# ECONOMIC VALUATION OF TIGER RESERVES IN INDIA: A VALUE+ APPROACH

**Phase II**

**JULY 2019**

**Published By**

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

***In Collaboration With***
**National Tiger Conservation Authority (NTCA), GoI**

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## A VALUE+ APPROACH

**PHASE-II**

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## SUPPORTED BY

**National Tiger Conservation Authority (NTCA),**
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## DISCLAIMER

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सत्यमेव जयते

मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
भारत सरकार
Minister
Ministry of Environment, Forest & Climate Change
Government of India

## MESSAGE

Tigers being an umbrella species are a symbol of the health of the ecosystem and its functions. Tiger reserves as pristine areas of wilderness have been an effective measure of conservation of forests and other natural ecosystems which have a vital role in ensuring and uninterrupted flow of ecosystem services and other crucial ecological functions to economic systems.

To prioritize conservation of Tiger Reserves, one needs to measure their benefits and impact in policy and economy. Economic valuation has emerged as one of the effective tools in recent times to further intensify conservation of tiger habitats.

From the 2015 NTCA-IIFM study, emerged a very important coefficient in the form of ***"Investment Multiplier"*** which represented the contribution of investment in tiger reserves to economic systems. In this context, looking at the triggered effect of investment in tiger reserves leading to the creation of multiple benefits, it would not be wrong to designate these tiger reserves as ***'the engines of economic growth'***. I am glad that the NTCA decided to extend the study to ten additional tiger reserves in Phase-II which not only presents the output of economic valuation of ecosystem services from the selected tiger reserves but also covers additional aspects to provide a comprehensive assessment. The study also makes a pioneering attempt at using ***IPBES*** (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) protocols for highlighting uniqueness of each tiger reserve in the form of case-studies, narratives and anecdotes.

I congratulate the team of NTCA for their vision, initiative and support for such a study and the team of Centre for Ecological Services Management at IIFM for their sincere efforts to accomplish such a study. I extend my heartfelt wishes for the release of this report and believe that the study will be appreciated among all stakeholders and will pave the way for even more intensive efforts to preserve the habitat and biodiversity of this fascinating species.

Date: 11.07.2019

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SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

# MESSAGE

As India is witnessing rapid economic development and growth, the natural resources and forest areas of this country are under immense pressure. This may lead to increase in environmental issues in the long run. The Ministry of Environment, Forest and Climate Change (MoEFCC) mandate has been supporting various research studies to conserve India's natural capital, its lakes, rivers, biodiversity, forests and wildlife, ensuring the welfare of animals, and the prevention and abatement of pollution. In this regard, to further illustrate the role of tiger reserves in human well-being, the socio-economic development and generate awareness for conservation, the current study presents findings of economic valuation of ten tiger reserves of India.

The current study has used the state of the art techniques/methodology for arriving at the economic valuation and is an improvement over the previous study, i.e. the Phase-I Study executed by the Indian Institute of Forest Management published in 2015. The Phase-II Study will assist in making a robust evidence base for conservation of tiger reserves in the context of increasing developmental pressure. It will also provide rationale for continued and enhanced investment in these areas. Mapping and modelling of ecosystem services will help in designing management interventions around key hotspots areas inside the tiger reserves. The current study is an example of increasing the scientific temperament of India towards natural resource conservation. Considering the extent of the economic contribution of tiger reserves to our economy and socio-cultural dynamics reveals the significance of conservation of tiger reserves.

Following a VALUE+ approach, the study demonstrates a wide range of monetary and non-monetary benefits, more aptly called ecosystem services, from the selected tiger reserves. In its 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 study highlights the interrelationship between health and forest areas of tiger reserves. It also encompasses modelling of three ecosystem services across ten tiger using the InVEST software suite. Other added features of the study include, exploring tiger reserves as Destination Brands and providing data collection protocols for facilitating data collection in all tiger reserves for future ecosystem services assessment.

I would like to compliment the initiative of the National Tiger Conservation Authority for envisaging and conducting the study. I would like to congratulate the team at the Centre for Ecological Services Management (CESM), IIFM, Bhopal for accomplishing such an extensive study and coming out with a detailed and useful report. I am certain that the study will be another benchmark in the field of protected area management, biodiversity conservation and environmental economics.

[C. K. Mishra]

New Delhi, the 23rd July, 2019

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**GOVERNMENT OF INDIA**
**MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE**

## Message

Tiger Reserves are the cornerstones of wildlife conservation and preserve natural ecosystems which support ecological processes responsible for providing various goods and services that are vital for human well-being. These reserves through conservation efforts provide repositories of natural ecosystems and biodiversity which continuously emanate a wide range of economic, social, cultural benefits, healthy and resilient environment essential for human well-being.

To determine the contribution of tiger reserves to our socio-economic scenario, a study was commissioned for assessing the economic value of six tiger reserves by the National Tiger Conservation Authority (NTCA) to the Centre for Ecological Services Management (CESM) at the Indian Institute of Forest Management (IIFM) during 2013-15. The study outcomes were published in 2015 and received nation-wide accolades. Realizing the significance of the study, the Phase-II Study was assigned under which valuation of ecosystem services from ten additional tiger reserves of the country has been conducted.

The current study presents findings of economic valuation of ten tiger reserves of India while also comprehensively covering additional aspects including modelling of ecosystem services, giving weightage to unique features of the tiger reserves, highlighting health benefits from forests, evaluating tiger reserves as destination brands and providing data collection formats for facilitating the data collection process. The study findings also indicate that a sizeable proportion of flow benefits are intangible, and hence often go unaccounted in the market transactions. These benefits flow way beyond the boundaries of the tiger reserves benefiting a much larger population. The report presents findings in various frameworks including the most recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services' (IPBES) framework highlighting the cultural values as well for effective communication among various stakeholders and general audience.

I congratulate the National Tiger Conservation Authority for taking the initiative of conducting such a study and the study executing team from CESM, Indian Institute of Forest Management for accomplishing the study successfully and bringing up such anin-depth report which will help to mainstream Tiger Reserves, Natural Capital and Ecosystem Services into policy and decision-making facilitating the realization of the wildlife habitat conservation mandate of the Ministry.

(Siddhanta Das)

New Delhi, the 24th July, 2019

प्रकृतिः रक्षति रक्षिता
Nature Protects if She is Protected

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**NATIONAL TIGER CONSERVATION AUTHORITY**

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डॉ. अनूप कुमार नायक

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## FOREWORD

### *Comprehensive Assessment of Tiger Reserves*

India, as a country, has taken numerous milestone initiatives in the wildlife conservation. Project Tiger is one such initiative under which 50 tiger reserves have been established since its inception in 1973. These tiger reserves are primary repositories of natural forests and associated ecosystems. In addition to this, tiger reserves are also areas of pristine wilderness and ensure perpetuity of natural evolution and provide numerous benefits in the form of ecosystem services not only to the state but to the entire country and beyond. In the context of rapid developmental pressure, the tiger reserves provide us the necessary resilience and sustainable solutions to a number of environmental challenges. They also contribute greatly towards meeting the national and international environmental commitments of India *viz.* Achieving the national target of 33 per cent of forest cover, creating additional carbon sinks, achieving SDGs targets etc. Realizing that the tiger reserves have large unaccounted contributions to the economy and well-being of the society, the National Tiger Conservation Authority (NTCA) decided to get the assessment done of the tiger reserves' contribution to the economic system.

To effect the same, a study "Economic Valuation of Tiger Reserves in India" was commissioned by the NTCA to the IIFM. The study which was accomplished in 2015, unveiled a range of values of 25 ecosystem services which received huge publicity and media attention. The study for the first time worked out a very useful coefficient termed as **investment multiplier** which demonstrated enormous returns on each rupee invested in management of tiger reserves and also worked out the cost of inaction for not conserving a tiger reserve. The study set forth a platform for expanding the tiger reserves network with increased budgetary allocation. The current study, i.e. the Phase-II Study was launched in 2016 with the intention to extend the research to additional ten tiger reserves across various tiger landscapes in India. It provides qualitative and quantitative estimates of economic valuation for 26 ecosystem services.

Acknowledging the fact that tiger reserves have complex natural ecosystems and many of these benefits in the form of ecosystem services may be difficult to estimate in monetary or physical terms, the study has made a commendable attempt to provide a comprehensive assessment of economic and non-economic values. The study not only highlights the immense economic benefits emanating from tiger reserves but also encompasses many indirect benefits such as health benefits into the valuation frameworks. It underlines that each tiger reserve is unique in itself by highlighting uniqueness value through cases and narratives. It endeavors to explore tiger reserves as Destination Brands which emphasizes that tourists cherish many other aspects of tiger reserves rather than just sighting a tiger. It also presents modelling outputs using Integrated Valuation of Ecosystem Service and Trade-offs (InVEST) suite of software for three ecosystem services and provides data collection formats for facilitating data collection at tiger reserve level on a regular basis.

I compliment the IIFM team, under the leadership of Dr. Madhu Verma, which has done a commendable job in compiling such extensive information and accomplishing the study report. The study presents much needed information for policy makers, conservationists, economists, academia and other stakeholders. This report will help mainstreaming nature's contribution and ecosystem services into policy and decision-making and will further help such valuation for the remaining tiger reserves.

(Dr. Anup Kumar Nayak)

Dated: 24.07.2019

प्रगतेः मूलं प्रकृतिः

भारतीय वन प्रबंध संस्थान
पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय, भारत सरकार का स्वायत्त संस्थान
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**Dr. Pankaj Srivastava,** IFS
Director

## PREFACE

**Adding to the list of Pioneer Studies from IIFM**

One cannot stress enough the environmental problems our world faces today. Our most significant defence against these challenges are our natural ecosystems. Our country is home to rich biodiversity and vital ecological hotspots. At the same time the natural ecosystems and biodiversity faces immense threat and loss which will gradually result in ecological misbalance and huge social and economic costs. These costs might go unnoticed on account of lack of proper valuation and lack of favourable environment. The Centre for Ecological Services Management (CESM) at IIFM, Bhopal has produced many landmark studies including the Net Present Value (NPV) and Cost Benefit Analysis (CBA) studies in 2014 for MoEFCC and studies commissioned by the Finance Commission for 12th, 13th, 14th and 15th Finance Commission which have provided strong inputs into the decision making system. The landmark study on 'Economic Valuation of Tiger Reserves in India' accomplished in 2015 covering six tiger reserves received accolades among a vast range of stakeholders worldwide. Now, expanding the list of such breakthrough studies, it gives me great pleasure to introduce the study report by the Indian Institute of Forest Management on 'Economic Valuation of Tiger Reserves in India: Phase-II". The study was initiated and assigned by the National Tiger Conservation Authority (NTCA), Ministry of Environment, Forest and Climate Change, Government of India as an extension to the Phase-I the Study to ten additional tiger reserves.

The current study presents the findings of economic valuation of ten tiger reserves of India and comprehensively covers additional aspects including modelling of ecosystem services, giving weightage to unique features of the tiger reserves, highlighting health benefits from forests, evaluating tiger reserves as destination brands and providing data collection formats for facilitating the data collection process. The study findings also indicate that a large proportion of flow benefits are intangible, and hence often unaccounted for in market transactions. These benefits flow way beyond the boundaries of the tiger reserves and hence benefiting a much larger population. Recognizing the expanse of such benefits is likely to create an evidence base which provides justification for conservation of protected areas like tiger reserves and reasons for enhanced investment in these repositories of genetic information. The report presents findings in various frameworks for effective communication among various stakeholders and general audience.

I take this opportunity to express my sincere gratitude to the National Tiger Conservation Authority, Ministry of Environment Forest and Climate Change, Government of India, for commissioning the Phase-II Study to IIFM and their support throughout the study. I congratulate Dr. Madhu Verma for her best endeavours along with her exceptional team at the Centre for Ecological Services Management for their sincere efforts towards accomplishing the study and bringing out this report. I am also thankful to the full-fledged support extended by the Forest Survey of India, Forest Department of various states and MoEFCC. I hope the findings of this report will provide a clearer picture and offer better decision support system for strengthening the policies related to conservation of protected areas in India. It is also believed that the report will immensely help in generating mass awareness about conservation values of the protected areas among the general public.

Date: 4/7/2019
Place: Bhopal

12/7/19
**(Dr. Pankaj Srivastava)**

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At the very outset, the team wishes to extend its deep gratitude to the then Hon'ble Minister of State (Independent Charge)Environment, Forests and Climate Change, Shri Prakash Javadekar for releasing our Phase I Study report in January 2015 and for his deep appreciation for our study findings relating to the importance of conservation of tiger habitats by demonstrating the stock and flow value of ecosystem services, investment multiplier and cost of recreating the tiger reserve which triggered immense interest among the policy makers, academicians, media and other concerned stakeholders.

We are extremely grateful to the Shri Chandra Kishore Mishra (Secretary, MoEFCC), Shri Siddhanta Das (DG & SS MoEFCC), Shri Saibal Dasgupta (ADG, FC MoEFCC), Shri Manmohan Singh Negi (ADG, WL MoEFCC).

We are truely indebted to Shri B.S. Bonal (the then ADG & Member Secretary, NTCA) for awarding Phase II Study for additional Ten Tiger Reserves to us and also chairing the dissemination workshop and giving us pathway for the next Phase of the study.

We are thankful to Dr.Debabrata Swain (the then ADG & Member Secretary, NTCA) for his wholehearted support and periodic interventions to direct Tiger Reserves for data provisioning and field support.

We also take this opportunity to extend our heartfelt thanks to Dr.Anup Kumar Nayak (ADG & Member Secretary, NTCA) for his deep interest in the study and for his constant review and suggestions.

We are extremely thankful to the Technical Advisory Committee members of NTCA viz., Shri Tishyarakshit Chatterjee (Former secretary, MoEFCC and NTCA, Member), Shri Ravi Singh (Secretary General and ECO, WWF-India and NTCA Member), Shri Himmat Singh Negi, (IGF, NTCA) and Shri M.S. Beniwal (Under Secretary, IFD, MoEFCC) for their continuous support and guidance for the study and for providing important information and sharing their knowledge and giving valuable input during the initial phase of the study.

The authors are extremely grateful to Dr. Amit Mallick (IG, NTCA), Shri Sanjay Pathak (former DIG, NTCA), Shri NishantVerma (DIG, NTCA), Shri SurendraMehra (DIG, NTCA), Shri Raja Ram Singh (AIG, NTCA), Shri Vaibhav C. Mathur (AIG, NTCA) for their fruitful comments and extending wholehearted support during the execution of the study.

We extend our appreciation to Field Directors of Ten tiger reserves under study – Shri S. Saravanan (Nagarjunasagar-Srisailam Tiger Reserve), Shri S Chandrashekhar (Valmiki Tiger Reserve), Shri M. P. Singh (Palamau Tiger Reserve), Shri T. Heeralal (Bandipur Tiger Reserve), Shri Vivek Jain (Panna Tiger Reserve), Shri M. S. Reddy (Melghat Tiger Reserve), Shri H. K. Bisht (Similipal Tiger Reserve), Shri Sunil Choudhary (Dudhwa Tiger Reserve), Shri TanaTapi (Pakke Tiger Reserve), Shri (Anamalai Tiger Reserve), for their active support and participation throughout the study period and support during the field visits and data collection process. Their valuable inputs on the related issues, out of the sheer work experience and tremendous knowledge of forest management inspired the project team in shaping the methodology and execution process. Such an extensive exercise within the stipulated time period would not have been possible without their cooperation.

We further extend our gratitude to Shri J.D. Pati (Deputy Director, Similipal Tiger Reserve) and Shri. D.S. Srivastava (Advisor, Palamau Tiger Reserve) for their close cooperation and supervision during the field that helped in the completion of the project.

We would like to acknowledge and extend our appreciation to the Dr.SubhashAshutosh (DG, FSI) for his support to access the desired data and maps. We are indebted to Shri Rajesh

Kumar (former DDG, FSI), Shri Hirendra Kumar Tripathi, Shri SushilaTripathi and Shri Manoj Uniyal of FSI, for the constant support and close collaboration that was extended to us. The forest spatial data helped us immensely in modelling and mapping of ecosystem services flowing from tiger reserves.

We are indebted to Dr. Gopal K. Kadekodi and Dr.KaracheponeNinan, world renowned Ecological Economists, our external experts in the study for their guidance and valuable comments from time to time which helped us immensely to refine the methodology and focus our approach on the study objectives. The efforts of Ms. Parul Sharma, expert Market Research,another external expert for her substantial help in refining the methodology by adding a component on Brand Valuation in the study to accomplish it. She provided constant guidance, in-depth discussions, and valuable comments periodically and also assisted in data collection during the field visits.

The project could not have been possible without the wholehearted support and encouragement of Shri. Tejinder Singh (former Director, IIFM), who has also been our mentor throughout this study.

We are also indebted to Dr. Pankaj Srivastava, Director, IIFM for his concentrated involvement and methodical leadership and for his support in completing the final report. Besides the administrative support, we also received considerable academic inputs from him in the project.

During the period of study, various consultation meetings and key informant discussion were conducted with experts in each tiger reserve to provide us with a list of issues which need consideration in the study. In this regard, the authors are very grateful to all experts consulted for taking time from their busy schedules and accepting our request to have a discussion with them. The study benefitted vastly from issues that arose during these meetings. It also helped in including the views of all major stakeholders in the study.

The project is executed by the Centre for Ecological Services Management (CESM) at IIFM (Bhopal), and we gratefully acknowledge the support provided through the Centre for execution of the project. In this regard, we sincerely acknowledge the diligent efforts of Ms. Charu Tiwari (SPA, CESM) for developing protocols and frameworks, data collection and conducting the economic valuation exercise. We further thank Mr. SumitAnand (SPA, CESM) for carrying out InVEST modelling that involved data collection and mapping of various ecosystem services for better representation of the economic values of Tiger reserves. We thank Mr. Prabhakar Panda and Mr. ZuhailThatey, SPAs at CESM, for their inputs throughout the study and in finalization of the report in May 2019.The team at CESM also helped in conducting roundtables, workshops and data collection for various tiger reserves and other concerned institutes.

We also wish to put on record our deep appreciation for the efforts made by Mr. DhavalNegandhi and Mr. Chandan Khanna, SPA's, CESM, in the Phase-I study whose diligent efforts set the base for conducting such mammoth valuation and modelling exercise which was immensely helpful to the current team in executing the study.

We wish to extend our sincere thanks to Ms. Anila Nair, Stenographer Grade-I for her constant secretarial support in the execution of the study and Mr. D.K. Verma, Senior Assistant for his CESM for help in the organization of various project activities.

To conclude, we once again wish to thank all the concerned individuals and their institutions who contributed their time and expertise to the realization of the objectives of the study.

**Dr. MadhuVerma**
*Principal Investigator*

**Dr. Advait Edgaonkar**
**Dr. Ashish David**
**Co-Principal Investigator**

# KEY MESSAGES

Tiger reserves are effective tools of conservation of natural forest and wilderness areas. They are vital to ensure perpetuity of natural evolutionary processes and also support ecological processes responsible for providing a range of various associated economic, social, cultural and spiritual benefits also termed as ecosystem services.

The ecosystem service is an interdisciplinary approach to the integrative study of both socio-economic and ecological systems. A proper understanding of the benefits in the form of ecosystem services from tiger reserves generates awareness and assists in assessing the trade-offs and strengthens the case for conservation of our natural heritage.

Economic valuation helps in recognizing, demonstrating and capturing the ecosystem services values into the mainstream socio-economic system and policy making. Recognition of these values is likely to provide an evidence base for enhanced investment and targeted management practices.

The current study aims to provide outcomes of quantitative and qualitative estimates of economic valuation for 27 ecosystem services in ten tiger reserves across various tiger landscapes in India. The study attempts to incorporate a wide range of the associated monetary and non-monetary values.

While this study attempts to estimate the quantum and value of the services being generated from the selected tiger reserves, admittedly there are several services for which the economic values cannot be estimated in monetary terms. Thus, the study adopts a VALUE+ approach where the "VALUE" represents all the benefits in monetary terms for those services where monetary economic valuation is possible and derived based on available knowledge, tools and methods. The "+" represents all those benefits for which economic valuation is currently not possible on account of lack of accepted methodologies, knowledge, available technology, current resources and/or understanding of the system.

The study also addresses the utility of Ecosystem Service mapping, modelling and valuation to communicate the diverse values embedded and emanating from tiger reserves. Based on the availability of input information/ data, InVEST modelling was used for bio-physical estimation of three ecosystem services, viz. Carbon Storage, Water Provisioning and Sediment Retention.

The study attempts to underline the association of health benefits from the tiger reserve ecosystems and its connect to overall well-being. The study also attempts to highlight uniqueness and cultural values via qualitative assessment in the form of case studies, featured characteristics and narratives for selected tiger reserves using IPBES protocols.

The study findings indicate that the monetary value of flow benefits from the selected ten tiger reserves range from Rs. 5094.91 crore to 16202.11 crore annually. These tiger reserves also conserve enormous stock of timber and carbon which is valued in the range of Rs. 13745.53 crore to Rs. 96744.71 crore. The per hectare values of these TRs fall in the range of Rs. 4.08 lakhs to Rs. 7.41 lakhs per year.

The Total Economic Value of these tiger reserves depend on the direct, indirect and option values of the ecosystem services from these tiger reserves. According to the study findings, it is estimated that the quantum of collective direct benefits generated are in the range of Rs. 8.97 crore to Rs. 101.87 crore. Interestingly, the indirect benefits from these tiger reserve are range from Rs. 4221.34crore to Rs. 13317.50crore per annum. The selected tiger reserves offer resilience for the climate change and other environmental challenges the world faces today by conserving what matters. These include potential for important new discoveries, e.g. in pharmaceuticals, crop resilience, bio-mimicry and other areas. Preservation of option values is a significant argument in its own right for managing and expanding the network of tiger reserves.

With the objective to explore the potential of tiger reserves as destination brands, an online survey was conducted for the six tiger reserves of Phase-I. A structured questionnaire was used in online survey via snowball sampling.

Presentation of findings through various frameworks for suitable communication of results was made to relevant stakeholders. To reach a wider audience, frameworks have been used to highlight linkages to human life and associated values such as socio-cultural fulfilment, protection from various parasites, benign physical and chemical environment and adequate human resources.

In order to ensure conservation of tiger habitats and its biodiversity, it is essential to integrate the tiger management in a landscape approach and enhance the ecological connectivity. It will provide a larger natural base for flow of ecosystems services.

It is essential to put ecosystem services as a focal area under tiger management. To integrate the same and streamlining data collection, protocols in the form of formats and guidelines are added for making a database for future assessments.

# EXECUTIVE SUMMARY

Ecosystems Services can be defined as benefits in terms of goods or services provided by nature which are of fundamental importance to human well-being, for health, livelihoods, and survival.

The tiger reserves are repositories of natural ecosystems and biodiversity which emanate ecosystem services essential for human well-being. They continuously disseminate a range of economic, social, cultural and spiritual benefits. Tiger reserves as protected areas preserve the wilderness and natural systems which support ecological processes responsible for providing various goods and services. For instance, forests in tiger reserves aid in conserving the soil by preventing soil erosion and leaching of nutrients. They play an important role in the water cycle and other bio-chemical cycles, help in regulating the climate and balance of gases in the atmosphere, and help in mitigating disasters and protect the genetic diversity. Tiger reserves are beneficial not only at local but regional, national and even global scales. The study findings indicate that at different scales the flow of ecosystem matrix varies accordingly. Economic valuation helps in recognizing, demonstrating and capturing these values into the mainstream socio-economic system and policy making. These forests not only provide benefits for present direct and indirect use but also ensure the perpetuity of these benefits for future generations.

The ecosystem service is an interdisciplinary approach to the integrative study of both socio-economic and ecological systems. A proper understanding of the benefits in the form of ecosystem services from tiger reserves generates awareness and assists in assessing the trade-offs and strengthen the case for conservation of our natural heritage.

The Centre for Ecological Services Management (CESM) at the Indian Institute of Forest Management (IIFM) executed the study entitled "Economic Valuation of Tiger Reserves in India: A Value+ Approach" commissioned by the National Tiger Conservation Authority (NTCA), during 2013-15. It was an attempt to showcase the value of nature's benefits and their immense contribution to people's well-being. The Phase-I Study (2013-15) conducted valuation in six tiger reserves in India — Corbett, Kanha, Kaziranga, Periyar, Ranthambore and Sundarbans, representing different tiger landscapes in the country, carried out a pilot study for application of spatial mapping tools for ecosystem service mapping and attempted to estimate the cost of re-creating a tiger reserve. The study used scientific and objective parameters and peer-reviewed methodology along with a 'Value+' approach to conduct quantitative and qualitative assessment of 25 ecosystem services. While natural landscapes such as tiger reserves in all practicality can never be recreated, the study attempted to determine the cost of re-creation of a tiger reserve if inadequate protection to existing tiger reserves necessitate establishment of new ones. Additionally, the study also demonstrated the application of InVEST– a suite of tools used for mapping ecosystem services.

Recognizing the management and policy relevance of the work, extension of the study was suggested by NTCA and hence the second phase of the study was sanctioned to conduct economic valuation of ten additional tiger reserves and also improve upon the estimated values from the previous six tiger reserves. To accomplish the same, Phase-II of "Economic Valuation of Tiger Reserves in India" was assigned to CESM, IIFM by NTCA, which is the present study executed during 2016-19.

## THE PHASE-II STUDY

The Phase-II Study was commissioned with the objective of accomplishing economic valuation of tiger reserves in ten tiger reserves, viz. Anamalai (Tamil Nadu), Bandipur (Karnataka), Dudhwa (Uttar Pradesh), Melghat (Maharashtra), NagarjunasagarSrisailam (Andhra Pradesh), Pakke (Arunachal Pradesh), Palamau (Jharkhand), Panna (Madhya Pradesh), Similipal (Odisha), and Valmiki (Bihar) with improved methodology and frameworks and also to further enrich the outcomes of the Phase-I Study by identifying underlying gaps. The TOR, as per MoU dated June 3, 2016 between NTCA and IIFM lays down three specific objectives to be fulfilled through the Phase-II Study:

General Objective: To estimate the economic value of ten additional tiger reserves in India in an integrated manner to highlight their contribution to human well-being using objective and scientific parameters.

Specific Objective-1: Disseminate findings of the Phase-I Study through a National workshop and execute an unbiased peer-review process, critically analyse the methodology used and identify gaps that could not be addressed in the Phase-I Study.

Specific Objective-2: Estimate the economic value of the ecosystem services from ten tiger reserves not covered during the Phase-I Study, viz. NagarjunasagarSrisailam, Palamau, Panna, Melghat, Similipal, Pakke, Valmiki, Dudhwa, Bandipur and Anamalai tiger reserves using scientific and objective parameters.

Specific Objective-3: Develop and standardised data collection protocols and suggest ways to internalize the results of valuation study in the management of tiger reserves through Tiger Conservation Plans (TCPs).

## HIGHLIGHTS OF PHASE-II STUDY

The Phase-II Study presents outcomes of quantitative and qualitative estimates of economic valuation for 27 ecosystem services from ten tiger reserves across various tiger landscapes. In addition, the current study aspires to complement the findings and add merit by:

- **Incorporating methods of best practices based on a thorough literature review and using scientific tools and the latest advancements in the field of valuation.**
- **Presentation of findings via various frameworks for suitable communication of results to relevant stakeholders.**
- **Incluing a range of non-monetary values from the selected tiger reserves through the EPA framework.**
- **Modelling and mapping of ecosystem services based on three models of InVEST, i.e. Carbon Storage, Water Yield and Sediment Retention for all the ten tiger reserves taken up in Phase-II.**
- **Underlining the association of health benefits from the tiger reserve ecosystems and its connect to overall well-being.**
- **Highlighting uniqueness and cultural values via qualitative assessment in the form of case studies, featured characteristics and narratives for selected tiger reserves.**
- **Adding data collection formats and protocols for streamlining the data collection process and making a database for future assessments.**
- **Destination branding for the selected tiger reserves of Phase-I Study.**

## STUDY METHODOLOGY

The present study endeavours to further evolve the methodology from the Phase-I Study and adopts an overall scientific approach and rigorous research process. Consultation and discussion with key stakeholders including officials/members of the National Tiger Conservation Authority, State Forest Departments, subject experts, secondary sources, workshops, roundtables and expert team consultation were held for support in data collection, fieldwork, and for reviewing the methodology, monitoring the study progress and in preparing draft versions of the report. In the initial stages of the study, Tiger Conservation Plans (TCPs) for the selected tiger reserves were studied in detail to identify the ecological and socio-economic context, important ecosystem services and data sources. Existing literature on the ecosystem service valuation was reviewed to internalize the best practices for the existing study.

A dissemination workshop was conducted in New Delhi on November 17, 2016 in which key stakeholders were invited for appraising the findings of Phase-I and discuss the draft methodology for this phase of the study. Field visits were conducted to understand the local context and ecosystem dynamics and incorporate the uniqueness value pertaining to each tiger reserve. The study mainly uses secondary data along with some primary data for quantification of ecosystem services. The secondary sources from which information has been obtained are forestry and statistical organizations like the Forest Survey of India (FSI), concerned departments, boards, ministries, local institutions; likewise, primary information from communities via focused group discussions and interviews, and other research institutions. Other than these, data from peer-reviewed and widely accepted research papers and journals, databases and published reports have been used for quantification and arriving at a reliable economic valuation of ecosystem services wherever applicable. 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 ten tiger reserves across the country.

## CAPTURING A RANGE OF ECOSYSTEM SERVICES

Tiger reserves are complex ecosystems and not all the benefits provided by nature can be quantified and assessed in monetary terms. Therefore, the study attempts to capture benefits beyond monetary values such as the number of indigenous tribes, footfall at the spiritual sites inside the TR, number of research studies undertaken for a particular TR, and medicinal plants of the TR. Further the study also highlights the benefits of forests on the health of human beings. The values are captured using the Environmental Protection Agency (2009) effect categories to provide a comprehensive overview of the whole spectrum of ecosystem services emanating from the tiger reserves.

## THE VALUE+ APPROACH

There is an increase in the number of researches and studies on ecosystem services and their valuation across the globe, but in spite of our increased appreciation and awareness about nature, our understanding is still very limited on its functions and processes. While this study attempts to estimate the quantum and value of the services being generated/ flowing from the selected tiger reserves, admittedly there are several services for which the economic values cannot be estimated in monetary terms. Such services can only be quantified using some bio-physical indicator or can only be qualitatively described. Also, it is difficult to translate subjective values in the ecological-social dynamics such as health, intrinsic values and connection to lives of human beings in the area etc., into a single unit "money".

Thus, the study adopts a VALUE+ approach where the "VALUE" represents all the benefits in monetary terms for those services where monetary economic valuation is possible and derived based on available knowledge, tools and methods. The "+" represents all those benefits for which economic valuation is currently not possible on account of lack of accepted methodologies, knowledge, available technology, current resources and/or understanding of the system. Since all the values of the system are not captured in the values, the estimates thus arrived in the study are conservative.

## ECOSYSTEM SERVICES MODELLING- INVEST

InVEST is an open source modelling software, designed under Stanford University's Natural Capital project. This model was used to map and value the goods and services from nature that sustain and fulfil human life. The model is often used to understand and establish linkages between ecosystems and how they benefit the people and communities. Hence, the model helps in evaluating tradeoffs, thereby facilitating decision-making. Ecosystems provide ecosystem benefits: the services that communities avail. These services can be divided into the following categories: provisioning, supporting, regulating, and cultural. While these services are indispensable, they are difficult to measure and visualize, and the accuracy of such efforts is often questionable. This model helps decision makers visualize the impacts of decisions and identify tradeoffs between environmental, economic, and social benefits.

