind.net/values/docs/value.pdf>>
70. Jain, S. K., Agarwal, P. K. & Singh, V. P. Hydrology and Water Resources of India. (Springer, 2007). at <<http://books.google.co.in/books?id=-AdqNQEACAAJ>>
71. Emerton, L., Seilava, R. & Pearith, H. Case studies of economic and development linkages: field study report. (International Centre for Environmental Management and IUCN - The World Conservation Union Regional Environmental Economics Programme, 2002).
72. Hansen, L. & Hellerstein, D. The value of the reservoir services gained with soil conservation. *Land Econ.* **83**, 285–301 (2007).
73. Gutman, P. Putting a Price Tag on Conservation: Cost Benefit Analysis of Venezuela's National Parks. *J. Lat. Am. Stud.* **34**, 43–70 (2002).
74. CWC. Handbook for flood protection, anti erosion and river training works. (Flood Management Organisation, Central Water Commission, 2012). at <<http://www.cwc.gov.in/main/downloads/Handbook-05-Jun-12.pdf>>
75. Golley, F. B. in *Tropical Rainforest Ecosystems* (ed. Golley, F. B.) 137–156 (Elsevier, 1983).
76. Jordan, C. F. Nutrient cycling in tropical forest ecosystems. (John Wiley & Sons, 1985).
77. Badola, R. et al. An assessment of ecosystem services of Corbett Tiger Reserve, India. *The Environmentalist* **30**, 320–329 (2010).
78. Pandey, A. N., Pathak, P. C. & Singh, J. S. Water, sediment and nutrient movement in forested and non-forested catchments in Kumaun Himalaya. *For. Ecol. Manag.* **7**, 19–29 (1983).
79. MoCF. Product-wise MRP and Subsidy Rates. Ministry of Chemicals and Fertilizers, Govt. of India (2012). at <<http://fert.nic.in/?q=product-wise-mrp-and-subsidy-rates>>
80. Prasad, K. & Goel, R. S. Environmental Management in Hydro Electric Projects: Proceedings of the National Seminar Held at India International Centre, New Delhi, on November 11 and 12, 1999. (Concept Publishing Company, 2000). at <<http://books.google.co.in/books?id=Gc-zbkAeg0YC>>

81. KTR. Tiger Conservation Plan for Kanha Tiger Reserve (2011-12 to 2020-21). (Kanha Tiger Reserve, 2011).
82. KTR. Office of the Field Director, Kanha Tiger Reserve. (Kanha Tiger Reserve (KTR), 2014).
83. WWF. Assessment of fuelwood consumption in Kanha Pench Corridor, Madhya Pradesh. (WWF India, 2014). at <http://awsassets.wwfindia.org/downloads/sml_factsheet_28_4.pdf>
84. Vasudha. Mandla District Energy Plan Report. (Vasudha Foundation, 2012). at <<http://www.vasudha-foundation.org/wp-content/uploads/3-DRAFT%20Energy%20Plan%20for%20Mandla%20District,Madhya%20Pradesh.pdf>>
85. ICIMOD. Resource Dynamics Project - Annual Reports 2000, 2001, 2002, 2003, 2004. (International Centre for Integrated Mountain Development, 2004).
86. PARDYP. People and Resource Dynamics - Annual Reports 1998-2004. (G. B. Pant Institute of Himalayan Environment and Development, 2004).
87. Verma, M. & Mishra, M. Forest resource accounting and economic valuation of forests of Madhya Pradesh: a case study of Kanha National Park. (Indian Institute of Forest Management, 2010).
88. Vasu, N. K. Kaziranga Tiger Reserve Tiger Conservation Plan (2013-14 to 2022-23). (Kaziranga Tiger Reserve (KZTR), 2013).
89. KZTR. Office of the Field Director, Kaziranga Tiger Reserve. (Kaziranga Tiger Reserve (KZTR), 2014).
90. Biswas, S. & Boruah, S. Fisheries ecology of the northeastern Himalayas with special reference to the Brahmaputra River. *Ecol. Eng.* **16**, 39–50 (2000).
91. Wakid, A. & Braulik, G. Protection of Endangered Ganges River Dolphin in Brahmaputra River, Assam, India. Rep. IUCN Gland Switz. (2009).
92. Wakid, A. Status and distribution of the endangered Gangetic dolphin (*Platanista gangetica gangetica*) in the Brahmaputra River. *Curr. Sci.* **97**, (2009).
93. Hussain, S. A. et al. An Analysis Of Livelihood Linkages Of Tourism In Kaziranga National Park, A Natural World Heritage Site In India. *PARKS* **18**, 32 (2012).
94. Bharali, A. & Mazumder, R. Application of travel cost method to assess the pricing policy of public parks: the case of Kaziranga National Park. *J. Reg. Dev. Plan.* **1**, 44–52 (2012).
95. Muley, P. Genetic and morphometric studies to differentiate between wild and domestic Asian water buffaloes (*Bubalus bubalis*) and their hybrids in Kaziranga National Park. Assam India. (University of Wisconsin-Madison, 2001).
96. Banerjee, G. Habitat use by the Great India One-horned rhino (*Rhinoceros unicornis*) and other sympatric species in Kaziranga National Park, Assam India. (Wildlife Institute of India, 2001).
97. Srivastava, R. J. Natural Resources uses and park-people relations at Kaziranga National Park and world heritage site, India. (University of Florida, 2002).
98. Jyothis, S. Willingness to participate in biodiversity conservation in Periyar Tiger Reserve: a contingent valuation. (2000).
99. Supreme Court of India. *Mullaperiyar Environmental Protection Forum v. Union of India (UOI) and Ors.* AIR2006SC1428, 2006(2)SCALE680, (2006)3SCC643 (2006). at <<http://www.ielrc.org/content/e0609.pdf>>
100. Shukla, R. R. Tiger Conservation Plan - Periyar Tiger Reserve. 735 (Periyar Tiger Reserve, 2011).
101. Supreme Court of India. *State of Tamil Nadu v. State of Kerala and Anr.* (2014). at <<http://supremecourtindia.nic.in/outtoday/41511.pdf>>

102. Franz, M. & Hassler, M. The value of commodity biographies: integrating tribal farmers in India into a global organic agro-food network. *Area* **42**, 25–34 (2010).
103. Champion, H. & Seth, S. *A Revised Survey of the Forest Types of India*. (Manager of Publications, 1968).
104. FSI. *Atlas of Forest Types of India*. (Forest Survey of India, 2011).
105. Luysaert, S. et al. Old-growth forests as global carbon sinks. *Nature* **455**, 213–215 (2008).
106. Nayar, M. P. *Hot spots of endemic plants of India, Nepal and Bhutan*. (Tropical Botanic Garden and Research Institute, 1996).
107. Ramachandran, K. K. P., Nair, V. N. P. & Easa, P. S. Ecology of larger mammals of Periyar Wildlife Sanctuary. *J. Bombay Nat. Hist. Soc.* **83**, 505–524 (1987).
108. Mohammed, P. J., Bhardwaj, A. K., Peeyuskutty, K. J. & Zacharias, V. J. Studies on the aquatic birds in Periyar Lake, Kerala. *Indian For.* **123**, 929–934 (1997).
109. Zacharias, V. J. & Bhardwaj, A. K. A preliminary list of Amphibian fauna of Periyar Tiger Reserve Thekkady, Kerala. *Indian For.* **122**, 247–249 (1996).
110. Zacharias, V. J., Bhardwaj, A. K. & Jacob, P. C. Fish fauna of Periyar Tiger Reserve. *J. Bombay Nat. Hist. Soc.* **91**, 39–43 (1996).
111. Elamon, S. *Butterflies of Periyar Tiger Reserve*. (1995).
112. Sasidharan, N. *Studies on the flora of Periyar Tiger Reserve*. 558 (Kerala Forest Research Institute, 1998).
113. Mallick, A. *Periyar Tiger Reserve*. (2014).
114. Balasubramanian, M. & Veeramani, A. *Ecodevelopment in Periyar Tiger Reserve: an assessment of resource dependency and ecological impact of local community*. 44 (Periyar Foundation, 2012).
115. Sáenz, L. & Mulligan, M. The role of Cloud Affected Forests (CAFs) on water inputs to dams. *Ecosyst. Serv.* **5**, 69–77 (2013).
116. GoTN. *Statistical handbook of Tamil Nadu*. (Department of Economics and Statistics, Government of Tamil Nadu, 2013). at <<http://www.tn.gov.in/deptst/index.htm>>
117. TNAU. *Minimum Support Price*. (2014). at <http://agritech.tnau.ac.in/pdf/2013/MSP_2013-14.pdf>
118. GEO. *Periyar Hydroelectric Power Project India*. Global Energy Observatory (2014). at <<http://globalenergyobservatory.org/geoid/4756>>
119. Madras High Court. *S.Mp Amalan vs The State Of Tamilnadu*. WRIT PETITION (MD) No.20935 of 2013 and WRIT PETITION (MD) No.20939 of 2013 and 111 of 2014 and M.P.(MD)Nos.1 of 2013 in W.P.(MD)No.20935 of 2013 and 1 of 2014 in W.P.(MD)No.111 of 2014 W.P.(MD)No.20935/2013 (2014). at <<http://www.indiankanoon.org/doc/127544179/>>
120. Prasannakumar, V., Vijith, H., Abinod, S. & Geetha, N. Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology. *Geosci. Front.* **3**, 209–215 (2012).
121. Sankar, S. *Nutrient partitioning in an evergreen forest ecosystem*. 17 (Kerala Forest Research Institute, 1990).
122. Periyar Foundation. *Revenue collection (2012-13)*. (2014).
123. Manoharan, T. R., Muraleedharan, P. K. & Anitha, V. in *Basic readings in Forest Economics* (eds. Muraleedharan, P. K., Subramanian, K. K. & Pillai, P. P.) 77–95 (Kerala Forest Research Institute, 1998).

124. Bulov, S. & Lundgren, T. An economic evaluation of Periyar National Park - a travel cost approach. (Lulea University of Technology, Department of Economics, 2007).
125. MoC. Wholesale Price Index. Office of the Economic Adviser to the Government of India Ministry of Commerce and Industry (2014). at <<http://eaindustry.nic.in/>>
126. Libison, K. B. & Muraleedharan, K. P. Economic benefits of pilgrimage tourism: a case study of Sabarimala Pilgrimage with special reference to Pandalam Rural Locality in Kerala (India). *South Asian J. Tour. Herit.* **1**, 57–64 (2008).
127. Pettorelli, N. et al. Tracking the effect of climate change on ecosystem functioning using protected areas: Africa as a case study. *Ecol. Indic.* **20**, 269–276 (2012).
128. RTR. Tiger Conservation Plan for Ranthambore Tiger Reserve (2013-14 to 2022-23). (Ranthambore Tiger Reserve (RTR), 2013).
129. Nair, T. & Krishna, Y. C. Vertebrate fauna of the Chambal River basin, with emphasis on the National Chambal Sanctuary, India. *J. Threat. Taxa* **5**, 3620–3641 (2013).
130. RTR. Office of the Field Director, Ranthambore Tiger Reserve. (Ranthambore Tiger Reserve (CTR), 2014).
131. Wheeler, M. 'The role the tiger plays in local economies. (2009).
132. Hironi, K. Landuse Planning and Geomorphology: A Study of Sawai Madhopur. (Concept Publishing Company, 1991). at <http://books.google.co.in/books?id=ziXB5_b1h3UC>
133. STR. Tiger Conservation Plan: Sundarban Tiger Reserve - 2012-13 to 2016-17. (Sundarban Tiger Reserve (STR), 2012).
134. Alfred, J. R. B. & Ramakrishna. Faunal diversity of tiger reserves in India (a commemorative volume of three decades of Project Tiger). **2**, (Zoological Survey of India and The Project Tiger, 2006).
135. Sanjappa, M., Singh, D. K., Singh, P. & Gopal, R. Floristic diversity of tiger reserves of India. (Botanical Survey of India, 2008).
136. Mitra, A. & Pal, S. The oscillating mangrove ecosystem and the Indian Sundarbans. (WWF-India, 2002).
137. Banerjee, K., Mitra, A., Bharracharyya, D. P., Das, K. L. & Choudhry, A. A preliminary study of phytoplankton diversity and water quality around Haldia Port-cum-Industrial Complex. (*Nat. Sem. Port. Environ.*, 2000).
138. Hazra, S. Temporal change detection (2001-2008) study of Sundarban. (School of Oceanographic Studies, Jadavpur University and WWF-India, 2010).
139. Building resilience for sustainable development of the Sundarbans: strategy report. (The World Bank, 2014).
140. STR. Office of the Field Director, Sundarban Tiger Reserve. (Sundarban Tiger Reserve (STR), 2014).
141. Ratul Saha. Personal communication. (2014).
142. Dasgupta, S. Sundarban Tiger Reserve. (2014).
143. Anurag Danda. Personal communication. (2014).
144. Lee, S. Y. et al. Ecological role and services of tropical mangrove ecosystems: a reassessment: Reassessment of mangrove ecosystem services. *Glob. Ecol. Biogeogr.* **23**, 726–743 (2014).
145. Mukherjee, J., Ray, S. & Ghosh, P. B. A system dynamic modeling of carbon cycle from mangrove litter to the adjacent Hooghly estuary, India. *Ecol. Model.* **252**, 185–195 (2013).