The study also addresses the utility of Ecosystem Service mapping, modelling and valuation to communicate the diverse values embedded and emanating from tiger reserves. Based on the availability of input information/data, InVEST modelling was used for bio-physical estimation of three ecosystem services, viz. Carbon Storage, Water Provisioning and Sediment Retention. The InVEST modelling process and outputs were then refined with team and external experts. InVEST models are spatially-explicit, using maps as information sources and produce results in biophysical terms or economic terms. InVEST quantifies the ecosystem services and thereby, valued the ecosystem services that are provided in the current landscape. The carbon model calculates the carbon stored in all tiger reserves. The water yield model calculates pixel level yields as the difference between precipitation and actual evapotranspiration. and thereby estimates mean annual water yield per watershed. The sediment model calculates generated and retained sediment at a pixel scale using USLE and routing. The sediment model thus estimates mean annual erosion and mean annual sediment retention per watershed. The detailed methodology of the three mentioned models is explained in further sections.

## ANAMALAI TIGER RESERVE

Anamalai Tiger Reserve (ATR) is one of the prominent reserves in the southern region of the Western Ghats providing a habitat for many endemic species and the presence of vast Shola forests. It is estimated that the ATR provides flow benefits worth Rs. 9776.5 crore per year (Rs. 5.62 lakh per hectare) and stock benefits of Rs. 46150.09 crore per year. Critical ecosystem services from ATR include provisioning of water (Rs. 38.19 crore per year), climate regulation (Rs. 1822.45 crore per year) and genepool protection (Rs. 1579.19 crore per year).

Under the Total Economic Value (TEV) framework, the annual direct-, indirect-benefits and option values were Rs. 22.71 crore, Rs. 8174.62 crore and Rs. 1579.19 crore, respectively. As per the MA framework, the value of provisioning services was Rs. 12.21 crore per year, that of regulating services was Rs. 9625.65 crore per year and for cultural services was Rs. 54.20 crore per year. The annual tangible and intangible benefits were found to be worth Rs. 12.21 crore and Rs.55914.39 crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 3823.33 crore), protection from disease (Rs. 18.48 crore), benign physical and chemical environment (Rs. 4293.37 crore), socio-cultural fulfilment (Rs. 62.14 crore) and ecosystem assets (Rs. 47729.28 crore). The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 17723.37 crore per year. The investment multiplier for ATR was calculated as 3750.10.

## BANDIPUR TIGER RESERVE

Part of the Nilgiri Biosphere Reserve, the Bandipur Tiger Reserve (BTR) is recognized as Mega Biodiversity Area and is home to a large population of elephants in the country. It is estimated that the tiger reserve provides flow benefits worth Rs. 6405.7 crore per year (Rs. 4.41 lakh per hectare) and stock benefits of Rs. 31476.15 crore per year. Vital ecosystem services that arise from this reserve include provisioning of water (Rs. 2066.95 crore per year), climate regulation (Rs. 1443.21 crore per year) and genepool protection (Rs. 1263.74 crore per year).

Under the Total Economic Value (TEV) framework, the annual direct-, indirect-benefits and option values were Rs. 56.35 crore, Rs. 5085.57 crore and Rs. 1263.74 crore, respectively. As per the MA framework, the value of provisioning services was Rs. 48.49 crore per year, that of regulating services was Rs. 6323.71 crore per year and for cultural services was Rs. 6.69 crore per year. The annual tangible and intangible benefits were found to be worth Rs. 48.49 crore and Rs. 37833.31 crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 2107.04 crore), protection from disease (Rs. 15.79 crore), benign physical and chemical environment (Rs. 3004.00 crore), socio-cultural fulfilment (Rs. 15.08 crore) and ecosystem assets (Rs. 32739.89 crore). The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 14966.45 crore per year. The investment multiplier for BTR was calculated as 716.34.

## DUDHWA TIGER RESERVE

Located on the Indo-Nepal border, Dudhwa Tiger Reserve (DTR) is a part of Shivalik Hills and Gangetic Plains tiger landscape complex in Uttar Pradesh that provides habitat for unique species including the endangered Rhinoceros and Bengal Florican.The tiger reserve generates flow benefits worth Rs. 5094.9 crore per year (Rs. 5.29 lakh per hectare) and stock benefits of Rs 56106.31 crore per year. Key ecosystem services that arise from this reserve include provisioning of water (Rs. 1643.16 crore per year), carbon sequestration (Rs. 1419.50 crore per year) and climate regulation (Rs. 1054.05 crore per year).

Under the Total Economic Value (TEV) framework, the annual direct, indirect-benefits and option values were Rs. 8.97 crore, Rs. 4221.34 crore and Rs. 864.61 crore, respectively. As per the MA framework, the value of provisioning services was Rs. 2.80 million per year, that of regulating services was Rs. 5025.89 crore per year and for cultural was Rs. 0.40 crore per year. The annual tangible and intangible benefits were found to be worth Rs. 2.80 crore and Rs. 61198.43 crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 1643.84 crore), protection from disease (Rs. 16.22 crore), benign physical and chemical environment (Rs. 2567.73 crore), socio-cultural fulfilment (Rs. 2.51 crore) and ecosystem assets (Rs. 56970.92 crore). The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 11013.92 crore per year. The investment multiplier for DTR was calculated as 573.83.

## MELGHAT TIGER RESERVE

Fondly known as Kipling Country marked with large tracts of hills and ravines in the Satpura mountain ranges, the Melghat Tiger Reserve (MTR) is a raptor's paradise with more than 260 species of birds. The tiger reserve provides flow benefits worth Rs. 12349.3 crore per year (Rs. 6.09 lakh per hectare) and stock benefits of Rs. 75043.33 crore per year. Important ecosystem services that arise from this reserve include provisioning of water (Rs. 3448.64 crore per year), carbon sequestration (Rs. 4120.48 crore per year) and genepool protection (Rs. 1984.95 crore per year).

Under the Total Economic Value (TEV) framework, the annual direct-, indirect-benefits and option values were Rs. 51.41 crore, Rs. 10312.99crore and Rs 1984.95 crore, respectively. As per the MA framework, the value of provisioning services was Rs. 36.20 crore per year, that of regulating services was Rs. 12263.41crore per year and for cultural services was Rs. 0.31 crore per year. The annual tangible and intangible benefits were found to be worth Rs. 36.20 crore and Rs. 87356.47crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 3484.84 crore), protection from disease (Rs. 15.92 crore), benign physical and chemical environment (Rs. 6863.32crore), socio-cultural fulfilment (Rs. 0.31 crore) and ecosystem assets (Rs. 77028.28 crore). The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 25380.47crore per year. The investment multiplier for MTR was calculated as 346.73.

## NAGARJUNASAGAR SRISAILAM TIGER RESERVE

One of the largest tiger reserve in the country in terms of area notified, Nagarjunasagar-Srisailam Tiger Reserve (NSTR) features undulating terrain, subterranean valleys and steep cliffs comprising Hardwickia forest and mixed dry deciduous forest. The tiger reserve home to ruins of past dynasties, now provides a prime habitat for many endangered species. The tiger reserve provides flow benefits worth Rs. 16202.1 crore per year(Rs. 4.29 lakh per hectare) and stock benefits of Rs. 50129.74 crore per year. Main ecosystem services that arise from this reserve include provisioning of water (Rs. 5055.24 crore per year), carbon sequestration (Rs. 2050.89 crore per year), climate regulation (Rs. 4301.14 crore per year) and waste assimilation (Rs. 325.14 crore per year).

Under the Total Economic Value (TEV) framework, the annual direct-, indirect- benefits and option values were Rs. 101.87 crore, Rs. 12883.35 crore and Rs. 3216.19 crore, respectively. As per the MA framework, the value of provisioning services was Rs76.70 crore per year, that of regulating services was Rs. 16041.15 crore per year and for cultural services was Rs. 1.74 crore per year. The annual tangible and intangible benefits were found to be worth Rs. 76.70 crore and Rs. 66254.44 crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 5128.94 crore), protection from disease (Rs. 24.15 crore), benign physical and chemical environment (Rs. 7827.39 crore), socio-cultural fulfilment (Rs. 4.74 crore) and ecosystem assets (Rs. 53345.92 crore). The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 34592.28 crore per year. The investment multiplier for NSTR was calculated as 7488.59.

## PAKKE TIGER RESERVE

Pakke Tiger Reserve (PKTR) located in the foothills of the Eastern Himalayas is home to four species of hornbills. Evergreen and broadleaved forests provide a key habitat for Clouded Leopard among numerous other faunal species. The tiger reserve generates flow benefits worth Rs. 8722.2 crore per year (Rs. 5.79 lakh per hectare) and stock benefits of Rs. 32201.19 crore per year. Vital ecosystem services that emanate from this reserve include provisioning of water (Rs. 3674.01 crore per year), carbon sequestration (Rs. 1168.14 crore per year) and climate regulation (Rs. 20.01 crore per year).

Under the Total Economic Value (TEV) framework, the annual direct-, indirect- benefits and option values were Rs. 20.36 crore, Rs. 7214.75 crore and Rs. 1487.09 crore, respectively. As per the MA framework, the value of provisioning services was Rs. 8.61 crore per year and that of regulating services Rs. 8675.41 crore per year. The annual tangible and intangible benefits were found to be worth Rs. 8.61

crore and Rs. 40914.77 crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 3682.62 crore), protection from disease (Rs. 10.84 crore), benign physical and chemical environment (Rs 3541.64 crore) and ecosystem assets (Rs. 33688.28 crore). The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 20849.31 crore per year.The investment multiplier for PKTR was calculated as 1946.49.

## PALAMAU TIGER RESERVE

The only tiger reserve in the state of Jharkhand, PalamauTiger Reserve (PLTR) was formerly used for cattle grazing and camping. The Sal(Shorearobusta) forests, mixed deciduous forest and bamboo groves make up the landscape delivering diverse ecosystem services. The tiger reserve provides flow benefits worth Rs. 12954.4 crore per year (Rs. 6.54 lakh per hectare) and stock benefits of Rs. 96744.71 crore per year. Major ecosystem services that arise from this reserve include carbon sequestration (Rs. 5979.57 crore per year), provisioning of water (Rs. 2853.85 crore per year), and climate regulation (Rs. 21.14 crore per year).

Under the Total Economic Value framework (TEV), the annual direct-, indirect- benefits and option values were Rs. 46.03crore llion, Rs. 11123.39 billion and Rs. 1785.01 crore, respectively. As per the MA framework, the value of provisioning services was Rs. 34.33 crore per year, that of regulating services was Rs. 12881.29 crore per year and cultural services was Rs. 0.77 crore per year. The annual tangible and intangible benefits were found to be worth Rs. 34.33 crore and Rs. 109664.82 crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 2888.17 crore), protection from disease (Rs. 20.39 crore), benign physical and chemical environment (Rs. 8260.08 crore), socio-cultural fulfilment (Rs. 0.77 million) and ecosystem assets (Rs. 98529.72 crore).The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 23101.71 crore per year.The investment multiplier for PLTR was calculated as 3450.55.

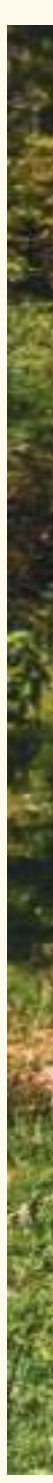
## PANNA TIGER RESERVE

Panna Tiger Reserve (PNTR) characterized with its extensive plateaus and gorges is situated in the Vindhyan mountain range of North Madhya Pradesh. It forms the northern most tip of the natural teak forests and the Ken river flows through the tiger reserve.The tiger reserve generates flow benefits worth Rs. 6954.6 crore per year (Rs. 4.08 lakh per hectare) and stock benefits of Rs. 13745.53 crore per year. Critical ecosystem services that emanate from this reserve include provisioning of water (Rs. 2582.73 crore per year), climate regulation (Rs. 2021.47 crore per year) and waste assimilation (Rs. 166.55 crore per year).

Under the Total Economic Value (TEV) framework, the annual direct-, indirect-benefits and option values were Rs. 78.80 crore, Rs. 5310.76crore and Rs. 1565.00 crore, respectively. As per the MA framework, the value of provisioning services was Rs. 67.14 crore per year, that of regulating services was Rs. 6847.69crore per year and cultural services was Rs. 1.84 crore per year. The annual tangible and intangible benefits were found to be worth Rs. 67.14 crore and Rs. 20632.95crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 2639.23 crore), protection from disease (Rs. 13.58 crore), benign physical and chemical environment (Rs. 2724.26crore), socio-cultural fulfilment (Rs. 12.48 crore) and ecosystem assets (Rs. 15310.53 crore The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 14455.42crore per year.The investment multiplier for PNTR was calculated as 1939.36.

## SIMILIPAL TIGER RESERVE

Similipal Tiger Reserve (STR) is part of the UNESCO World Network of Biosphere Reserves rich with more than 1000 species of plants including 94 species of orchids. The reserve comprises of different forest types including Sal (Shorearobusta)forest, moist deciduous forest and semi-evergreen patches. The tiger reserve provides flow benefits worth Rs. 16030.1 crore per year (Rs. 5.89 lakh per hectare) and stock benefits of Rs. 49832.80 crore per year. Main ecosystem services that arise from this tiger reserve include provisioning of water (Rs. 7033.05 crore per



year), Genepool protection (Rs. 2623.08 crore per year) and climate regulation (Rs. 3482.72 crore per year).

Under the Total Economic Value (TEV) framework, the annual direct-, indirect-benefits and option values were Rs. 89.53 crore, Rs. 13317.50crore and Rs. 2623.08 crore, respectively. As per the MA framework, the value of provisioning services was Rs. 69.21 crore per year and that of regulating services was Rs. 15894.86crore per year. The annual tangible and intangible benefits were found to be worth Rs. 69.21 crore and Rs. 65793.71crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 7042.03 crore), protection from disease (Rs. 20.34 crore), benign physical and chemical environment (Rs. 6284.43crore), socio-cultural fulfilment (Rs. 60.23 crore) and ecosystem assets (Rs. 52455.88 crore). The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 29897.49crore per year.The investment multiplier for STR was calculated as 3038.31.

## VALMIKI TIGER RESERVE

The only tiger reserve in Bihar, Valmiki Tiger Reserve (VTR), sets an excellent example of Shivalik Hills and Gangetic Plains landscape with a mosaic of dense forests, open woodlands, swamps and grasslands. The tiger reserve provides flow benefits worth Rs. 6900.3 crore per year (Rs. 7.41 lakh per hectare) and stock benefits of Rs. 43682.86 crore per year. Critical ecosystem services that arise from this tiger reserve include provisioning of water (Rs. 2216.04 crore per year), carbon sequestration (Rs. 2590.89 crore per year) and climate regulation (Rs. 1122.90 crore per year).

Under the Total Economic Value (TEV) framework, the annual direct-, indirect-benefits and option values were Rs. 39.70 crore, Rs. 5987.39 crore and Rs. 873.20 crore, respectively. As per the MA framework, the value of provisioning services was Rs. 33.24 crore per year and that of regulating services was Rs. 6846.06 crore per year. The annual tangible and intangible benefits were found to be worth Rs. 33.24 crore and Rs. 50549.92 crore, respectively. In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 2249.28 crore), protection from disease (Rs. 7.71 crore), benign physical and chemical environment (Rs. 3770.11 crore) and ecosystem assets (Rs. 44556.07 crore). The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 11637.86 crore per year. The investment multiplier for VTR was calculated as 1235.6.

## HUMAN VALUES AND ECOSYSTEM ASSETS FROM TIGER RESERVES

Ecosystem services are crucial for human well-being and therefore highlights the synergies between human values and ecosystem services. The study uses the Ken J. Wallace (2007) framework to present those ecosystem functions and processes that are the means to achieve the end product, i.e. our ecosystem services. Rearranging the ecosystem services values in this framework helps in conveying linkages between ecosystem services, ecosystem assets and human values such as socio-cultural fulfilment, protection from various parasites, benign physical and chemical environment and adequate human resources. The study findings indicate that the natural ecosystems in the tiger reserves provide adequate resources to humans in the range of Rs. 1643-7042 crore. They offer protection from disease, predators and parasites, which is an avoided cost in the range of Rs. 7.7 crore to Rs. 24.15 crore.

They also help in maintaining a benign physical and chemical environment for amenable living conditions by providing necessary infrastructure and ecosystem services worth Rs. 2567-8260 crore. The tiger reserves play a significant role in the lives of local communities and conserve a range of traditional values apart from providing recreation and leisure. Thus the socio-cultural fulfilment benefits from these TRs range from 0.3 crore to 62.144 crore. They conserve ecosystems and natural assets worth Rs. 15310-98530 crore.

## HEALTH BENEFITS AND TIGER RESERVES

"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1948)

The forestshav been enjoyed by humans for a long time because of the quiet atmosphere, beautiful scenery, moderated climate and clean, fresh air. Apart from providing these physical benefits, natural capital services impact human health by forming part of the natural infrastructure that supports well-being and economic prosperity. Forests have been conserved through contribution of tiger reserves. Nature provides fresh water, clean air and food, influences disease occurrence and spread, supports local economies and is the source of many current and potential medicines. They provide places for physical activity, social connection, inspiration and calm contemplation. They affect people's mental, physical, cultural, and spiritual health and well-being. Protected areas are not only the custodians of natural ecosystems but are also natural solutions for securing our health and well-being while adapting to the impact of climate change. Nature-based interventions like horticulture therapy, nature assisted therapy or nature-guided therapy and conservation therapy are becoming increasingly popular.

Well-being is inextricably linked to natural ecosystems. Wilderness experience, night walks, night sounds, and stargazing are opportunities for connecting people to nature through various methodologies, such as stories of cultures and lore. There is much evidence that highlight the interplay between ecosystem function and human health. Forests help in improving psychological well-being, reduce stress, boost immunity, enhance productivity and promote healing.

Today, health is viewed as a holistic and positive state embracing the individual in relation to his/her entire life situation (including biological, cultural, social and environmental aspects. Environmental sustainability and human health are two of the world's most pressing challenges. Vibrant, thriving ecosystems in the tiger reserves have a powerful impact on human health, economic vigour, and social vitality.

In the study, well-being is discussed from different perspectives including livelihood dependency; importance to health and healing; maintaining traditional culture and knowledge systems; social empowerment, stewardship, good governance and holistic planning for a country. Findings so far indicate that protected areas such as tiger reserves and other natural environments play a vital role in human health and well-being through providing access to nature. These divergent researches come to a central notion that contact with nature is beneficial, perhaps even essential, to human health and well-being; also urging a socio-political-ecological approach to health—a deeper understanding of the interaction between population, environment, power and disease, including economic drivers.

The study highlights the holistic impact of tiger reserves on the health and overall well-being of human beings. The health benefits generated can be considered as a collective product of significant ecosystem services such as genepool protection, carbon storage, carbon sequestration, water provisioning, biological control, pollination, cultural heritage, recreation, nature interpretation, gas regulation, and climate regulation services that have a huge direct and indirect impact on human health.The collective worth of the mentioned ecosystem services having direct indirect impact on human health was found to be in the range of Rs. 11014 crore to Rs. 34593 crore per year for the selected tiger reserves.

## UNIQUENESS VALUE OF TIGER RESERVES- HIGHLIGHTED USING IPBES FRAMEWORK

Each tiger reserve has its own unique ecology and features. To demonstrate such uniqueness of tiger reserves, prominent features have been captured using the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) inclusive approaches like the Multiple Evidence Based (MEB). These approaches emphasize the need for co-production through the engagement of different stakeholders, such as scientists from different disciplines, practitioners and disseminators, and Indigenous and Local Knowledge (ILK) holders. The IPBES protocols promote participatory economic valuation approaches like cultural and social valuation methods. Such methods are particularly encouraged to engage a trans-disciplinary approach which bridges multiple disciplines and includes non-scientist participants as partners assume greater importance. In this study, wherever applicable, various methods such as Ethno-Ecological, Narrative Valuation and Preference Assessment have been used to depict the uniqueness of each tiger reserve through case studies, narratives and anecdotes.

All tiger reserves are a part of the natural green tract connecting various tiger landscapes. Some of these areas are remarkably placed in terms of its location for acting as a corridor and/or buffer in a tiger landscape joining crucial tiger habitats and meta populations such as Bandipur Tiger Reserve, Pakke Tiger Reserve, Dudhwa Tiger Reserve and Valmiki Tiger Reserve. The habitat value of all the tiger reserves is enormous which is portrayed in its distinctive features. Tiger reserves which are unique in ecosystem and habitat value are Dudhwa Tiger Reserve with its Shivalik Hills and Gangetic Plains landscape features and a unique combination of wetland-grassland-woodland ecosystem, similarly Anamalai Tiger Reserve also encompasses a mosaic of ecosystems, Pakke Tiger Reserve depicts unique Indo-Malaysian landscape and North-Eastern ecosystem and Panna Tiger Reserve has distinctive grassland-riverine-woodland ecology. Anamalai TR is also unique in terms of the shola forests within the TR which contains Grass Hill National Park and Kariyan Shola Forest both of which are critical biodiversity hotspots, rich in wildlife and contain many endangered and medicinal species. Panna Tiger Reserve is home to vultures and is an example of a successful tiger re-introduction case. Dudhwa Tiger Reserve and Valmiki Tiger Reserve are also unique in terms of their placement along the international border and landscape sharing with Nepal. Tiger reserves like Melghat are one of the oldest and largest tiger reserves conserving tigers and the biodiversity of its habitat. Tiger reserves are unique in terms of the outstanding flora and fauna, such as SimilipalTiger Reserve which is the only tiger reserve as the home of the Melanistic Tiger, DudhwaTiger Reserve has swamp deer, and AnamalaiTiger Reserve has NilgiriTahr. NSTR is one of the largest tiger reserves and shows that a proper management can help in coexistence of human and natural infrastructure. All the tiger reserves are bestowed with rivers, springs, streams and other forms of waterbodies acting as vital sources of water in the lean season for the nearby areas.

## EXPLORING TIGER RESERVES AS DESTINATION BRANDS

A destination brand is a set of cultural and symbolic meanings related to a place. The tangible assets of the destination brand could include geographical features such as mountains, forests, historical sites, and attractions; intangible assets might include culture, customs, and history. Consumers going to a destination are seeking to experience tangible or intangible features that are different from those they can experience at home. To explore the potential of tiger reserves as destination brands, a pilot exercise was conducted for the six tiger reserves of Phase-I in the form of an online survey. A structured questionnaire was used in Online Survey via snowball sampling. The attributes captured in the survey primarily included, awareness, perception, intention to revisit and recommendation of the respective tiger reserve. Brand perception was asked for the destinations the respondents were aware of, whereas, intention to revisit and recommendation were administered only to the visitors of the destination brand. For six TRs of Phase-I (Corbett, Ranthambore, Kanha, Periyar, Sundarbans and Kaziranga). Online Survey was conducted to study tourists' attitudes towards brand equity covering the parameters of destination brand. The parameters used for Destination Brand Measurement were Awareness/ Brand Identity, Image Attributes/Brand Perception and Recommendation and Willingness to Visit. Brand equity can be understood as a multidimensional construct composed of brand strength and brand value. While brand equity deals with a consumer-based perspective; brand value is more of a company-based perspective. In case of tiger reserves, judging through consumer perspective seemed more appropriate. As calculating brand value was not possible because the exercise is too data intensive, as the surrogate, brand equity was considered to measure Destination Brand.

The primary survey helped assess the brand equity of tiger reserves in terms of awareness, brand perception, intention to revisit and recommendation. The survey findings indicate that visitors to Tiger Reserves seek natural beauty and not just tigers. Tiger Reserves like Corbett, Ranthambore and Kanha rank high in brand awareness. In terms of Brand Image- Sundarbans and Kanha are perceived to be unique destinations by 54% and 48 per cent respondents (higher than others). In terms of presence of religious, historical and cultural places, Ranthambore (49 per cent) stands out among the lot. Tiger reserves like Corbett (60 per cent) and Kanha (63 per cent) are highly associated with scenic natural beauty. In the management aspect, Kanha outperforms on the service related parameters. Visitors have different perceptions across tiger reserves. The TR Corbett, Ranthambore and Kanha are perceived to be better on most of the parameters. The Brand Equity score is highest for Kanha (296) followed by Ranthambore (258) and Corbett (228)

## CONCLUSION AND WAY FORWARD

The study findings indicate that the monetary value of flow benefits from the selected ten tiger reserves range from Rs. 5094.91 to 16202.11 crore annually. These tiger reserves also conserve enormous stock of timber and carbon which is valued in the range of Rs. 13746 crore to 96745 crore. The stock serves as a basis for the natural systems to flourish and emanate flow of ecosystem services. The per hectare values of these TRs fall in the range of Rs. 4.08 lakh to 7.41 lakh per year. The study findings also indicate that a sizeable proportion of flow benefits (as well as stock) are intangible and hence are often unaccounted for in the socio-economic scenario and policy formulation. Economic valuation helps in recognizing these benefits and internalise them into policy actions.

The Total Economic Value of these tiger reserves depends on the direct, indirect and option values of the ecosystem services from these tiger reserves. According to the study findings, it is estimated that the quantum of collective direct benefits generated is in the range of Rs. 8.97 crore to Rs. 101.87 crore. Interestingly, the indirect benefits from these tiger reserves are valued at Rs. 4221.34 crore to Rs. 13317.50 crore per annum. The tiger reserves offer resilience for climate change and other environmental challenges the world faces today by conserving what matters. They are crucial if future generations are to have an opportunity to enjoy natural landscapes that exist today. 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. This is illustrated in the enormous option value in the range of Rs. 864crore to Rs. 3216crore. These include the potential for novel discoveries, e.g. in pharmaceuticals, crop resilience, bio-mimicry and other areas. Preservation of option values is a significant argument in its own right for managing and expanding the network of tiger reserves.

For better management, it is important to put ecosystem services as a focal area in Tiger management. 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. Comprehensive analysis of ecosystem services may result in establishing partnerships with relevant stakeholders, effective policies and mechanisms for incentivizing conservation. Further, since tiger reserves generate such an immense quantum of values, adequate investment in natural capital contained in tiger reserves is essential to ensure the flow of ecosystem services in future. 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.

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. It is essential to integrate and utilize the values from these tiger reserves into management of a broader landscape and thus enhance ecological connectivity.

To streamline data collection for future endeavours, data collection formats have been provided with the report so that there is standardization and periodic data collection at tiger reserve level. Also, such protocols for data collection for ecosystem services should be incorporated in the Tiger Conservation Plans (TCPs) to ensure a formal system of data collection and reporting.

# 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 per cent.

**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 per cent.

**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 associates 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).

# ABBREVIATIONS

| | |
|---|---|
| ACU | Adult Cattle Unit |
| AET | Actual Evapo-Transpiration |
| AGB | Above Ground Biomass |
| ATR | Anamalai Tiger Reserve |
| AWC | Available Water Content |
| BES | Biodiversity and Ecosystem Services |
| BGB | Below Ground Biomass |
| BTR | Bandipur Tiger Reserve |
| CBET | Community-Based Eco-Tourism |
| CTH | Critical Tiger Habitat (Core Area) |
| CTR | Corbett Tiger Reserve |
| CVM | Contingent Valuation Method |
| DAP | Diammonium Phosphate |
| DEM | Digital Elevation Model |
| DTR | Dudhwa Tiger Reserve |
| DW | Dead Wood |
| EDC | Eco-Development Committee |
| FAO | United Nations Food and Agricultural Organization |
| FSI | Forest Survey of India |
| FTG | Forest Type Group |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| ICIMOD | International Centre for Integrated Mountain Development |
| IEDP | India Eco-Development Project |
| IIFM | Indian Institute of Forest Management |
| IPCC | Intergovernmental Panel on Climate Change |
| IT | Information Technology |
| IUCN | International Union for Conservation of Nature |
| JNNRUM | Jawaharlal Nehru National Urban Renewal Mission |
| KL | Kilo Litres |
| KTDC | Kerala Tourism Development Corporation |
| kWH | Kilo Watt Hour |
| KZNP | Kaziranga National Park |
| KZTR | Kaziranga Tiger Reserve |
| LPCD | Litres Per Capita Per Day |
| LPG | Liquefied Petroleum Gas |
| LULC | Land Use Land Cover |
| MA | Millennium Ecosystem Assessment |
| MAI | Mean Annual Increment |
| MDF | Moderately Dense Forest |
| MLD | Million Litres a Day |
| MoEFCC | Ministry of Environment, Forests and Climate Change |
| MSP | Minimum Support Price |
| MTR | Melghat Tiger Reserve |
| MW | Mega Watt |
| NABARD | National Bank for Agriculture and Rural Development |
| NAEB | National Afforestation and Eco-development Board |
| NPK | Nitrogen Phosphorus Potassium |
| NPV | Net Present Value |
| NSTR | NagarjunasagarSrisailam Tiger Reserve |
| NTCA | National Tiger Conservation Authority |
| NWFP | Non-Wood Forest Produce |
| OF | Open Forest |
| PAWC | Plant Available Water Content |
| PET | Potential Evapo-Transpiration |
| PKTR | Pakke Tiger Reserve |
| PLTR | Palamau Tiger Reserve |
| PNTR | Panna Tiger Reserve |
| PPP | Purchasing Power Parity |
| RUSLE | Revised Universal Soil Loss Equation |
| SCI | Selection-Cum-Improvement |
| SOM | Soil Organic Matter |
| SRTM | Shuttle Radar Topography Mission |

STPF Special Tiger Protection Force

STR Similipal Tiger Reserve

TCM Travel Cost Method

TDDF Tropical Dry Deciduous Forests

TEEB The Economics of Ecosystem and Biodiversity

TEF Tropical Evergreen Forests

TEV Total Economic Value

TMDF Tropical Moist Deciduous Forests

TSEF Tropical Semi-Evergreen Forests

UNEP United Nations Environment Programme

UNESCO United Nations Educational, Scientific and Cultural Organization

USD United States Dollar

USGS United States Geological Survey

USLE Universal Soil Loss Equation

VDF Very Dense Forest

VTR Valmiki Tiger Reserve

WC Working Circle

WII Wildlife Institute of India

WPI Wholesale Price Index

WTA Willingness to Accept

WTP Willingness to Pay

WWF World Wide Fund for Nature

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# 01

## PHASE-II STUDY:

# TAKING THE BATON FORWARD

# 1. TAKING THE BATON FORWARD

The chapter provides the background of the current study. It entails the Phase-I Study findings, the current study, i.e. Phase-II Study objectives and their key deliverables, study site description, and highlights of this study. It also offers a brief overview of the report structure and limitations of the study.

## Key Insights

Acknowledging the enormous quantum of benefits or ecosystem services provided by tiger reserves, a study was commissioned by the National Tiger Conservation Authority (NTCA) to internalize the value of their contribution into the economic and policy system. The study was titled 'Economic Valuation of Tiger Reserves in India: A Value+ Approach' and was accomplished during 2013-15. The study findings were perceived to be useful in policy formulation, designing management interventions and making a case for conservation of tiger habitat. In 2016, Phase-II of the study was extended to include ten additional tiger reserves across various tiger landscapes and add value to the findings of the Phase-I study.

The Phase-II Study provides qualitative and quantitative estimates for 27 ecosystem services for the ten selected tiger reserves. Apart from the estimates, the study incorporates additional aspects such as mapping and modelling of three ecosystem services, i.e. carbon storage, water yield/provisioning and sediment retention using InVEST software suite and also explores tiger reserves as Destination Brands. The study also aims to highlight the interlinkages between human health and forests.