146. Mitra, A., Sengupta, K. & Banerjee, K. Standing biomass and carbon storage of above-ground structures in dominant mangrove trees in the Sundarbans. *For. Ecol. Manag.* **261**, 1325–1335 (2011).
147. Mitra, A., Sengupta, K. & Banerjee, K. Spatial and Temporal Trends in Biomass and Carbon Sequestration Potential of *Sonneratia apetala* Buch.-Ham in Indian Sundarbans. *Proc. Natl. Acad. Sci. India Sect. B Biol. Sci.* **82**, 317–323 (2012).
148. K. Sengupta et al. Spatial variation of stored carbon in *Avicennia alba* in Indian Sundarbans. *Discov. Nat.* **3**, 19–24 (2013).
151. Ray, R. et al. Carbon sequestration and annual increase of carbon stock in a mangrove forest. *Atmos. Environ.* **45**, 5016–5024 (2011).
152. Phillips, O. L. et al. Changes in the Carbon Balance of Tropical Forests: Evidence from Long-Term Plots. *Science* **282**, 439–442 (1998).
153. Badola, R. & Hussain, S. A. Valuation of the Bhitarkanika mangrove ecosystem for ecological security and sustainable resource use. (Wildlife Institute of India, 2003). at <http://www.irade.org/eerc/pdf/WB_FR_RuchiBadola.pdf>
154. MoCF. Product-wise MRP and Subsidy Rates. Ministry of Chemicals and Fertilizers, Govt. of India (2012). at <<http://fert.nic.in/?q=product-wise-mrp-and-subsidy-rates>>
155. Das, S. & Crépin, A.-S. Mangroves can provide protection against wind damage during storms. *Estuar. Coast. Shelf Sci.* **134**, 98–107 (2013).
156. Kathiresan, K. & Rajendran, N. Coastal mangrove forests mitigated tsunami. *Estuar. Coast. Shelf Sci.* **65**, 601–606 (2005).
157. Williams, N. Tsunami insight to mangrove value. *Curr. Biol.* **15**, R73 (2005).
158. EJF. Mangroves: nature's deference against Tsunamis - A report on the impact of mangrove loss and shrimp farm development on coastal defences. (Environmental Justice Foundation, 2006). at <http://ejfoundation.org/sites/default/files/public/tsunami_report.pdf.PdfCompressor-1022348.pdf>
159. Alongi, D. M. Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuar. Coast. Shelf Sci.* **76**, 1–13 (2008).
160. Dudley, N. et al. Natural solutions: protected areas helping people cope with climate change. (IUCN-WCPA, TNC, UNDP, WCS, The World Bank and WWF, 2010). at <http://cmsdata.iucn.org/downloads/natural_solutions.pdf>
161. WWF. Sundarbans: Future Imperfect. (WWF India, 2010).
162. Sathirathai, S. Economic valuation of mangroves and the roles of local community in the conservation of natural resources: case study of Surat Thani, south of Thailand. (EEPSEA, 1998). at <<http://idl-bnc.idrc.ca/dspace/bitstream/10625/15261/39/108378.pdf>>
163. Das, S. & Vincent, J. R. Mangroves protected villages and reduced death toll during Indian super cyclone. *Proc. Natl. Acad. Sci.* **106**, 7357–7360 (2009).
164. Badola, R. & Hussain, S. A. Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environ. Conserv.* **32**, 85–92 (2005).
165. MoHA. Census of India. Census of India (2011). at <<http://censusindia.gov.in/>>
166. Barbier, E. & Strand, I. Valuing Mangrove-Fishery Linkages – A Case Study of Campeche, Mexico. *Environ. Resour. Econ.* **12**, 151–166 (1998).
167. Barbier, E. B. Valuing the environment as input: review of applications to mangrove-fishery linkages. *Ecol. Econ.* **35**, 47–61 (2000).

168. Nagelkerken, I. & Faunce, C. H. What makes mangroves attractive to fish? Use of artificial units to test the influence of water depth, cross-shelf location, and presence of root structure. *Estuar. Coast. Shelf Sci.* **79**, 559–565 (2008).
169. Tse, P., Nip, T. H. M. & Wong, C. K. Nursery function of mangrove: A comparison with mudflat in terms of fish species composition and fish diet. *Estuar. Coast. Shelf Sci.* **80**, 235–242 (2008).
170. Aburto-Oropeza, O. et al. Mangroves in the Gulf of California increase fishery yields. *Proc. Natl. Acad. Sci.* **105**, 10456–10459 (2008).
171. Lal, P. Conservation or conversion of mangroves in Fiji: an ecological economic analysis. 108 (East-West Environment and Policy Institute, 1990).
172. De Graaf, G. J. & Xuan, T. T. Extensive shrimp farming, mangrove clearance and marine fisheries in the southern provinces of Vietnam. *Mangroves Salt Marshes* **2**, 159–166 (1998).
173. Guha, I. & Ghosh, S. A glimpse of the tiger: how much are Indians willing to pay for it? (South Asian Network for Development and Environmental Economics, 2009).
174. UNEP. The importance of mangroves to people: a call to action. (United Nations Environment Programme World Conservation Monitoring Centre, 2014). at <<http://www.unep-wcmc.org/medialibrary/2013/07/29/7e06f93d/Options%20for%20REDD%202013%20lowres%20complete%202.pdf>>
175. MoUD. Jawaharlal Nehru National Urban Renewal Mission. (2014). at <<http://jnurm.nic.in/>>
176. Tallis, H. T. et al. InVEST 3.0.0 User's Guide. The Natural Capital Project. (Natural Capital Project, 2013).
177. Asmal, K. & others. Dams and development: a new framework for decision-making. The report of the World Commission on dams. *Dams Dev. New Framew. Decis.-Mak. Rep. World Comm. Dams* (2000).
178. Ennaanay, D. Impacts of land use changes on the hydrologic regime in the Minnesota River basin. (University of Minnesota, 2006. Major: Water resources science., 2006).
179. Fu, B. On the calculation of the evaporation from land surface. *Sci Atmos Sin* **5**, 23–31 (1981).
180. Zhang, L. et al. A rational function approach for estimating mean annual evapotranspiration. *Water Resour. Res.* **40**, (2004).
181. Allen, R. G., Pereira, L. S., Raes, D., Smith, M. & others. Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *FAO Rome* **300**, (1998).
182. Donohue, R. J., Roderick, M. L. & McVicar, T. R. Roots, storms and soil pores: Incorporating key ecohydrological processes into Budyko's hydrological model. *J. Hydrol.* **436**, 35–50 (2012).
183. Yang, H., Yang, D., Lei, Z. & Sun, F. New analytical derivation of the mean annual water-energy balance equation. *Water Resour. Res.* **44**, (2008).
184. Wischmeier, W. H., Smith, D. D. & others. Predicting rainfall erosion losses-A guide to conservation planning. *Predict. Rainfall Eros. Losses- Guide Conserv. Plan.* (1978).
185. Desmet, P. & Govers, G. A GIS procedure for automatically calculating the USLE LS factor on topographically complex landscape units. *J. Soil Water Conserv.* **51**, 427–433 (1996).
186. National Tiger Conservation Authority. List of Tiger Reserves Core & Buffer Areas. at <http://projecttiger.nic.in/content/109_1_ListofTigerReservesCoreBufferAreas.aspx>
187. Household Consumer Expenditure and Employment - Unemployment Situation in India. (National Sample Survey Organisation Ministry of Statistics & Programme Implementation, Government of India, 2003).

188. Gopalan, S. V., Nair, A., Kumar, K. S., Merilä, J. & George, S. Morphology of *Indirana semipalmata* (Boulenger, 1882)(Amphibia; Anura) adults and tadpoles from the Western Ghats, India. *Herpetol. Notes* 5, 263–273 (2012).
189. NAP. National Afforestation Programme Guidelines. (Ministry of Environment & Forests, Govt. of India, 2009).
190. National Bank for Agriculture and Rural Development (NABARD). Power Fencing. NABARD-Power Fencing at <<https://www.nabard.org/english/power2.aspx>>
191. P K Mathur & Neha Midha. in *Mapping of National Parks and Wildlife Sanctuaries IV*, (Wildlife Institute of India, 2008).





01

APPENDIX



**APPENDIX 1 –
METHODOLOGY WORKSHOP NOTE
METHODOLOGY WORKBOOK
ON
ECONOMIC VALUATION OF
TIGER RESERVES IN INDIA**

24-25th March 2014

India International Centre, New Delhi

Supported by:



National Tiger Conservation Authority

Executed by:



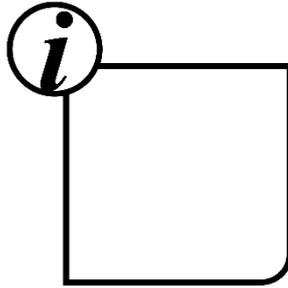
प्रगते: मूलं प्रकृति:

**Centre for Ecological Services Management,
Indian Institute of Forest Management**

**PLEASE RETURN THE FILLED-IN WORKBOOK BEFORE LEAVING THE WORKSHOP.
SIGNS USED IN THE WORKBOOK**

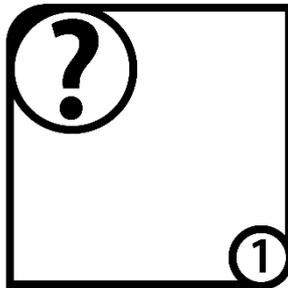
IMPORTANT INFORMATION

This refers to an important information which the reader may take note of. The sign is used for key concepts used, important assumptions made and other important arguments.



DISCUSSION POINT

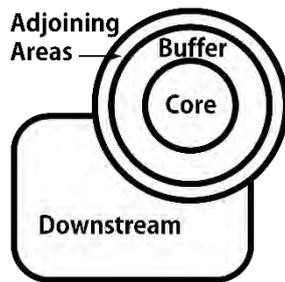
This refers to a discussion point. Based on our review and field visits, these are the points where we would like all stakeholders to discuss and give their comments. At each of these points, space is provided where you can give your suggestions. **Your agreement or disagreement with our proposal on this point accompanied with focused argument will be greatly appreciated. We would assume by default that the suggestion is general in nature and would apply to all tiger reserves. If your suggestion is for a specific tiger reserve, kindly mention it clearly within your comment.** If you need more space than provided, kindly use blank sheets at the end of the workbook and mention the discussion point number (on lower right) of your response. Your suggestions will help us greatly to modify the methodology appropriately.



VALUATION BOUNDARY

This refers to the spatial scope of valuation. Ecosystem services may accrue beyond the administrative boundaries. The core and buffer in the sign refers to the notified core and buffer of a tiger reserve. A 5 kilometer area around the tiger reserve is termed as the adjoining area.

A region apart from notified core, notified buffer and adjoining area which benefits from a particular ecosystem service is termed as the “downstream” region. Although the term “downstream” has a hydrological connotation, the term is used in a much broader sense here. **The sign would accompany each ecosystem service discussion and the greyed area relates to the spatial scope of economic**



valuation proposed for that ecosystem service. If you have suggestions in this regard, kindly use the space after each ecosystem service discussion to provide your responses. A more detailed explanation on the concept and its description is also provided in the Section on Methodological Framework.

RATIONALE

The tiger is a unique animal which plays a pivotal role in the health and diversity of an ecosystem. It is a top predator and is at the apex of the food chain. Therefore the presence of tigers in the forest is an indicator of the well-being of the ecosystem. Protection of tigers in forests also protects habitats of several other species. In addition, indirect benefits of tiger conservation include protection of rivers and other water sources, prevention of soil erosion and improvement of ecosystem services like pollination, ground water recharge and a range of other services which benefit mankind.

While conservation initiatives till now have largely focused on in-situ conservation of tigers by establishing tiger reserves in India, an important aspect that needs further research is the economic contribution of tiger reserves to the national economy by ensuring the flow of essential ecosystem services. In addition to conservation of this flagship species, many life-supporting services emanate from these tiger reserves which not only benefit the human population residing in the vicinity but also the country at large which needs to be estimated and internalized.



Tiger is an umbrella species. Its conservation leads to conservation of other species and ecosystems.

OBJECTIVES

General Objective

Estimate the economic value of 6 tiger reserves in India to highlight their contribution to the national economy using objective and scientific parameters.

Specific Objectives

 Estimate the economic value of ecosystem services

using scientific and objective parameters emanating from 6 tiger reserves namely: 1) Corbett Tiger Reserve; 2) Kanha Tiger Reserve; 3) Periyar Tiger Reserve; 4) Kaziranga Tiger Reserve; 5) Sunderbans Tiger Reserve; and 6) Ranthambore Tiger Reserve;

-  Model the impact of change in tiger population in these tiger reserves on the economic value of ecosystem services from them and its significance for the national economy;
-  Identify the distribution of economic value of tiger reserves for different stakeholders and how it would change if tiger population changes

PREVIOUSLY ACCOMPLISHED WORK

The Centre for Ecological Services Management at the Indian Institute of Forest Management has been involved in research studies that have fed into important policies at the national level. A recently accomplished study on Recalculation

of Net Present Value Rates for different class/category of Forests conducted for the Ministry of Environment & Forests, Govt. of India has estimated the economic value of forest diversion on the basis of loss of 12 ecosystem services from forests. While the current study seeks to estimate the economic value of conservation, some cues can be taken from the NPV study, which actually provided the inspiration to take up the study on economic valuation of tiger reserves. A list of ecosystem services to be considered in this study along with their definition and the approach used for estimation & valuation of those considered in the NPV study are as follows:



The NPV study estimated the value of forest diversion while this study seeks to estimate the value of conservation.

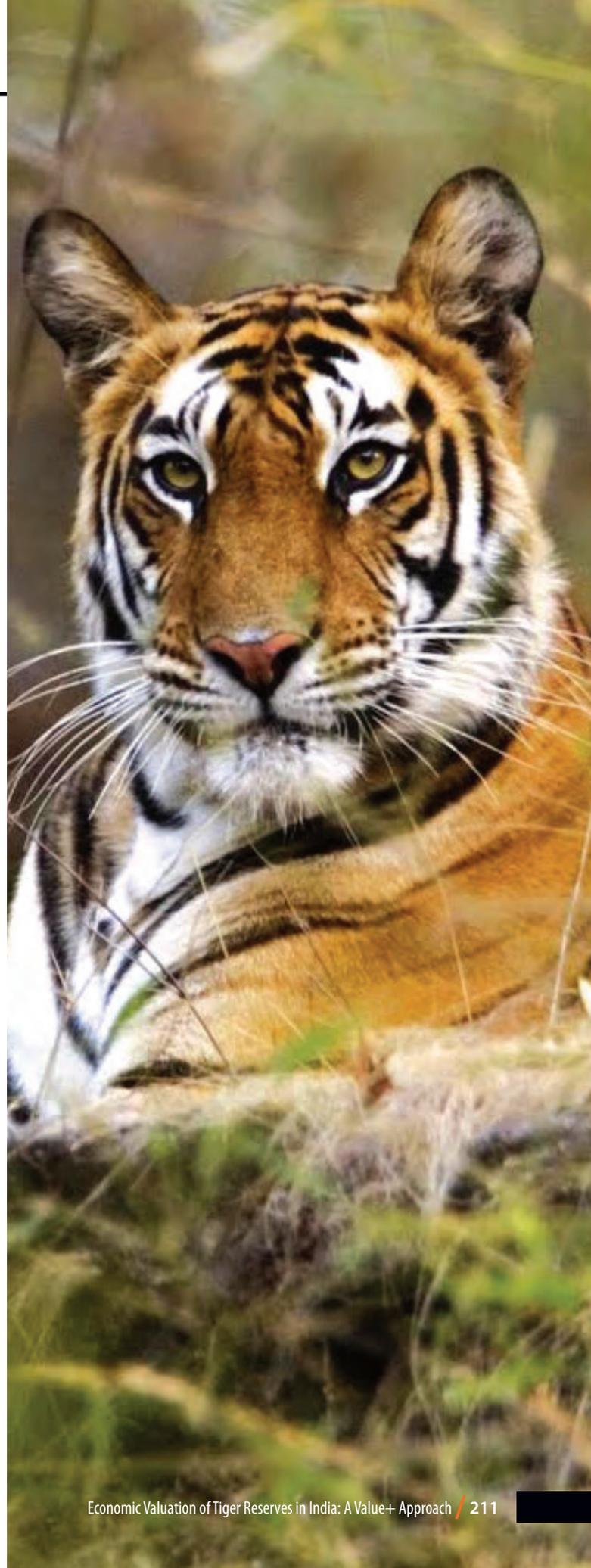


Table 55

– List of ecosystem Services considered for the study

Ecosystem service	Description in the context of the current study	Approach used for valuation in the NPV study
Food	Food that people obtain from highly managed systems inside the tiger reserve such as crops, livestock, fisheries and aquaculture as well as harvesting of wild plants and animals.	NOT CONSIDERED
Fuel wood	Extraction and consumption of fuel wood from tiger reserve for cooking and heating purpose.	Consumption based on state-wise collection of fuel wood from forests
Fodder	Provisioning of grazing services for livestock of local community.	Consumption by total Adult Cattle Units completed dependent on forests for grazing
Timber	Timber is used for a variety of building, manufacturing and other needs. Although no harvesting of timber is taking place right now inside the tiger reserve, this represents a stock of resource which needs to be valued.	Estimation of mean annual increment from the growing stock estimates
NWFPs	These include goods of biological origin other than wood derived from tiger reserve.	Production of 12 major NWFPs
Bioprospecting & gene-pool	A wide variety of species – plants, animals and microbial – and their genes contribute to commercial products in such industries as pharmaceuticals, botanical medicines, crop protection, cosmetics, horticulture, agricultural seeds, and a variety of manufacturing and construction sectors. Genetic diversity distinguishes different breeds or races from each other thus providing the basis for locally well-adapted cultivars and a gene pool for further developing commercial crops and livestock.	Results of Rauser and Small (2000) model based on state-wise total number of plant species
Carbon storage	Ecosystems in the tiger reserve act as sinks of greenhouse gas and thereby help in mitigating the perilous effects of climate change. Similarly to timber, the stock of carbon already present in the tiger reserve has a very important storage function.	State-wise carbon stock in various pools
Carbon sequestration	As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues. This is the flow function of ecosystems in the tiger reserve which act as sinks of greenhouse gases that annually sequestration large amounts of carbon from the atmosphere.	Annual carbon sequestered based on growing stock estimates and IPCC methodology
Water flow regulation	The tiger reserves play a vital role in the regional hydrological cycle, as they regulate the flow and purification of water. Vegetation and forests influence the quantity of water available locally.	Simple water balance equation to estimate water recharge
Water purification		Benefits –transfer approach used to adjust the values derived in other countries

Ecosystem service	Description in the context of the current study	Approach used for valuation in the NPV study
Moderation of extreme events	Tiger reserves play important roles in modulating the effects of extreme events on human systems. The reserves affect both the probability and severity of events, and they modulate the effects of extreme events. For e.g. forest soils store large amounts of water, facilitate transfer of surface water to groundwater, and prevent or reduce flooding. Mangroves, wetlands and lakes attenuate floods by absorbing runoff peaks and storm surges.	NOT CONSIDERED
Soil conservation and maintenance of soil fertility		Avoided loss of nutrients (nitrogen, potassium and phosphorus) due to soil erosion
Pollination & seed dispersal	Insects and wind pollinate plants and trees which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds and bats. Some 87 out of the 115 leading global food crops depend upon animal pollination including important cash crops such as cocoa and coffee.	Replacement cost of natural forest regeneration by National Afforestation Programme
Biological control	Ecosystems within the tiger reserves are important for regulating pests and vector borne diseases that attack plants, animals and people. These ecosystems regulate pests and diseases through the activities of predators and parasites. Birds, bats, flies, wasps, frogs and fungi all act as natural controls and help in reducing the incidence of various infectious diseases.	NOT CONSIDERED
Habitat for species	Habitats provide everything that an individual plant or animal needs to survive: food; water; and shelter. Each ecosystem provides different habitats that can be essential for a species' lifecycle. Migratory species including birds, fish, mammals and insects all depend upon different ecosystems during their movements.	NOT CONSIDERED
Recreation & tourism	Ecosystems and biodiversity play an important role for many kinds of tourism which in turn provides considerable economic benefits and is a vital source of income for the local economy.	NOT CONSIDERED

?

Ecosystem Services

Do you think any important ecosystem service has been missed in this list? If so, kindly suggest. 1

METHODOLOGICAL FRAMEWORK

Scope of the study

The major objective of the study is to estimate the economic value of ecosystem services emanating from selected tiger reserves in India. Thus, ecosystem services from all major ecosystems (natural as well as agro-ecosystem) located inside the tiger reserve shall be estimated in the study. The study shall not estimate the economic value of manmade infrastructure e.g. reservoirs constructed inside the tiger reserves. However, the contribution of tiger reserves in creating value from these manmade infrastructures shall be considered in the study. For example, only the marginal hydropower production that can be attributed to ecosystem services such as water flow regulation and sediment retention from a tiger reserve shall be considered in the study. [Please provide your views on Question 2]

i

The study is not about economic value of a tiger. It is about the economic value of tiger reserves.

Secondly, although the study is on economic valuation of tiger reserves, it does not aim to estimate the economic value of a tiger. Tiger reserves are dynamic ecosystems which ensure sustainable flow of a wide range of ecosystem services which this study seeks to estimate. Further, the study seeks to estimate the total economic value of selected tiger reserves at current point of time. Estimation of marginal or additional benefits ensured due to notification of the site as a national park or a tiger reserve is not in the purview of the study objectives. The current study would however provide much-needed initial estimates of economic value of tiger reserves based on such studies that further seek to estimate the finer details and nuances can be conducted.

Finally, it is well recognized that not all ecosystem services can be estimated in monetary measures, many times due to unavailability of required data and many times due to inadequateness of any (or a set of) indicator to truly reflect the ecosystem service in question. Thus, while the study will strive to estimate as many ecosystem services from the tiger reserves as possible in monetary terms, the study shall also list other ecosystems in terms of those that cannot be monetized but quantified in biophysical terms and some indicators for economic benefits exist; those that cannot be monetized and although can be quantified in biophysical terms, no indicators for economic benefits exist; and lastly those that only be qualitatively described.



**Manmade
Infra**

**Do you agree with the
exclusion of manmade
infrastructure from the
scope of the study?
Please elaborate.**

2

 **Ecosystem services**

Costanza et al. (1997) provided one of the initial reflections on the economic value of different types of ecosystems in the world. The Millennium Ecosystem Assessment conducted groundbreaking research in the area of ecosystem services. The current study will be drawing from the ecosystem services defined by MA (2005) as well as other subsequently studies such as The Economics of Ecosystems and Biodiversity (TEEB) and many others. Based on these studies, the exhaustive list of ecosystem services to be estimated for the tiger reserves is as listed in Table 1. It may kindly be noted that not all ecosystem services may be significant at all tiger reserves, and hence only a selected bunch will be estimated for each tiger reserve.

 **Biodiversity is not an ecosystem service**

While many studies consider biodiversity as an ecosystem service, there have been growing concerns to distinguish between biodiversity and diversity. The Convention on Biological Diversity defines biodiversity as “the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”. It is thus argued that biodiversity is integral to sustainable functioning of all ecosystems, and is thus vital for availability of all ecosystem services. However, the value element of biodiversity is considered in bioprospecting and gene-pool protection in the study.

 **Legal versus actual harvest**

It is generally agreed upon that many tiger reserves experience illegal grazing and fuel wood collection due to a variety of factors. A point of discussion in this regard is whether to consider what is legally permitted or the actual harvest, the latter in many cases may turn out to be much higher than the former but is illegal. While the true value can be derived only from actual exploitation, using such an approach has serious implications. Firstly, it would turn out that a less protected tiger reserve with more illegal grazing and fuel wood collection is more “valuable” than a tiger reserve with higher protection that reduces illegal harvest. Secondly, there is a temporal dimension associated with trade-offs between ecosystem services which would need to be analyzed further. Illegal harvest may increase the economic value associated with fodder and fuel wood for a tiger reserve with associated implications on degraded ecosystems in future, thereby reducing the flow of other ecosystem services and hence the economic value of tiger reserve in years to come. However, the current study would only estimate the economic value of ecosystem services at this point of time and hence would not reflect this trade-off.

?

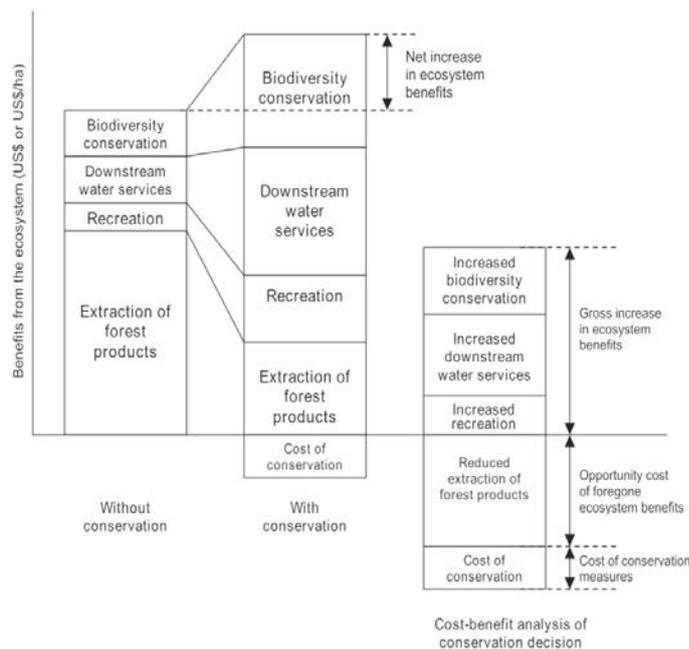
Legal or Actual

Should legally permitted or actually harvested value be used for economic valuation?

3

To better understand how the findings of economic value of forest diversion can be used in the current study; refer to the Figure 1 and conceptualize it within the context of tiger reserves. A patch of forests, as it is, for example provide ecosystem services as shown in the first bar (“without conservation”). However, without conservation objective, there is a tendency to overexploit the resources, especially the provisioning services, which leads to degradation of these forests. As a result, after some years, the benefits derived from these very forests start decreasing. However with conservation objective, the exploitation of provisioning services decreases but there is an associated enhancement in other ecosystem services i.e. the regulating, cultural and supporting services. This is represented in the second bar with clear net increase in total benefits from the tiger reserve as compared to the ‘without conservation’ scenario. The second scenario however entails other types of costs such as the costs incurred in managing the forests for conservation. The third bar gives the cost-benefit analysis of these two scenarios which clearly depict the different types of costs and benefits when managing an ecosystem with conservation objective. The current study also aims to estimate these opportunity costs and benefits. However, it may be noted that the objective of the study is to estimate the economic value of selected tiger reserves and hence the study would not aim to analyze with and without conservation scenarios.