The study emphasizes the uniqueness quotient of each tiger reserve using IPBES protocols and assessment guidelines. Various frameworks have been used in the study to capture the non-monetary values, showcasing the relationship between ecosystem services and human life and presentation of economic values to suit different needs of various stakeholders. To facilitate future assessments and the data collection process for tiger reserves protocols including step-wise guidance and formats have been provided in the report.

## 1.1 INTRODUCTION

The Centre for Ecological Services Management (CESM) at the Indian Institute of Forest Management (IIFM) executed the study titled "Economic Valuation of Tiger Reserves in India: A Value+ Approach" commissioned by the National Tiger Conservation Authority (NTCA), during 2013-15. The seminal study demonstrated a range of economic values of ecosystem services emanating from six tiger reserves of India namely, Corbett, Kanha, Kaziranga, Periyar, Ranthambore and Sundarbans. The report turned out to be a landmark study which received overwhelming attention and appreciation from all corners for being a one-of-its-kind study while also receiving comments for further enrichment of such endeavours. It was an attempt to showcase the value of nature's benefits and their immense contribution to people's well-being.

The quantum of ecosystem services, huge expanse of values generated and the remarkable economy-wide investment multiplier, which is a measure of the extent of flow benefits generated on each rupee invested in such natural systems, was an eye-opener for the general public, policy makers and concerned officials. The report provided conservative estimates and followed a 'Value+' approach which highlighted that there is potential for further research for identifying enormous unaccounted values in the natural systems playing a crucial role in both the existence and well-being of humans.

Recognizing the management and policy relevance of the work, extension of the study was suggested by NTCA and hence the second phase of the study was sanctioned to conduct economic valuation of 10 additional tiger reserves and also improve upon the estimated values from the previous six tiger reserves. To accomplish the same, Phase-II of "Economic Valuation of Tiger Reserves in India" was assigned to CESM, IIFM by NTCA and which has been executed during 2016-19. The following sections in the report present outcomes of the Phase-II Study.

## 1.2 A BRIEF DESCRIPTION OF PHASE-I STUDY

The Phase-I Study (2013-15)1conducted valuation in six tiger reserves in India: Corbett, Kanha, Kaziranga, Periyar, Ranthambore and Sundarbans, representing different tiger landscapes in the country. It also carried out a pilot study for application of InVEST-spatial mapping tools for ecosystem service mapping and to attempt to estimate the cost of re-creating a tiger reserve. The study used scientific and objective parameters and peer-reviewed methodology along with a 'Value+' approach to conduct quantitative and qualitative assessment of 25 ecosystem services. While natural landscapes such as tiger reserves in all practicality can never be recreated, the study attempted to determine the cost of re-creation of a tiger reserve if inadequate protection to existing tiger reserves necessitate establishment of new ones. Additionally, the study also demonstrated the application of InVEST– a suite of tools used for mapping ecosystem services.


### 1.2.1 KEY FINDINGS OF PHASE-I STUDY

The study findings indicated that the monetary values of flow of ecological and economic benefits emanating from these six selected tiger reserves range from Rs. 8.3 billion to Rs. 17.6 billion annually in the year 2014-15.

- **Annual flow benefits emanating in the range of Rs. 50,000 to Rs. 190,000 per hectare per year.**
- **In addition, selected tiger reserves protect and conserve forest stock valued in the range of Rs. 22 billion to Rs. 656 billion.**
- **It also indicated that a large portion of flow benefits (as well as stock) was intangible and hence often unaccounted for in market transactions.**
- **A large proportion of benefits extend to a national scale and at global levels.**
- **Investment multiplier, i.e. the extent of benefits generated per rupee invested in these tiger reserves ranges from Rs. 200 to 530, the highest being for Sundarbans Tiger Reserve.**
- **Modelling and mapping of ecosystem services via InVEST 3.0 in Periyar and Kanha. Three out of seventeen models applied which include Carbon Storage and Sequestration, Climate Regulation Model, the Water Yield: Reservoir Hydropower Production and the Sediment Retention: Avoided Dredging and Water Purification Model. The findings from InVEST highlighted the intensity of the flow of values throughout the tiger reserve landscape.**
- **Adopting a case-study approach for study estimating the cost of inaction in terms of cost of re-creating a tiger reserve and willingness to pay for tiger conservation in Dudhwa-Pilibhit landscape. The conservative estimates, based on selected categories of costs, approximately equal to Rs. 491,800 million which translates to Rs. 4.62 million per hectare.**

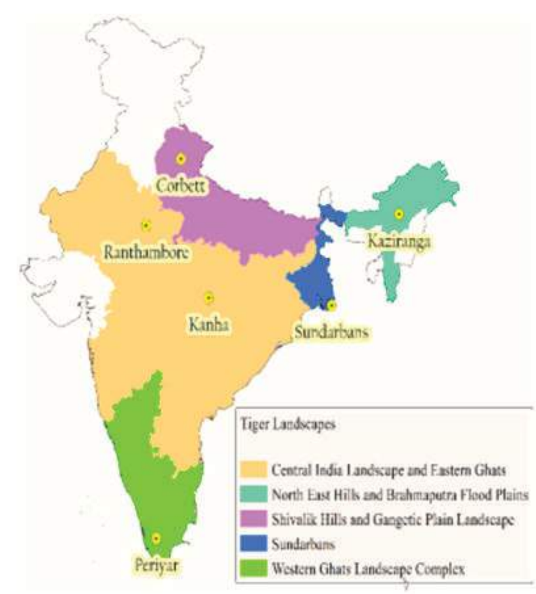


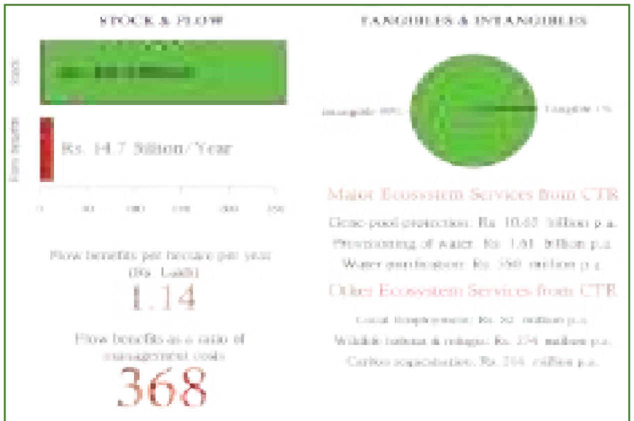

*Figure 1Linkages of RDC approach*

# 1. TAKING THE BATON FORWARD

The first phase of the study used multiple valuation frameworks including Total Economic Value; Millennium Ecosystem Assessment; Stock and Flow Analysis; and Tangible and Intangible Benefits to communicate the diverse values embedded in and emanating from tiger reserves.

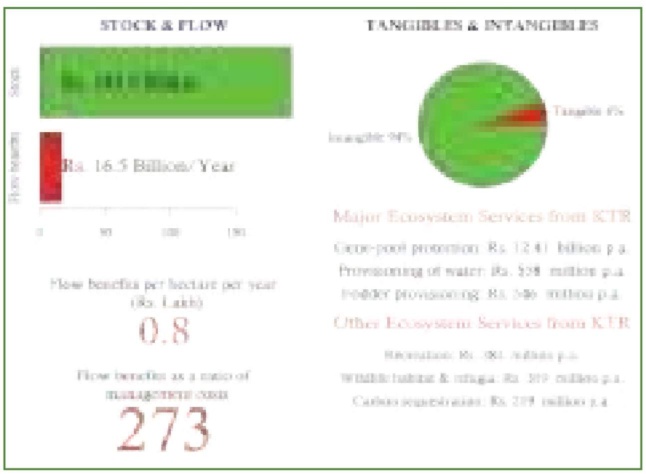
The study acknowledged the fact that in spite of our increased appreciation of many of nature's functions and processes, we still have a limited understanding of how we benefit from nature. There is an inherent ambiguity and uncertainty about the most appropriate economic valuation method that often leads to underestimation of benefits we receive from nature. There are several services for which the economic value could not or cannot be estimated monetarily. It, therefore, used a 'VALUE+' approach. The 'VALUE' represents all benefits for which monetary economic valuation is possible and estimable 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 our current understanding of natural systems.

The study provided a rationale for conservation-based enhanced financing for the tiger reserves based on the flow benefits emanating from these natural systems. It concluded with policy recommendations like expanding the network of tiger reserves to make them comprehensive and representative, integration of management of tiger reserves into the broader landscape and enhance/restore ecological connectivity among tiger reserves and their wider environment.

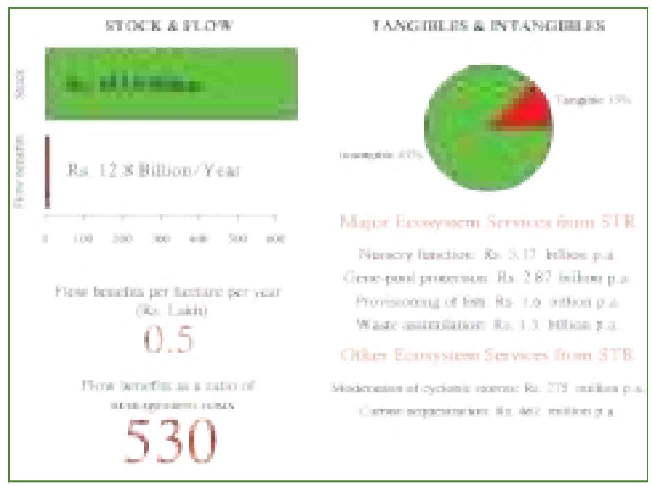




Corbett Tiger Reserve

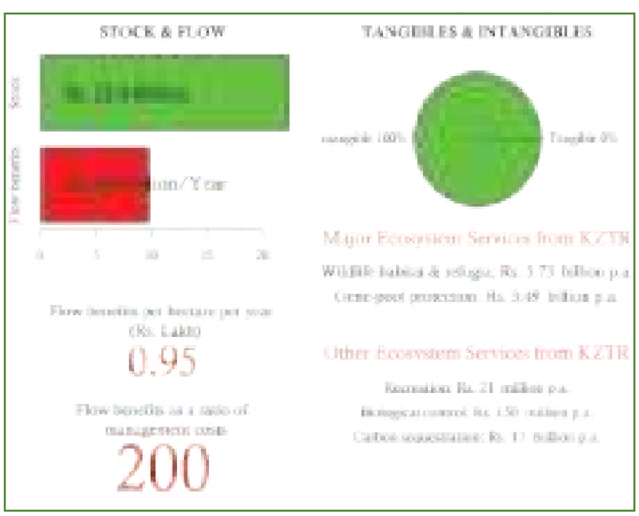

Periyar Tiger Reserve



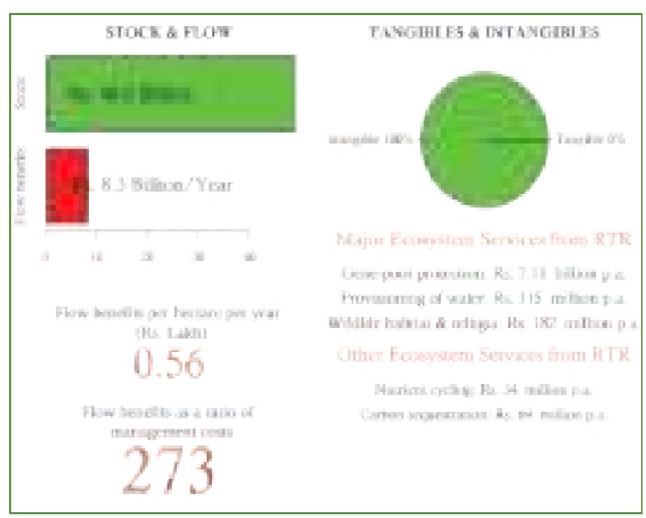

Kanha Tiger Reserve




Sundarbans Tiger Reserve




Kaziranga Tiger Reserve

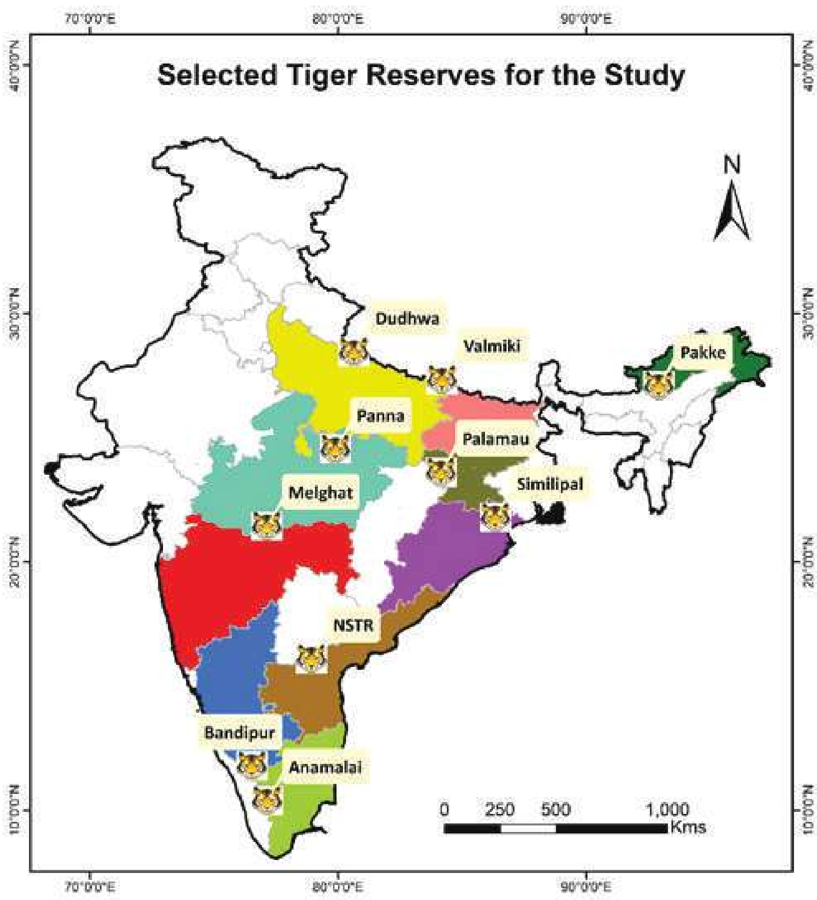



Ranthambore Tiger Reserve

## 1.3 OBJECTIVES FOR PHASE-II STUDY

The Phase-II Study has been executed with an improved methodology at the ten additional tiger reserves and also to further enrich the outcomes of Phase-I Study by identifying underlying gaps or scope of improvement and add value to its findings.

The TOR, as per MoU dated June 3, 2016 between NTCA and IIFM lays down three specific objectives to be fulfilled through the Phase-II Study.




General Objective: To estimate the economic value of ten additional tiger reserves in India in an integrated manner to highlight their contribution to human well-being using objective and scientific parameters.

Specific Objective-1: Disseminate findings of the Phase-I Study through a national workshop and execute an unbiased peer-review process, critically analyse the methodology used and identify gaps unaddressed in the Phase-I study.

Specific Objective-2: Estimate the economic value of the ecosystem services from ten tiger reserves not covered during the Phase-I study, viz. NagarjunasagarSrisailam, Palamau, Panna, Melghat, Similipal, Pakke, Valmiki, Dudhwa, Bandipur and Anamalai tiger reserves using scientific and objective parameters.

Specific Objective-3: Develop data collection protocols and suggest ways to internalize the results of valuation study in the management of tiger reserves through tiger conservation plans.

## 1.4 SITE SELECTION

Catering to the increasing need for demonstrating the significance of tiger reserves in terms of economic valuation, ten tiger reserves representing various ecological sites and socio-economic conditions of India were identified by the National Tiger Conservation Authority (NTCA) based on their Management Effectiveness Evaluation (MEE) rankings as project sites for this study. These tiger reserves together are representative of major landscapes of the country and their unique biological diversity.

**Table 10: Methodology in Detail**

| S.No.. | Tiger Reserve | Tiger Landscape | State | Year of Declaration |
|---|---|---|---|---|
| 1 | Anamalai | Western Ghats | Tamil Nadu | 2008-09 |
| 2 | Bandipur | Western Ghats | Karnataka | 1973-74 |
| 3 | Dudhwa | Shivalik Gangetic | Uttar Pradesh | 1987-88 |
| 4 | Melghat | Central Indian and Eastern Ghats | Maharashtra | 1973-74 |
| 5 | Nagarjunasagar Srisailam | Central Indian and Eastern Ghats | Andhra Pradesh | 1982-83 |
| 6 | Pakke | North-East Hills and Brahmaputra Flood Plains | Arunachal Pradesh | 1999-2000 |
| 7 | Palamau | Central Indian and Eastern Ghats | Jharkhand | 1973-74 |
| 8 | Panna | Central Indian and Eastern Ghats | Madhya Pradesh | 1994-95 |
| 9 | Similipal | Central Indian and Eastern Ghats | Odisha | 1973-74 |
| 10 | Valmiki | Shivalik Gangetic | Bihar | 1989-90 |

In addition to diversity in terms of ecosystem, these ten tiger reserves also symbolize sites with distinctive blends of forest-type, socio-cultural context and other signature wildlife species. Based on all these factors, the selected tiger reserves capture a comprehensive set of indicators that allow us to present a rather holistic platter of values.

## 1.5 DELIVERABLES

Deliverables of the current study are based on the TOR as per the MoU and its specific objectives mentioned above. The description of the response for each specific objective is as follows:

### 1.5.1 RESPONSE TO SPECIFIC OBJECTIVE-1 (SO-1)

Specific Objective-1 (SO-1): Disseminate findings of the Phase-I through a national workshop and an unbiased peer-review process, critically analyse the methodology used and identify gaps unaddressed in the Phase-I study.

- **National Dissemination Workshop: Responding to specific objective-1, findings of the Phase-I Study were disseminated via a national dissemination workshop organized jointly by NTCA-IIFM on November 17, 2016 at New Delhi. The workshop's objective was to present the findings of Phase-I Study as well as gather comments of the stakeholders for evolving**

# 1. TAKING THE BATON FORWARD


Ecosystem Services

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

Madhu Verma, Dhaval Negandhi, Chandan Khanna, Advait Edgaonkar, Ashish David, Gopal Kadekodi, Robert Costanza, Rajesh Gopal, Bishan Singh Bonal, Satya Prakash Yadav, Sanjay Kumar

ARTICLE INFO

ABSTRACT

Media Coverage: The Phase-I report received ample media attention and was highlighted in major

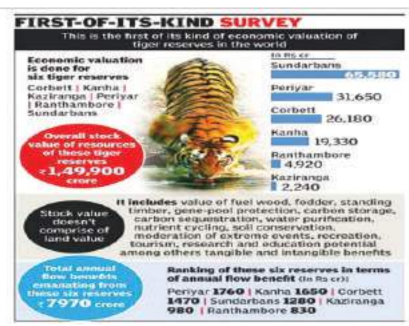

THE TIMES OF INDIA Flora & Fauna

6 tiger reserves worth Rs 1.5 lakh crore, says valuation study

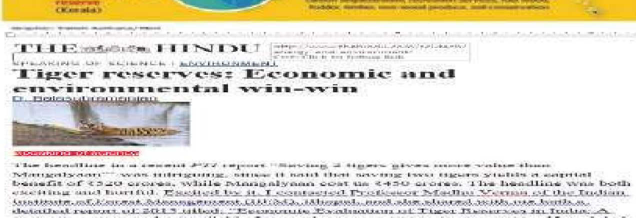
NEW DELHI: In a first of its kind exercise, India has conducted economic valuation of six of its tiger reserves and placed their value at Rs 1,49,900 crore. The study has also noted that these six reserves have been generating annual monetary benefits worth Rs 7,970 crore.

The six tiger reserves which were surveyed for this study are Corbett, Kanha, Kaziranga, Periyar, Ranthambore and Sundarbans.

India has 47 tiger reserves covering over 2% of






THE HINDU

Tiger reserves: Economic and environmental win-win


Green Eco: Saving 2 tigers gives more value than Mangalyaan!

methodology for the next phase. Workshop participants included officials from NTCA, forest departments, Phase-I and Phase-II tiger reserves and reputed experts in the field of ecosystem service valuation.

- Unbiased Peer-Review of Methodology: Published paper in the internationally acclaimed and peer-reviewed Elsevier's journal 'Ecosystem Services' journal 'Making the Hidden Visible: Economic Valuation of Tiger Reserves in India'2(Link: https://www.sciencedirect.com/science/article/pii/S2212041617303339 ) for up-scaling the dissemination of findings to a wider audience.

Other Outreach Activities: The Phase-I Study findings were presented and disseminated on various platforms such as:

- **Poster presentation during Natural Capital (NTACAP) symposium at Stanford University during 23-25th March 2015titled 'Steps towards better management of Tiger Reserves- A case of InVEST Implementation in Periyar&KanhaTger Reserves in India'.**
- **Publication of seven policy briefs – Overall and individual tiger reserve wise for effective communication of general findings and findings for each of the six tiger reserves.**
- **Information brief published for GTF for the World Bank in 2015.**
- **Presentation on Study Findings and Methodology at the Regional Capacity Building on Tiger Landscape Valuationin Myanmar during 29th May 2015.**
- **Display of findings through Standee at the Asia Ministerial Conference during 12-14th April, 2016 at VigyanBhawan, New Delhi.**
- **Individual Presentation at the Asia Ministerial Conference titled 'Economic Valuation of Tiger Reserves in India: A Value+ Approach' in the Technical session: Business and Industries on 13th April 2016.**
- **Presentation of Case Study on Valuing Tiger Habitats in India to the GTF study participants during (i) international participants Northen Snow Leopard countries in November, 2016 at Leh, Laddakh, (ii) Indian participants in November 2016 at Sariska Tiger Reseve, (iii) international participants East Asian Snow Leopard countries in December 2016 at Jakarta, Indonesia.**
- **Presentation of the case study on Valuing Tiger Habitats in India (i) to the International Training Program for International Training program for Auditors from various countries participants during March 2016 at NOIDA(ii) to Indian Audit& Accounts Services officers during September 2016 at ICED, Jaipur; (iii) to the Provosts of Clemson University and South Carolina University in March 2017.**
- **Presentation on Economic Valuation of Tiger Reserves in India: A Value+ Approach & Manual on Valuation of Ecosystem Services from Tiger & Snow Leopard Landscapes at the International Snow Leopard & Ecosystem Forum (ISLESF) 24-25thAugust, 2017, Bishkek, Kyrgyztan.**
- **Presentation on Economic Valuation of Protect Areas with case study on Tiger Habitats during the Ecosystem Partnership (ESP) ASIA CONFERENCE 2018 at Dehradun on 9th October 2018 and on 'Tiger Reserve Valuation: Communicating and Engaging in Policy and Practice' during a panel discussion on 11th October 2018.**
- **Plenary presentation on 18th March 2019 titled 'Valuing Natural Capital From Urban Wetlands to Tiger Reserves Decision making and policy formulation in India based on the paradigm of Conservation & Development' at theNatural Capital Symposium organized by the Stanford University, California, USA during 18th-21st March, 2019.**

### 1.5.2 Response to Specific Objective-2 (SO-2)

Specific Objective-2 (SO-2): Estimate the economic value of the ecosystem services from ten tiger reserves not covered during the Phase-I study, viz. NagarjunasagarSrisailam, Palamau, Panna, Melghat, Similipal, Pakke, Valmiki, Dudhwa, Bandipur and Anamalai using scientific and objective parameters.

Corresponding to the Specific Objective-2, the current study accomplishes economic valuation for ten selected reserves. Detailed findings are presented in Chapters 2 to 7.

### 1.5.3 Response to Specific Objective-3 (SO-3)

Specific Objective-3 (SO-3): Develop data collection protocols and suggest ways to internalize the results of valuation study in the management of tiger reserves through tiger conservation plans.

Corresponding to the Specific Objective-3, under the current study data collection frameworks and formats have been developed which will help to streamline the data collection process for future valuation studies. The same are attached as Annexures in this report.

## 1.6 HIGHLIGHTS OF THE CURRENT (PHASE-II) STUDY

Apart from presenting outcomes of economic valuation of 27 ecosystem services for ten tiger reserves, the current study adds substance and value to the findings by incorporating the following additional components:

- Incorporating methods of best practices based on thorough literature review and using scientific tools and the latest advancements in the field of valuation.
- Presentation of findings via various frameworks for suitable communication of results to relevant stakeholders.
- Incluing a range of non-monetary values from the selected tiger reserves through EPA framework.
- Modelling and mapping of ecosystem services based on three models of InVEST, i.e. Carbon Storage, Water Yield and Sediment Retention for all the ten tiger reserves of Phase-II.
- Underlining the association of health benefits from the tiger reserve ecosystems and its connect to overall well-being.
- Highlighting uniqueness and cultural values via qualitative assessment in the form of case studies, featured characteristics and narratives for selected tiger reserves using IPBES protocols.
- Adding data collection formats and protocols for streamlining the data collection process and making a database for future assessments.
- Destination branding for the selected tiger reserves of Phase-I Study.

## 1.7 LIMITATIONS OF THE STUDY

The current study presents findings pertaining to the economic valuation of ten selected tiger reserves of Phase-II. Rigorous efforts and extensive care has been taken to cover most of the values and provide scientific and objective estimates. However, there is always scope for improvement. Listed below are some of the limitations of the current study:

- Economic Valuation is a complex and evolving field. Acknowledging our limited understanding of natural processes and their associated values, the methods used in this study have been selected among the range of accepted methodologies based on the existing knowledge and understanding, data availability, feasibility of execution and time required. Thus, the report follows a VALUE+ approach where 'VALUE' represents all benefits for which monetary valuation is achievable. The '+' represents all such benefits for which such valuation if currently not possible either on account of lack of accepted methodologies, knowledge and/or understanding and derived data.
- The study attempts to present estimates for 26 ecosystem services for ten tiger reserves. Since each tiger reserve is unique in its own sense, there may be some values which are uniformly included for all the selected tiger reserves. However, there are other values which have been covered for only some tiger reserves and not found relevant during the study owing to our current understanding and data availability. It may be noted that these values may not be absent entirely from that tiger reserve and may be associated and quantified in future assessments given further extensive research of the site's natural ecosystems.
- The given estimates are conservative and broad estimates based on preliminary assessment. The estimates are obtained in order to provide policy inclusion to the unaccounted positive externalities of tiger reserves and not for putting a price tag on the tiger reserves or the ecosystem services. The estimates are not suited for market transactions and the study authors strongly advise against using them for commoditisation of any forest area.
- Despite the best efforts of the study team there was a lack of data at the end of the tiger reserve management leading to data gaps for assessment for some values. Wherever possible, such data gaps have been addressed using proxy values and methods to include most of the present ecosystem service into the valuation matrix.
- While collection of primary data can be a preferred option in many other studies, owing to given time and resources the study has used mostly secondary data from sources like local forest department offices, other government agencies and institutions such as the Forest Survey of India to arrive at the values.

- **Biophysical quantification and economic valuation of tiger reserves is an intricate process which requires intensive data. Primarily in case of regulating services, where the data requirement and collection is an extremely technical and long-term process, the method of benefits transfer has been used. However, for future assessments, it would be more appropriate to use primary data or local-based estimates should be used for achieving the best and fair estimates of values for which data as per provided protocols may be generated at the tiger reserve level. As also recommended in the Phase-I Study, data collection for ecosystem services should be a part of the Tiger Conservation Plans (TCPs) for facilitating such assessments.**
- **The study team has used the method of stakeholder consultation, roundtables and team discussions to arrive at generic assumptions that have been used to arrive at the values of various ecosystem services. Wherever applicable, such assumptions have been mentioned in the text under the particular or specific ecosystem service.**
- **The study team observed some inconsistency in the data given by different agencies for the same tiger reserve(s). To resolve the issue, after multiple rounds of discussions with NTCA and within the team, data given by the Forest Survey of India (FSI) has been used throughout the study to achieve a uniform set of values.**

## 1.8 STRUCTURE OF THE REPORT

The report can broadly be divided into two parts from Chapter 2 to 8. The first five chapters are designated to enhance theoretical knowledge in the context of providing background and description of basic concepts related to economic valuation. After building context, Chapters 6 and 7 present findings of the study. Chapter 2 begins with the introduction of ecosystem services emanating from tiger reserves, their identification and importance to human well-being. It also provides justification for selection of tiger reserves as sites for economic valuation, brief description of some of the studies undertaking such endeavours in the past and sets forth mapping of ecosystem services across selected tiger reserves for this study. Chapter 3 describes the modelling of ecosystem services, various modelling software available for the purpose and describes the InVEST models used in the current study. The following chapter revolves around the need for valuation practices and explains fundamental concepts regarding valuation and ecosystem services. It also attempts to establish linkages between ecosystem services and human well-being by showcasing the effect of natural systems on health. It also describes the concept of incentive-based mechanisms and recommendations on policy instruments. Chapter 5 then provides highlights of the methods and their application in the Phase-II Study (current study) along with its outcomes and value additions. Chapter 6 presents detailed site-specific findings and Chapter 7 presents findings of the destination branding of tiger reserves. Chapter 8 finally summarizes the findings and provides conclusions and discusses the way forward. Attached with the report are data collection formats incorporating seeds for future betterment by providing streamlined data collection protocols for structured and useful data collection practices.

# 02

# ECOSYSTEM SERVICES FROM TIGER RESERVES IN INDIA

# 2. ECOSYSTEM SERVICES FROM TIGER RESERVES IN INDIA

## Overview

The chapter provides a brief account of biodiversity and ecosystem services in India. It entails a description of the ecosystem services concept and presents a review of their association with tiger reserves. It further underlines the importance of tiger reserves and why they should be selected as sites for economic valuation.

### Key Insights

India is rich in biodiversity and has been making continuous efforts for its conservation via various policies and initiatives. Tiger is an umbrella species symbolizing, regulating and empowering the ecosystem functions in its habitat. Declaring a tiger reserve is also one of the measures of protecting the habitat of this charismatic species and its associated biodiversity. The tiger reserves apart from providing protection to tigers also emanate a number of ecosystem services crucial for human well-being and sustainable future.

Ecosystem services can be defined as a complex of living organisms and the abiotic environment with which they interact in a specified location. Simply put, they are the material and immaterial benefits received by humans critical for maintaining their overall well-being, livelihoods and survival. A number of studies have accomplished measuring the ecosystem services emerging from tiger reserves and their economic valuation. This study attempts to map 26 ecosystem services across ten tiger reserves of India.

## 2.1 BIODIVERSITY IN INDIA

India is a mega-diverse country with 2.4 per cent of the world's land area supporting 7-8 per cent of all recorded species3. Its unique combination of different types of biomes/ ecosystems, climatic-zones and varied geography imparts an unparalleled significance in the world's biodiversity scenario. As a country, India has made continuous efforts in conserving its biodiversity and is committed towards internalizing these efforts as a national priority3. Establishment of tiger reserves is one of the most widely accepted means of conserving biodiversity as a part of recognizing the crucial linkages of biodiversity with people's well-being4.

Broadly, biological diversity can be defined as the total aggregation of genes, species and ecosystems on the planet5. It is directly linked to benefits provided by nature such as direct consumption by locals of products like fuel, food and construction materials; production for commercial purposes of such items as timber, medicines, fish and game, and new domesticated plants; and indirectly linked to watershed protection, climate regulation and future options and many intrinsic values. However, linking economic benefits to conservation is difficult where wildlife is highly endangered, pressure on biomass resources is high, and the stakeholders are many. Biodiversity can generate a range of economic benefits through sustainable use, proper management and appropriate policy interventions.