Figure 1
Economic Value of Conservation (Pagiola et. al 2004)

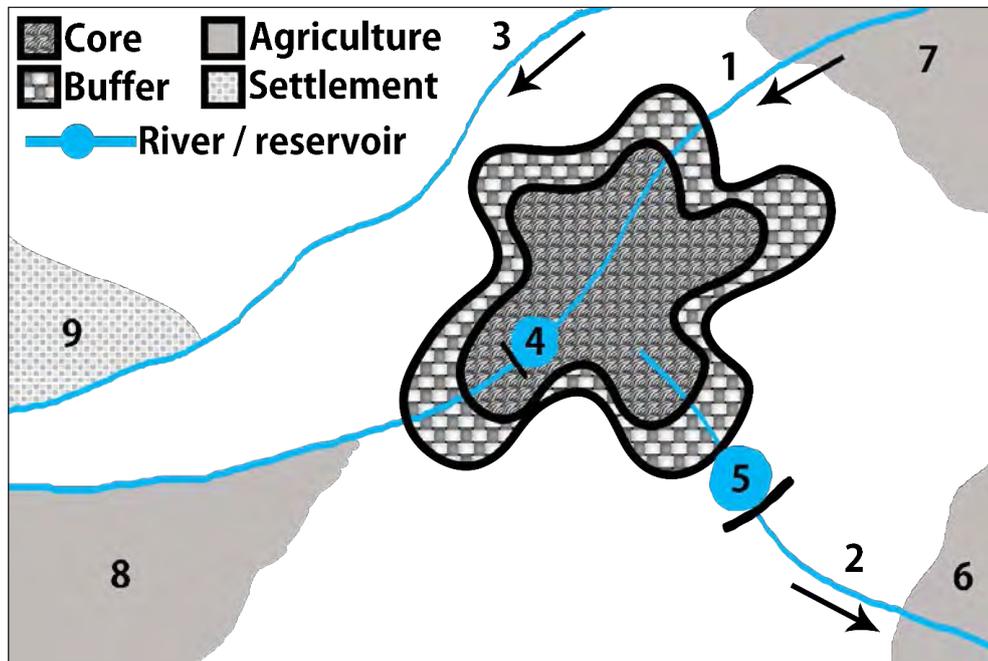


Valuation boundary – the serviceshed approach

One of the pressing needs for valuation of tiger reserves in India is to reflect the fact that the benefits of conservation are not limited in-situ but flow well beyond the boundaries of the tiger reserve. In order to demonstrate and internalize this aspect in the study, the concept of serviceshed will be used. For the purpose of this study, serviceshed refers to the entire service benefitting area for a particular ecosystem service. Let us explain the concept in greater detail for water provision service of a tiger reserve with the help of diagram below.

Figure 2

The concept of serviceshed



There are three rivers which are fed by forested catchment of the tiger reserve i.e. rivers 1, 2 and 3 with the arrows indicating the direction from upstream to downstream. The serviceshed for water provision service in this case would be the entire downstream area of these rivers. A very evident aspect that needs to be considered while using this approach is to apportion the benefits to tiger reserve from the total benefits provided by the riverine ecosystem as well as other ecosystems upstream to the tiger reserve. Thus, if for example, river 2 originates from the tiger reserve and is completely fed by the catchment lying in the tiger reserve, then the entire water provision service for the river can be attributed to the tiger reserve. In contrast, only a part of the catchment feeding river 1 is in the tiger reserve and thus, the water provision service for river 1 will have to be appropriately apportioned for the tiger reserve from the total service. Similarly, if there are two reservoirs i.e. reservoir 4 and 5, one of them (reservoir 4) built inside and on a river originating upstream of the tiger reserve and the other (reservoir 5) built outside but on a river originating inside the tiger reserve, only a part of benefits produced by reservoir 4 can be attributed to the tiger reserve as against reservoir 5, whose entire benefits can be attributed to the tiger reserve.

While the term ‘downstream’ has a hydrological connotation, we shall be using the term in a broader sense and referring to service benefitting areas apart from the core, buffer and the adjoining as “downstream areas”. Thus, for an ecosystem service such as nursery function of

Mangrove forests, the downstream area can be the entire coastline and marine areas along which aquatic animals which have spent a part of their early lifecycle in Sundarbans are caught. As this concept deserves greater attention and is specific to each ecosystem service, the details are discussed in subsequent sections for each ecosystem service.

? Service-shed

Do you think the service-shed approach can help in accounting benefits that accrue outside the tiger reserve? **4**

z

? Service-shed

What other approaches do you suggest to appropriately apportion the benefits? **5**



DRAFT METHODOLOGY FOR EACH ECOSYSTEM SERVICE

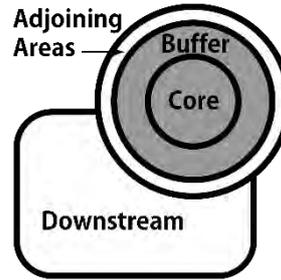
Food

Why this service?

A portion of the tiger reserve area, albeit small, is often used for food production activities. As the study entails economic valuation of all benefits from a tiger reserve, this service is included in the list of ecosystem services to be estimated.

Scope

The provisioning of food from tiger reserves would mainly include food production from agriculture and fisheries. The spatial boundary for this service would be the notified areas of tiger reserve i.e. the core and the buffer. Thus only agriculture and fisheries carried out within the notified boundary of a tiger reserve shall be included in the valuation.



Proposed approach for estimation

The food production estimates for each of the activities shall be used in conjunction with the local market price of the produce to arrive at the economic value of food production from a tiger reserve.

? Food
Do you agree that food production from tiger reserves should be included in economic valuation? **6**

? Food
Would you suggest any other approach to estimate food production from the tiger reserve? **7**

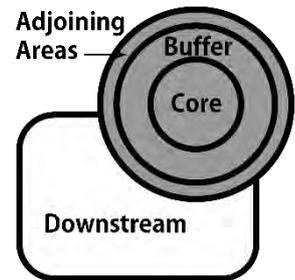
Fuel wood

Why this service?

Forests are major sources of fuel for cooking and heating in rural India. About 40 percent of the primary energy consumption in the country comes from biomass. Fuel wood is of major importance in remote areas which till date do not have access to other sources of energy for cooking, heating and lighting. While this may not apply to all selected tiger reserves, *nistar* rights give local communities the right to collect fuel wood from the buffer areas of a tiger reserve.

Scope

The valuation for this service shall be carried within the notified boundaries of the tiger reserves i.e. the core and the buffer as well as the adjoining areas (5 kilometer buffer around the tiger reserve). The latter is included based on the assumption that communities living just outside a tiger reserve may also be depending on fuel wood from forests in the reserve.



Proposed approach for estimation

To estimate the economic value of fuel wood from a tiger reserve, average consumption of fuel wood from each household in core, buffer and adjoining areas shall be used with the price of fuel wood in the nearest local market. To derive the intrinsic value of fuel wood, the economic value shall be adjusted to account for the opportunity cost of collection. To account for underreporting of fuel wood collection, the economic value may be adjusted upwards based on consultation with stakeholders.

?

Fuel-wood

Do you agree with the definition of adjoining areas? Should this area be included in valuation?

8

?

Fuel-wood

How do you suggest to account for under-reporting of fuel wood collection from tiger reserves?

9

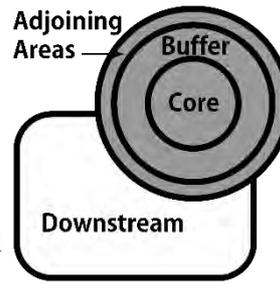
Fodder

Why this service?

Forests are very important source of fodder for livestock of local communities. Livestock are vital for livelihoods in these difficult conditions for people living in and around the tiger reserve. While this may not apply to all selected tiger reserves, *nistar* rights for local communities give them the rights to graze their cattle in buffer areas of the tiger reserve.

Scope

The valuation for this service shall be carried within the notified boundaries of the tiger reserve i.e. the core and the buffer. Further, it shall be assumed that livestock in the adjoining areas (5 kilometer buffer around the tiger reserve) shall be grazing inside the tiger reserve. It shall also be assumed that all livestock inside a tiger reserve and in the adjoining areas are grazed in forests except in the case when information and evidence on stall feeding is available.



Proposed approach for estimation

In order to estimate the services associated with provisioning of fodder for livestock, the number of Adult Cattle Units (ACUs) completely dependent on tiger reserve for fodder shall be used in conjunction with an assumed daily consumption of 22 kilograms of fodder per ACU. The market value of fodder in the nearest local market shall be used to derive the economic value of fodder after adjusting it for opportunity cost of collection.

? **Fodder**

Do you agree with the definition of adjoining areas? Should this area be included in valuation?

10

? **Fodder**

Would you suggest any other approach to estimate the grazing services?

11

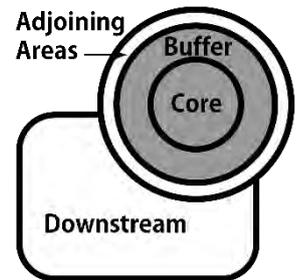
🐾 Timber

🐾 Why this service?

Although extraction of timber within the tiger reserves is not allowed, these tiger reserves are storehouses of large quantities of timber. While timber is not harvested, the growing stock has a financial value. It may however be noted that this is not a flow function and hence shall not be included in the annual array of benefits derived from the tiger reserves. An annual value would nevertheless be estimated representing mean annual increment i.e. the financial value of timber added annually.

🐾 Scope

The estimation will include entire growing stock of forests in a tiger reserve. The economic valuation shall be carried out within the notified boundaries of a tiger reserve i.e. the core and the buffer.



🐾 Proposed approach for estimation

Growing stock shall be used for estimation of timber within a tiger reserve. Von Mantel's formula (Armitage 1998), a conservative approach of yield determination shall be used for deriving the mean annual increment on the basis of rotation period estimated for each tiger reserve based on dominant tree species. Based on the market value of timber and the associated maintenance & transportation cost, the intrinsic value of timber (both stock value as well as annual flow value) shall be estimated.

?

Timber

Do you agree that the value of standing timber should be estimated? Please elaborate.

12

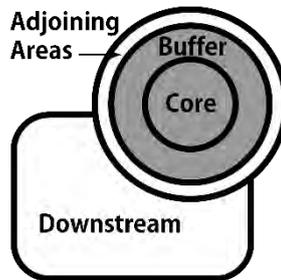
🐾 Non-Wood Forest Produce

🐾 Why this service?

Non-wood forest produces from tiger reserves in many cases occupy a prime place in rural communities' livelihoods, both for products sold and for auto-consumption. The role of NWFPs as a gap-filling or "safety-net" function is also very vital. These help communities survive in case of failed monsoon, emergencies, in periods between crop harvests, and in many cases constitute the main source of income for landless or unemployed.

🐾 Scope

All NWFPs collected from the notified tiger reserve areas i.e. core and buffer, shall be included in the economic valuation of NWFPs.



🐾 Proposed approach for estimation

A list of NWFPs allowed for collection from each tiger reserve shall be finalized in consultation with concerned authorities and local communities. For each NWFP, harvest estimates along with price in nearest local market shall be used to derive its economic value. The value shall then be adjusted for the opportunity cost of collecting it.

? NWFP
How do you suggest we account for underreporting of NWFP collection?
13

? NWFP
If you are aware of NWFPs collected in any of these tiger reserves, kindly list them here.
14

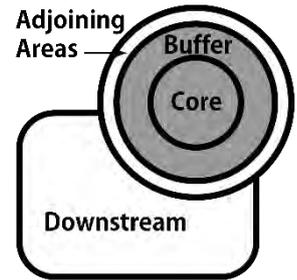
🐾 Bioprospecting and gene-pool protection

🐾 Why this service?

At the backdrop of increasing species extinction rates across the globe, the role of tiger reserves in conserving species that may have future economic value is increasingly being recognized. This insurance value of tiger reserves relates to the option value in the Total Economic Value framework.

🐾 Scope

The spatial boundary for this ecosystem service shall be the notified areas of the tiger reserve i.e. the core and the buffer. The role of genetic diversity in pharmaceutical industries for future drug discoveries as well as those for improvement in agricultural crops by injection of genes from wild varieties shall be considered.



🐾 Proposed approach for estimation

While the approaches for estimating the economic values of gene-pool are still in their nascent stage, a starting point estimate can still be developed. Based on the total number of medicinal plant species, species of conservation importance and total number of species, an option value for the tiger reserve with respect to potential for future drug discoveries shall be estimated. The approach to be used for estimation of economic value of gene-pool for crop improvement is still being reviewed.

?

Gene-pool

Are you aware of any important medicines discovered from the tiger reserves?

15

?

Gene-pool

Are you aware of any wild varieties which have been used for crop improvements?

16

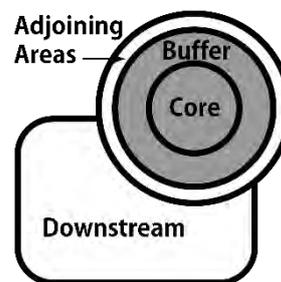
Carbon storage

Why this service?

Trees and forests in the tiger reserve store carbon. A number of studies suggest potentially a very large size for these carbon storage functions. To the extent that this carbon stored in tiger reserves is at risk of being released into the atmosphere, it has a high economic value with regards to the associated impacts of climate change. It may kindly be noted that this ecosystem service related to carbon currently stored in biomass.

Scope

Carbon stored in various types of ecosystems in tiger reserves shall be included for this service. Specially, the carbon pools to be considered include above ground biomass, below ground biomass, soil biomass and dead organic matter. The spatial boundary for this service would include the notified boundaries of the tiger reserve i.e. the notified core and buffer area of the tiger reserve.



Proposed approach for estimation

Carbon stock estimates in pools such as above ground biomass, below ground biomass, soil biomass and dead organic matter.

Social cost of carbon for India estimated by Yale University.

Carbon sequestration

Why this service?

In addition to the carbon storage functions of tiger reserves, they also have a flow function i.e. annual sequestration of carbon from the atmosphere.

Scope

Proposed approach for estimation

Carbon sequestration estimation based on growing stock figures for forests. For other land-uses, default IPCC methodology to be used.

Social cost of carbon for India estimated by Yale University.

Water flow regulation

Why this service?

About 119,000 cubic kilometers of water rains annually onto the Earth's land surface (Shiklomanov 1993). Much of this water is soaked up by soils and gradually meted out to plant roots or into aquifers and surface streams. When natural forested landscapes are denuded, rain can compact the surface and turn soil to mud; mud clogs surface cavities in the soil, reduces infiltration of water, increases runoff, and further enhances clogging

Scope

Proposed approach for estimation

Difference between current water recharge annual water recharge if forests are converted to bare land using simple water balance equation.