## 2.2 WHY TIGER RESERVES?

Tiger is not only a charismatic species but also an apex predator of the wild animal food chain. Its presence is vital in regulating and perpetuating ecological processes which makes it an umbrella species6. Its protection also conserves habitats of several other species and thereby ensures continuity of the natural evolutionary process in the wild. It thrives as a keystone species, the basis on which the integrity of the ecosystem is maintained7. Moreover, it is equally a creature that prowls the human imagination and has woven itself intricately into the cultural fabric of all those who share its native range across Asia.

It has been recorded over recent decades that the tiger's historical range and numbers have reduced dramatically. Only five out of nine sub-species now survive, mostly in South East Asia and in some isolated pockets of China and Russia. India, in particular, has a stronghold with an estimated 60 per cent of the world's wild tiger population. The last country-wide estimate in 2014, had estimated India's tiger population at 2,226, up from 1,706 in 20108. Tigers as an umbrella species have been at the forefront of the conservation efforts in India. The success of Project Tiger launched in 1973 by the Government of India, and the constitution of the National Tiger Conservation Authority (NTCA) in 2006 are both reflected in the statistics. During the Phase-I of this study, published in 2015, there were 47 tiger reserves in India. Now, there are 50 covering an area of 72749.02sq km8, which is more than 2.21 percent of the country's geographical area. The next assessment of the tiger population in India's 50 tiger reserveshas been completed and the estimation results are to be released in public domain.

Project Tiger was a milestone in the domain of wildlife conservation9. It emphasized the fact that in order to protect our national animal, it is important to conserve its habitat. Conserving natural ecosystems, such as forests, wetlands and grasslands, helps to protect important species, habitats and sustain essential ecological processes. The indirect benefits of tiger conservation include soil and water conservation and habitat quality improvement which in turn support pollination, biological control, nursery function, climate regulation and enrich biodiversity. Therefore, by conserving wild tigers, the whole natural system is conserved which provides us with a range of associated economic, social, cultural and spiritual benefits as ecosystem services. As per the Secretariat of the Convention on Biological Diversity (2008) there has been increasing recognition of the importance of such protected areas to the quality of human life. Demarcation of inviolate areas in tiger reserves as core areas was done to achieve conservation goals and peripheral areas were marked as a buffer zone to establish a coexisting relationship among nature and man. This was done in the amendment in 2006 to the Wildlife (Protection) Act, 1972.

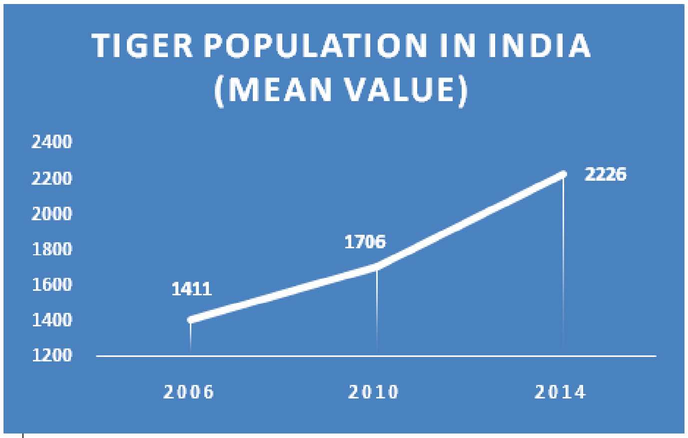



*Figure 2.2 1 TIgers in India (Source: All India Tiger Estimation, NTCA)*

Natural ecosystems including water bodies, forests, grasslands, a network of different species, geological and geographic landmarks, etc., not only sustain life within but also affect communities and the environment surrounding it through a range of indirect and flow benefits. Forests are repositories of natural resources and provide shelter to wildlife and human beings who are dependent on forests, whether directly for their livelihoods or indirectly for food and other products.

## 2.3 WHAT ARE ECOSYSTEM SERVICES?

The Convention on Biological Diversity (1992) defines an ecosystem as "a complex of living organisms and the abiotic environment with which they interact in a specified location." In simpler terms, it is a network of interacting flora and fauna and the landscape in which they survive and thrive. An ecosystem can be defined at the most basic level as a natural unit of living things (animals, plants and micro-organisms) and their physical environment. The living and non-living elements in an ecosystem function together as an interdependent system – if one part is damaged it can have a cascading impact on the whole system. Ecosystems can be terrestrial or marine, inland or coastal, rural or urban. They can also vary in scale from the global to the local. In many cases, ecosystems overlap and interact10.

Ecosystems provide a range of services, many of which are of fundamental importance to human well-being, for health, livelihoods, and survival11–13. An Ecosystem Service (ES) therefore, is a direct, measurable benefit from an ecosystem. Nature underpins the human economy, and ecosystem services represent an attempt to measure, and more importantly to explain, that dependence14. Some of these ecosystem services are well known including food, fibre and fuel provision and the cultural services that provide benefits to people through recreation and cultural appreciation of nature. Other services like regulation of climate, purification of air and water, flood protection, soil formation, retention and nutrient cycling10are intangible benefits which are generally not accounted for in the system. People benefit from ecosystem goods and services like nutrition, access to clean air and water, health, safety, and enjoyment. The benefits derived from ecosystem services cover various dimensions of human well-being, namely basic human needs, economic needs, environmental needs and subjective happiness15.

## 2.4 ECOSYSTEM SERVICES EMANATING FROM TIGER RESERVES

A range of ecosystem services emanate from tiger reserves. The emphasis on tiger reserves in this document is for the simple reason that in the context of natural resource development they are the primary repositories of forests and other natural ecosystems. They help in preserving wilderness and are one of the chief means of maintaining intact natural ecosystems while conserving biodiversity in a world that is becoming increasingly urbanized.

Pimentel et al.(1997), estimated that some 300 million people obtain part or their entire livelihood and food from forests, that non-timber forest products worth about USD 90 billion are harvested each year, and that forests play critical and pivotal roles in maintaining the productivity of agricultural and environmental systems.

Services like NTFPs provisioning, grazing, water conservation, soil protection, carbon sequestration, nutrient cycling, air purification, biodiversity, pollination, and recreation have been mapped from Nagarhole National Park in Karnataka17. Chaudhry, Kumar& Yogesh (2016) studiedPakke Tiger Reserve in Arunachal Pradesh and have identified services like employment generation, carbon sequestration, biological control, Habitat for Species, genepool protection, gas regulation, and pollination. Likewise, services like fuelwood, fodder grazing, and revenue generation, carbon sequestration, watershed protection, increased soil fertility, and recreation have been identified from Corbett Tiger Reserve, Uttarakhand19.

Economic Valuation of Periyar, Kanha, Corbett, Kaziranga, Ranthambore and Sundarbans Tiger Reserves have been carried out in the Phase-I Study1 in which 25 major ecosystem services were identified such as employment generation, agriculture, fishing, fuelwood, fodder, timber, NTFP, genepool protection, carbon storage, carbon sequestration, water provisioning, water purification, soil conservation, nutrient retention, biological control, moderation of extreme events, pollination, nursery function, habitat, cultural heritage, recreation, spiritual tourism, research, education and nature interpretation, gas regulation and waste assimilation.

## 2.5 MAPPING OF ECOSYSTEM SERVICES ACROSS SELECTED TIGER RESERVES

In the light of growing development pressures, there is an urgent need to provide a stronger argument for conservation of these natural systems. Conservation and effective management of tiger reserves thus ensure the flow of vital intangible resources from ecosystems on local, regional as well as national/global scale. The current study attempts to identify and enlist the major ecosystem services provided by the selected tiger reserves.

| | ATR | BTR | DTR | MTR | NSTR | PKTR | PLTR | PNTR | STR | VTR |
|---|---|---|---|---|---|---|---|---|---|---|
| Employment Generation | ■ | ■ | ■ | | ■ | | | ■ | ■ | |
| Fishing | ■ | | | | ■ | ■ | | | | |
| Fuelwood | ■ | ■ | ■ | | ■ | ■ | ■ | | | ■ |
| Fodder | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Timber (Stock) | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Timber (Flow) | | ■ | | | | ■ | | | | |
| Bamboo | ■ | | | | ■ | ■ | | | | |
| NTFP | ■ | ■ | | | ■ | ■ | ■ | | | |
| Genepool Protection | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Carbon storage | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Carbon Sequestration | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Water Provisioning | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Water Purification | ■ | | | ■ | ■ | | | ■ | ■ | |
| Soil Conservation/Sediment Retention | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Nutrient Retention | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Biological Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Moderation of Extreme Events | | | | | | | | | | |
| Pollination | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Nursery Function | | | | | | | | | | |
| Habitat for Species | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Cultural Heritage | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Recreation | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Spiritual Tourism | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Research, Education and Nature Interpretation | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Gas Regulation | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Waste Assimilation | | | | | ■ | | | ■ | | |
| Climate Regulation | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

*Table 2.5 1Relevant Ecosystem Services across TRs (In Progress). Anamalai Tiger Reserve (ATR), Bandipur Tiger Reserve (BTR), Dudhwa Tiger Reserve (DTR), Melghat Tiger Reserve (MTR), NagarjunasagarSrisailam Tiger Reserve (NSTR), Pakke Tiger Reserve (PKTR), PalamauReserve (PLTR), Panna Tiger Reserve (PNTR), Similipal Tiger Reserve (STR) and Valmiki Tiger Reserve (VTR).*

# 3 Chapter 3: Modelling of Ecosystem Services Using InVEST

***Overview***

This chapter focuses on InVEST for mapping and analyzing the dynamics of ecosystem services for more sustainable management decisions in landscapes. It also presents a comparative analysis of other available models and provides rational for using InVEST for modelling ecosystem services in this study.

***Key Insights***

In recent years, geospatial technology has become a powerful tool for mapping and assessing the provision of ecosystem services. Mapping and modelling ecosystem services helps in analysing and integrating the ecological and economic value-dimensions of ecosystem services to more accurately calculate monetary values.

InVEST is a very adaptable tool to quantify and map ecosystem services. On account of paucity of time for collecting the required information, InVEST could only be applied to three models at ten selected tiger reserves. The model includes 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.

Assistance in identification of ecosystem service hotpots is a crucial outcome of carrying out the InVEST exercise. It is expected to facilitate better management and conservation of tiger reserves. Hence, it would be highly recommended to expand the scope of this application to all tiger reserves across the country, while ensuring standardized collection of specific input data necessary for InVEST models.

## 3.1 Introduction

Ecosystem services are the benefits that the community and the economy receive from nature directly or indirectly[12,13]. Human activities are degrading the environment at a pace and scale that threatens our geological epoch, the Holocene and triggering a transition towards a new epoch: the Anthropocene[20]. This transition might have negative impacts on ecosystem services which depend on the Earth's systems functioning. Several studies have reported a widespread decline in and unsustainable use of ecosystem services across the world[12,21]. Areas that are important for maintaining ecosystem components and functions that provide ecosystem services have to be carefully managed to secure the provision of ecosystem services presently and in future[22–24].

Mapping ecosystem services help us to understand and communicate the full spectrum of ways in which the natural environment contributes to people's well-being. Ecosystem services can be described spatially at all scales, from the local to national level. Modelling and visualization tools are means of bringing complex analysis to multi-stakeholder dialogues in ways that are understandable and meaningful to all stakeholders and that encourage constructive debate on environmental development options. Remote sensing is believed to have the potential to greatly contribute to monitor ecosystem services where fieldwork is time-consuming and resource intensive.

In particular, computer models explicitly generate spatial information about ES are commonly used to inform decisions[25]. The information models produced often illustrate how landscapes provide different amounts and patterns of ES under diverse present and future alternative scenarios. Several studies have been conducted to compare the performance and outcomes of ecosystem assessment tools[26]. Decision support tools can provide quick estimation on a large scale and promote the implementation of ecosystem services valuation into planning and management. Numerous spatially-based decision support tools have emerged for ES assessment[27]. Open source tools such as InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs), ARIES (ARtificial Intelligence for Ecosystem Services),TESSA (Toolkit for Ecosystem Service Site-based Assessment), SolVES (Social Values for Ecosystem Services), and EVT (Eco-system Valuation Toolkit) have been developed and tested in private and public environmental decision contexts[25]. To improve support and expand the reach of ES tools, it is vital to track how, where, and when they are being used. Concerted efforts were made in developing modelling tools to promote the integration of ecosystem services value into the decision-making process and assist management. There are tools which access environmental data and model the number of services provided by an ecosystem according to known biophysical processes and finally estimate the value of ecosystem services using coefficients obtained from other studies. Examples of such decision support tools are Artificial Intelligence for Ecosystem Services (ARIES), Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), and Multi-scale Integrated Models of Ecosystem Services (MIMES)[28].

The paper[27] evaluated 17 multiple ecosystem service tools and their applicability to environmental decision-making across both public- and private-sector contexts. These tools were identified that assess, quantify, model, value and map ecosystem services. Table 1 provides a list of tools and approaches available to help organize complex information for decision-making on natural capital. The majority of ecosystem service tools seek to quantify services and their tradeoffs at a landscape scale in order to support scenario analysis using simplified underlying biophysical models or "ecological production functions"[29]. Also, the most appropriate tools and approaches depend on the issue to be addressed, the data and resources available, and the technical capacity to conduct assessments. Many of the tools listed in Table 3.1-1 are complementary and can be used at different stages of the process of assessing in natural capital.

*Table 3.1-1 Description of All Ecosystem Service Tools[27].*

| Tool | Quantifiable, Approach to Uncertainty | Time Requirements | Capacity for Independent Application | Level of Development and Documentation | Scalability | Generalizability | Nonmonetary and Cultural Perspectives | Affordability Insights, Integration with Existing Environmental Assessment |
|---|---|---|---|---|---|---|---|---|
| ESR | Qualitative | Low, Depending on Stakeholder Involvement in the Survey process | Yes | Fully Developed and Documented | Multiple Scales | High | No Valuation | Most Useful as a Low-Cost Screening Tool |
| InVEST | Quantitative, Uncertainty Through Varying Inputs | Moderate to High, Depending on Data Availability to Support Modelling | Yes | Models Fully Developed and Documented | Watershed or Landscape Scale | High, Though Limited by Availability of Underlying Data | Biophysical Values can be Monetised | Spatially explicit ecosystem service tradeoff maps |
| ARIES | Quantitative, Uncertain Through Bayesian Networks and Monte Carlo Simulation | High to Develop New Case Studies, Low for Preexisting Case Studies | Yes, Through Web Explorer or Standalone Software Tool | Fully Documented; Case Studies Complete But Global Models and Web Tool Under Development | Watershed or Landscape Scale | Low Until Global Models Are Completed | Biophysical Values can be Monetised | Spatially Explicit Ecosystem Service Tradeoff, Flow, and Uncertainty Maps; Currently time Consuming For New Applications |
| LUCI | Quantitative, Currently Does Not Report Uncertainty | Moderate; Tool is Designed for Simplicity and Transparency, Ideally with Stakeholder Engagement | Yes, Detailed User Manual Available | Initial Documentation and Case Study Complete | Site to Watershed or Landscape Scale | Relatively High; a Stakeholder Engagement Process is Intended to Aid in "Localising the Data and Models" | Illustrates Tradeoffs Between Services but Does not Include Valuation | Spatially Explicit Ecosystem Service Tradeoff Maps; Designed to be Relatively Intuitive to Use and Interpret |
| MIMES | Quantitative, Uncertainty Through Varying Inputs | High to Develop and Apply New Case Studies | Yes, Assuming User has access to SIMILE Modelling Software | Some Models Complete but not Documented | Multiple Scales | Low Until Global or National Models are Completed | Monetary Valuation via Input-Output Analysis | Dynamic Modelling and Valuation using Input-Output Analysis; Currently time Consuming to Develop and Run |
| EcoServ | Quantitative, Uncertainty Through Varying Inputs | High to Develop New case Studies, Low for Pre-existing Case Studies | Yes | Under Development, Not yet Documented | Site to Landscape Scale | Low Until Global and National Models are Completed | Biophysical Values can be Monetised | In Development, will Offer Spatially Explicit Maps of Ecosystem Service Tradeoffs |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Co$ting Nature | Quantitative | Low | Yes | Partially Documented | Landscape level | High | Output indexed, bundled ecosystem service values | Rapid analysis of indexed, bundled services based on global data, along with conservation priority maps |
| SolVES | Quantitative, no explicit handling of uncertainty | High if Primary Surveys are Required, Low if Function Transfer Approach is Used | Yes, Assuming User has ACCESS to ArcGIS | Fully Developed and Documented | Watershed or Landscape Scale | Low Until Value Transfer can be Shown to Successfully Estimate Values at New Sites | Nonmonetary Preferences (Ranking) of Relative Values for Stakeholders | Provides Maps of Social Values for Ecosystem Services; Time Consuming for New Studies but Lower Cost for Value Transfer |
| Envision | Quantitative | High to Develop New Studies | Yes | Developed and Documented for Pacific and Northwest Case Study Sites | Landscape Level | Place Specific | Allows Non Monetary Tradeoff Comparison, Also Supports Monetary Valuation | Cost-effective in Regions Where Developed; Time Consuming for New Applications |
| EPM | Quantitative | High to Develop New Case Studies, Low for Existing Case Studies | Yes, Through Web Browser | Developed and Documented for Three Case Study Sites | Watershed or Landscpe Scale | Place Specific | Ecological Economic, and Quality of Life Attributes Could Support Non Monetary Valuation | Cost-effective in Regions where Developed; Time Consuming for New Applications |
| InFOREST | Quantitative | Low, Accessed Through Online Interface | Yes, Through Web Browser | Developed and Documented Only for Virginia | Site to Landscape Scale | Currently Place Specific | Designed as a Credit Calculator, no Economic Valuation | Cost-effective in Regions Where Developed; Time Consuming for New Applications |
| EcoAIM | Quantitative | Relatively low for basic Mapping, Greater for Non Monetary Mapping | No | Public Documentation Not Available | Watershed or Landscape Scale | High | Incorporates Stakeholder Preferences via Modified Risk Analysis Approach | Spatially Explicit Ecosystem Service Tradeoff Maps; Relatively Time Consuming To Run |
| ESValue | Quantitative, Uncertainty Through Monte Carlo Simulation | Relatively High To Support Consultant Stakeholder Valuation Process | No | Public Documentation not Available | Watershed or Landscape Scale | High | Nonmonetary Preferences via Ranked Analysis of Tradeoffs by Stakeholders | Stakeholder Based Relative Ecosystem Service Value Assessment; Relatively Time Consuming |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Eco Metrix | Quantitative | Relatively Low to Support Field Visits and Data Analysis | No | Public Documentation Not Available | Site Scale | High Where Ecological Production Functions are Available | Designed as Credit Calculator, no Economic Valuation | One Method for Site Scale Ecosystem Services Assessment |
| NAIS | Quantitative, Reports Range of Values | Variable Depending on Stakeholder Involvement in Developing the Study | No | Developed but Public Documentation Unavailable | Watershed or Landscape Scale | High, Within Limits of Point Transfer | Dollar Values Only | Point Transfer for "Ballpark Numbers" Building Awareness of Values |
| Ecosystem valuatIon Toolkit | Quantitative, Reports Range of Values | Assumed to be Relatively Low | Yes | Under Development | Watershed or Landscape Scale | High, Within Limits of Point Transfer | Dollar Values Only | Point Transfer for "Ballpark Numbers" Building Awareness of Values |
| Benefit Transfer And Use Estimating Model Toolkit | Quantitative, Uncertainty through varying inputs | Low | Yes | Fully Developed and Documented | Site to Landscape Scale | High | Dollar Values Only | Low cost Approach to Monetary Valuation |

## 3.2 WHY InVEST?

InVEST is best known for the generalizable, public domain tool[27]. InVEST an ecosystem services specific tool is the most appropriate for comparing multiple ecosystem services simultaneously or in looking at both water-related and non-water-related ecosystem services[30]. InVEST uses spatial data as model inputs and encode ecological productions in deterministic models. InVEST outcomes are in biophysical units, to which per-unit monetary values can be applied. This study examines the ecosystem services using one particular tool – InVEST, which was developed by Stanford University at Woods Institute for the Environment.

The Natural Capital Project (NatCap) was formed in 2006 under the premise that biodiversity and ecosystem services (BES) information can be used to inform decisions and thus improve the well-being of both people and nature collectively. NatCap aims to integrate ecosystem services approaches into all major resource decisions that affect the earth's natural resources. NatCap's primary goal was to transform decisions affecting the environment and human well-being by providing clear and credible ecosystem service information for decision-makers. To support this work,standardized BES assessment tool was used known as InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs), an open source software platform.

InVEST is an open source modelling software, designed under Stanford University's Natural Capital project. This model was used to map and value the goods and services from nature that sustain and fulfil human life. The model is often used to understand and establish linkages between ecosystems and how they benefit the people and communities. Hence, the model helps in evaluating tradeoffs, thereby facilitating decision-making. Ecosystems provide ecosystem benefits: the services that communities avail. These services can be divided into the following categories: provisioning, supporting, regulating, and cultural. While these services are indispensable, they are difficult to measure and visualize, and the accuracy of such efforts is often questionable]. This model helps decision-makers visualize the impacts of decisions and identify tradeoffs between environmental, economic, and social benefits.

**InVEST can provide insights to following questions:**

- Where do ecosystem services originate and where are they consumed?
- How can InVEST be used to design a sustainable forestry management plan with balanced trade-offs between 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 area of a watershed can provide the maximum carbon sequestration, biodiversity, and tourism values?
- Demarcating reforestation sites for improved downstream water quality benefits while regulating water flows.
- What are the impacts of climate change and population growth on ecosystem services and biodiversity?
- What are the ancillary benefits of marine spatial planning in addition to provisioning services?

The software is a plethora of models that are suitable for various kinds of ecosystems. Sixteen different models come in the package that caters to terrestrial, freshwater, and marine. InVEST groups the models into three primary categories: 1) supporting services, 2) final services, and 3) tools to facilitate ecosystem service analyses. Supporting services impact other ecosystem services without directly providing benefits to people. Final services are those which directly provide benefits to people.

## 3.3 InVEST Models Used in the Current Study

InVEST helps decision-makers visualize the impacts of decisions and identify tradeoffs and compatibilities between environmental, economic, and social benefits. InVEST provides maps of service use (who and where people are benefiting from service provision) and monetary value (the value that people receive from the use of service). InVEST models are applied on ecosystem service concepts and tools in various tiger reserves to demonstrate the impact of ecosystem service approaches in policy and decision outcomes. With available data and inputs, we have applied three models to conduct quantitative and qualitative assessment of ecosystem services and estimate the economic value of three services. The Project magnifies the impact of its work by understanding ES and sharing the lessons learned by engaging a broad community of leaders, including government institutions, civil societies, and conservationist. The study aims to make it easy to quantify, map and value ecosystem services. In the current study the following three models have been used :-

**1. Water Yield: Reservoir Hydropower Production**

**2. Sediment Delivery Ratio Model**

**3. Carbon Storage and Sequestration: Climate Regulation**

### 3.3.1 Water Yield: Reservoir Hydropower Production

The InVEST water yield model determines the annual average quantity of water produced by a watershed. It also identifies how much water yield of the landscape contributes annually. The model generates three components:

water yield, water consumption, and valuation. The first two components use data on average annual precipitation, plant available water content, annual reference evapotranspiration, root restricting layer depth, land use and land cover, elevation, root depth, saturated hydraulic conductivity, and consumptive water use. The model uses data on hydropower market value and production costs, the remaining lifetime of the reservoir, and a discount rate for valuation. The models do not consider surface-groundwater interactions or the temporal dimension of water supply.

### 3.3.2 Sediment Delivery Ratio Model

The InVEST sediment delivery model maps the overland sediment generation and delivery to the stream. The sediment model generates spatial information onsoil loss, as well as the amount of sediment eroded in the catchment and retained by topographic and vegetation features. The model values in terms of water quality maintenance or avoided reservoir sedimentation, and accounts how land use changes may impact the cost of sediment removal.

### 3.3.3 Carbon Storage and Sequestration: Climate Regulation

The InVEST carbon model estimates the amount of carbon currently stored or the amount of carbon sequestered over time by using maps of land use land cover and carbon stocks in four carbon pools (above ground biomass, below ground biomass, soil, dead organic matter(incl. litter)). Optionally model estimates the economic value of carbon sequestered between the current and the future/REDD landscape dates by providing data on the market or social value of carbon sequestered and its annual rate of change, and a discount rate. The model generates maps of carbon storage densities to land use land cover rasters which include types such as forest, agricultural land or grassland. The carbon model complies results into spatial outputs of storage, value, as well as aggregate totals.

### 3.3.4 Other InVEST Models Available:

#### 3.3.4.1 Habitat Quality

The habitat quality model of InVEST combines details on Land use land cover and threats to biodiversity to generate habitat quality maps. InVEST models habitat quality and rarity by estimating the extent of habitat and vegetation types acloss a landscape, and their state of degradation. Rarity maps generate a map of the rarest habitats on the landscape relative to the baseline chosen to represent the mix of habitats on the landscape that is most appropriate for the study area’s native biodiversity.

#### 3.3.4.2 Habitat Risk Assessment

The InVEST Habitat Risk Assessment (HRA) model assesses the increasing influence of pressure associated with human activities on habitats and species, plenty of which provide essential ecosystem services. The InVEST Habitat Risk Assessment model assesses the risk posed to coastal and marine habitats by human interference and the potential consequences of exposure for the delivery of ecosystem services and biodiversity. The HRA model calculates the risk or impact to ecosystem components by incorporating exposure and consequence.

#### 3.3.4.3 Pollinator Abundance: Crop Pollination

The pollination model focuses on wild bees as a key animal pollinator.It uses information of floral resources and nest sites within bee flight ranges to derive an index of the abundance of bees nesting on each cell on a landscape (i.e. pollinator supply). The model requires inputs as land use land cover map, land cover attributes, guilds or species of pollinators present, and their flight ranges. The model does not account for pollinator persistence over time or the effects of land parcel size.

#### 3.3.4.4 Forest Carbon Edge Effect Model

The carbon edge model accounts for forest carbon stock degradation, owing to the creation of forest edges. Carbon edge model generates carbon map by calculating the edge effects in carbon storage and combines estimates with carbon inventory data.

#### 3.3.4.5 Coastal Blue Carbon

The Coastal Blue Carbon of InVEST model simplifies the carbon cycle by accounting for storage in three main pools (biomass, sediment carbon and standing dead carbon). The model predicts the amount of carbon stored and sequestered over a coastal zone due to changes in land cover. The model quantifies the marginal value of storage and sequestration.

#### 3.3.4.6 Nutrient Delivery Ratio Model

The Nutrient Delivery Ratio model uses a mass balance approach, describing the movement of mass of nutrients through space. The model spatially visualizes the nutrient sources from watersheds and their transport to the stream and also assesses the service of nutrient retention by natural vegetation. The retention service can be valued in socio-economic terms (e.g. avoided treatment costs, improved water security through access to clean drinking water).

#### 3.3.4.7 Scenic Quality Standalone Beta

The model generates information about potential tradeoffs between nearshore and offshore development projects proposal and the visual impacts of those projects. The model creates viewshed maps to identify coastal areas that are most likely to be affected by additions to the seascape.

#### 3.3.4.8 Visitation: Recreation and Tourism

The InVEST recreation model predicts the spread of person-days of recreation, based on the locations of natural habitats that factor into people's decisions about where to recreate and thereby quantifies the value of natural environments. The tool estimates the visitation rate in a simple linear regression. The model predicts how future changes to natural features will alter visitation rates by using photo-user-day estimates.

#### 3.3.4.9 Wave Energy Production

The InVEST wave energy model (WEM) maps and values the electricity generation potential of ocean waves and allows for the evaluation of tradeoffs that might arise when siting wave energy conversion (WEC) facilities. The model calculates the net present value of constructing and operating a wave energy conversion facility by estimating expected wave power and harvested energy.

#### 3.3.4.10 Offshore Wind Energy Production

The InVEST offshore wind energy model spatially maps the energy resource availability, energy generation potential, and energy generation value to evaluate siting decisions, use tradeoffs, and an array of other marine spatial planning questions. The model provides information like wind power potential, offset carbon emissions, energy generation, net present value, and levelized cost of energy, all given at the farm level.

#### 3.3.4.11 Fisheries

This model uses the life history characteristics (e.g. age at maturity, recruitment, migration and natural mortality rates), fishery behaviour (e.g. fishing pressure), habitat dependencies (e.g. importance and availability of nursery habitat), and economic valuation (e.g., price per unit biomass) as input parameters. The model generates the volume and economic value of harvest within the area(s) designated.

#### 3.3.4.12 Crop Production

The InVEST crop production model is based on the "percentile" and "regression" model. The percentile based yield model, covering 175 crops worldwide, and a regression based model that accounts for fertilization rates on 12 crops. The results of models are paired with observed information from the same region for quality control checks as well as nutrition information of 33 macro and micronutrients.

#### 3.3.4.13 Coastal Vulnerability Model

The InVEST Coastal Vulnerability model generates qualitative estimates of the Vulnerability Index in terms of differentiating areas with inundation during storms and relatively high or low exposure to erosion. The model determines areas along a given coastline where humans are most vulnerable to storm waves and surge with additionally taking global population information.

#### 3.3.4.14 InVEST GLOBIO Model

Based on mean species abundance (MSA), the average population-level response across a range of species, to different stressors, including land-use change, fragmentation, and infrastructure, the GLOBIO model estimates an index of biodiversity. The model determines how a change in any of the stressors would lead to a stress in biodiversity or ecosystem integrity, as indicated by MSA.

# 4 Chapter 4: Economic Valuation of Ecosystem Services: Need and Approaches

***Overview***

This chapter provides an overview of various concepts like economic valuation, its importance and diverse approaches used to arrive at economic value. It also highlights linkages between forest areas and overall human health and how they play a key role in our well-being by providing crucial ecosystem services. Finally, it describes incentive-based mechanisms and enlists relevant policy instruments for given ecosystem services.

***Key Insights***

Economic valuation of ecosystem services is a medium for improving our understanding of nature's contribution towards humankind. It is a tool for internalizing externalities into the decision-making process and hence better evaluate the impacts of habitat loss and land conservation not only to nature but to our economy and well-being. It provides a framework for better articulation of trade-offs which helps policymakers to make informed decisions and explore options to restore natural systems so that nature's benefits are available for generations to come.

Attribution of a value for the ecosystem services can be a challenge. There are numerous methods and approaches from which a desired valuation process can be designed keeping in mind the local context and policy use. The importance of ecosystem services is widely recognized, but operational mechanisms and approaches for integrating them into policy-making and management practices are still in a developing phase. It is important to note that many of these methods may underestimate the full range of economic values specific to given resources and hence the estimates derived in this study are only a conservative estimate. Other limiting factors are the availability of adequate data and our understanding of the cause-effect linkages between the ecosystem services and the marketed commodities. Several studies have been carried out in this field in India.

Environmental sustainability and human health are two of the world's most pressing challenges. Well-being is inextricably linked to natural ecosystems. There is sufficient evidence that highlights the interplay between ecosystem function and human health. Tiger reserves are not only the custodians of natural ecosystems but are also natural solutions for securing our health and well-being while adapting to the impact of climate change. Wilderness experience, night walks, night sounds, and stargazing are opportunities for connecting people to nature through various methodologies, such as stories of cultures and lore. Exposure to nature fostered psychological well-being by reducing stresses associated with urban living, restoring mental fatigue, improving mood and perceived health. It also helps in boosting physical health by providing opportunities for improving levels of physical activity, provide nutrition and regulation of many diseases. They are repositories of genetic information and potential bio-chemicals which can be used to develop effective medicines. In addition, forests have been a part of local traditions, knowledge and medicine for a long time. Local knowledge-based traditional medicines have been found effective in curing various diseases.