Economic value of water for India (Rs. 5/m³)

Water purification

Why this service?

Scientific evidence suggests that forests improve the quality of water. Water purity, e.g. for drinking water, hydroelectric power plants or fishing, is likely to be better from forested catchments than otherwise. Tiger reserves thus provide very important function of purifying water for downstream water use.

Scope

Proposed approach for estimation

Water consumption downstream

Replacement cost approach using purification by an artificial water purification plant

Soil conservation and maintenance of soil fertility

Why this service?

Scope

Proposed approach for estimation

Avoided loss of N, P and K from soil due to forests

Market price of fertilizers

Moderation of extreme events

Why this service?

Scope

Proposed approach for estimation

Avoided loss to lives and property

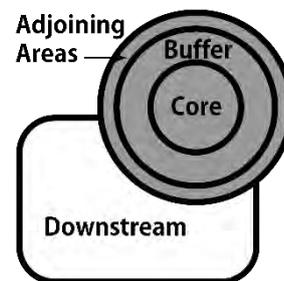
Pollination & seed dispersal

Why this service?

The value of pollination and seed dispersal services from forests is increasingly being recognized in a country such as India where majority of the workforce is dependent on agriculture for their livelihoods. The impact of degradation of such services has also been greatly felt in India (including impact on apple production in Himachal Pradesh) due to shrinking of forests.

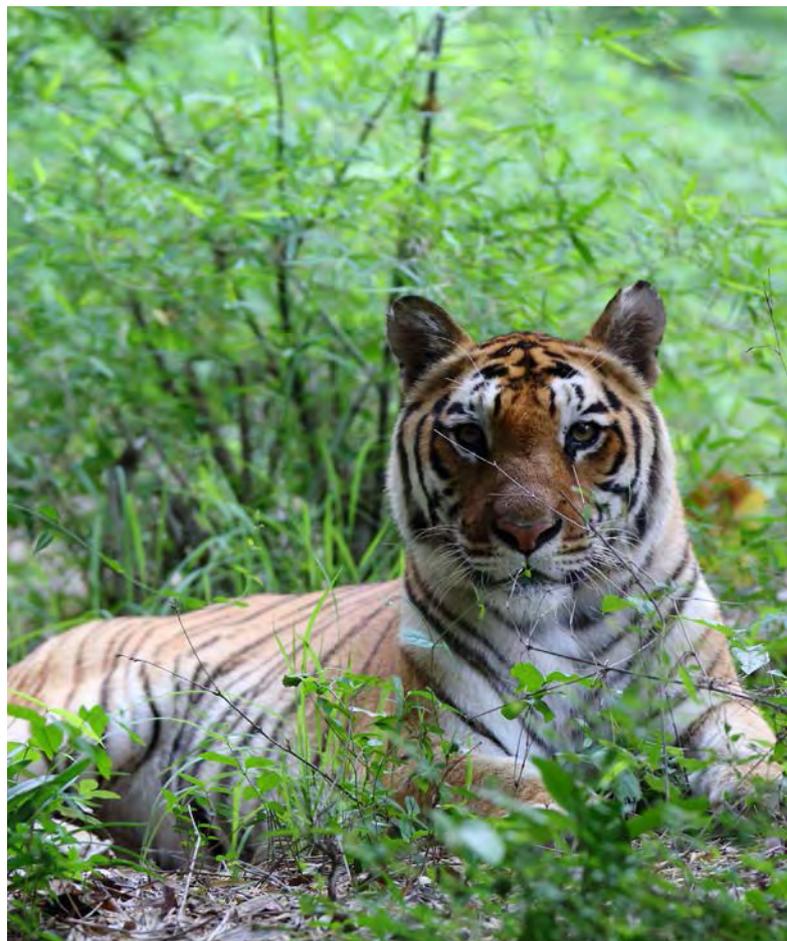
Scope

The study will consider two sets of benefits of this ecosystem service. The first one relates to natural forest regeneration and the other relates to pollination services for agro-ecosystems. For both benefits, the spatial boundary for valuation would include the notified areas of tiger reserve i.e. the core and the buffer as well adjoining regions (defined for the study as 5 kilometer buffer around the notified tiger reserve).



Proposed approach for estimation

The economic value of pollination and seed dispersal service for natural forest regeneration shall be estimated based on replacement cost for doing plantations according to the model cost recommended by the National Afforestation Programme Guidelines. For pollination services to agro-ecosystems, acreage and market price of crops with high dependence on pollination shall be used in a simple spreadsheet model developed by FAO to estimate the economic value of pollination.



? **Gene-pool**
 Are you aware of any important medicines discovered from the tiger reserves?
 15

? **Gene-pool**
 Are you aware of any wild varieties which have been used for crop improvements?
 16

 **Biological control**

 *Why this service?*

 *Scope*

 *Proposed approach for estimation*

Decrease in incidence of livestock diseases within and around tiger reserve as compared to the district average

Market price of livestock

 **Habitat for species**

 *Why this service?*

 *Scope*

 *Proposed approach for estimation*

Replacement cost approach – provision of habitat in zoo

 **Nursery function**

 *Why this service?*

 *Scope*

 *Proposed approach for estimation*

Production function approach – establish linkages to how much benefits downstream can be attributed to the nursery function

 **Recreation & tourism**

 *Why this service?*

 *Scope*

 *Proposed approach for estimation*

Willingness to pay of tourists

Economic contribution to petty sectors to be derived based on conversion factors (e.g. per 100 tourists visiting the area and their WTP)

 **MAJOR ECOSYSTEM SERVICES**

For each of the tiger reserve, if you had to divide 100 marbles across these services, with number of marbles allocated to a particular service signifying its degree of importance, how would you distribute these 100 marbles? While you are free to allocate any number of marbles to each of the service in each tiger reserve, please ensure that the total of all ecosystem services for each tiger reserve equals 100.

Ecosystem Service	Kanha	Corbett	Ranthambore	Periyar	Kaziranga	Sundarbans
Food (agriculture & fisheries)						
Fuel wood						
Fodder						
Timber						
Non-Wood Forest Produce						
Bioprospecting & gene-pool protection						
Carbon storage						
Carbon sequestration						
Water flow regulation						
Water purification						
Soil conservation & maintenance of soil fertility						
Pollination & seed dispersal						
Biological control						
Habitat for species						
Nursery function						
Recreation & tourism						
Other (please specify)						
Other (please specify)						
TOTAL	100	100	100	100	100	100

02

APPENDIX



METHODOLOGY WORKSHOP SUMMARY

<p>The study is very timely and in the light of growing developmental pressures, the study estimates will provide stronger argument for conservation of the wild and thereby good reasons for enhanced investment.</p>	
<ul style="list-style-type: none"> • Valuation would help in communicating the need to invest in green endowment to the policy-makers. • It shall also help in prioritizing investments and allocation of funding at state and national level. 	
<p>Many benefits from tiger reserves flow outside the administrative boundaries and hence a serviceshed approach that takes into account benefits accruing outside the notified tiger reserve is essential to reflect its true value.</p>	
<p>There is a need to move beyond anthropocentric approach to valuation of ecosystem services from tiger reserves.</p>	
	<ul style="list-style-type: none"> • While the utilitarian approach has limitations, it has significance when decisions related to investment or financial allocations are taken.
<p>As the main objective behind establishing protected areas of tiger reserves is to stop extinction of species, the study methodology should estimate the cost of extinction. One approach of calculating this could be what it would cost to recreate the tiger reserve on a barren patch of land.</p>	

<ul style="list-style-type: none"> • It is very difficult to estimate the value of preventing extinction. However, what the study may try to estimate is the cost of inaction on the assumption that if we do not allow certain basic ecosystem functions to operate, then the rate of extinction would become higher. And this cost of inaction can be valued as the value of these ecosystem functions and services. 	<ul style="list-style-type: none"> • Our understanding of ecosystems and the dynamics within is very limited to articulate all that we would need to recreate the system. • Replacement cost is not an appropriate approach to use when we are talking about tiger reserves, because in all practical terms, replacement is impossible. • The study would very clearly state in the preamble itself that these tiger reserves, along with its ecosystems and functioning are irreplaceable. These need to be in place, in perpetuity.
<p>On a related aspect to preventing species extinction, tiger reserves also ensure that the evolutionary processes continue. The study should make an attempt to estimate the value of these processes.</p>	
<ul style="list-style-type: none"> • Some way needs to be found to value the natural evolution process because that is the argument that will win when conservation is fighting against development 	
<p>Human health benefits such as mitigation of air and water pollution from the tiger reserves should be included in the valuation methodology.</p>	
<p>The study should compare the benefits of conservation to the cost of inaction.</p>	
<p>The methodology does not include many of the important cultural services apart from recreation & tourism.</p>	
<ul style="list-style-type: none"> • The cultural significance of tigers and the entire ecosystem is particularly important. • Qualitative parameters may be used to estimate such services. • Presence of many indigenous communities inside the tiger reserve may also be included in the cultural services to be considered. 	
<p>The study should estimate the additional / incremental benefits derived from an area due to being notified as a tiger reserve.</p>	
<ul style="list-style-type: none"> • The benefits estimated can be compared to the next best alternative without protection e.g. a reserve forest. • This can be very useful for management purposes. 	<ul style="list-style-type: none"> • The study is seeking to capture the total economic value of a tiger reserve. The differential or incremental value can easily be derived by using already available estimates such as the NPV value of a nearby forest area. • We can split the total value in two parts subsequently – the value irrespective of notification and the incremental value due to notification.

The study should estimate the intrinsic value (bequest / existence) value of these tiger reserves.	
<ul style="list-style-type: none"> • Stated preference methods may be used to estimate these values. • Revealed preference approach (e.g. revenues from television shows) may also be used. • If monetary estimation is not possible in the time available, it should be very clearly stated in the preamble that although this is not valued, it is very significant. • While the methodology is still evolutionary in process, there is no dearth of literature showing the value of this methodology and its use in the study is strongly encouraged. • We need to understand here that the purpose of using this method is not to come at an absolutely correct number. The purpose here is to get an indicator (rough idea) of how much the relevant groups would be willing to pay for expansion of a particular programme. 	<ul style="list-style-type: none"> • Should it be intrinsic value of tiger or all species of conservation importance (e.g. Rhinoceros, Hard Ground Barasingha) or of the entire tiger reserve? • The study will need to account for a lot of bias that are associated with such estimations. • While acknowledging that this method may be good for comparing value across society, giving an absolute value based on this approach would be an absolute disaster for tigers in India. • The study will need to clearly distinguish between whether we are trying to estimate the absolute value of any species or we are trying to estimate what additional amount or premium an average citizen would be willing to pay for its conservation.
The ecosystem services may need to be regrouped according to some criteria for clearer understanding. One approach could be to classify them as embedded in and emanating from the tiger reserve. The other approach could in terms of products and processes.	
As the list of ecosystem services to be estimated is fairly long, there is scope for combining some of the related services e.g. water flow regulation and soil conservation.	
<ul style="list-style-type: none"> • Considering the available time and number of tiger reserves to be covered, it may not be possible to estimate the value of all ecosystem services at all tiger reserves. • 2-3 important ecosystem services may be identified and estimated in each tiger reserve and a hypothetical tiger reserve may be considered which has ecosystem services from all the tiger reserves and the value of this reserve may then be derived from estimated values. 	<ul style="list-style-type: none"> • Not all ecosystem services will be relevant for all tiger reserves. Thus there will only be limited ecosystem services that are relevant for a particular tiger reserve. • The objective of the study is to make an attempt in reflecting the value that these tiger reserves provide and combining ecosystem services may reduce the final value.
The definition of “adjoining areas” in the service-shed concept should be flexible to account for different contexts across sites and ecosystem services.	
The study should highlight that it seeks to use the ‘Value+’ approach and not all important services can be monetized or expressed quantitatively.	

<ul style="list-style-type: none"> • The use of ‘Total Economic Value’ may be avoided because we may not be valuing all services in monetary or quantitative terms. 	
<p>It may be emphasized that the current endeavour should be seen as a pilot study to start reflecting the values that these tiger reserves provide and subsequent phases would continue to refine the methodology further and provide more objective estimates.</p>	
<ul style="list-style-type: none"> • It is envisaged to cover all the tiger reserves of the country in future. 	
<p>It should be decided whether we are seeking to estimate the gross benefits or the net benefits of these tiger reserves. The net benefits will need to account for the costs of conservation as well e.g. man-animal conflict.</p>	
<ul style="list-style-type: none"> • Inclusion of both benefits as well as cost will highlight how the local community bears the cost of conservation which benefits stakeholders at regional, national and global level and hence provide useful insights for developing incentive-based mechanisms. 	
<p>The harvest of prohibited goods from the tiger reserves (especially the core area) such as fuel wood, fodder and others should not be completely discounted.</p>	
<ul style="list-style-type: none"> • The tiger reserves provide these benefits and hence they need to be accounted for. • These may be referred to as “unrecorded” or “unaccounted” in the methodology. 	<ul style="list-style-type: none"> • Inclusion of these would signal inefficiency in management on the part of tiger reserve authorities.
<p>The ecosystem service of biological control may be excluded from the study as it is two dimensional – has benefits as well as associated costs.</p>	
<ul style="list-style-type: none"> • While tiger reserves may prevent epidemic of diseases due to natural regulation, these reserves are also reservoirs of diseases. • Diseases are actually knowledge aspects and they only reflect the current understanding about human reaction to certain species. Hence, this aspect may be excluded from the valuation methodology. 	
<p>The study should not include the benefits of anthropomorphic activities such as a dam in the value of the tiger reserve.</p>	
<ul style="list-style-type: none"> • The contribution of tiger reserves in enabling such infrastructure to generate these values would however need to be accounted for. • For e.g. the benefits of water recharge in streams, preventing siltation of reservoir, etc. to a dam inside the tiger reserve can be attributed to the reserve and will need to be considered. 	

The negative impacts of near-by towns such as Ramnagar or Thekkady on reducing the value generated by the tiger reserve may also be highlighted.	
<ul style="list-style-type: none"> • If it is not possible to cover the aspect in detail, a case-study on one of the tiger reserves in this regard may be useful. 	
While the study considers benefits related to carbon sequestration and storage, a greater focus on the role of tiger reserves in mitigating climate change may be required.	
<ul style="list-style-type: none"> • The study being the first-of-its-kind will be discussed on global platforms, including those related to climate change, and hence the focus may be useful. • The proxy for this can be the cost that India will be incurring for the Green India Mission. 	
The study needs to clearly state in the preamble that the objective of the study is not to compare the benefits of the tiger reserve with any economic venture e.g. mining.	
<ul style="list-style-type: none"> • The issue of exchange values it not at all applicable in this context. • The study may highlight that the reserves should continue to be inviolate and the value is not proposed for comparison to developmental projects. 	
Cultivar e.g. wild rice in Kanha Tiger Reserve contains wild genes which may have potential use for crop improvement in future. The study should make an attempt to estimate the economic value of such cultivars.	
<ul style="list-style-type: none"> • In case of cultivars / endemic species, if there are no revealed values, then valuation may be difficult. There would be some part of the society – whether human or non-human dependent on such species and a stated preference approach may be used in this regard. • Rice varieties in Sundarbans which were no longer in practice in the agricultural fields were brought back due to various reasons such as salinity, inundation, etc and these are now sold in the market. A conservative approach of using the lowest price can also be used to value such wild varieties. 	<ul style="list-style-type: none"> • Any species in the wild is an evolving species and cannot be compared to the same species outside in for e.g. zoo or a botanical garden. Thus, for such species with evolutionary significance, valuation may not be possible; neither is it required to justify its conservation. The presence of such endemic species in itself makes it fit for conservation. • If valuation is not possible, this aspect should be very clearly stated in the preamble of the study.
With respect to bioprospecting & gene-pool protection, it was suggested that the concept of bioprospecting is excluded from the study due to its commercial connotation. The service may be referred to as “gene-pool protection” only.	
There were concerns raised whether inclusion of timber as well as carbon storage will lead to double-counting in the valuation methodology.	

<ul style="list-style-type: none"> • Including both timber and carbon sequestration, does not necessarily lead to double counting because timber is sold with a definitive purpose in the market and nowadays IPCC also considers the carbon stored in wood products. 	
<p>The employment generated by tiger reserves should also be included in the valuation methodology.</p>	
<ul style="list-style-type: none"> • Project Tiger at the national level generates more than 25 lakh man-days annually. • Incomes derived by EDCs should also be accounted in the valuation study. 	
<p>The value of tiger reserves by acting as source population and thus adding value to the entire landscape may also be highlighted.</p>	
<p>The production of food inside the tiger reserve (both core and buffer area) should not be considered as a serve included in the value estimation of tiger reserve. However, contribution of tiger reserve in production of food outside the tiger reserve should be accounted for.</p>	
<ul style="list-style-type: none"> • Inclusion of food value inside the tiger reserve may lead to argument of giving more land to cultivation inside the tiger reserve. • Cultivation is more productive outside and hence should not be included. 	<ul style="list-style-type: none"> • The cultivated areas lie inside the administrative boundaries of the tiger reserve and hence are technically part of the tiger reserve. • Similar to cultivated areas outside, these areas also benefit from the ecosystem services generated by the tiger reserve.
<p>Many of these tiger reserves are big brand names in themselves. The brand value of these tiger reserves may also be included in the valuation methodology.</p>	
<ul style="list-style-type: none"> • There is value in being associated with the brand and hence should be included in the study. • A lot of tourists come to India just to see tigers and hence the brand value of tiger may also be considered. 	<ul style="list-style-type: none"> • It may be more useful if the concept of brand value is extended to something that relates to people's lifestyle. For e.g. if we can say that per household, Rs. X is coming to each household due to existence of Corbett Tiger Reserve may be more logical. • The brand value should be conceptualized along the concept of incremental values i.e. over and above the value associated with other tiger reserves. • Name valuation of brand is different from place valuation of brand. If we are sticking to name valuation of the brand, doing this for lesser known tiger reserves may be a problem.
<p>The study findings will need to be repackaged for different stakeholders such as local policy makers, national policy makers and politicians, local community, citizens at large, judiciary, research community, businesses, etc in order to communicate the results effectively.</p>	

Another aspect that the study may want to consider is the coverage or the type of ecosystems within the tiger reserve. So the spectrum of ecosystems that the tiger reserve covers is one additional value that it can possess.	
<ul style="list-style-type: none"> • Although it may be difficult to quantify this aspect in economic terms, it is an important ecological concept to be considered. 	
As many of the tiger reserves selected for the study have a long conservation history such as Ranthambore, Kaziranga and Periyar, it may be interesting to look at the historical evolution of ecosystem values at these sites.	
<ul style="list-style-type: none"> • A case-study for any of these tiger reserves may be a useful addition. • The aspect of co-habitation may be particularly highlighted. 	
As some the selected tiger reserves also have places of high religious significance, the study will need to decide how the value of such sites is considered in the valuation methodology.	
<ul style="list-style-type: none"> • The tiger reserve along with its serenity and wilderness contributes to the religious significance of such places by ensuring that the pilgrims feel closeness to nature and God. This needs to be accounted for in the study. • A portion of revenue generated from religious tourism is mandated to be ploughed back into the Tiger Conservation Foundation / Panchayats which is used further for community development programmes. The study can be very useful to build our case in this regard 	<ul style="list-style-type: none"> • The value of the temple would have been there irrespective of the fact whether tiger reserve existed or not so we should ideally not take this element into account.
The livelihood of a large proportion of people in small towns near such tiger reserves is highly dependent on tourism in these reserves e.g. Ramnagar in Corbett, Thekkady in Periyar and Kohora in Kaziranga. This aspect should be considered in the valuation methodology.	
<ul style="list-style-type: none"> • The study should consider all the petty / secondary sectors of the local economy dependent on tourism. 	
Two of the six sites selected for the study i.e. Sundarbans and Kaziranga are World Heritage Sites. This aspect of recognition of world heritage for these sites may also be internalized in the study methodology.	
<ul style="list-style-type: none"> • A premium on the values estimated may be considered for such World Heritage Sites. 	
With the help of science and community programmes in these tiger reserves, the governance of protected areas is improving. This improved governance may also be highlighted in the study.	
<ul style="list-style-type: none"> • This may be included as a case-study and include qualitative measures. • What may also be worth a mention is that the valuation of these tiger reserves may also be done by maintaining records at the community level as done in Periyar. 	

The valuation for water-flow regulation services in terms of irrigation services should only consider the incremental production due to irrigation over and above the rain-fed / dry-land agricultural systems.

The benefits of in-situ habitat protection and improvement provided by these tiger reserves should be considered in the valuation methodology.

- The provision of food by the tiger reserve for herbivores should also be included in the methodology to make the transition from anthropocentric to ecosystem centric approach.
- The study intends to address this aspect partially through the provision of habitat for species which may be valued through the replacement cost approach for e.g. cost of maintaining such species in a zoo.

The cost of alternate infrastructure that is coming up in the periphery can be used as an indicator of the value that is placed on the tiger reserve and may be considered as a proxy for some of the values that the current study seeks to estimate.

- For example, there are proposals for diverting the National Highway that currently passes through the tiger reserve at the cost of Rs. 3,000 Crores.



03

APPENDIX



SUMMARY OF INVEST WORKSHOP AT PERIYAR TIGER RESERVE (27-31 MAY 2014)

InVEST Training (27-28 May 2014)

Before the detailed InVEST workshop targeted to potential users of the tool, 2-day training was organized for general research and management staff at Periyar Tiger Reserve to give an exposure to the tool.

Day 1 (27 May 2014, Tuesday)

- Assistant Field Director, Periyar Tiger Reserve (PTR) welcomed all the participants to the workshop. The list of participants can be found in Annexure 1.
- Dr. Madhu Verma then gave a **background of the study** on economic valuation of tiger reserves and the **role of InVEST** in mapping and valuing ecosystem services.
- Dr. Amit Mallick, Field Director, PTR then gave a **short presentation on the tiger reserve** with focus on ecosystem services from PTR. He also expressed his happiness that PTR was chosen by IIFM to conduct the InVEST workshop and assured that all required **data support** would be provided by PTR. He also emphasized how results from the main study as well as InVEST would help in management of the reserve.
- Dr. Adrian Vogl then gave an **introduction to the**

Natural Capital Project and how the tools (InVEST, RIOS) developed have been influencing policy decisions globally in areas of spatial planning, payment for ecosystem services, climate adaptation and hazard mitigation, development impacts and permitting, restoration planning and corporate risk management. She also discussed the context in which InVEST should be used and gave a brief introduction to the terrestrial models of InVEST.

- Stacie Wolny then discussed an **application of InVEST in Sumatra**, Indonesia. The study had mapped spatial distribution of ecosystem services (carbon storage and sequestration, water yield, sediment retention and nutrient retention) and tiger habitat in 2008 and determined whether areas with high service levels contained significantly more tiger habitat.
- Mr. Sanajayan, Deputy Field Director, PTR gave closing remarks for the opening session. He emphasized that there are many ecosystem services that we are now starting to notice such as soil tillage benefits of earthworks, arresting extinction of species, health benefits by mitigating pollution, among others whose valuation may be attempted.

- Stacie Wolny then discussed the **habitat quality and rarity** model, **carbon storage and sequestration** model and **pollination** model from InVEST. Dr. Adrian Vogl further discussed freshwater models of InVEST and mentioned that these models provide their output at sub-watershed scale. She also emphasized that the freshwater models do not differentiate between surface water and ground water and if there is a need to include seasonality in greater detail, other software packages can be explored. With the freshwater models, Dr. Vogl gave an introduction to **water yield, nutrient retention** and **sediment retention** models.
- Among all the **terrestrial models**, considering the time available, it was decided to implement 4 models for PTR i.e. habitat quality, water yield, sediment retention and carbon sequestration & storage.

Day 2 (28 May 2014, Wednesday)

- Dr. Advait Edgaonkar, Assistant Professor, IIFM gave a recap of issues and models discussed on the first day of the workshop.
- Dr. Amit Mallick then invited Dr. G. A. Kinhal, Director, IIFM to give his address. Dr. Kinhal mentioned that IIFM has been entrusted with this challenging assignment on valuation of tiger reserves and as a part of this assignment, we are piloting application of InVEST at PTR. PTR, in addition to being one of the best management tiger reserves of the country, is also blessed with a wide array of ecosystem services that the study wishes to cover. He thanked the team from Natural Capital Project and wished the workshop a great success.
- The data requirements for each of the four models to be implemented in PTR were then discussed one by one. Where required data was not available, the group discussed what proxy measures can be used instead.
- The research team from PTR was then requested to compile the required data for hands-on-training on the shortlisted models from Day 3.

InVEST Workshop (29-31 May 2014)

The next 3 days included detailed workshop sessions for the shortlisted models. The participants for the workshop included the team from the Natural Capital Project, study team from IIFM and potential InVEST users at PTR including biologists and remote sensing & GIS experts.

Day 3 (29 May 2014, Thursday)

- The participants worked on the Carbon storage and

sequestration model. As data for sequestration rates was not available, the model was run to only obtain carbon storage estimates for PTR. Based on growth equations for old growth forests, as the case in PTR, carbon sequestration estimates can be easily derived when required.

- The rest of the day was spent in preparing data for the freshwater models of InVEST. Data preparation included delineating hydrologically correct watersheds and sub-watersheds; filling the soil attributes table; literature search for getting data on parameters such as root restricting layer depth, plant available water content, etc; making precipitation and evapo-transpiration raster from weather-monitoring station data points; and land cover raster for the entire study area. Mr. Shivakumar gave important inputs that would help in application of the results for management of the tiger reserve.

Day 4 (30 May 2014, Friday)

- The data preparation for freshwater models continued on Day 4.

Day 5 (31 May 2014, Saturday)

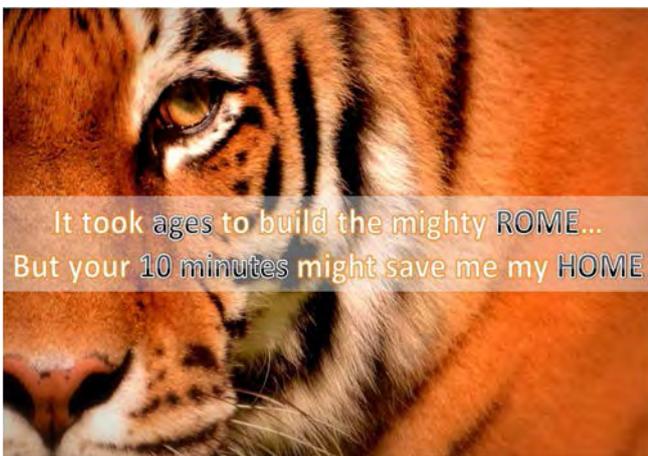
- Both freshwater models – water yield and sediment retention were then run and it was decided to obtain outputs disaggregated at the level of sections for management purposes.
- Data preparation for habitat quality model was done but due to lack of time, the model could not be run during the workshop. The results were however obtained subsequently.
- Details of models run, inputs required, source of each input and how it was prepared was documented.
- For some of the inputs which required refinement, the team from PTR would remain in touch with study team from IIFM and provide the required data.
- Dr. Amit Mallick then gave the closing remarks for the workshop. He mentioned that the team from PTR had a lot of value addition during this workshop and will continue to work on the data sources for refining the results obtained. He added that the results would help greatly in improving the management of the tiger reserve. He once again thanked the team from Natural Capital Project, IIFM and NTCA for conducting the workshop at Periyar.
- Dr. Madhu Verma thanked all the participants for their enthusiasm and support during the workshop, especially Dr. Amit Mallick for extending warm hospitality.