Using an ecosystem services-based approach enables us to measure value and benefits and is a more inclusive approach to benefits, integrating environmental, economic and community benefits. Ecosystem services accounting and evaluation frameworks provide the means to manage tiger reserves in a more effective manner – that is, expressing the values and benefits of protected areas in the language of other sectors. Tiger reserve management benefit from economic valuation findings, which will help communicating to the external stakeholders about the benefits of investing in nature and in "green" initiatives that improve the health of ecosystems and people. As a part of turning policy into action, economic valuation can provide a strong basis for setting up policy mechanisms for incentivizing conservation.

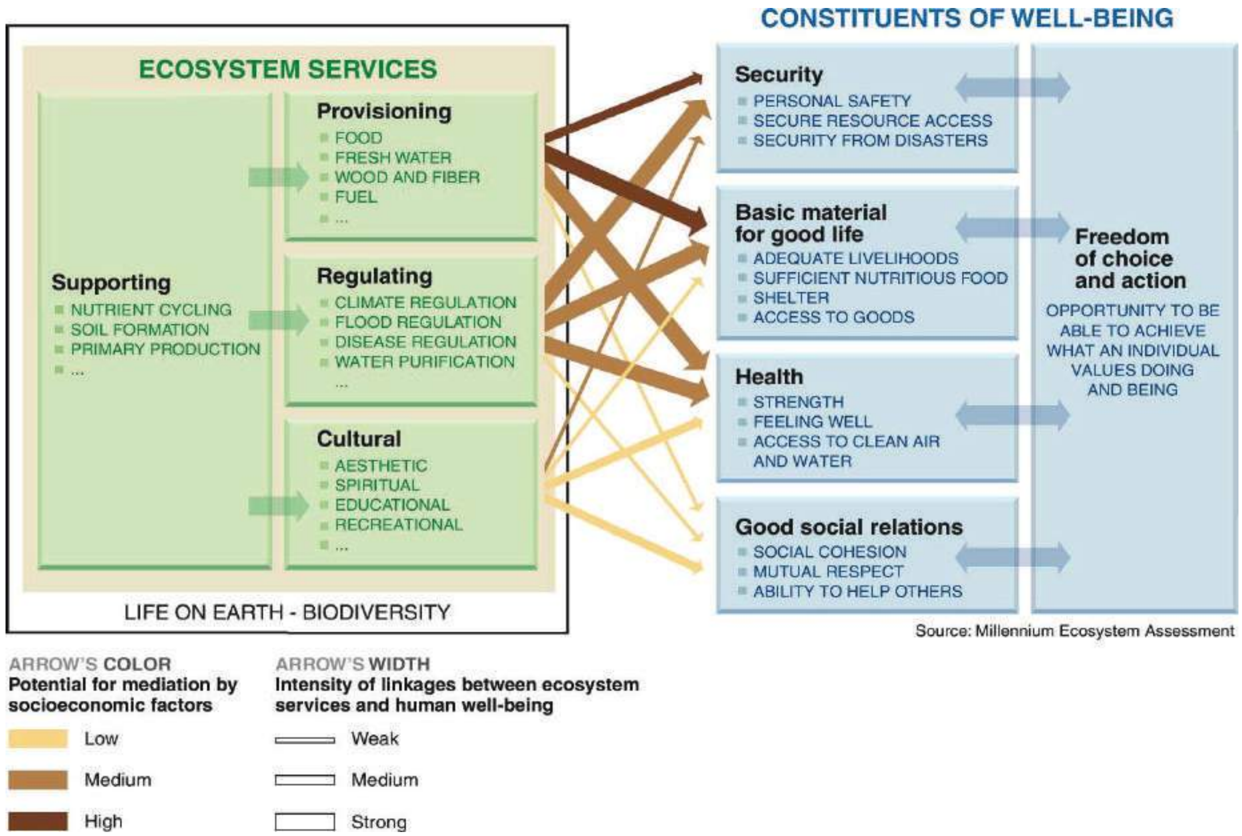
## 4.1 Need for Valuation

Forest ecosystems are exposed to a range of environmental, economic and social pressures that challenge their sustainability. The forest sector is influenced by the unprecedented pressures arising from climate change and the growing demands of society on natural resources. These changes place enormous pressure on the health and resilience of forest ecosystems and affect biodiversity and human well-being. Also, as the effects of climate change are becoming more apparent, conserving natural forests are becoming increasingly important; providing fresh water, clean air and regulating the climate to limit extreme weather, such as droughts and storms.

> "Defining the 'true' value of ecosystem services is a major challenge. There is no accepted universal method but instead a range of approaches."
> *Source: (CBD, 2007)*

**Economic Valuation as a Tool for Decision Making**

A study for the Scheldt estuary, the Nete catchment in Antwerp, Belgium showed that floodplains can provide a cheaper protection against flooding than the construction of higher dikes only. But insufficient knowledge of ecosystem services and their value can lead to wrong decisions and even catastrophes. The overexploitation of the Aral Lake in Kazakhstan and Uzbekistan has reduced this once largest inland water mass with 90 per cent, leaving a desert and causing large economic losses and illness to the surrounding population[183].




The need to recognize these values thus becomes important from an economic perspective as many of them are unacknowledged. The Economics of Ecosystems and Biodiversity (TEEB) maintains that the best way to mainstream the total ecosystem service approach is to make the previously invisible changes in nature's flows into the economy visible through economic valuation and communicate the value of ecosystems "in the language of the world's dominant economic and political model"[31]. Monetary valuation of ecosystem services is also endorsed by the Natural Capital project[32], and assigning a monetary value to ecosystem components and functions has become one of the most researched topics in ecosystem service literature[33].

Valuation of ecosystem services is a medium for improving our understanding of nature's contribution towards humankind. It is a tool for internalizing externalities into the decision-making process and hence better evaluates the impacts of habitat loss and land conservation not only to nature but to our economy and well-being. It provides a framework for better articulation of tradeoffs which helps policymakers to make informed decisions and explore options to restore natural systems so that nature's benefits are available for generations to come.

Economics is about choice, and every decision is preceded by a weighing of values among different alternatives[13]. While people can differ over whether or not nature should be described in economic terms, the fact is, nature produces a range of goods and services that are economically valuable. The process of identifying nature's values should be treated as a means to communicate better and take account of nature's importance with particular reference to human well-being[31]. While this is neither necessary nor sufficient to stop all ecosystem degradation and biodiversity loss; it can prove extremely useful if an appropriate valuation framework is created, it can help understanding relationships with nature and alerting us to the true consequences of our behaviour and choice.

An ecosystems approach to valuation provides a framework for looking at whole ecosystems in decision making, and for valuing the ecosystem services they provide, to ensure that we can maintain a healthy and resilient natural environment now and for future generations[10].

## 4.2 Economic Valuation Approaches

The importance of ecosystem services is widely recognized, but operational mechanisms and approaches for integrating them into policy-making and management practices are still in a developing phase. The logic behind ecosystem valuation is to unravel the complexities of socio-ecological relationships, make explicit how human decisions would affect ecosystem service values, and to express these value changes in units (e.g. monetary) that allow for their incorporation in public decision-making processes[34,35]. The definition and classification of ecosystem services is still debated[12,31,36–39]. But over the last decade and a half, the concept has gained considerable attention across science and policy arenas, especially on how the ecosystem services can be defined, valued and integrated into conservation and sustainable development agendas[13,35].

Defining the 'true' value of ecosystem services is a significant challenge. There is no accepted universal method but instead a range of approaches[40]. While there are numerous methods and techniques available for the valuation of a particular ecosystem service, this report includes only those which are widely accepted and are used in the valuation process for this study.

**Market-Based Approaches**- These are based on the interaction between consumers and producers regarding the demand and supply of goods and services. They are among the standard and widely accepted economic techniques for economic valuation.

Market price-based approaches are most often used to obtain the value of provisioning services, since the commodities produced by provisioning services are often sold in, e.g. agricultural markets. In well-functioning markets, consumer preferences and the marginal cost of production do reflect in a market price, which implies that these can be taken as relevant information on the value of commodities.

Cost-based approaches are based on estimates of the costs that would be incurred if ecosystem service benefits needed to be recreated through artificial or alternative means[41]. Different techniques exist, including, replacement cost method, through which estimates of the costs incurred in replacing ecosystem services with artificial technologies are deduced.

**Replacement Cost Method-** This technique of valuation includes assessment of the cost of replacing the natural system or asset with a human-made system under the given or current technological scenario. The cost is then taken as the value of that ecosystem service/asset which nature provides free-of-cost. It takes into account the current market conditions (price, etc.) of the replaceable equivalent mechanism and the state of technological advancement, i.e. available choices of mechanisms.

**Avoided Damage Cost-** Similar to replacement cost method, this method attempts to estimate the value of an ecosystem service by the cost of damages avoided due to the presence of the ecosystem service or function or asset or system. In other words, it takes into account the costs that would have to be incurred in the absence of that ecosystem service in the form of damages or loss of benefit thereof. The assessment of cost is done on the basis of current market conditions (price, etc.) of the equivalent mechanism and the state of technological advancement, i.e. available mechanism.

**Benefits Transfer Method-** This method is primarily used in cases where direct or surrogate measures are not available. In the Unit Value Transfer method, valuations derived from any of the aforementioned existing methods and transferred to new landscape and resource contexts. In other words, values of specific ecosystem services at a study site are expressed as a value per unit (per area or per beneficiary) and then extrapolated to the units (area or number of beneficiaries) at the policy site to estimate the economic values of policy site. The values transferred from the study site to policy site are done after due adjustment of various socio-economic factors.

**Travel Cost Method (TCM) -** This method is widely used for determining the value of recreation related to biodiversity and ecosystem services. It is based on the rationale that recreational experiences are associated with a cost such as direct expenses and the opportunity cost of time[42,43]. The method is based on the premise that the time and travel cost expenses incurred by the visitors to a particular site indicated their Willingness to Pay (WTP) for the recreational value of the site.

**Production Function-Based Approaches (PF)** estimate how much a given ecosystem service (e.g. regulating service) contributes to the delivery of another service or commodity which is traded on an existing market. In other words, the PF approach is based on the contribution of ecosystem services to the enhancement of income or productivity[44,45].

It is important to note that many of these methods are likely to underestimate the full range of economic values specific to given resources. For example, a market price-based analysis of water provisioning will likely underestimate the full value of the ecosystem services from the watershed because it measures only the values of services captured by the market prices. This is typically limited to marketable services (and goods) values and may exclude values associated with other services (non-marketable), such as water quality and habitat for wildlife. Also, other factors limiting the valuation process are the availability of adequate data and our understanding of the cause-effect linkages between the ecosystem services and the marketed commodities[46,47]. Furthermore, the methods have inherent limitations and assumptions which may result in over/underestimation of values, and therefore it is essential to realize that the values of ecosystem services thus obtained are intended to be included in market transactions (acquisition or commodification) but for internalizing them into policy scenarios as broad estimates.

## 4.3 Forest Ecosystem Service Valuation in India: A Review

Forest ecosystem functions providea number of ecosystem services to humans. Ecosystem services and their valuation have gained considerable momentum in recent years. In India, one of the earliest attempts was made in the study by Das, 1979, after which economic valuation of forests received a lot of attention as a research theme. The study highlighted the benefits provided by a tree and calculated the monetary value of these benefits. Another study was done by Chaturvedi (1992), where it attempted to calculate water supply benefits from Almora, Uttarakhand forests using various methods. The study done by Haripriya (2003), estimated carbon storage value from Indian forests as Rs. 20,125 lakhs per hectare using species-wise forest inventory data. In a similar kind of study, the value was calculated for biomass extraction at Rs. 1.2 lakhs per hectare[50].

Taking regulating services into account, Chopra & Kadekodi (1997) estimated the value of the Yamuna basin watershed for soil conservation as INR 2.0 lakh/ha metre of soil by the replacement cost method. The value of soil conservation in Doon valley was calculated by Kumar (2004) using the replacement cost method. In the context of developing countries, Ferraro, Lawlor, Mullan, & Pattanayak (2011) carried out a study on the forest for their economic valuation of ecosystem services and policy evaluation. Kadekodi, Murthy and Kumar also published a book in the year 2000 titled 'Water in Kumaon: Ecology, Value, and Rights'[54] in which they arrive at the value of water in the regional context of Kumaon (Uttarakhand) as a basic necessity for human life and explore its ecological linkages with the Himalayan ecosystem. The study adopts a watershed approach and includes cases studies on the value of water all along the river Ramganga in Kumaon. It aims to derive policy suggestions for the betterment of the water ecology scenario of the region.

Among the cultural services, a study by Murty & Menkhaus (1994) applied the Contingent Valuation Method (CVM) for measuring ecotourism benefits in Keoladeo National Park, Bharatpur is one of the earliest examples of the application of CVM for recreation in India. For his study, Chopra (1998) used the Travel Cost Method for economic valuation of recreation at the same site. The study assesses the consumer surplus to measure the recreational benefits and value of eco-tourism. Contingent valuation method was also used for calculating willingness to pay[57] for Borivili National Park in Mumbai; by Manoharan (1996) for Periyar Tiger Reserve, Kerala; by Chopra & Kadekodi (1997) for Ecological functions (Use Value) for local residents in the Yamuna Basin. Likewise, there are several other studies on the valuation of natural resources, already tried out and policy tested.

For Instance, the value of recreation of a sacred lake in Sikkim Himalaya (Khecheopalri Lake) and Khangchendzong National Park, Sikkim was calculated by Maharana, Sharma, & Sharma (2000) using contingent valuation to estimate willingness to pay (WTP) for managing the forest site. Sinha & Mishra (2015) also calculate willingness to pay for ecosystem services for enhancing conservation and livelihoods in a sacred village in the landscape of the Indian Himalayas. In another study, Yashoda & Reddy (2012) estimated the recreational willingness to pay for conservation of a forest ecosystem in Basavana Betta State Forest in Karnataka.

Western Ghats is a popular area for research in the field of ecosystem service. Anitha & Muraleedharan (2006) estimate the economic value of ecotourism development of a recreational site in the natural forests of the southern Western Ghats. Another study by Blicharska, Mikusiński, Godbole, & Sarnaik (2013) attempt to safeguard biodiversity and ecosystem services of sacred groves in the northern Western Ghats. Both studies focus on cultural services.

Economic valuation of biodiversity at the national level for India has been accomplished by institutions like the World Bank in 2013. Vandermeulen et al. (2011) use economic valuation to create public support for green infrastructure investments in urban areas, and Bahuguna & Bisht (2013) estimate the value of ecosystem goods and services for the Indian forests. Nilanjan Ghosh, et al. (2017) have calculated the value of ecosystem services at landscape level from the Terai Arc landscape in Uttarakhand.

On the protected area level, studies like economic valuation of tiger reserves in India, Verma et al. (2015 take into account six tiger reserves from six different landscapes to calculate the value of 25 ecosystem services emanating from them. Among others, the forests of Himachal Pradesh, Uttarakhand and Arunachal Pradesh have been valued for their ecosystem services in many of the studies[1,67,68]. Ninan & Kontoleon (2016) value forest ecosystem services from Nagarhole National Park in Karnataka and Chaudhry, Kumar, & Yogesh (2016) calculate the same for Pakke Tiger Reserve in Arunachal Pradesh. Badola et al. (2010) assess the ecosystem services from Corbett Tiger Reserve.

## 4.4 Health Benefits from Tiger Reserves

The forest environment has been enjoyed by humans for a long time because of the serene atmosphere, beautiful scenery, moderate climate and clean, fresh air. Apart from providing these physical benefits, natural capital services have a direct link to human health and well-being in local communities and form part of the natural infrastructure that supports well-being and economic prosperity. For example, forest bathing trips help in strengthening the immune system.

> "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1948)

There is a growing body of evidence on the connections between nature and well-being. Nature provides fresh water, clean air and food, upon which all human life and health depend. It influences disease occurrence and spread, supports local economies and is the source of many current and potential medicines. Nature provides places for physical activity, social connection, inspiration and calm contemplation. Nature benefits people's mental, physical, cultural, and spiritual health and well-being.

Protected areas are not only the custodians of natural ecosystems but are also natural solutions for securing our health and well-being while adapting to the impact of climate change[69]. During recent decades, the effect of forests or protected areas on human health has drawn the attention of researchers globally. Beneficial properties are attributed to both on-site activities/experiences and off-site flows. Nature-based interventions like horticulture therapy, nature assisted therapy or nature-guided therapy and conservation therapy are becoming increasingly popular[70].

In the mid-1990s, the Centre for International Forestry Research (CIFOR) recognized the importance of human health from forest management and had documented various factors associated with this aspect. Health professionals have also identified important links between the environment and health (e.g. Engelman, 1998; Gardner-Outlaw and Engelman, 1999; Walsh, Molyneux and Birley, 1993; Patz et al., 2000; Patz and Wolfe, 2002). CIFOR published a document in 2006, titled "Forest and Human Health: Assessing the Evidence" linking the state of human health to forests and investigate causal links between them. The study focused on four parameters, i.e. (1) forest foods, emphasizing the forest as a food-producing habitat, human dependence on forest foods for deriving nutrition; (2) disease and other health problems; (3) medicinal products; and (4) cultural interpretations of human health among forest inhabitants, including holistic worldviews that impinge on health and indigenous knowledge.

### 4.4.1 Prevalent Theories

In this context, there is already evidence for how the psychological benefits increase in proportion to the species richness of urban green spaces based on biological complexity and biodiversity conservation[71]. The Biophilia Hypothesis was developed by Edward Wilson to describe the innate human tendency to be drawn to the natural world also known as the Aesthetic-Affective Theory (Wilson 1984).There is another approach called the ecological approach which relies on early models of eco-therapy deriving mainly from the philosophical movement of eco-psychology[70].It primarily aimed at reuniting man with the natural environment to heal from illness and distress, challenging the separation from nature we have in theory experienced since the Industrial Revolution, especially in the Western world.

The Kaplans' 'Attention Restoration Theory' (ART) was developed[72] considering the restorative importance of natural environments for effective human functioning and well-being.The Stress Reduction Theory (SRT) is very similar to ART and is based on human responses to the natural environment (reducing stress and providing a calming effect) when there are biodiversity and landscapes with features, such as views of the sky and water bodies like oceans, seas, lakes, ponds, wetland [73].These include other geographical features where water moves from one place to another (rivers, streams, canals, etc.). Rachel Kaplan and Stephen Kaplan have developed the notion of "restorative environments" that foster recovery from this state of mental fatigue[72,74,75].

> "A nature-based therapeutic setting should be regarded as a special form of applied art"
>
> (Stigsdotter and Grahn 2002)

Complementary to the theories established by others, the opportunity to develop strong connections with natural places based on the spiritual benefits that natural environments can provide, has provided support for the development of several place-based theories[76]. An ecosystem approach to human health has also been suggested to enhance the health of communities by instituting ecosystem–management methods, which will foster the sustainability of the ecosystem itself and the health of the human beings, who are part of it.

### 4.4.2 Mental Well-Being

Being in nature can evoke wonder and awe and give people truly transformational experiences that can positively affect our communities and the environment. Interactions of people with trees and forests have a complex effect on the lives and well-being of people. The causes of illness or forgone wellness are not just presence of pathogens but are deeply rooted in our lifestyles, such as an increasingly sedentary life, physical inactivity, chronic psychological stress, and more and more people staying indoors[77].

It is widely accepted that exposure to nature fostered psychological well-being, reduced the stresses associated with urban living and promoted physical health[78]. These presumptions have been used as justification for providing parks and other natural areas in cities, and preserving wilderness areas outside cities for public use[78–80]. Scientists have found that being among plants produced “lower concentrations of cortisol, lower pulse rate, and lower blood pressure,” among other things. The effect includes reducing stress, restoring mental fatigue and improving mood, self-esteem and perceived health[81].

The immune system including natural killer (NK) cells plays a vital role in defence against bacteria, viruses and tumours. It is well known that stress inhibits immune function. Forest environment may reduce stress. Lower levels of NK has shown to be associated with a higher risk of cancer[82]. Proximity to natural environment or forests is effective in reducing stress. Therefore, the forest environment may have a beneficial effect on the immune function by reducing stress. Some empirical data suggest that chemical compounds from forests and forest odours have a distinct impact on physiological processes, with potential impact on, for example, our immune[83,84].

[83 83]investigated NK (natural killer) activity, the numbers of NK cells, and intracellular levels of anti-cancer proteins such as perforin, granzyme and granulysin in human lymphocytes during subjects visiting forest fields. The results have shown that forest bathing trips reduce the scores of anxiety, depression, anger, fatigue and confusion, and increase the score of vigour. Even a one-day trip to a forest park increases the expression of anti-cancer proteins in lymphocytes. Also, it was observed that forest visits significantly reduce blood pressure and blood glucose, have preventive effects on hypertension, diabetes, and metabolic syndrome. Forest visits stabilize the activity of autonomic nerves by increasing the activity of parasympathetic nerves and decreasing the activity of sympathetic nerves.

**Forest Bathing *(Visitation to Forest)***

A forest bathing trip is a short leisure trip visiting a forest, called "*Shinrinyoku*" in Japanese, which is similar to a natural aromatherapy. The purpose of forest bathing trip is relaxation and recreation by breathing in volatile substances from trees, called phytoncides, such as alpha-pinene and limonene. Incorporating forest bathing trips into a good lifestyle was first proposed in 1982 by the Forest Agency of Japan, and the first kick off meeting was held at *Akasawa* in Nagano prefecture located in northwestern Japan. Now it has become a useful and popular relaxation and stress management method in Japan.

It has also been proven that proximity to natural ecosystems helps in faster healing and rehabilitation process in patients with severe stress and depression[85]. People with access to nearby natural settings or parks have been found to be healthier overall than other individuals, and the long-term, indirect impacts of “nearby nature” can include increased levels of satisfaction with one’s home, job, and with life in general[74].

A number of other studies indicate that visiting forests and proximity to green environment has a positive impact on the general health of people. Looking out on and being in the green elements of the landscape around us seem to affect health, well-being and feelings of social safety[86]. A research programme studies effects of green space in the living environment on health, well-being and social safety in Netherlands, using observational studies, combining existing data on land use and health interview survey data, and collecting new data through questionnaires and interviews along with multilevel analysis and GIS techniques has shown that a natural environment has a positive effect on well-being through restoration of stress and attentional fatigue, positive mental health and life longevity [86].

According to a study conducted in Switzerland, Germany and Austria, observing wildlife can help to reduce stress, inspire companionship and provide an opportunity to connect with nature[79]. Primarily people’s perception of forests is that they offer cheap opportunities for leisure.

### 4.4.3 Physical Well-Being

#### 4.4.3.1 (A) Increased Physical Activity

Proximity to forests has a positive impact on physical and mental health; it also helps in increased physical activities that aids in prevention of illness[87]. The study by [88 88] reinforces the need for green spaces for a mentally and physically healthier lifestyle.

Outdoor natural environments may provide some of the best all-round health benefits by increasing physical activity levels with lower levels of perceived exertion and altering physiological functioning [89]. All these benefits can influence body composition, physiological and biomechanical indicators related to physical ability, reduce risk and raise the quality of life, which are markers of health. They should be taken into account when fighting the growing incidence of both physical inactivity and non-communicable disease[90].

**Greenpath: Fitness and Parks**

"Greenpath, developed by Delaware North, is an innovative environmental management system that helps minimize human impacts on parks' natural resources. In partnership with the United States National Park Service, Delaware North applies simple measurements to activities in parks such as calories used in walking on trails which raises the awareness of the benefits of parks to the users. The company took the business that it learnt from working in Yosemite National Park, incorporated it into its business model and now operates globally in national parks and World Heritage Areas." *(Case from (IUCN, 2014), Healthy Parks Healthy People Congress, Session 13: Inspiring Business Solutions for Healthy Parks Healthy People).*

#### 4.4.3.2 (B) Disease Control

Descriptive information ascribes both positive and negative health effects related to forested environments. Health and forest interactions are complex, but in the general trend, the loss of forest habitat leads to increased vulnerability to diseases while proximity to forests may also lead to more instances of certain diseases. For example, malaria–the causal links between deforestation and the incidences of malaria are difficult to distinguish. Logging processes can lead to standing water and increases mosquito breeding sites. In a few places, such as Panama and the Terai region of Nepal, forest clearing has allowed populations to enter areas that malaria had previously rendered uninhabitable[91].

There are observations about the relationship between forest clearing, subsequent changes in rodent species (as disease vectors) and the introduction of vulnerable human populations, as important factors in the appearance of arena viruses[91]. [92 92] provide a complete global survey of the correlation between diseases and forest clearing. [93 93] provides a long list of factors that can influence health and then examines them in the context of north-eastern Thailand (a deforested area). His findings are mixed: Some of the changes have resulted in worse health, some to improved health.

**Malaria and Deforestation**

"Malaria is one of the major disease in and near forested areas, particularly in Africa. The causal links between deforestation and incidence of malaria are difficult to distinguish. Logging processes can lead to standing water and increases in mosquito breeding sites. In a few places, such as Panama and the Terai region of Nepal, forest clearing has allowed populations to enter areas that malaria had previously rendered uninhabitable". (Source: CIFOR[91])

However, there is enough evidence indicating linkages between deforestation, habitat loss and various vector-borne diseases. In some cases, pathogens and vectors may be lost. But in many other cases, disease incidents have been observed to increase after deforestation[94]. Some examples of linkages between forest (deforestation) and disease incidents have been documented in CIFOR's Occasional Paper (No. 45) according to which there are evidence of linkages between diseases like Malaria, Ebola, Plague, Dengue and other diseases to dams construction, irrigation, urbanization, and deforestation in different countries of the world[91].

Forests also offer climate resilience and hence help in combating potential disease threats which may arise due to climate change[95]. Environmental changes influence the occurrence and range of infectious diseases in humans and animals. For instance, climate changes, including significant warming, have increased the frequency and severity of extreme weather events, and changes in the hydrological cycle are leading to widespread biotic and abiotic variations across the globe. The ever-increasingurbanization of human populations is creating a strain on food production and tremendous burdens on health provision with subsequent socio-economic consequences. The resulting modifications of community structures, ecosystem dynamics, host vulnerability, and the ecology of infectious diseases are changing in complex and sometimes unanticipated ways, which may result in the emergence of new infectious diseases and zoonoses (diseases transmitted between species).

#### 4.4.3.3 (C) Bio-Prospecting: Source of Current and Potential Medicines

Forests are important repositories of numerous medicinal compounds from wild organisms, including some common foods and drinks. Wild forest resources include bio-chemical compounds alkaloids, like reserpine, quinine, ipecac, ephedrine, caffeine, and nicotine; and antibacterial compounds, as well as antifertility compounds. [96] give some examples: "These drugs carry important therapeutic properties including contraceptives, steroids and muscle relaxants for anaesthesia and abdominal surgery (all made from the wild yam, *Dioscorea villosa*); quinine and artemisinin against malaria; digitalis derivatives for heart failure; and the anticancer drugs vinblastin, etoposide and taxol."

Various forest plants and animals produce certain bio-chemicals like poisons, fungicides, antibiotics and other biologically active compounds as defence mechanisms which may have medicinal uses. Some of the Western pharmaceutical products are derived from tropical forest species, e.g. quinine from Cinchona spp.; cancer-treating drugs from rosy periwinkle (*Catharanthus roseus*); treatments for enlarged prostate gland from *Prunus africana*; forskolin, which has a variety of medicinal uses, from the root of *Coleus forskohlii*; medicine for treating diabetes from *Dioscorea dumetorum and Harungna vismia*; and several medicines based on leaves of the succulents of the *Mesembryanthemaceae* family[91]. Some of these products are now synthesized, but others are still collected from the wild.

Literature is abundant on potentially useful plant species. He & Sheng (1997), for instance, report that the official Pharmacopoeia of the People's Republic of China lists 709 drugs, with only slightly more than 40 being animal or mineral. Plant material accounts for more than 80 percent of the drugs sold, and of the 1000 most commonly used medicinal plants, 80 percent of the species are wild.

### 4.4.4 Cultural Linkage: Repository of Traditional Knowledge

Many people in developing and developed countries rely on traditional medicines to maintain health, improve well-being or treat illness. These conventional practices include medicines, foods and ecosystem- or geographically-linked diets, access to sacred and healing landscapes, and practitioners who are aware of the differential benefits of resources and ecosystem types. The economic value of traditional medicines is considerable; Achieng (1999), for instance, reported that the bark of *Prunus africana* alone was worth US$220 million annually to the pharmaceutical industry in 1999.

**Herbanisation**

"This was the case in Cape Town where too many people tried to get their traditional medicinal herbs from too few forests. 'Herbanisation' is a project developed with the Khoi (Rastafari traditional healers) in Cape Town suburbs. It consists of an indigenous medicinal street garden that now has more than 30 species, with 1500 plants, all planted and propagated by local communities with the help of conservation professionals and support of donors." *(Case from (IUCN, 2014), Healthy Parks Healthy People Congress, Session 16: Linking Traditional Medicine, Good Healthcare Access and Conservation)*

Local people in tropical Asia, Africa and Latin America have considerable knowledge of medicinal plants. Their traditional healthcare systems are widely considered important, especially given the absence of more formal healthcare services. The market for traditional medicines is large and expanding; there is also growing scientific evidence of the efficacy of some of these widely used traditional remedies[98].The rise in popularity of complementary medicines may not only be due to disenchantment with modern techniques but also the expression of a desire to take a more natural approach to health[91]. Many patients cite "naturalness" as the appeal of complementary medicine, yet others are drawn by spiritualism or the emphasis on holism [91].

Bhattarai (1997) reports that 85 percent of Nepal's population uses folk herbal remedies; Shankar and Majumdar (1997) estimate that for 400 million to 500 million people in India, traditional medicines are the only alternative. Ignacimuthu, Ayyanar, & Sivaraman K. (2006) have carried out a study on medicinal plants available in the forests of Madurai district, Tamil Nadu. A total of 60 ethno-medicinal plant species distributed in 32 families are documented in this study. Mahapatra & Panda (2002) found 215 wild plants used medicinally by forest villagers in Odisha. Anyinam (1995) reports that in all of India, some 2500 plants are used medicinally. WHO estimates that 80 percent of people in the developing world rely on traditional medicines, particularly plants, for their primary healthcare.

**Recovery and Nature**

"Japan created a new national park as part of the recovery programme post-earthquake and tsunami. They are working with local people who survived the disaster to tell stories and educate park visitors. A new 700 km-long coastal trail aims to get people using the area and enjoying the seafood from the area. This was an extraordinary and moving story of landscape and personal recovery entwined." *(Case from (IUCN, 2014), Healthy Parks Healthy People Congress, Session 10: Sustaining parks and improving human health together – Part 2).*

### 4.4.5 Providing Nutrition

While communities near the forest areas depend predominantly on forest-derived foods for nutrition, there are many factors like their role in food security scenario, potential benefits from wild cultivars, distribution of food within households, and quality of forest foods, all these factors of forest foods influence human health[91].Local communities get their protein and other nutritional requirement fulfilled by forest resources[102].

## 4.5 Forests and Health: A Holistic Approach

Looking at the condition of people's health in and around forests, there are also some notable examples of increased health threats from forests. For sure, tropical forests also provide essential foods, medicines, healthcare and mental health benefits to people all over the world. The amount of these benefits generally increases with proximity to the forest[91,98]. But there is also some significant evidence that, in many cases, activities intended to promote economic development, such as construction of dams, roads and mines and other activities which may lead to deforestation, have worsened the health of those living near forests[91]. Regarding the impacts of these links, effects of forest loss on the health of people living in and around forests vary but are often negative.

"Nature is not optional, it is absolutely essential to living a happy, healthy and meaningful life."