04

APPENDIX



INSTRUMENT USED FOR ESTIMATING NON-USE VALUE OF TIGERS



Conservation Authority (NTCA) being conducted by Centre for Ecological Services Management (CESM); a center of excellence at Indian Institute of Forest management (IIFM), Bhopal. The purpose of this survey is to find out how people in India think about Tiger Conservation in the country. It will take about 25 minutes to complete this questionnaire in Tiger conservation

context. The tiger is a unique animal which plays a pivotal role in the health and diversity of an ecosystem. It is a top predator and is at the apex of the food chain. Therefore the presence of tigers in the forest is an indicator of the well-being of the ecosystem. Protection of tigers in forests also protects habitats of several other species. In addition, indirect benefits of tiger conservation include protection of rivers and other water sources, prevention of soil erosion and improvement of ecosystem services like pollination, water table retention and a range of other services which benefit human kind. The tiger population in India is officially estimated to be between 1,520 - 1,909 individuals. Many of the tiger populations across the nation, particularly those outside protected reserves, face a variety of threats, including habitat fragmentation, encroachment, and poaching and developmental projects, such as mining, hydroelectric dams and construction of highways are also taking their toll on the tiger's habitat. Despite all these problems, India still holds the best chance for saving the tiger in the wild. With this objective Project Tiger was launched in India in 1973, with the goal of

saving the tiger and its habitat in India. With an initial list of 9 Tiger Reserves, this Project has went on to cover 47 Tiger Reserves across the country. Tigers occur in 18 States within India, with 10 States reportedly having populations in excess of 100 tigers. There are still areas with relatively large tiger populations and extensive tracts of protected habitat. A concerted effort is required to combat poaching and habitat loss, if this magnificent animal is to survive into the future. This survey is about how people value the tiger and how much they are willing to contribute for ensuring tigers exist in the wild for future generations to come.

1. In your opinion what are the THREE BIGGEST PROBLEMS our country is facing today? *

Choose only 3

- a) Economic Problems (e.g. inflation)
- b) Poverty
- c) Education
- d) Health
- e) Crime, violence, inequality
- f) Government & governance
- g) Infrastructure (e.g. roads, water)
- h) Environment
- i) Terrorism
- j) Relation with other countries

2. Do you think adequate measure and priority is given to our environment and natural resources? Please tick your choice? *

- Yes
- No

3. What do you think are the THREE (3) MOST important issues related to nature and human impact on the natural environment? *

Choose only 3

- a) Air Pollution
- b) Water Pollution
- c) Solid Waste
- d) Endangered species
- e) Deforestation
- f) Traffic Problems
- g) Flooding due to soil erosion

- h) Enhanced greenhouse effect
- i) Destruction of coral reefs
- Other:

4. Do you consider Tiger to be of value? *

- Yes
- No

5. Have you ever seen Tigers in the wild? *

- Yes
- No

6. Have you visited any Tiger reserve in India? If yes, Please mention them.

Value Scale Questions

There is no right or wrong answer to these questions. We only want to find out your honest opinion.

7. Endangered species conservation should be a high priority concern of the government. *

Mark only one oval.

- 1 2 3 4 5
- Strongly Disagree Strongly Agree

8. The government should allocate more funds to deal with environmental problems in the country. *

Mark only one oval.

- 1 2 3 4 5
- Strongly Disagree Strongly Agree

9. Households that have more income should pay higher taxes in order to pay for endangered species conservation. *

Mark only one oval.

- 1 2 3 4 5
- Strongly Disagree Strongly Agree

10. The government should first invest in helping people before it spends money on endangered species protection. *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

11. The government should raise taxes to pay for more endangered species protection *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

12. Endangered species are important even if I don't get to see them. *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

13. Citizens should contribute to endangered species conservation by making cash donations to this cause. *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

14. It is everyone's duty to ensure that plants and animals as we know them today shall exist for mankind in the future. *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

15. The Tiger is valuable only because it is a source of revenue and employment *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

16. I believe that Tiger doesn't contribute to the country's economy *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

17. Tiger is worth conserving regardless of the government expenditure on Tiger Reserves. *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

18. The cultural/historical value of Tiger is important to me *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

19. I consider the "aesthetic" value of Tiger to be the most important *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

20. I do not believe any national park would be worth conserving if tigers are gone *

Mark only one oval.

1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

21. Tigers should exist even if I can't see them *

Mark only one oval.

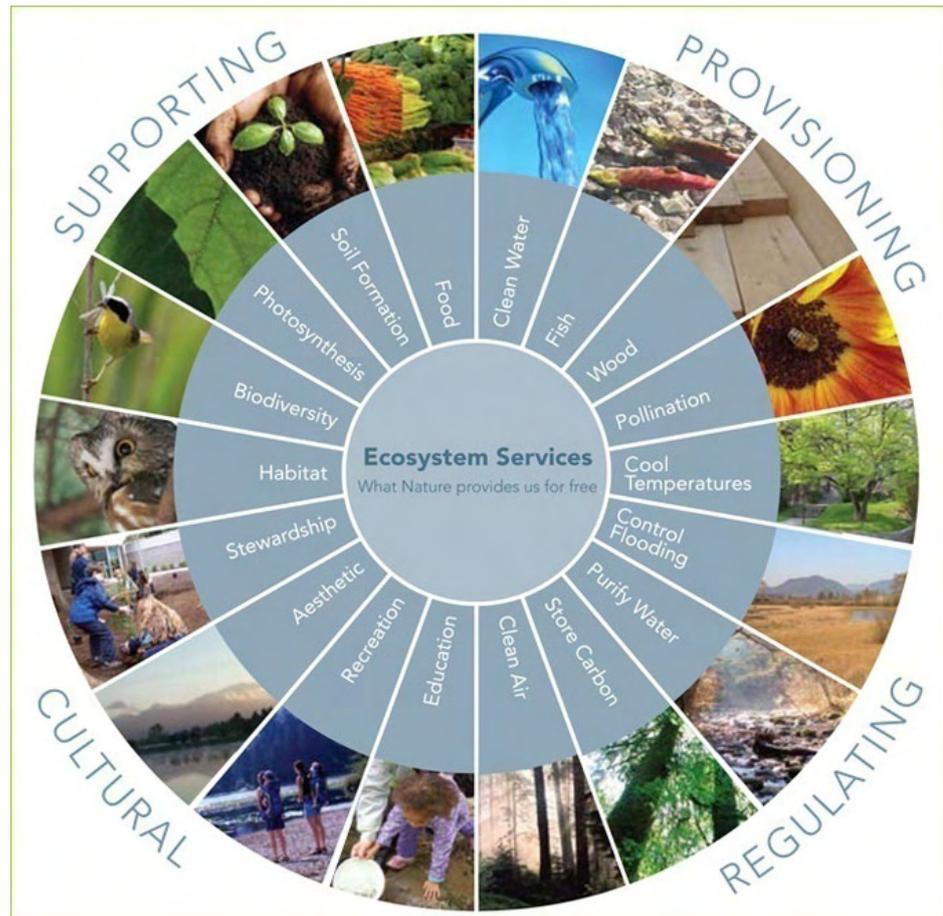
1 2 3 4 5
Strongly Disagree ○ ○ ○ ○ ○ Strongly Agree

Tiger Conservation Programme

A Conservation Plan is being proposed for Protection of Wild Tigers. But to implement the program a high amount of investment needs to be made across various activities. The government of India regularly earmarks a portion of its budget for Tiger protection, through NTCA. However, this is not enough to cover the expenses for the implementation of the Conservation Program. One possible source of fund is to set up a Tiger Trust Fund (TTF) wherein residents of India will give an amount to the Fund by way of the Tiger Conservation Fee (TCF). We are undertaking this survey to find out if enough people in India would be willing to pay a share to the fund to make it self sustaining. One proposal for fund collection is that people would give to the trust fund by paying a surcharge to their electricity bill which would serve as their part for setting up TTF. The amount of the surcharge would be fixed for all households (meaning it would not vary by the level of household's electricity consumption and it would not vary in time).

We know that there is not such a close connection between tigers and electricity bill. Given this situation, we are assuming that people would be willing to pay the surcharge and ALL the money would be transferred to TTF and will only be used for Tiger Conservation Program. Naturally, the very poor households in our society who do not have electricity connection will not be required to pay anything for the conservation. The purpose of this referendum is to see what per cent of people in India are willing to support a plan to add-on a monthly fixed surcharge on everyone's electricity bill. PLEASE REMEMBER: The survey you are participating in today is only to find out your opinion about this matter. From past experience with such surveys, it may as well be the case that people saying 'yes' without actually committing to pay. Therefore we requesting that you would answer based on how you would contribute if there will be an actual collection. Please vote positively in this survey only if you are really willing to pay a surcharge in your electricity bill for Tiger Conservation Program.

Benefits from Tiger Reserves



22. Would you vote in favor of Tiger Conservation Programme? *

By agreeing to this surcharge you are indicating that you value the existence of tigers in the wild for generations to come to enjoy. your voting for or against the surcharge should bear in mind that your household income is limited and has many competing alternative uses.

- Yes
- No

23. IF you voted 'YES' to the proposal of setting up the Tiger Conservation Program given that this will cost your household a monthly payment of Rs.300 over 5 years, would you be willing to pay to support Tiger Conservation Program?

Mark only one oval.

- Yes
- No

24. If you voted 'Yes', what was it about the Conservation program that convinced you to vote positively for it?

Check the most appropriate answer.

- I value the fact that tigers exist in the wild for generations to come
- The tiger is a special animal and should be protected
- This initiative can lead to more protection efforts for other endangered species in the country.
- Other:

25. If you voted 'Yes', Would you like to increase your contribution from Rs. 300 per month?

Check the most appropriate answer.

- Yes
- No
- Other:

26. If you voted 'NO' for question No. 22, what are the reasons why you did not vote for the program?

Please tick the most appropriate answers (limit your answers to 3).

- I think it is not worth conserving tigers
- I do not believe that the money I will pay will actually be used for Tiger Conservation.
- I think that other species are more important than Tigers.
- I do not like adding the amount to my electricity bill. Find other alternative means except electricity surcharge.
- A lot of poor people will be affected adversely
- I prefer giving money to humanitarian cause instead
- I do not earn enough money that can pay for the Tiger Trust Fund
- Only people who directly benefit from Tiger conservation should pay for this
- Only those from higher income groups should pay for this.
- Tigers are doomed to extinction and hence no point in paying
- Other:

27. Please rank the following according to how important you think they would be in encouraging people to contribute to a Tiger Conservation Fund. *

Mark only one oval per row.



	Most Important	Important	Least Important
Provide more information to the public about the problems of Tiger Conservation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provide more information about the conservation organizations and their activities so people know the channels how to help	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Create more transparency and accountability about how to help	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rely on celebrities to promote and disseminate information about the importance of protecting tigers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Make it convenient for people to donate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Get conservation organizations & government to publicize their activities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

28. When you decided on your vote, did you like the proposal to collect people's contribution as a surcharge on their electricity bill? *

- Yes
 No

29. If No, why not? Please check your answer/s.

Limit your answer to three

- a) The electricity bill is always increasing. I'm afraid that paying for the Conservation program will further cause the increase of my bill.
- b) I can't see any connection between electricity and tiger conservation – it doesn't have any basis.
- c) Not everyone is connected to NTCA – how can you collect from those not connected?
- d) The collection should not be mandatory every month - why can't we just pay when we want to?
- e) Monthly collection is too complicated - why not make this an annual payment?
- Other:

Household Data

We are almost finished but before we wrap up, we'd like to ask some general information about you and your household/ family to know you better.

30. Does your household pay the entire electricity bill, or share the bill with anyone outside your household? *

- Household paid entire bill
 Shared bill with someone else

31. How much was your household's own electricity bill last month? Or, if you share the bill, how much was your share? *

32. How old are you? *

Kindly mention your age (in years).

33. Gender? *

34. Marital Status? *

35. Highest Educational Attainment. *

- Intermediate
- Graduate
- Post Graduate
- Doctorate

Other:

36 Please list number of family members who are above 18
Years in age *

37. How many in your family, including yourself, are
earning income?

38. Please check the monthly HOUSEHOLD income
bracket where your household belongs. *

Include the cash earnings of all family members who are
working or gainfully employed, including yourself.