- Amber Bill, Wellington City Council, New Zealand (IUCN, 2014)

Well-being is inextricably linked to natural ecosystems. Wilderness experience, night walks, night sounds, and stargazing are opportunities for connecting people to nature through various methodologies, such as stories of cultures and lore. There is much evidence that highlight the interplay between ecosystem function and human health. Forests help in improving psychological well-being, reduce stress, boost immunity, enhance productivity and promote healing.

"Nature brings value to the 'experience economy'."

*- Isabelle Wolf, New South Wales National Parks and Wildlife Service, Australia (IUCN, 2014)*

Today health is viewed as a holistic and positive state embracing the individual in relation to his/her entire life situation (including biological, cultural, social and environmental aspects). In a well-designed healing natural setting all the above mentioned aspects may take place. Remarkably enough, this new perspective on health could be viewed as a return to more ancient beliefs and moving towards a more nature-centred lifestyle.

Environmental sustainability and human health are two of the world's most pressing challenges. Environmental health and human health are inextricably linked. Vibrant, thriving ecosystems have a powerful impact on human health, economic vigour, and social vitality.

In the sections above, well-being is discussed from different perspectives including livelihood dependency; importance to health and healing; maintaining traditional culture and knowledge systems; social empowerment, stewardship, good governance and holistic planning for a country. While several of these studies mentioned above explored the multi-faceted dimensions of well-being in relation to people's interactions with and dependency on nature, internalizing international approaches such as One Health, EcoHealth, UNESCO's Geoparks and Healthy Parks Healthy People are fostering international research, collaboration and actions across sectors.

Investigations have just begun assessing the extent of 'How dependent on nature humans are, and exactly what benefits can be gained from interacting with nature'. Findings so far, however, indicate that protected areas and other natural environments play a vital role in human health and well-being through providing access to nature. These divergent researches come to a central notion that contact with nature is beneficial, perhaps even essential, to human health and well-being; also urging a socio-political-ecological approach to health—a deeper understanding of the interaction between population, environment, power and disease, including economic drivers.

**Finding Inner Peace**

"The Bush Circle, in Sydney, managed by WEAVE, an Australian youth and community services organisation. The Bush Circle is a service offered to young people without adult models dealing with alcohol and drug addictions who are trying to cope with their lives. At the Bush Circle, the participants are brought to nature for five days of outdoor activities. The participants mentioned going to this camp in order to find their spirituality, their inner child, to find peace and self-reflection. The participants also described some elements that the experience brought to them including: stress relief, choice, meaning, perspective and inner-connection (opposite to isolation), and improved confidence." *(Case from (IUCN, 2014), Healthy Parks Healthy People Congress, Session 17: The Healing Power of Nation)*

## 4.6 Economic Valuation as a Basis for Setting up Mechanisms for Economic Incentive

Using an ecosystem services-based approach enables us to measure value and benefits and is a more holistic approach to benefits, integrating environmental, economic and community benefits. Ecosystem services accounting and evaluation frameworks provide the means to manage parks in a more business-like manner – that is, expressing the values and benefits of protected areas in the language of other sectors. As a part of turning policy into action, economic valuation can provide a strong basis for setting up policy mechanisms for incentivizing conservation.

Economic valuation helps in capturing the attention of policymakers in internalizing externalities and making policy instruments. Protected Area managers may benefit from becoming more economically literate, so they can communicate to the external stakeholders about the benefits of investing in nature and in "green" initiatives that improve the health of ecosystems and people. Although introduction of the Sustainable Development Goals has incorporated environmental objectives into policy action, there is still the need to integrate biodiversity and sustainable development outcomes at all levels. Nature should be viewed as part of the solution to current challenges. Nature is the natural infrastructure that provides for the supply of basic needs. Without nature protection, access to essential requirements, including water, food, and energy, cannot be guaranteed.

Some common policy instruments that can be implemented are:

*Table 4.6-1 Policy Based Incentive-based Instruments*

| **Ecosystem Service from Tiger Reserve** | **Policy/Incentive Instruments** |
|---|---|
| Employment Generation | Tax Benefits, fee collection |
| Fishing | Biodiversity credits/ fishing permits |
| Fuelwood and Timber/ Standing Timber | Subsidizing LPG. FSC certification, tax incentives for bio-energy/renewable energy usage, emission reduction credits/ carbon storage credits, access rights |
| Fodder / Grazing | Community/participatory forestry, charge on grazing |
| Non-Wood Forest Produce | Benefit sharing, debt-for-nature swaps, forest certification, biodiversity cess, clean development mechanisms |
| Gene-pool protection | Biodiversity credits, bioprospecting credits, bioprospecting rights, debt-for-nature swaps, critical ecosystem partnerships, research permits, gene-pool bank |
| Carbon Storage and Carbon sequestration | Carbon credits, emission reduction credits, REDD+, CDM, social tax, compensatory afforestation, transferable restoration credit |
| Water Provisioning and Water Purification | Tradable wetland mitigation credits, water cess, watershed conservation, water quality credits, incentives to upstream conservation |
| Soil Conservation / Sediment regulation and Nutrient Cycling / Retention | Tax incentives for organic farming, organic certification, tax subsidies, watershed management fund, eco-tax, transferable restoration credits, nutrient/soil conservation credits |
| Biological Control | Biodiversity credits, bioprospecting rights, debt-for-nature swaps, promotion of organic farming, medical subsidies, healing camps |
| Moderation of Extreme Events | REDD+, Disaster management funds, climate care warranties |
| Pollination | Biodiversity credits, bioprospecting rights, debt-for-nature swaps |
| Nursery Function and Habitat for Species | Biodiversity cess, critical ecosystem partnerships, fish breeding credits, tradable development rights, |
| Cultural Heritage | Ecotourism use, research permits, schemes for indigenous communities, sacred grove conservation, entry fees, community development funds |
| Recreation | Ecotourism use/ natural resource management agreements; ecotourism concessions; photographic permits, entrance rights, access permits, ecotourism concessions, land acquisition, land lease |
| Research, Education And Nature Interpretation | research permits, photography permits, research grants, fee from interpretation centre |
| Gas Regulation | Eco-labels, performance linked incentives, energy efficiency credits |
| Waste Assimilation | Waste generation cess, waste-management credits, direct-in-indirect payments, environmental tax, conservation easements, debt-for-nature swaps |
| Climate Regulation | REDD+, CDM, Disaster mitigation fund, performance-based local grants system that integrates climate change adaptation and environment management, differential land-use tax, transferable development permits, climate mitigation credits |

# 5 Chapter 5: Study Methodology

***Overview***

The chapter includes the description of methods used for biophysical assessment and economic valuation of the selected ecosystem services in the following sections.

***Key Insights***

The study adopts a **VALUE+ approach** where the "VALUE" represents all the benefits in monetary terms for those services where monetary economic valuation is possible and derived based on available knowledge, tools and methods. The "+" represents all those benefits for which economic valuation is currently not possible on account of insufficient accepted methodologies, knowledge, available technology, current resources and/or understanding of the system. Since all the values of the system are not captured in the values, the estimates thus arrived in the study are conservative.

The present study endeavours to further evolve the methodology from the Phase-I Study. Methods and tools for quantification and valuation of each ecosystem service have been refined at various stages through systematic processes, engaging stakeholders and including more and more objective parameters. In the initial stages of the study, Tiger Conservation Plans (TCPs) for the selected tiger reserves were studied in detail to identify the ecological and socio-economic context, important ecosystem services and data sources. The study mainly uses secondary data along with some primary data for quantification of ecosystem services. Modelling using InVEST for three ecosystem services has been included to get better estimates. Attempts have been made to get local values and fair estimates so that they closely reflect benefits emerging from these reserves.  The study also supports a pilot study exploring tiger reserves of Phase-I study as Destination Brands.

Since quantification and monetary economic valuation of each ecosystem service is not possible, different effect categories are defined in the report of the EPA science advisory board have been used to include non-monetary benefits and provide a comprehensive assessment. Various other frameworks such as Human Values and Ecosystem Assets framework by Ken J. Wallace (2007) are used to demonstrate the linkage of ecosystem services and human life; IPBES protocols and methods have been used to highlight the uniqueness value of each tiger reserve. Other frameworks such as Millennium Assessment (MA), Stock and Flow, Tangible/Intangible and Total Economic Value (TEV) framework have been used to facilitate the communication of the range of values for various stakeholders.

## 5.1 Study Methodology and Data Collection Tools

The present study endeavours to further evolve the methodology from the Phase-I Study and adopts an overall scientific approach and rigorous research process. Methods and tools for quantification and valuation of each ecosystem service have been refined at various stages through systematic processes, engaging stakeholders and including more and more objective parameters. Consultation with key stakeholders including members of the National Tiger Conservation Authority, State Forest Departments, subject experts, secondary sources, workshops, roundtables and expert team consultation were held for support in data collection, fieldwork, and for reviewing the methodology, monitoring the study progress and in preparing draft versions of the report. These also include consultation with a number of national and international experts and extensive literature review for developing the methodology, appraisal of the study progress and further acquiring guidance at various stages of the study.

In the initial stages of the study, Tiger Conservation Plans (TCPs) for the selected tiger reserves were studied in detail to identify the ecological and socio-economic context, important ecosystem services and data sources. Workbooks containing a description and initial approach for each ecosystem service were also sent to selected tiger reserve management offices, relevant departments and concerned officials to get the necessary input and guidance for further developing the methodology. Existing literature on the ecosystem service valuation was reviewed to internalize the best practices into the existing study. A dissemination workshop was conducted in New Delhi on November 17, 2016 in which key stakeholders were invited to appraise the findings of Phase-I and discuss the draft methodology for this phase of the study. Based on the discussions and suggestions, the study methodology was appropriately modified such as inclusion/exclusion of ecosystem services for the study, selecting methodology for valuation and quantification, scheduling field visits and presentation of values in various frameworks. Recently a guidance manual was also published by the project team, lessons and experience in developing it have also been used to develop the methodology and approach for this report.

The study is mostly based on information obtained during field visits to each of the selected tiger reserves. These visits were conducted to understand the local context and ecosystem dynamics and incorporate the uniqueness value pertaining to each tiger reserve. The visits included a survey of major types of ecosystems and understanding interactions between them, short-listing of major ecosystem services for each tiger reserve, collection of data already available at the Field Director's Office such as micro-plans, older management plans, TCPs, geospatial files, consultation meetings with stakeholders, state forest department officials, 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 the linkage between ecosystem services from tiger reserves and local livelihoods.

The study mainly uses secondary data along with some primary data for quantification of ecosystem services. The secondary sources from which information has been obtained are forestry and statistical organizations like the Forest Survey of India (FSI), concerned departments, boards, ministries, local institutions; likewise, primary information from communities via focused group discussions and interviews, and other research institutions. Other than these, data from peer-reviewed and widely accepted research papers and journals, databases and published reports have been used for quantification and arriving at a reliable economic valuation of ecosystem services wherever applicable. In addition to this, modelling for three ecosystem services has been included to get better estimates. Attempts have been made to get local values and fair estimates so that they closely reflect benefits emerging from these reserves.

### 5.1.1 InVEST

> **InVEST** is a set of models spanning terrestrial, freshwater, and marine environments, that use production functions to estimate changes in biodiversity and ecosystem services under different demographic, land-use, and climate scenarios. The InVEST includes models for quantifying, mapping, and valuing the benefits provided by terrestrial, freshwater, and marine systems.

The study also addresses the utility of ES mapping and valuation to communicate the diverse values embedded and emanating from tiger reserves. A thorough literature review was carried out to review the trends of remote sensing applications in quantifying and mapping ecosystem services. The **InVEST** user-friendly ES tool was selected on account of its adaptability around the world and its flexibility to analyse ES at local, regional, or global scales. InVEST requires area-wide information on land use/land cover, evapotranspiration, precipitation, and topography. These relevant data were acquired from the Forest Survey of India , based on literature review and also from open source. Based on the availability of input information/data, InVEST modelling was used for bio-physical estimation of three ecosystem services viz. Carbon Storage, Water Provisioning and Sediment Retention. The InVEST modelling process and outputs were then refined with team and external experts. InVEST models are spatially-explicit, using maps as information sources and produce results in biophysical terms or economic terms. InVEST quantifies the ecosystem services and thereby, valued the ecosystem services that are provided on the current landscape. The carbon model calculates the carbon stored in all tiger reserves. The water yield model calculates pixel level yields as the difference between precipitation and actual evapotranspiration. and thereby estimates the mean annual water yield per watershed. The sediment model calculates generated and retained sediment at a pixel scale using USLE and routing. The sediment model thus estimates the mean annual erosion and mean annual sediment retention per watershed. The detailed methodology of the three mentioned models is explained in further sections.

### 5.1.2 Destination Brand Value

Tiger reserves are popular tourist destinations. In order to assess this part of cultural services emanated by tiger reserves, a primary survey was conducted among recent and potential visitors of tiger reserves. The exercise was an attempt to study tourists' attitudes towards brand equity (brand awareness and brand image of tiger reserves) and value proposition, exploring the value as a destination brand. This included an online survey, the link of which was sent to target respondents. The sample covered was mostly through Snowball sampling except for Kanha Tiger Reserve visitors for which database was available, and hence the same was used as the sampling frame. A more detailed explanation of this component is given in Chapter 7 of this report.

Other components like uniqueness value, case-studies and stories have been added along with the valuation findings to present a holistic picture and initiate appreciation for other dimensions of looking at the 'value' of tiger reserves in India. The monetary calculations rely mostly on estimates of data obtained from the literature, which effectively calculate the cost to society if the services that are given by forest regions are actually not provided. We note that, as we are only able to focus on a narrow slice of benefits due to data and methodological limitations, the values presented in this report should be considered lower end estimates of the benefits provided by these PA regions.

The ecological services that forests provide are manifold and go beyond tangible benefits like timber, NTFP or carbon storage. Many forests offer opportunities for recreation and are critical for the conservation of biodiversity. Forests may also be the location of culturally important places and practices. Although it can be difficult to assign specific monetary values for many of these on a realistic scale because of the lack of data, their importance should not be underestimated.

### 5.1.3 Value+ Approach for Economic Valuation of Ecosystem Services

There is an increase in the number of researches and studies on ecosystem services and their valuation across the globe, but in spite of our increased appreciation and awareness about nature, our understanding is still very limited on its functions and processes. There is an inherent ambiguity and uncertainty associated with each method of quantification and valuation of ecosystem services which may lead to underestimation or undercounting of the benefits emanating from our forests. While this study attempts to estimate the quantum and value of the services being generated/ flowing from the selected tiger reserves, admittedly there are several services for which the economic values cannot be estimated in monetary terms. Such services can be only quantified using some bio-physical indicator or can only be qualitatively described. Also, it is difficult to translate subjective values in the ecological-social dynamics such as health, intrinsic values and connection to lives of human beings in the area into a single unit "money".

Thus, the study adopts a VALUE+ approach where the "VALUE" represents all the benefits in monetary terms for those services where monetary economic valuation is possible and derived based on available knowledge, tools and methods. The "+" represents all those benefits for which economic valuation is currently not possible on account of insufficient accepted methodologies, knowledge, available technology, current resources and/or understanding of the system. Since all the values of the system are not captured in the values, the estimates thus arrived in the study are conservative.

Since quantification and monetary economic valuation of each ecosystem service is not possible, different effect categories are defined in the report of the EPA science advisory board (2009)[103]. These help to broaden the spectrum of study to showcase the whole range of values, using an appropriate approach as per its category.

*Table 5.1-1 Categories of Benefits Received from the Tiger Reserves in the Study (Adapted from EPA, 2009)* [103]

| | |
|---|---|
| Category 1 | Effects for which benefits can be assessed and monetized using available ecological models and appropriate economic valuation methods, including benefits transfer |
| Category 2 | Effects for which benefits cannot be monetized, but can be quantified in bio-physical terms using available ecological models and for which some indicator(s) of economic benefits exist |
| Category 3 | Effects that can be quantified in biophysical terms but for which no indicators of economic benefits exist |
| Category 4 | Effects that can be qualitatively described and generally related to benefits based on available ecological and social science, even if they cannot be quantified |
| Category 5 | Effects that are most likely to generate important non-economic values |

These categories help in articulating the Value+ approach as they help in internalizing all ecosystem services benefits mapped on to the valuation process. Some effects can fall under multiple categories depending on the context. Categories 1-4 provide information regarding economic benefits and the Category 5 includes supplemental information about other values that may be of interest to policymakers and the stakeholders but does not come under the principles of cost-benefit analysis. These categories are further used in the presentation of the findings of this study.

## 5.2 Valuation Frameworks

Presentation of values in different formats is essential to cater to the needs of different sets of stakeholders and suit different policy contexts. In order to consider the categories of benefits as shown in Table 5.1-1 above derived from the selected tiger reserves, the current study uses following frameworks under which different benefits have been categorized and quantified.

- Total Economic Value (TEV)
    - Stock and Flow Benefits
    - Tangible and Intangible Benefits
- Millennium Ecosystem Assessment (MA)
- The Economics of Ecosystem and Biodiversity (TEEB) Framework and Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) Protocols
- Human Assets and Ecosystem Assets Framework

Apart from the above-mentioned frameworks, findings are also presented in terms of investment multiplier and a framework highlighting synergies between human life/values and ecosystem services. In addition to this, the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) Protocols are also used to highlight the cultural or uniqueness value via cases, stories and narratives. All these platforms and classification systems are briefly explained in the following sections.

### 5.2.1 Total Economic Value (TEV)

The Total Economic Value (TEV) framework [14] for environmental valuation presents a broad conceptual framework, which includes all the benefits from goods and services that flow from the forests and tiger reserves, and environmental externalities, classified as Use Values and Non-Use Values (Fig 5.2-11).

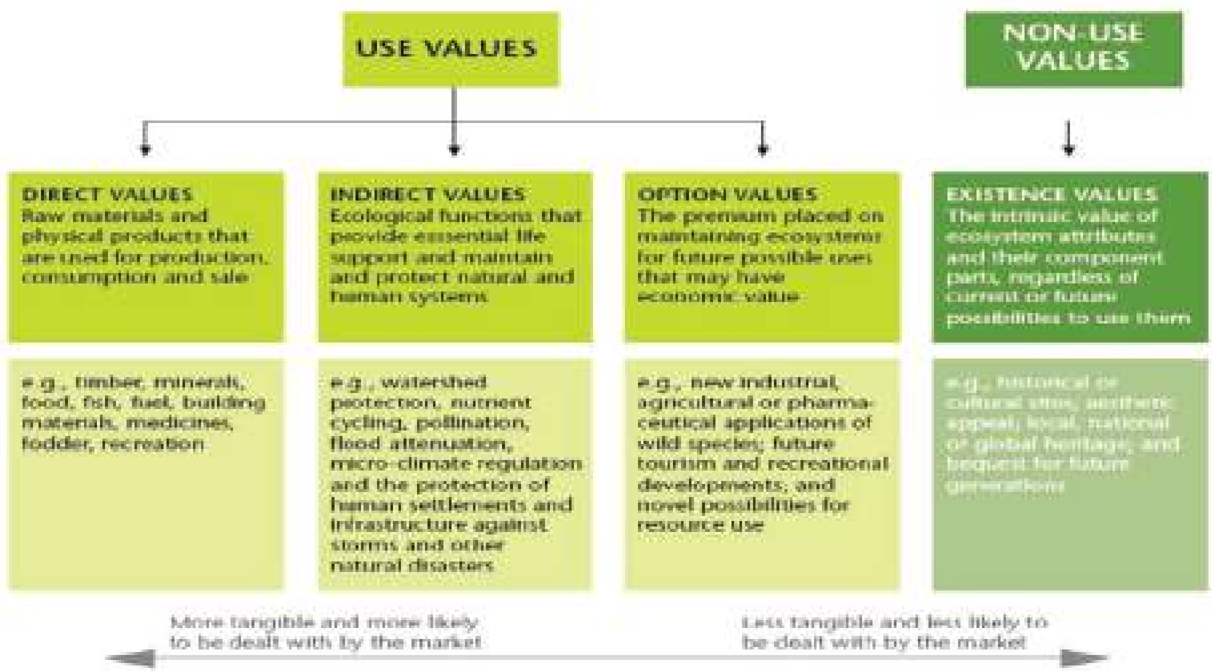



*Figure 5.2-11 TEEB Economic Valuation Framework of Ecosystem Services (Source: TEEB)*

**Use Values:** These can be associated with private or quasi-private goods, for which market prices usually exist. Use values are divided further into two categories:

**Direct Use Values:** These are related to the benefits obtained from direct use of ecosystem services. Such use may be extractive or non-extractive use.

**Indirect Use Values:** These are usually associated with regulating services, such as air quality regulation or erosion prevention, which can be seen as public services, generally not reflected in market transactions.

**Option Value:** Placed on the potential future ability to use a resource even though it is not currently used and the likelihood of future use is very low. This reflects the willingness to preserve as an option for potential future use.

**Non Use Value-** Placed on a resource, not from its current use but , dervied from the value of satisfaction from preserving that natural environment or a historic environment (i.e. natural heritage or cultural heritage) for future generations.

#### 5.2.1.1 Stock and Flow Benefits

Benefits emerging from the tiger reserve can be broadly classified as stock and flow benefits. The stock refers to natural resource stock serving as the base for generating benefits; and it also refers to the potential supply, while flow benefits refer to the actual flow of benefits. In this study, standing timber and carbon storage are taken as stock benefits and carbon sequestration is taken as a flow benefit.

#### 5.2.1.2 Tangible and Intangible Benefits

Tangible benefits refer to goods and other material benefits obtained from the tiger reserves and the intangible benefits refer to the set of services which contribute towards human well-being indirectly. While the tangible benefits comprise an important part of livelihoods and lifestyle of the surrounding community, the current study also highlights the intangible benefits as many of these are not properly recognized. The study hence deliberately attempts to internalize and emphasize these intangibles for policy making.

#### 5.2.1.3 The Economics of Ecosystems and Biodiversity (TEEB)

As per TEEB (2010), the value of an ecosystem should be counted for its aggregated value of the ecosystem service benefits provided in a given state as well as the system's capacity to maintain these values in the face of variability and disturbance.

*Table 5.2-1 Typology of Ecosystem Services in TEEB (Adapted from Costanza et al. (1997), De Groot et al. (2002), MA (2005a), Daily et al. (2008) [11361246]).*

| Typology of ecosystem services in TEEB | |
|---|---|
| S. No. | **Main service types** |
| | **PROVISIONING SERVICES** |
| 1 | **Food** (e.g. fish, game, fruit) |
| 2 | **Water** (e.g. for drinking, irrigation, cooling) |
| 3 | **Raw Materials** (e.g. fiber, timber, fuel wood, fodder, fertilizer) |
| 4 | **Genetic resources** (e.g. for crop-improvement and medicinal purposes) |
| 5 | **Medicinal resources** (e.g. biochemical products, models & test-organisms) |
| 6 | **Ornamental resources** (e.g. artisan work, décorative plants, pet animals, fashion) |
| | **REGULATING SERVICES** |
| 7 | **Air quality regulation** (e.g. capturing (fine)dust, chemicals, etc) |
| 8 | **Climate regulation** (incl. C-sequestration, influence of vegetation on rainfall, etc.) |
| 9 | **Moderation of extreme events** (eg. storm protection and flood prevention) |
| 10 | **Regulation of water flows** (e.g. natural drainage, irrigation and drought prevention) |
| 11 | **Waste treatment** (especially water purification) |
| 12 | **Erosion prevention** |
| 13 | **Maintenance of soil fertility** (incl. soil formation) |
| 14 | **Pollination** |
| 15 | **Biological control** (e.g. seed dispersal, pest and disease control) |
| | **HABITAT SERVICES** |
| 16 | **Maintenance of life cycles of migratory species** (incl. nursery service) |
| 17 | **Maintenance of genetic diversity** (especially in gene pool protection) |
| | **CULTURAL & AMENITY SERVICES** |
| 18 | **Aesthetic information** |
| 19 | **Opportunities for recreation & tourism** |
| 20 | **Inspiration for culture, art and design** |
| 21 | **Spiritual experience** |
| 22 | **Information for cognitive development** |

### 5.2.2 Millennium Ecosystem Assessment (MA)

In the Millennium Ecosystem Assessment (MA) framework [12] ecosystem services are the benefits people obtain from functional ecosystems including provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain the other services.

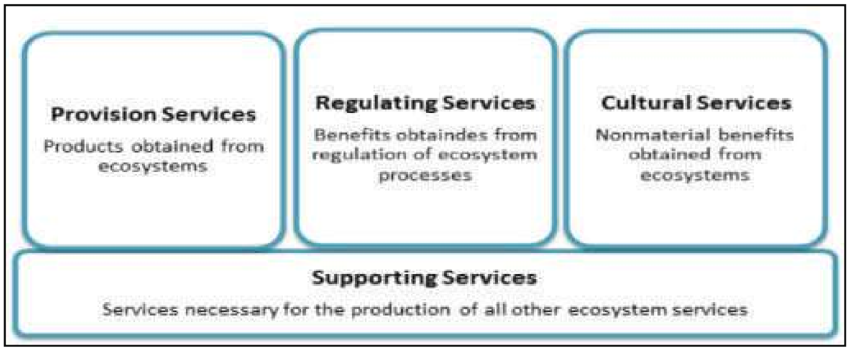



*Figure 5.2-2 Ecosystem Services (MA, 2005)*

As per the Economics of Ecosystems and Biodiversity (TEEB) classification and based on the MA all the values are grouped as follows:

**Provisioning Services**: Provisioning Services are ecosystem services that describe the material or energy outputs from ecosystems. The products obtained from ecosystems, including, for example, genetic resources, food and fibre, several raw materials for direct use and fresh water, etc.

**Regulating Services**: They are the benefits obtained from the regulation of ecosystem processes or the services that ecosystems provide by acting as regulators, for example, local climate and air quality regulation, carbon sequestration, moderation of extreme events such as floods and droughts, waste-water treatment, waste assimilation, erosion prevention and maintenance of soil fertility, pollination, biological control, etc.

**Cultural Services**: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, inspiration for art, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values.

**Supporting Services**: The ecosystem services necessary for the production of all other ecosystem services. For example, biomass production, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.

### 5.2.3 Human Values and Ecosystem Assets Framework

Ecosystem services are crucial for human well-being and therefore this classification highlights the synergies between human values and ecosystem services. This framework helps in classifying the ecosystem functions and processes that are the means to achieve the end product which are our ecosystem services. It highlights the linkages between ecosystem services, ecosystem assets and human values such as socio-cultural fulfilment, protection from various parasites, benign physical and chemical environment and adequate human resources[39]. Following table shows the relation between these values.

*Table 5.2-2 Description of category of human values (Source: [39])*

| Proposed classification of ecosystem services and links to human values, ecosystem processes, and natural assets | | |
|---|---|---|
| Category of human values | Ecosystem services – experienced at the individual human level | Examples of processes and assets that need to be managed to deliver ecosystem services |
| Adequate resources | | *Ecosystem processes* |

| | | |
|---|---|---|
| Protection from<br>predators/disease/parasites<br>Benign physical and chemical environment<br><br>Socio-cultural fulfilment | • Food (for organism energy, structure, key chem- ical reactions)<br>• Oxygen<br>• Water (potable)<br>• Energy (eg, for cooking – warming component under physical and chemical environment)<br>• Dispersal aids (transport)<br>• Protection from predation<br>• Protection from disease and parasites<br>Benign environmental regimes of:<br>• Temperature (energy, includes use of fire for warming)<br>• Moisture<br>• Light (eg, to establish circadian rhythms)<br>• Chemical<br>Access to resources for:<br>• Spiritual/philosophical contentment<br>• A benign social group, including access to mates and being loved<br>• Recreation/leisure<br>• Meaningful occupation<br>• Aesthetics<br>• Opportunity values, capacity for cultural and biological evolution<br>– Knowledge/education resources<br>– Genetic resources | • Biological regulation<br>• Climate regulation<br>• Disturbance regimes, including wildfires, cyclones, flooding<br>• Gas regulation<br>• Management of ''beauty'' at landscape and local scales.<br>• Management of land for recreation<br>• Nutrient regulation<br>• Pollination<br>• Production of raw materials for clothing, food, construction, etc.<br>• Production of raw materials for energy, such as firewood<br>• Production of medicines<br>• Socio-cultural interactions<br>• Soil formation<br>• Soil retention<br>• Waste regulation and supply<br>• Economic processes<br>*Biotic and abiotic elements*<br>Processes are managed to provide a particular composition and structure of ecosystem elements. Elements may be described as natural resource assets, eg:<br>• Biodiversity assets<br>• Land (soil/geomorphology) assets<br>• Water assets<br>• Air assets<br>• Energy assets |
| Ecosystem services consistently relate to specific human values, but processes and assets do not. Most processes and assets contribute to a wide range of services. | | |

*Table 5.2-3 Human Values and Assets Framework (Source: [39])*

| Category of Human Values | Corresponding Ecosystem Services- Experienced at Individual Level |
|---|---|
| Adequate Resources | Food (for energy, structure and key chemical reactions) |
| | Oxygen |
| | Potable water |
| | Energy (for cooking-warming component under physical and chemical environment) |
| | Dispersal aids (transport) |
| Protection from Predators/Diseases/Parasites | Protection from predation |
| | Protection from disease and parasites |
| Benign Physical and Chemical Environment | Benign environmental regimes of temperature (energy, includes use of fire for warming) |
| | Moisture regimes |

| | |
|---|---|
| | Light (eg. to establish circadian rhythm) |
| | Chemical cycles |
| Socio-Cultural Fulfilment | Access to resources for spiritual/philosophical contentment |
| | Social company- a benign social group including access to mates and being loved |
| | Recreation/leisure |
| | Meaningful occupation |
| | Aesthetics |
| | Opportunity values- capacity for cultural and biological evolution (knowledge/education and genetic resources) |

### 5.2.4 Environmental Protection Agency (EPA) Framework

As described earlier in Table 5.1-1 the effect categories showcase a range of values. Ecosystem services for which values have not been estimated monetarily should not be overlooked in the valuation process. To emphasize the non-monetary values, indirect benefits and capture a more holistic assortment of values, EPA framework[103] has been adopted to present findings of economic valuation for the tiger reserves.

### 5.2.5 The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Framework

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is an independent intergovernmental body established in 2012 open to all the member countries of the United Nations. It was established with the goal of 'strengthening the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development'[104]. Inspired by other international assessments, specifically the Millennium Ecosystem Assessment (MA) and the Intergovernmental Panel on Climate Change (IPCC) and cater to the issues and challenges related to biodiversity. IPBES was designed to proactively develop assessments matched to policy needs, and to support capacity building across scales and topics[105].

Since its formation, IPBES has evolved incorporating standardized protocols for capturing a range of biodiversity and cultural values; or as per its new nomenclature- Nature's Contribution to People (NCPs). The interactive process of IPBES considered diverse views of scientific disciplines, stakeholders, and knowledge systems, including indigenous and local knowledge and provided the following conceptual frameworks, which is defined as 'a concise summary in words or pictures of relationships between people and nature' is depicted in Central Framework.

One of the most significant features of the IPBES process is its inclusive approaches like the Multiple Evidence Based (MEB) approach which acknowledges that there are aspects of each knowledge system or even discipline, for example, social and natural sciences that cannot be fully translated from one into another. These approaches emphasize the need for co-production through the engagement of different stakeholders, such as scientists from different disciplines, practitioners and disseminators, and Indigenous and Local Knowledge(ILK) holders.

The IPBES protocols promote participatory economic valuation approaches like cultural and social valuation methods. Such methods are particularly encouraged to engage a trans-disciplinary approach which bridges multiple disciplines and includes non-scientist participants as partners assume greater importance. Some of these methods include:

(i) Ethnography, which is a method defined by long-term living within a community, participant observation, daily note-taking, and the writing of a descriptive monograph;

(ii) Ethno-ecological methods which focus on understanding how people conceptualize, value, and use their local natural environments; Geographic methods, in particular methods of cultural geography, are especially useful for the valuation of nature and its benefits in that they identify and map values that are place-based, spatial or spatializable;

(iii) Historical methods which reveal how and why values of nature and its benefits have formed and changed over time.

(iv) Narrative valuation which refers to descriptive methods capture the importance of nature and its benefits to people, expressed via stories, influence diagrams and other visual and verbal summaries.

(v) Preference assessment which is a direct consultative method for analysing perceptions, knowledge and values associated with nature's benefits.

To further explain the IPBES protocol in a structured manner, the following (Figure 5.2-3) depicts the six steps according to the proposed protocol for valuation and assessment processes. Orange and green colours indicate that the scoping applies to methods for both valuation and integration/bridging.

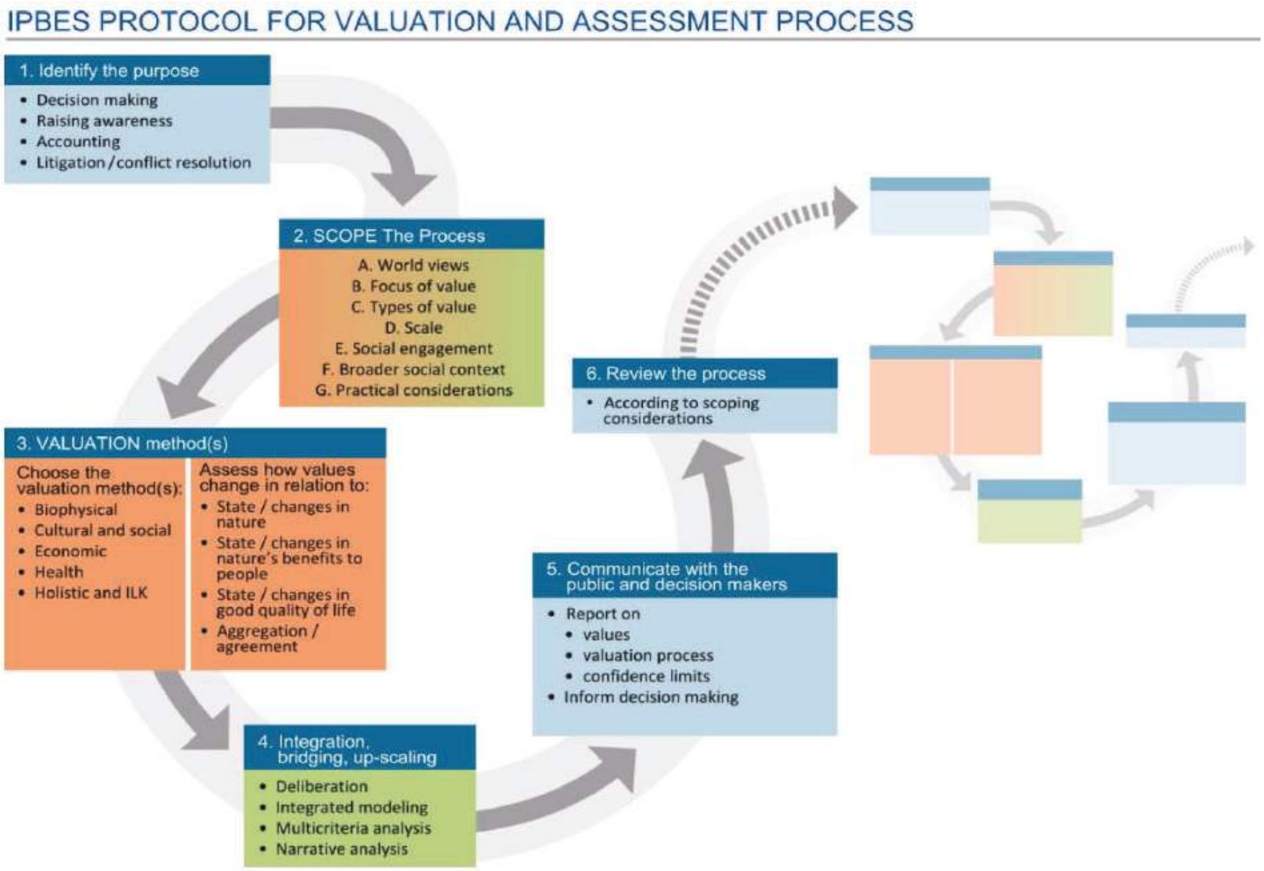



*Figure 5.2-3 IPBES Protocol for Valuation and Assessment Process (Source: IPBES Assessment Tools)*

In the current study, wherever found applicable, IPBES protocols have been used in the form of ethno-ecological methods, narratives, cases and other qualitatively descriptive techniques to exhibit set of uniqueness value of the particular tiger reserve.

### 5.2.6 Other Interpretations Derived from Economic Valuation of Ecosystem Services

Apart from the above mentioned frameworks, the study also presents arranging of values to highlight specific social causes or policy issues such as-

#### 5.2.6.1 Health Benefits

Health benefits as explained in the above sections are closely linked with ecosystem services emerging from tiger reserves. All ecosystem services play a pivotal role in maintaining the overall well-being of humans, having a direct and indirect impact. To further articulate the importance and linkages, this report highlights vital ecosystem services from each tiger reserve which have an impact on human health. The values of major ecosystem services have been arranged and aggregated together to arrive at a broad estimate of indirect health benefits from the tiger reserves.

#### 5.2.6.2 Investment Multiplier

Investment multiplier is an indicative value of the quantum benefits retuned by the tiger reserve and their natural systems into the human well-being calculus for each rupee spent towards their management. The aggregate flow benefit from forests is compared with its management costs to obtain the 'Investment multiplier'. These aggregate flow benefits are derived from the ecosystem services that are possible to value in monetary terms. The management costs are derived from the annual sanction to the tiger reserves by the NTCA. It is a unique representation of a cost benefit matrix which highlights the magnitude of benefits and importance of investing in nature and protecting ecosystems.

## 5.3 Methodology: Economic Valuation of Ecosystem Services from Tiger Reserves

The study has adopted the Millennium Ecosystem Assessment and the TEEB frameworks for identification of the Ecosystem Services (ESs) in the ten selected tiger reserves. The following section discusses the definitions and methodologies used for valuation of each of the ES. The assumptions made for any service during valuation along with suitable caveats are also given with the respective ES description. These assumptions have been made based on discussions with stakeholders, review of literature and relevant conditions in selected tiger reserves. It may be noted that not all ESs listed may be applicable in a particular tiger reserve.

### 5.3.1 Employment Generation

Tiger reserves act as sources of employment opportunities for the local communities. Local people are engaged in the day-to-day operations and are also appointed as support staff. Such employment opportunities are highly valued by the local communities in the otherwise poverty-prone and income-deprived remote locations around the tiger reserves[1].

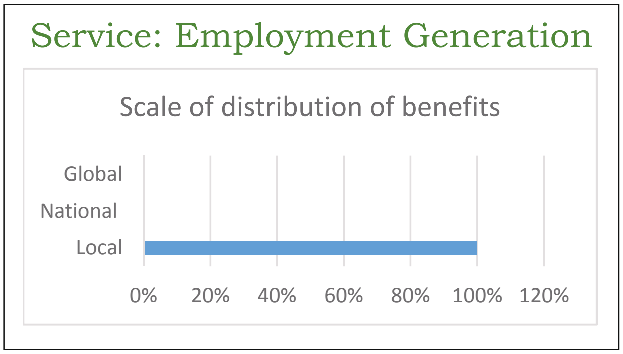



*Figure 5.3-1 Distribution of benefits at various scales ((Verma et al., 2015))*

The scope of this service is defined in the study based on the conjecture that the flow of the benefits is mainly limited to locals. To measure the contribution of this service, the concept of "man-days" of employment generated is followed to generate physical estimates which are then multiplied with the respective wage rates to arrive at monetary employment benefits. The jobs which are included in the service are daily-wage labours inducted by the park management[1]. Additionally, salaries of tourism staff employed by the tiger reserve such as safari guides, gypsy drivers and/or naturalists has been included under the umbrella of employment generation[106]. In some cases, where data regarding man-days is not available, direct consolidated estimated from park management in terms of labour expenditure or wages paid is taken.

One of the major limitations in calculating this service was of unavailability of seasonal and categorical information on involvement of labour (generation of man-days of employment), for different jobs, collated on a tiger reserve level or for all divisions. To resolve this, basic assumptions have been taken to arrive at a reasonable value. Wherever applicable such assumptions have been mentioned in the text.

## 5.3.2 Fishing

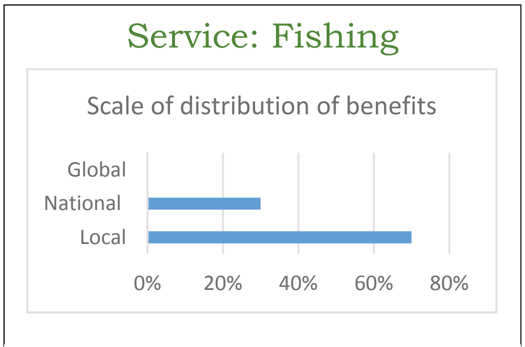



*Figure 5.3-2 Distribution of benefits at various scales ((Verma et al., 2015))*

Local communities practise fishing from the water bodies inside tiger reserves. However, it may be noted that the extraction of products, including fishing, is only allowed from the buffer areas of these reserves. While this service may only be applicable to tiger reserves having waterbodies, wherever applicable, the economic value of this service is calculated using annual fish catch estimates, i.e. the total quantity of fishes caught in a year which may include various local variety of fishes in conjunction with local market prices of the respective species[1]. Scope for calculating the flow of benefit from this service is kept limited to the notified boundaries i.e., the core and buffer of the tiger reserve. Since fishing is mostly done on a local basis and is sold in informal local markets, one of the major limitations in calculating total annual fish catch is the absence of any data collecting or regulating body and lack of seasonal fish-catch data[106]. Broad estimates have been derived wherever necessary using data given by the Forest Department, as per discussions with local villagers during field visits, pointers from Focused Group Discussions (FGDs) or by extrapolating estimates from other tiger reserves.

## 5.3.3 Fuelwood

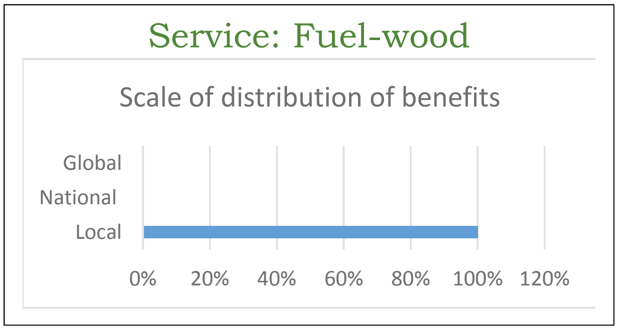



*Figure 5.3-3 Distribution of benefits at various scales ((Verma et al., 2015))*

Most of the local communities are dependent on fuelwood collection from forests for meeting their energy requirements. As in the case of other products, extraction of fuelwood, wherever allowed, is only permitted from the buffer areas of the reserve. Scope for calculating the flow benefit from this service is kept limited to the notified boundaries, i.e. the core and buffer of tiger reserves. In such cases, economic value of fuelwood collection is estimated using annual fuelwood collection estimates valued at local market prices[1,106]. To calculate annual fuelwood collection data given by the Forest Department, information given in the Tiger Conservation Plan (TCP), household data, discussion with local villagers during field visits and pointers from Focused Group Discussions (FGDs) have been used. In some instances where there was a data gap, data from NSSO (per capita fuellwood consumption) or extrapolation of information from other tiger reserves has been used, as deemed necessary to arrive at broad estimates for the purpose of including the servcie in the valutaion process.

## 5.3.4 Fodder

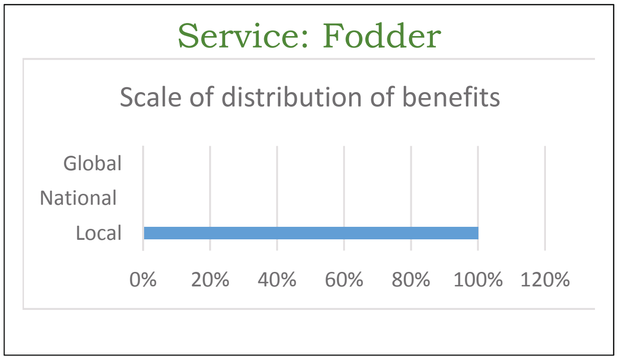



*Figure 5.3-4 Distribution of benefits at various scales ((Verma et al., 2015))*

Livestock plays a vital role in providing livelihood to forest communities and forests are an important source of fodder for them. While this may not apply to all tiger reserves, *nistar* rights enable the local communities to graze their cattle in the buffer areas of the reserve. Scope for calculating the flow benefit from this service is kept limited to the notified boundaries, i.e. the core and buffer of the tiger reserve. Wherever applicable, the economic value of this service is generally calculated in three steps. First by obtaining the number of Adult Cattle Units (ACUs) dependent on tiger reserves for fodder[106] and secondly by using standard forage quantity[107] to estimate the physical quantity of fodder. The physical quantity is then valued at the local market price of fodder to generate economic value estimates[1]. Where there was insufficient data on type and number of livestock, broad estimates have been calculated using basic assumptions or extrapolating livestock data from other tiger reserves wherever deemed necessary. Such instances have been mentioned in the text. To facilitate the calculations, it is assumed that all livestock are dependent on forests and are grazed in the forest except in the case when information and evidence on stall feeding is available.

### 5.3.5 Timber Stock

Existing timber biomass represents stock which is a storehouse of quality timber having huge financial value. To measure the timber stock in a particular tiger reserve, growing stock estimates of timber have been derived from the National Forest Inventory (NFI) data obtained from the Forest Survey of India (FSI)[1]. The growing stock estimates from the NFI data for each forest type have been used with respect to their forest cover/canopy cover class i.e. Very Dense Forest (VDF), Moderately Dense Forest (MDF) and Open Forest (OF). Only these three broad canopy cover classes have been used for the sake of simplicity and standardization.

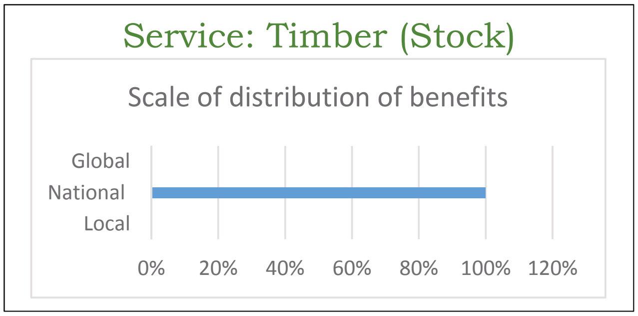



*Figure 5.3-5 Distribution of benefits at various scales ((Verma et al., 2015))*

This data has been then extrapolated to the entire park using category-wise area for specific canopy cover classes for each forest type. To achieve uniformity, the category wise area estimates are also derived based on the Remote Sensing and GIS data provided by the FSI[108] for individual tiger reserves. The data has been used as an input for modelling in InVEST Carbon Stock model which among other result generated the area estimates. The stock estimates thus calculated are then valued standard market prices of timber after due adjustments for maintenance or transportation. The estimate will include entire growing stock of forests in a tiger reserve.

During the data cleaning and analysis phase, to attain homogeneity, some basic assumptions have been made after multiple discussions with the team:

- In some instances, for the forest types where data was not available for each canopy class but for one or two of them, to fill in the gaps, it is assumed that VDF class has the highest growing stock followed by MDF and then OF. Thus, in calculations if the growing stock of VDF is 100 percent then MDF is taken as 50 percent of the VDF growing stock; and OF is taken as 50 percent of the MDF growing stock.
- In the data obtained, there was a category of Non-Forest (NF) in the forest type as well as a canopy class under each forest type. Since the Non-Forest canopy class had lower values and its definition was generic as per the FSI website[1], to avoid mix-up it has been excluded from the calculations of growing stock. As for the NF as a forest type, to avoid any complications, all the canopy classes under it have been clubbed to present one consolidated estimate.
- The same has been done for 'Plantation' under the Forest Type section, a consolidated value is presented.
- There were other canopy classes in some instances for a few tiger reserves such as scrub which had negligible growing stock and water. Growing stock estimates for both these classes have been excluded from calculations.
- In rare instances where there was some mis-match between the forest types given in the NFI data for the TR and the forest types obtained from the modelling output using Remote Sensing-GIS based data, such a forest type has been dropped out of calculations.

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[1]It is mentioned "All such instances which haven't been categorized into any of the above classes/types" (Source http://www.fsi.nic.in/scheme-of-classification as accessed on May 9, 2019)

- The area used for extrapolation is based on various forest types and hence area under settlement or water is not included in calculations. Thus, the aggregate total area used for timber calculation will be less than the actual total area of the tiger reserve.

All the assumptions made are based on the premise of providing conservative estimates. Wherever applicable such assumptions have been mentioned in the text. Scope for calculating the flow benefit from this service is kept limited to the notified boundaries, i.e. the core and buffer of the tiger reserve. It may be noted that it is classified as a stock benefit as per the stock and flow benefit framework.

### 5.3.6 Timber (Flow)

Although harvesting of timber is discontinued in most of the tiger reserves, in some parks, roadside trees are felled after due permission from the authorities. Wherever applicable, economic value of timber flow has been calculated based on the estimates of timber felled as given by the park management in conjunction with the local market price of timber after due adjustments for maintenance/transportation.

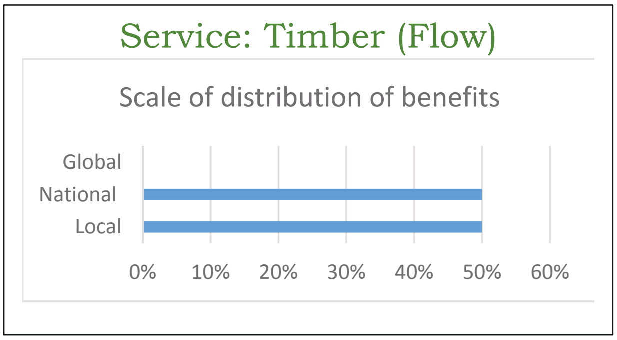


*Figure 5.3-6 Distribution of benefits at various scales ((Verma et al., 2015))*

### 5.3.7 Bamboo

Several tiger reserves have bamboo patches/plantations. Local communities may collect bamboo from buffer areas periphery near to their village for household and self-consumption purposes. The benefit of such bamboo provisioning, wherever applicable, from tiger reserves is calculated using annual collection estimates[106] which are obtained locally during the field visits or as per the figures provided by the tiger reserve management. This physical quantity is then valued at the available local market price to estimate the economic value of this bamboo provisioning[106]. The scope for calculating the flow of benefit from this service is kept limited to the notified boundaries, i.e. the core and buffer areas of the tiger reserves.

### 5.3.8 NTFP

Non-timber forest produce (NTFP) plays a significant role in providing livelihoods to local communities as gap-fillers or safety nets between cropping seasons and during emergency times. It is also a supplementary source of income and nutrition for landless or unemployed people. As in the case of other products, extraction of NTFP, wherever allowed, is only permitted from the buffer areas of the reserve which may be further regulated by Eco-Development Committees (EDCs). In such cases, to evaluate the economic benefits from NTFP collection, major NTFPs of the tiger reserve are shortlisted. Then annual collection estimates for each category of NTFP are obtained from the TR management or finalized in consultation with local communities and concerned authorities[1,106]. Where there was insufficient data on the type and quantity of NTFP collected, broad estimates have been calculated using basic assumptions or by extrapolating similar data from other tiger reserves wherever deemed necessary. Such instances have been mentioned in the text. The physical estimates are subsequently converted to economic value by using the local market price for the respective NTFP. Scope for calculating the flow of benefit from this service is kept limited to the notified boundaries, i.e. the core and buffer of the tiger reserve.

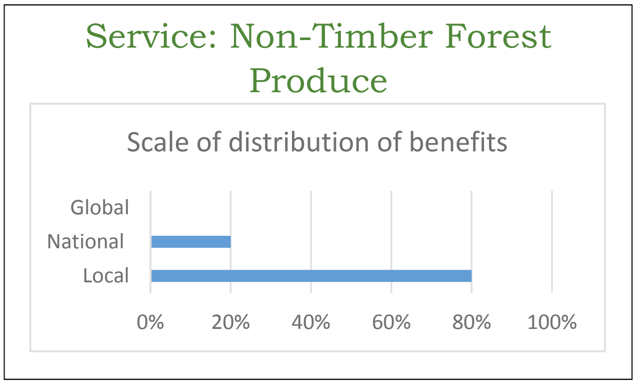


*Figure 5.3-7 Distribution of benefits at various scales ((Verma et al., 2015))*

### 5.3.9 Genepool Protection

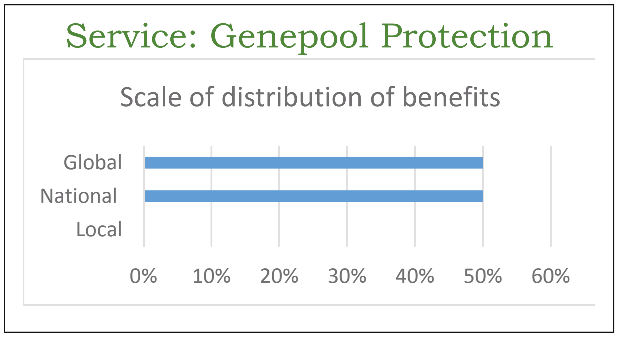


*Figure 5.3-8 Distribution of benefits at various scales ((Verma et al., 2015))*

Tiger reserves are guardians of biodiversity which provide a natural resilience system and carry genetic information. Protection of biodiversity is envisaged in this study in terms of genepool protection service[1]. It can be further explained in terms of its biological information value and insurance value. These are discussed briefly in the following section.

#### 5.3.9.1 Biological Information Value

Genes are storehouses of information pertaining to evolutionary processes. Owing to this they are not only resilient to natural change but also adapt using various features like chemical compounds to escape predators, prey capture, enhance reproductive success, increased immunity and survival rates[109]. These compounds can be adapted for various human uses, especially for pharmaceutical industries, agriculture sector as wild cultivars or germ plasm for crops[110–113].

#### 5.3.9.2 Insurance Value

Tiger reserves generally provide resilient ecological systems on a local, regional and national scale which offer insurance for future generations towards maintaining flow of ecosystem services. It is generally agreed that high biodiversity and more complexity in a system lead to resistance to environmental changes and shocks[110,114,115]. This value is becoming increasingly higher in the context of present-day environmental challenges.

While it is relatively easy to identify the benefits obtained from individual components if biodiversity and its associated information value, it is particularly difficult to describe and estimate the benefits of variability itself. On account of scarcity of site-specific studies for estimating economic value of genepool protection, the method of benefits transfer is used. Based on unit area values for genepool protection for different ecosystems from a global meta-analysis study[116], the economic value of this service has been arrived at for selected tiger reserves. While the benefits of this service flow goes to local, regional as well as national scale, notified area, i.e. the core and buffer areas of the tiger reserves are used for calculations.

### 5.3.10 Carbon Storage

Carbon storage is recognized as one of the important ecosystem services and plays an important role in understanding interaction among climate and productivity. Carbon flows naturally in the earth system through the atmosphere, biosphere and lithosphere in an ensemble of processes known as the carbon cycle. However, emissions of carbon in the form of carbon dioxide, one of the major greenhouse gases, have increased over time both due to the use of fossil fuels for energy and to historic anthropogenic land use and land cover (LULC) changes. These processes have largely increased its atmospheric concentration, contributing to climate change and increasing the likelihood of environmental and economic losses in the future. Hence, the reduction of anthropogenic emissions of greenhouse gases is of utmost importance to balance the composition of the atmosphere and mitigate future damages, as underlined recently in the Paris Climate Conference (COP21) Agreement (Paris Agreement). An estimated 40 percent of forests suffer degradation and low productivity. There is large-scale degradation of land and forests and therefore, modelling the potential impacts of forest degradation on carbon storage is necessary. Mapping carbon over the area of interest gives an estimate of the total carbon locked up in the vegetation.

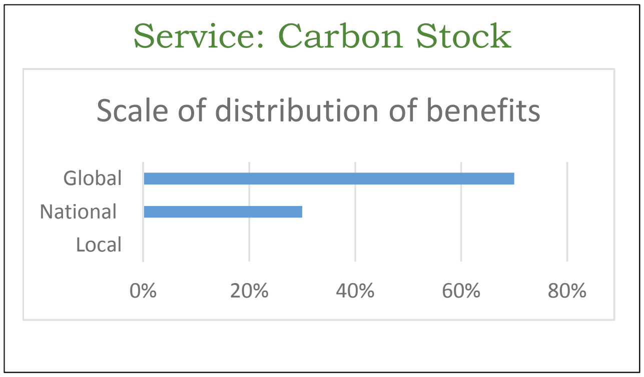


*Figure 5.3-9 Distribution of benefits at various scales ((Verma et al., 2015))*

Managing landscapes for carbon storage and sequestration requires information about how much and where carbon is stored, how much carbon is sequestered or lost over time, and how shifts in land use affect the amount of carbon stored and sequestered over time. Since land managers must choose among sites for protection, harvest, or development, maps of carbon storage and sequestration are ideal for supporting decisions influencing these ecosystem services.

Such maps can support a range of decisions by governments, NGOs, and businesses. For example, governments can use them to identify opportunities to earn credits for reduced (carbon) emissions from deforestation and degradation (REDD). Knowing which parts of a landscape store the most carbon would help governments efficiently target incentives to landowners in exchange for forest conservation.

Tiger reserves are storehouses of carbon and are effective tools for maintaining the carbon balance via their forests, wetlands and other ecosystems. This huge stock of carbon is significant not only to combat climate change but also to maintain health benefits at various scales. To assess the value of this service, physical stock of carbon stored in different types of forests is used. Carbon modelling has been used via InVEST using data from secondary sources to obtain stock estimates of carbon stored in different forest types and their canopy classes in a tiger reserve. To calculate the economic value of stored carbon, the social cost of carbon is taken into account[117].

#### 5.3.10.1 Carbon Model Function

There are four kinds of "Carbon Pools" that dictate carbon storage of an ecosystem: aboveground biomass, belowground biomass, soil, and dead organic matter. The InVEST model on carbon storage and sequestration aggregates the amount of carbon stored in these four pools according to the land use and classifications maps[118]. Aboveground biomass includes all living plant material above the soil (e.g. bark, trunks, branches, leaves), while belowground biomass, as the name suggests, consists of the living root systems of aboveground biomass. Soil organic matter, which is also the largest terrestrial carbon pool, is the organic component of soil. Litter, lying and standing dead wood comprises the dead organic matter.

This model is used to estimate the net amount of carbon stored in a piece of land over time and the market value of the carbon sequestered in remaining stock using LULC maps and the amount of carbon stored in carbon pools.

The outcome maps are in the form of carbon storage densities to land use, land cover (LULC) raster and forest type raster which includes types such as forest, pasture, or agricultural land. The result is summarized into raster outputs of storage, value, as well as aggregate totals.

For each land use classification, an estimate of the amount of carbon in at least one of the four pools described above is required for the model to run. If the data is available for more than one pool, the results will be more complete and accurate. The model simply applies these estimates to the LULC map to produce a raster of carbon storage in the carbon pools included.

This model can also be used to assess changes in the carbon storage over a course of time and the social value of this change by feeding into the model LULC maps for the different time points.

The model can be run to the current landscape and a projected future landscape, and the difference in storage can be calculated. This exercise can also be easily replicated for multiple future scenarios, the differences between the current and future landscape can be compared. A REDD scenario land cover map can also be treated as an additional future scenario and the results can be summarized. Model outputs are expressed as Mg of carbon per grid cell. They can also be expressed as the value of sequestration in currency units per grid cell. It is strongly recommended to use the social value of carbon sequestration in expressing sequestration in monetary units. The social value of a sequestered ton of carbon is the social damage avoided by not releasing the ton of carbon into the atmosphere.

The amount of carbon sequestrated dictates the economic values of sequestration (not storage). This economic values also depends on the monetary value of each unit of carbon, monetary discount rate, and the change in sequestration value over the course of time. Hence, valuation can be only done if the model is fed with a future scenario. Also, storage is not used for estimating the valuation because market prices are related only to sequestration. The monetary discount rate, which also factors in the model, is a multiplier that reduces the value of sequestration over time.

This discounting is of two types. The first one reflects the fact that people typically value immediate benefits more than future benefits. This is the standard economic procedure of financial discounting. The other one adjusts the social value of sequestration over time. This value is bound to change as the impact of carbon emissions on climate-related issues change.

Manifestly, carbon sequestrated in the current scenario will have a greater impact on climate change mitigation if carbon sequestrated in future has this second discount rate as positive.

We have used Version 3.4.4 of InVEST Carbon model for all 10 tiger reserve. The InVEST model assumed that each forest type with density map corresponds to a total carbon density aggregated by aboveground carbon density, belowground carbon density, soil organic carbon density, and dead organic matter carbon density[118]. Therefore, based on the forest type with density map and carbon densities of each class the carbon storage has been quantified and visualized. The input parameter is summarized in the Table 5.3-1.

*Table 5.3-1 Input Parameter for Carbon Model*

| Information | Type | Source |
|---|---|---|
| Carbon Density in Aboveground Mass | Per LULC | Forest Survey of India |
| Carbon Density in Belowground Mass | Per LULC | Forest Survey of India |
| Carbon Density in Soil | Per LULC | Forest Survey of India |
| Carbon density in Dead Mass | Per LULC | Forest Survey of India |
| Forest Type | Map (Raster) | Forest Survey of India |
| Forest Cover | Map (Raster) | Forest Survey of India |

**Limitations and Simplifications**

The model has its limitations: It simplifies the carbon cycle, to make the model run on lesser date inputs. It assumes that none of the LULC types in the landscape is gaining or losing carbon over time, or, fixed storage levels. These fized stage levels are the average of measured storage levels within each land classsification type. Hence, the only changes measures in the model are the ones that arise from land use change. In other words, any grid cell that does not change its LULC type will have a sequestration value of 0 over time. However, this is far from reality as even without a classification change, the sequestration value changes owing to natual succession and other factors.

However, this discrepancy can be taken care of to a substantial extent by dividing each LULC type into age classes. This essentially adds more LULC types. An example of this is the three ages of a forest. The parcels can move from one age class to another, thereby changing their storage values as a result, and thereby increasing the accuracy of the model. Another crucial limitation is that the results are only as detailed and reliable as the LULC classification fed into the model. Carbon storage clearly differs among land use classifications. However, there are significant variations within the classification type as well. For example, carbon storage within a "tropical moist forest" is affected by elevation, rainfall, temperature, and the number of years since a major disturbance (e.g. clear-cut or forest fire). The variety of storage values within a broadly defined classification type can be corrected to some extent by using the carbon pool table which stratifies coarsely defined LULC types with relevant environmental and management variables. For example, forest LULC types can be sub-classified by elevation, climate bands or time intervals since a major disturbance. However, this detailed methodology does demand extensive data sets describing the amount of carbon stored in each of the carbon pools of these finer classes.

Also, 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. However, this inter-pool transfer of storage is not captured by the model.

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 subsequent years, the model's economic valuation of carbon 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 5.3-11).