- Under Rs. 7,500
- Rs. 7,500 to 16,500
- Rs. 16,500 to 83,000
- Above Rs. 83,000

39. In the past year, did your household make donations to
any charitable causes?

- Yes
- No

40. Are you a member of any environmental organizations?

- Yes
- No

41. How are you associated with India? *



05

APPENDIX



ASSUMED COST OF BUILDINGS FOR ASSESSING COST OF RE-CREATING A TIGER RESERVE

Category	Number of units	Cost (₹unit ⁻¹)	Net Expenditure (₹)
Head Office	1	20000000	20000000
Range Offices	5	7500000	37500000
Residential Quarters	50	2500000	125000000
Check-posts	10	250000	2500000
Barracks	30	500000	15000000
Monitoring Stations	10	500000	5000000
Rest Houses	5	7500000	37500000
Veterinary Hospital (incl. Equip)	1	100000000	100000000
Tourist Shed & Ticket Counter	5	500000	2500000
Facilities(for tourists)	5	10000000	50000000
Labouratory	1	10000000	10000000
Watch Tower	10	200000	2000000
Store House	1	1000000	1000000
Total			408000000

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ASSUMED COST OF VEHICLES FOR ASSESSING COST OF RE-CREATING A TIGER RESERVE

Category	Number of units	Cost (₹unit ⁻¹)	Amount (₹)
Maruti Gypsy (Petrol)	20	60000	1200000
Jeep (Diesel)	10	50000	500000
Motor Cycle	25	6000	150000
Total			1850000



07

APPENDIX

ASSUMED COST OF EQUIPMENT FOR ASSESSING COST OF RE-CREATING A TIGER RESERVE

Category	Number of units	Cost (₹unit ⁻¹)	Amount (₹)
Fixed Set	48	10000	480000
Fixed Set (different frequency)	6	10000	60000
High-frequency Set	4	15000	60000
Walkie-Talkie	48	8000	384000
Walkie-Talkie (different frequency)	9	8000	72000
RT Tower	1	100000	100000
Computer	25	50000	1250000
Laptop	10	60000	600000
GPS	50	7000	350000
Printer	2	5000	10000
Scanner	5	5000	25000
Projector	10	80000	800000
Fax Machine	2	10000	20000
Xerox Machine	4	10000	40000
Video Camera	1	25000	25000
Digital Camera(camera trap)	50	15000	750000
Digital Camera	20	20000	400000
Night-vision Binocular	10	2500	25000
Binocular	50	2000	100000
Television Set	5	40000	200000
Telephone	40	3000	120000
Intercom	1	5000	5000
Mobile Set	10	15000	150000
Generator	10	400000	4000000
Pump Set	5	50000	250000
Air-Conditioner	20	30000	600000
Search Light	50	1500	75000
Solar Lantern	100	3000	300000
Trap Cages	20	8000	160000
Translocation Cages	10	10000	100000
Squeeze Cage	10	5000	50000
Total			14351000

08 APPENDIX

ASSUMED COST OF ARMS AND AMMUNITION FOR ASSESSING COST OF RE-CREATING A TIGER RESERVE

Category	Number of units	Cost (₹unit ⁻¹)	Amount (₹)
Tranquillizing Gun	10	100000	1000000
Dart Pistol	10	80000	800000
Rifles	100	150000	15000000
Air Rifles	9	100000	900000
Pistols	40	80000	3200000
Darts	100	1000	100000
Rifle Bullets	2000	150	300000
Pistol Bullets	10000	80	800000
Total			22100000



09

APPENDIX

ASSUMED REQUIREMENT OF HUMAN RESOURCES FOR ASSESSING COST OF RE-CREATING A TIGER RESERVE

Sr. No.	Category of Post	Number
1	CF & FD	1
2	DFD	1
3	AFD	1
4	Research Officer	1
5	Lab. Asstt.	1
6	Veterinary Officer	1
7	Head Clerk	1
8	Accountant	1
10	PA	1
11	Clerk-cum-Typist	6
12	Typist	1
13	Forest Ranger	20
14	DR/Fr.	40
15	Head Forest Guard	10
16	Forest Guard	100
22	Driver	25
23	Chowkidar	2
25	Peon	10
	TOTAL	223

(Footnotes)

- 1 Source: (Pandey et al., 1983)
- 2 Source: MoCF (2012)
- 3 Source: (Pandey et al., 1983)
- 4 Source: MoCF (2012)
- 5 Source: 25 except for Grasslands – savannah and Waterbody. The carbon storage for Grassland-savannah and Waterbody is based on Local Expert Knowledge
- 6 Source: 1¹³
- 7 Litres per capita per day
- 8 Source: Sankar (1990, 11). Estimates for the top soil (0-20 cm) from the study have been used here.
- 9 Source: MoCF (2012)
- 10 Source: (Pandey et al., 1983)
- 11 Source: MoCF (2012)
- 12 Source: 2⁵
- 13 Source: 6⁰



AUTHOR'S PROFILES



MADHU VERMA

mverma@iifm.ac.in

Dr. Madhu Verma is a Biological Science graduate with Masters, M.Phil & Ph.D in Economics and works as a Professor of Environment & Developmental Economics and Coordinator for the Centre for Ecological Services Management, Indian Institute of Forest Management, Bhopal. She has been a Visiting Professor at the University of Massachusetts, Amherst and a Visiting Scholar at the University of California, Berkeley, USA (2001) for her Post Doctoral research work. She is a Lead International Fellow(2007) and a Fulbright Fellow (2012). She does action and policy research in the areas of valuation & environmental modelling of forest, wetland and agriculture ecosystems and biodiversity; green accounting; PES, livelihoods economics; conservation finance. In her career of 30 years she has worked with various Ministries and Commissions of Govt. of India and several national and international funding and research organisations. She has large number of publications to her credit and her many research recommendations have been internalised in the decision making process of the government and creation of conservation instruments.



DHAVAL NEGANDHI

dhaval.negandhi@mespom.eu

Dhaval Negandhi is a Subject Expert in the area of Environment & Developmental Economics at the Centre for Ecological Services Management. He has Post-Graduate Diploma in Forestry Management and Erasmus Mundus Master's in Environmental Science, Policy and Management from three universities across Europe. His research interests and publications include valuation of ecosystem services (especially those from forest, wetland and agriculture ecosystems), spatial analysis, climate change, carbon accounting and statistical analysis.



CHANDAN KHANNA

chandankhanna1984@gmail.com

Chandan Khanna is working as Subject Expert at the Centre for Ecological Services Management (CESM), IIFM, Bhopal, which acts as an interdisciplinary centre to address crucial policy issues on ecosystem management. He has more than 6 years of research experience with major focus on economic aspects of natural resource, in development planning, environmental management and policy development. Prior to this position with CESM he has worked with Madhya Pradesh State Government in developing Climate Change Action plan for the state. Chandan holds a Bachelor of Engineering in Electrical & Electronics Engineering and Post Graduate Diploma in Forestry Management from IIFM.



ADVAIT EDGAONKAR

advait@iifm.ac.in

Advait Edgaonkar is a faculty member in the Faculty of Ecosystem and Environment Management. He did his PGDFM from Indian Institute of Forest Management, an MSc in Wildlife Ecology from Wildlife Institute of India, Dehradun and PhD in Wildlife Ecology and Conservation from the University of Florida, Gainesville. Advait teaches research methodology, wildlife ecology and impact evaluation at IIFM. His area of academic interest is research in wildlife ecology and sampling techniques in impact evaluation.



ASHISH DAVID

adavid@iifm.ac.in

Dr. Ashish David has an applied social sciences background that includes post graduation from the Tata Institute of Social Sciences and Phd. from the Indian Institute of Technology, Bombay. Having joined IIFM in Jan 2008 has developed courses on Social Impact Assessment and Ecotourism and Nature Conservation. His previous exposure to natural resource economics includes a Contingent Valuation study of Borivali National Park, Mumbai at IGIDR. Having worked with the Wildlife Institute of India after the doctoral work has gained exposure to issues of human wildlife interface conflict and Protected Area Management, wildlife surveys over large landscapes such as the Terai Arc Landscape.



GOPAL KADEKODI

gkkadekodi@hotmail.com

Gopal K Kadekodi is currently an Honorary Professor, and earlier a Research Professor for five years at the Centre for Multi-Disciplinary Development Research, Dharwad. He was formerly the Director of the Institute for Social and Economic Change, Bangalore and a Professor at the Institute of Economic Growth, New Delhi for twenty five years, a Visiting Professor at Erasmus University, Rotterdam, and Technical University, Twente in the Netherlands. He holds Ph.D. in Economics from University of South California, Los Angeles, USA and his areas of research include Common Property Resources, Energy, Ecology, Environment, and Economic Development. In the past, he was the President of the Indian Society for Ecological Economics, a Woodrow Wilson Fellow and a Fulbright Fellow, Member of NTCA and currently on several Boards and Commissions. He authored 14 books and more than 100 articles in national and international journals.



ROBERT COSTANZA

robert.costanza@anu.edu.au

Dr. Robert Costanza is a Chair in Public Policy at Crawford School of Public Policy. Dr. Costanza received BA and MA degrees in Architecture and a Ph.D. in Environmental Engineering Sciences (Systems Ecology with Economics minor) all from the University of Florida. Dr. Costanza is co-founder and past-president of the International Society for Ecological Economics, and was chief editor of the society's journal, Ecological Economics from its inception in 1989 until 2002. He is founding co-editor (with Karin Limburg and Ida Kubiszewski) of Reviews in Ecological Economics. He currently serves on the editorial board of ten other international academic journals. Dr. Costanza is the author or co-author of over 500 scientific papers and 23 books. His work has been cited in more than 11,000 scientific articles and he has been named as one of ISI's Highly Cited Researchers.



ROHIT SINGH

rohitsingh415@gmail.com

Rohit is a sustainability professional who has had diverse professional experiences. After completing his Post Graduate Diploma in Forestry Management, he initiated his professional career working with Axis Bank Ltd. in the Rural and inclusive Banking Vertical, in particular the Agri Business Division (focusing on the credit requirement of the Poor and Marginal farmers, its assessment and providing advances). He managed the operations for the state of Rajasthan and was responsible for maintaining the Agri-portfolio's health. He is currently working as a Subject Expert on Ecological Economics at the Centre for Ecological Services Management (CESM) at Indian Institute of Forest management. His subjects of interest include Climate Change, Valuation of ecosystem Services and Policy research in Environment and Development sectors.





INSTITUTIONS INVOLVED

INDIAN INSTITUTE OF FOREST MANAGEMENT (IIFM)

Established in 1982, the Indian Institute of Forest Management is a sectoral management institute, which constantly endeavours to evolve knowledge useful for the managers in the area of Forest, Environment and Natural Resources Management and allied sectors. It disseminates such knowledge in ways that promote its application by individuals and organizations. The mandate of IIFM is appropriately reflected in its mission statement, "to Provide Leadership in Professional Forestry Management Aimed at Environmental Conservation and Sustainable Development of Ecosystems."

CENTRE FOR ECOLOGICAL SERVICES MANAGEMENT (CESM), IIFM

CESM is a centre of excellence established in 2006 at Indian Institute of Forest Management with a mission to conduct action and policy research for ecosystem services management. The goal of the centre is to function as a think tank to generate useful database and an appreciation for ecosystem services, their physical assessment, valuation and establish incentive based mechanisms to promote conservation. The centre has contributed significantly in many important policy-decisions in the area of forest and natural resource management in the country.

NATIONAL TIGER CONSERVATION AUTHORITY

The National Tiger Conservation Authority is a statutory body under the Ministry of Environment, Forests and Climate Change constituted under enabling provisions of the Wildlife (Protection) Act, 1972, as amended in 2006, for strengthening tiger conservation, as per powers and functions assigned to it under the said Act. The National Tiger Conservation Authority has been fulfilling its mandate for strengthening tiger conservation in the country by retaining an oversight through advisories/normative guidelines, based on appraisal of tiger status, ongoing conservation initiatives and recommendations of specially constituted Committees. 'Project Tiger' is a Centrally Sponsored Scheme of the Ministry of Environment, Forests and Climate Change, providing funding support to tiger range States, for in-situ conservation of tigers in designated tiger reserves, and has put the endangered tiger on an assured path of recovery by saving it from extinction, as revealed by the recent findings of the All India tiger estimation using the refined methodology.



प्रगतेः मूलं प्रकृतिः

Indian Institute of Forest Management

(an autonomous Institute of Ministry of Environment, Forests and Climate Change, Govt. of India)

P. O. Box 357, Nehru Nagar, Bhopal (462003),
Madhya Pradesh, India

Phone: +91-755-277 5716, 277 3799

Fax: +91-755-277 2878, 267 1929

Web: www.iifm.ac.in



National Tiger Conservation Authority

Ministry of Environment, Forest & Climate Change,
Government of India,

First Floor, East Tower, NBCC Place,
Bhishma Pitamah Marg,

New Delhi - 110003, India

Phone: +91-11-24367552

Fax: +91-11-24369646

Web: www.projecttiger.nic.in

ABOUT THE REPORT

India is at the forefront of conserving tigers in the wild. Recent assessments have suggested that although the tiger population has risen by about 20 per cent in the country, the spatial occupancy of tigers has declined by 12 per cent. This contradiction is on account of the degrading quality of habitats in the peripheral areas that they are unable to support a viable population of tigers and is a worrying situation. Ever since its initiation in 1973, the Project Tiger has supported tiger conservation in the country by establishment of tiger reserves with the primary objective of ensuring continuity of evolutionary processes. However, in the process, a number of benefits are indirectly generated from tiger reserves which benefit society, but are completely ignored on account of their intangibility.

Indian Institute of Forest Management has been whole-heartedly pursuing development of useful policy briefs for conservation of biodiversity since its establishment. In furthering this cause, a study titled “Economic Valuation of Tiger Reserves in India: A VALUE+ Approach” initiated and supported by the National Tiger Conservation Authority, Ministry of Environment, Forests and Climate Change, Government of India has been undertaken by IIFM. Following a rigorous research process in collaboration with a team of experts and a thorough consultation process with relevant stakeholders, the study attempts to provide quantitative and qualitative estimates of the natural capital stored in selected tiger reserves of India to make benefits emanating from and embedded in these tiger reserves visible to economies and society. Recognition of benefits is likely to create an evidence base which will pave the way for more targeted and enhanced investment in these repositories of genetic information. The findings of the report will assist the policy makers appreciating the economics of tiger conservation in India. Developing and further strengthening policy frameworks for conservation of natural ecosystems and help to manage the transition to a resource efficient economy is the way forward.



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Contact information:

Centre for Ecological Services Management,
Indian Institute of Forest Management
P. O. Box 357, Nehru Nagar, Bhopal (462003), M.P., India
Tel: +91-755-277 5716 (Ext: 334)
Fax: +91-755-577 2878, 267 1929
Email: mverma@iifm.ac.in; cesm@iifm.ac.in
Web: www.iifm.ac.in/cesm