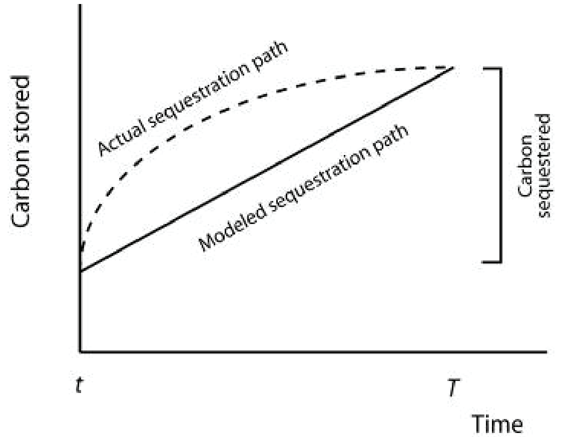


*Figure 5.3-11 Difference between Actual Sequestration and InVEST Approach (Source: Sharp et al. 2018)* [118]

### 5.3.11 Carbon Sequestration

Tiger reserves are not only storehouses of carbon but also add carbon annually to their existing stock. The same has been estimated based on the growing stock data for respective forest types of each tiger reserve. This data has been obtained from the forest inventory database [108]. This has been used to derive total biomass per unit area for each forest type and then calculation of mean annual increment (MAI) using the Von Mantel's Formula[119]. The rotation period for each forest type is taken for calculation of MAI[120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in above ground biomass has been converted to carbon sequestration in dry matter[1,106]. It may be noted that the carbon sequestration estimated thus arrived at are gross estimates and not "net carbon sequestration" as we have only considered the above ground cabon sequestration. To estimate the monetary value of the sequestered carbon, the latest values of social cost of carbon for India[117] has been used.

> Social cost of carbon aims to estimates the cost of avoided damage in such a scenario if all carbon was released into the atmosphere.

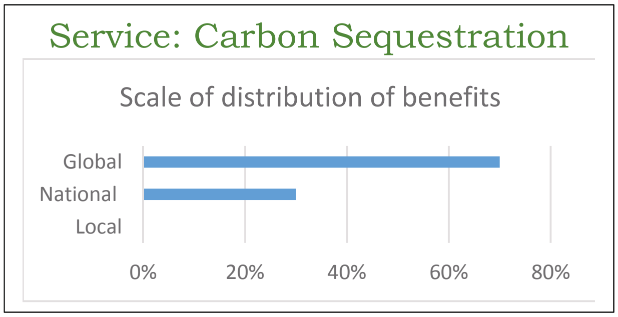


*Figure 5.3-10 Distribution of benefits at various scales ((Verma et al., 2015))*

### 5.3.12 Water Provisioning

Forests play a pivotal role in augmenting water flows. Tiger reserves conserving the forests, wetlands and other ecosystems have a profound impact on the hydrological processes of the watershed. When precipitation falls on a forested area, it is intercepted by dense canopy cover, thereby reducing its intensity[1]. Some of the water that reached the surface evaporates back, some of it goes as run-off and some of it is absorbed by the roots of the trees and moves out into the atmosphere through the process of transpiration. After the soil moisture reaches its field or saturation capacity, the remaining water recharges the groundwater table. To estimate the economic value of the provisioning of water, InVEST- Water Yield model has been used.

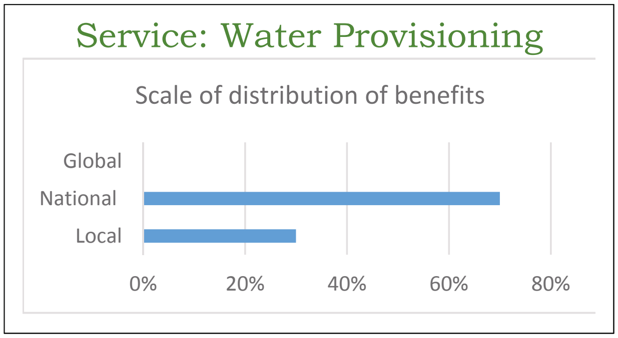


*Figure 5.3-12 Distribution of benefits at various scales ((Verma et al., 2015))*

Annual water yield from a catchment, with the intended end use of reservoir hydropower production is estimated using the "Water Yield: Reservoir Hydropower Production" model of InVEST suite. It calculates the annual average quantity of water produced by a watershed by estimating the relative contribution of each land parcel to annual average water yield. The administrative boundary of tiger reserves was considered as a base for the calculation of water yield. Since the data is available within the administrative boundary, the boundary of watershed has been clipped to the boundary of tiger reserves. The parts of watershed outside the tiger reserve boundary has not been considered to calculate the water yield as the conservative values. The water yield model is based on an empirical function which is known as the Budyko curve and annual average precipitation [118]. The water yield model takes the input as raster format and runs on the gridded map. Annual water yield Y (x) is determined for each pixel on a landscape x as follows:

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

where AET(x) is the annual actual evapotranspiration for pixel x and P(x) is the annual precipitation on pixel x. Figure 5.3-13 The diagram of the water balance model is as follows[118].

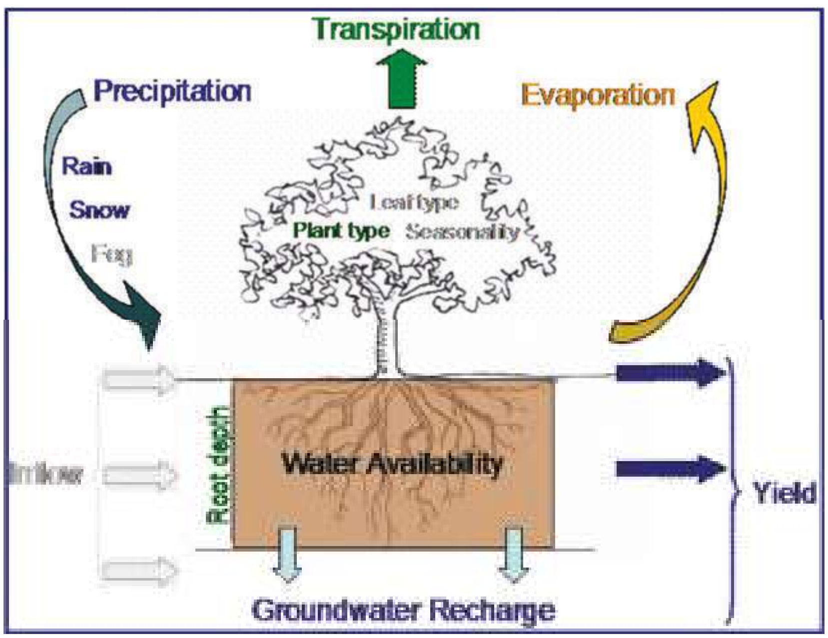


*Figure 5.3-13 Evapo-Transpiration Process*

For vegetated LULC, the evapotranspiration portion of the water balance, AET(x)P(x) , is based on an expression of the Budyko curve proposed by [122,123]:

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

where PET(x) is the potential evapotranspiration and ω(x) is a non-physical parameter that characterizes the natural climatic-soil properties, both detailed below.

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

$$PET(x) = K_c(l_{x)} \cdot ET_o(x)$$

where $ET_o(x)$ denotes the reference evapotranspiration from pixel x and Kc(ℓx) is the plant (vegetation) evapotranspiration coefficient associated with the LULC ℓx on pixel x. ET0(x) represents local climatic conditions using evapotranspiration of reference vegetation such as grass grown at that location. Kc(ℓx) is mainly dependent on the vegetative characteristics of the land use/land cover found on that pixel [124]. Kc adjusts the ET0 values to the crop or vegetation type in each pixel of the land use/land cover map.

ω(x) is an empirical parameter that can be expressed as a linear function of AWC∗NP, wherein, N is the number of events per year, and AWC is the volumetric plant available water content. While further research is being conducted to determine the function that best describes global data, we use the expression proposed by [125] in the InVEST model, and thus define:

$$W(x) = z\frac{AWC(x)}{P(x)} + 1.25$$

where:

AWC(x) is the volumetric (mm) plant available water content, dependent on the soil texture and effective rooting depth. It represents 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 (PAWC) and the minimum of root restricting layer depth and vegetation rooting depth:

**AWC(x)= Min(Rest . layer . depth, root . depth) · PAWC**

The soil depth at which root penetration is inhibited because of physical or chemical characteristics is called the root restricting layer depth. Vegetation: The depth at which 95 percent of a vegetation type's root biomass occurs is the vegetation rooting depth. PAWC is the plant available water capacity, i.e. the difference between field capacity and wilting point.

Z, also occasionally referred to as the "seasonality factor", is an empirical constant which captures the rainfall 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 ω(x), which represents the value for bare soil (when root depth is 0), as explained by[125]. Following the literature[125,126], values of ω(x) are capped to a value of 5.

The reference evapotranspiration ET0(x) computes the actual evapotranspiration for other LULC (open water, urban, wetland), and has an upper limit defined by the precipitation:

$$AET(x) = Min(K_c(l_x) \cdot ET_o(x), P(x))$$

where ET0(x) is the reference evapotranspiration, and Kc(ℓx) is the evaporation factor for each LULC.

We used Version 3.4.4 of InVEST Hydrological model for all 10 tiger reserves[118]. Based on the annual water balance, the water yield in each grid point is calculated by the difference between precipitation and actual evapo-transpiration. As an input, we have provided information such as maps of land use and land cover, precipitation, potential evapo-transpiration, soil depth and Plant Available Water Content (PAWC), besides crop factor (Kc) and root depth information for all 10 tiger reserves. Thus the model calculates actual evapo-transpiration by[123] formulation, and, at last, the water yield. Another parameter needed for the Zhang formulation in InVEST is an empirical Z parameter[125]. The input parameter is summarized in Table 5.3-2.

*Table 5.3-2 Input Parameter for Water Yield Model*

| Information | Type | Source |
|---|---|---|
| Land use | Map (Raster) | Forest Survey of India |
| Precipitation | Map (Raster) | Indian Meteorological Department |

| | | |
|---|---|---|
| ET | Map (Raster) | Estimated using MODIS long-term average data |
| Soil Depth | Map (Raster) | Hengl et al., 2017[127] |
| PAWC | Map (Raster) | FAO & IIASA, 2009[128] |
| Kc | per LULC | Allen, R.G., Pereira, L.A., Raes, D., Smith, 2006[129]<br>Sharp, R., Tallis, H.T., Ricketts, T., Guerry, A.D., Wood, S.A., Chaplin-Kramer, R., Nelson, E. et al., 2018[118] |
| Root depth | per LULC | Allen, R.G., Pereira, L.A., Raes, D., Smith, 2006[129] |
| Z | constant | Estimated based on number of rainy days |

**Limitations and Simplifications**

1. The model evaluates how and where the changes in a watershed may affect water yield for reservoir systems, but this model is not intended for devising detailed water plans. The basis of this model are the annual averages, and hence, extremes and temporal dimensions of water supply are not taken into account.

2. There is an assumption 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-groundwater interactions are entirely neglected in the model, in spite of the fact that they may be a cause for errors, 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 take into account the sub-annual patterns of water delivery timing. Water yield is 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 a greater concern when considering drivers such as climate change. Modelling the temporal patterns of overland flow requires detailed data that are not appropriate for the 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. However, 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. Multiple aspects of water resource allocation are represented by a single variable (d), which may misrepresent the complex distribution of water among uses and over time.

6. The model does not account for a seasonal variation in energy production and assumes that hydropower production and pricing remain constant over time. Even if sub-annual production or energy prices change, however, the relative value between parcels of land in the same drainage area should be accurate.

## 5.3.13 Water Purification

Forests not only regulate the flow of water but also help in maintaining quality. Natural ecosystems within tiger reserves, filter out and decompose wastes introduced into inland water, coastal and marine ecosystems. Tiger reserves thus provide a water purification function to downstream areas and prevent the cost of water treatment for drinking and other purposes. In this study, wherever applicable, two approaches have been used to calculate the economic value of this service[1,106]. Firstly, the direct quantities of annual drinking requirements met by the tiger reserve without the need of a water treatment plant have been taken using data obtained during the field visits. Alternatively, the number of beneficiaries have been mapped and estimates of per capita per day domestic water requirement is used to derive the total domestic water requirement[130] and considering a conservative value of ten percent of the total requirement is for drinking which is met by the tiger reserve and does not require any treatment. To assess the economic value of the service, the average cost of treating water for domestic supply from local authorities[131] has been used.

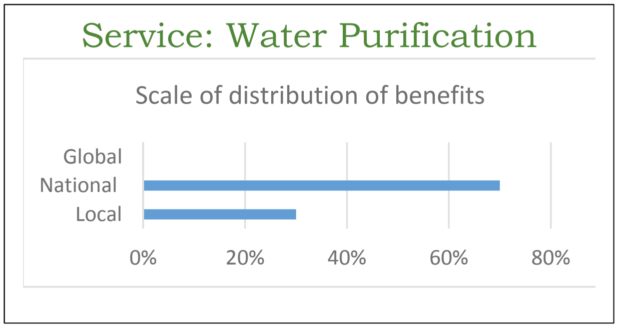


*Figure 5.3-14 Distribution of benefits at various scales ((Verma et al., 2015))*

## 5.3.14 Soil Conservation/Sediment Retention

Forests ecosystem play an important role in regulating sediment flow due to dense canopy cover which intercepts rainfall intensity and a thick layer of humus which reduces soil run-off. The avoided soil loss owing to the good canopy, undergrowth, dense leaf litter, humus content, and consequent high interception and infiltration rate in the forests is a crucial function provided by tiger reserves. The economic value of soil conservation or sediment retention is estimated using avoided offsite costs approach. For bio-physical quantification of the service, the InVEST Sediment Retention model has been used. To capture its economic value of soil loss avoided by the forests, the cost of dredging/de-siltation has been considered[132]. To convert the soil loss avoided into soil mass estimates from Eshwara Reddy et. al (2012) have been used[133].

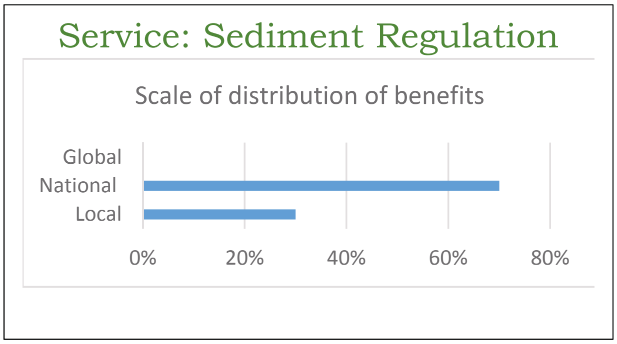


*Figure 5.3-15 Distribution of benefits at various scales (Verma et al., 2015)*

The sediment retention service is mentioned among the regulation ecosystem services in all the main international classifications. Erosion and sediment retention are natural processes that govern the sediment concentration in streams. Sediment retention refers to the capacity of ecosystems to regulate the quantity of eroded sediment reaching the stream network and thus delivering benefits like maintaining soil and water quality and reservoir functions. Sediment dynamics at the watershed level are mainly determined by climate (in particular the rain intensity), soil properties, topography, and vegetation; and anthropogenic factors such as agricultural activities or dam construction and operation. Poor land management and vegetation removal operations can have significant adverse effects on water courses and can dramatically modify the amount of sediment running off a catchment.

Increase in erosion and sedimentation in many places, dramatically affects water quality and reservoir management. Understanding where the sediments are produced and delivered allow them to design improved strategies for reducing sediment loads. Changes in sediment load can have impacts on downstream irrigation, water treatment, recreation and reservoir performance. The InVEST sediment model assesses the sediment load delivered to the stream at an annual time scale, as well as the amount of sediment eroded in the catchment and retained by vegetation and topographic features. The model provides two options for valuation of the sediment retention service, through appropriate valuation approaches will be highly dependent on the particular application and context, and may need to be implemented independently of InVEST.

**Model Function**

SDR is a spatially-explicit model working at the spatial resolution of the input DEM raster, using an approach proposed by[134]. For each cell, the model estimates the amount of eroded sediment, then the sediment delivery ratio (SDR). SDR is the proportion of soil loss actually reaching the catchment outlet.

**Annual Soil Loss**

The amount of annual soil loss on pixel$_i$, USLE$_i$ (ton. $ha^{-1}yr^{-1}$), is given by the revised universal soil loss equation (RUSLE1):

**USLEi = Ri· Ki ·LSi· Ci · Pi**

where

- $R_i$ is the rainfall erosivity (MJ·mm(ha·hr)$^{-1}$),
- $K_i$ denotes soil erodibility (ton·ha·hr(MJ·ha·mm)$^{-1}$),
- $LS_i$ is the slope length-gradient factor
- $C_i$ is the crop-management factor
- and $P_i$ is the support practice factor[135,136].

and $LS_i$ factor is given from the method developed by[137] for two-dimension surface:

$$LS_i = S_i \frac{(A_{i-in} + D^2)^{m+1} - A_{i-in}^{m+1}}{D^{m+2} \cdot x_i^m \cdot (22.13)^m}$$

where

- $S_i$ the slope factor for grid cell calculated as function of slope radians θ
  - o S=10.8·sin(θ)+0.03 where θ<9 percent
  - o S=16.8·sin(θ)−0.50, where θ≥9 percent
- $A_i$–in the contributing area (m2) at the inlet of a grid cell which is computed from the d-infinity flow direction method
- D the grid cell linear dimension (m)
- $x_i=|\sin\alpha_i|+|\cos\alpha_i|$ where $\alpha_i$ is the aspect direction for grid cell i
- m = RUSLE length exponent factor.

To avoid overestimation of the LS factor in heterogeneous landscapes, long slope lengths are capped to a value of 333m[135,137].

The value of m, the length exponent of LS factor, is based on the classical USLE, as discussed in[21]:

- m=0.2 for slope <= 1 percent:
- m=0.3 for 1 percent < slope <= 3.5 percent
- m=0.4 for 3.5 percent < slope <= 5 percent
- m=0.5 for 5 percent < slope <= 9 percent
- m=β/(1+β) where β=sinθ/0.0986/(3sinθ0.8+0.56) for slope >= 9 percent

The SDR model computes the connectivity index based on the work by[134]:

$$IC = \log_{10}\left(\frac{D_{up}}{D_{dn}}\right)$$

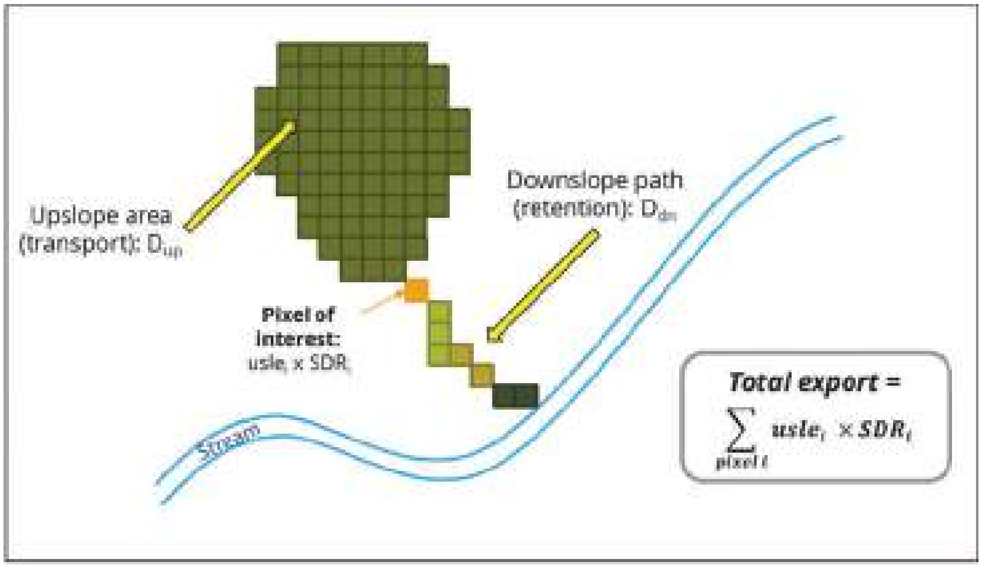


*Figure 5.3-16 Conceptual Approach Used in the Model (Source: Sharp et al. 2018)*[118].

The sediment delivery ratio (SDR) is a function of the upslope area and downslope flow path

$D_{up}$ is the upslope component defined as:

$$\boldsymbol{D_{up} = \overline{CS}\sqrt{A}}$$

where C¯ is the average C factor of the upslope contributing area, A is the upslope contributing area ($m^2$) and S is the average slope gradient of the upslope contributing area (m/m). The upslope contributing area is delineated from the D-infinity flow algorithm[138].

Downslope component $D_{dn}$ is denoted by:

$$D_{dn} = \sum_i \frac{d_i}{C_i S_i}$$

where $d_i$ is the length of the flow path along the ith cell according to the steepest downslope direction (m) (se), $C_i$ and $S_i$are the C factor and the slope gradient of the ith cell, respectively. Downslope flow path is determined by the D-infinity flow algorithm[138].

In order to prevent infinite values for IC, slope values S are forced to a minimum of 0.005 m/m if they occur to be less than this threshold, and an upper limit of 1 m/m to limit bias due to very high values of IC on steep slopes[139].

The SDR ratio for a pixel i is then derived from the conductivity index IC following[140]:

$$SDR_i = \frac{SDR_{max}}{1 + exp\left(\frac{IC_0 - IC_i}{k}\right)}$$

where $SDR_{max}$ is the maximum theoretical SDR, set to an average value of 0.8[140], and $IC_0$ and k are calibration parameters that define the shape of the SDR-IC relationship (increasing function).

**Sediment Load**

The sediment load from given pixel i, $E_i$ (ton. $ha^{-1}yr^{-1}$) is denoted by:

$$E_i = usle_i \cdot SDR_i$$

The total catchment sediment load E (ton. $ha^{-1}yr^{-1}$) is given by:

$$E = \sum_i E_i$$

E means the value used for calibration/validation purposes, in combination with other sediment sources.

Similarly, we have used Version 3.4.4 of InVEST SDR model for all 10 tiger reserves[118]. The SDR model predicts the change in sedimentation with a change in land use land cover. It estimates the capacity of a land parcel to retain sediment. The required data on geomorphology, climate, vegetation and management practices in the form of rainfall erosivity index, elevation model (DEM), land use/land cover (LULC), soil erodibility, subwatersheds, support practice factor and cover-management factor for the USLE, threshold flow accumulation and $IC_o$ and kb were calibrated for all 10 tiger reserves. The administrative boundary of tiger reserves was considered as a base for the calculation of SDR outputs. Since the data is available within the administrative boundary, the boundary of watersheds has been clipped to the boundary of tiger reserves. The part of watershed outside tiger reserves boundary has not been considered to calculate the SDR outputs as the conservative values. The input parameter summarized in Table 5.3-3.

*Table 5.3-3 Input Parameter for Sediment Retention Model*

| Information | Type | Source |
|---|---|---|
| Land Use | Map (Raster) | Forest Survey of India |
| DEM | Map (Raster) | ASTER |
| Rainfall Erosivity Index | Map (Raster) | Singh., 1981[141] |
| Soil Erodibility | Map (Raster) | Sarathi & Padmini, 2015[142] |
| Subwatershed | Map (Raster) | Based on DEM |
| USLE C | per LULC | Sarathi & Padmini, 2015[142]<br>K Kuok, S Mah, & Chiu, 2013[143] |
| USLE P | per LULC | Panagos et al., 2015[144]<br>Devatha, Deshpande, & Renukaprasad, 2015[145] |

**Limitations and Simplifications**

One of the key limitations of the model is its reliance on the USLE[135]. Although widely used, it is limited in scope, only representing rill/inter-rill erosion processes. Other sources of sediment include gully erosion, streambank erosion, and mass erosion. A possible modelling approach for gully and streambank erosion is suggested by Wilkinson et al., 2014 Another limitation is the fact that mass erosion (landslide) is not represented in the model in spite of it being a significant source in some areas or under certain land use change, such as road construction.

A corollary is that the descriptions of the impact on ecosystem services (and any subsequent valuation) should account for the relative proportion of the sediment source from the model compared to the total sediment budget.

Also, USLE has shown limited performance, given the fact that it is an empirical equation developed in the United States, even when focusing on sheet and rill erosion. Based on local knowledge, the soil loss equation can be modified that is implemented in the model by adjusting the R, K, C, P inputs to reflect findings from local studies[146].

The model is very sensitive to the k and IC0 parameters. The literature on the modelling approach used in the InVEST model[139,140,146] provides guidance to set these parameters. However, this limitation has to be kept in mind while interpreting the model's value.

Since this model simplifies the actual process in order to cater to the dearth of a plethora of parameters and their data, the model is very sensitive to the few input parameters it works upon. Any errors in these parameters, therefore, have a large bearing on the predictions. Sensitivity analyses, hence, become strongly desired to investigate the confidence intervals in input parameters and their effect on the study conclusions.

### 5.3.15 Nutrient Retention

It is widely accepted that forests not only prevent soil erosion but also maintain and improve the quality/fertility of soil. Indirect benefit of soil conservation service is retention and replenishment of nutrients by various ecosystem functions[133]. As per scientific literature, economic value of nutrient retention service is estimated mostly by the replacement cost method[106,147] in which the cost of artificial fertilizers is taken into account[148]. Using this method and taking the local context of and landscape of a particular tiger reserve into account, the economic value of this service has been estimated[1,106]. Soil loss avoided estimates from the sediment retention model of InVEST software have been used to estimate the avoided nutrient loss for N, P and K for that particular reserve.

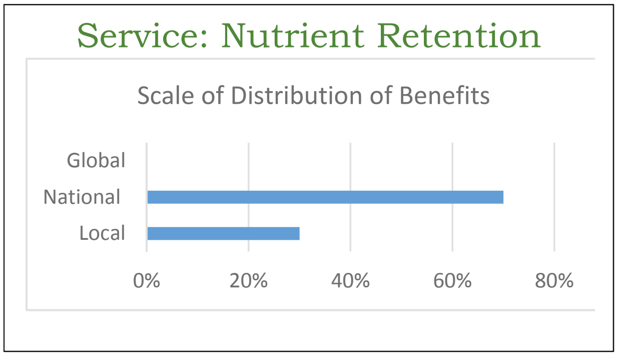


*Figure 5.3-17 Distribution of benefits at various scales ((Verma et al., 2015))*

### 5.3.16 Biological Control

Natural ecosystems within tiger reserves act as moderators for controlling the population of disease organisms (viruses, bacteria and parasites), their hosts, potential pests and intermediate disease vectors (e.g. rodents and insects). They are like restraining forces lowering the risk of spread of infectious diseases by various biotic interactions or biological control mechanisms. Such regulating functions further limit the need of applying artificial pest control and reduce incidents of various diseases. Evidence suggests that deforestation results in an increased spread of human infectious diseases[149]. Although a key function, not much research, especially with regard to economic valuation has been conducted in India on this service. Thus on account of lack of site specific studies of estimating economic value of the ecosystem service related to biological control which includes regulation of diseases, the method of benefits transfer has been used in this study[1]. Based on unit area values from a global meta-analysis study [116]the economic value of this service has been derived for selected tiger reserves.

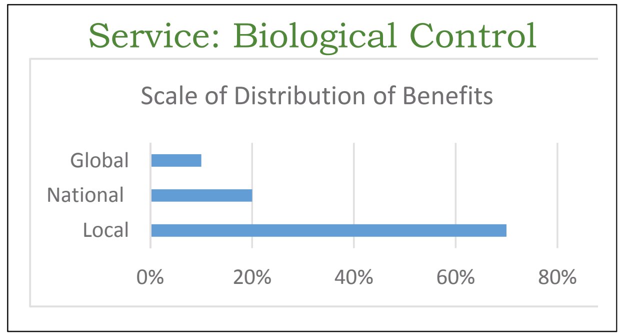


*Figure 5.3-18 Distribution of benefits at various scales (Verma et al., 2015)*

### 5.3.17 Moderation of Extreme Events

Natural ecosystems of tiger reserves help in moderating incidents as well as mitigating impacts of extreme events owing to dense vegetation and various ecological functions. They also act as a buffer and provide a kind of cushion cover or padding to absorb effects of disasters. They have the potential to dramatically reduce damage caused by cyclonic storms and large waves or flash floods. The economic value of this service has been estimated in two components: avoided loss of lives and avoided damage to property. Wherever applicable, mapping and estimating these components using secondary literature have been derived[1]. Using the benefits transfer method, the economic value has been followed for selected tiger reserves based on unit area values from a global meta-analysis study[116].

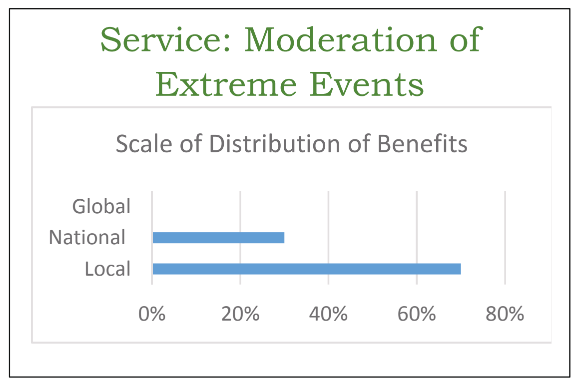


*Figure 5.3-19 Distribution of benefits at various scales (Verma et al., 2015)*

### 5.3.18 Pollination

In an agrarian economy like India, the value of pollination service is crucial. Tiger reserves are significantly important as habitats of pollinator species which consequently help in increasing quantity and quality of pollinator dependent crops in the surrounding areas. On account of insufficient site-specific studies for estimating the economic value of pollination, the method of benefits transfer has been used[1]. Based on unit area values from a global meta-analysis study[116] the economic value of this service has been derived for selected tiger reserves.

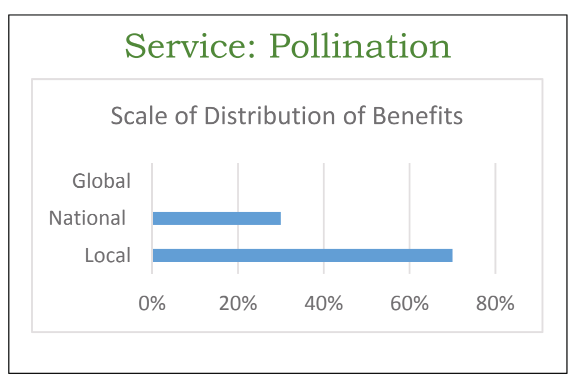


*Figure 5.3-20 Distribution of benefits at various scales (Verma et al., 2015)*

### 5.3.19 Nursery Function

Some tiger reserve act as breeding, reproduction and nursery grounds for many species. While the service pertains to all types of wildlife, this study has limited its scope to the nursery function for aquatic animals. This is one of the less researched areas in ecological economics. However, to highlight the importance of tiger reserves as important nursery grounds this service is considered for selected tiger reserves. Wherever applicable, based on secondary estimates and models developed at other sites, the quantity of offshore marine catch attributable to a unit area of tiger reserve is calculated. This is further used to derive the economic value of nursery function from that particular tiger reserve[1].

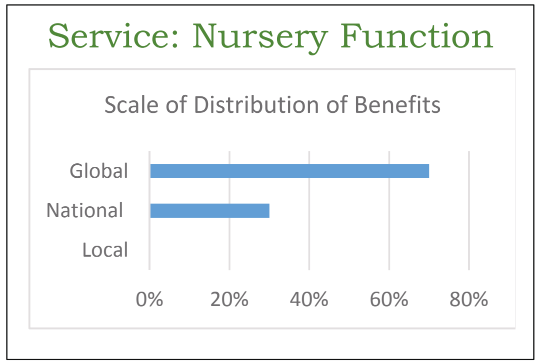


*Figure 5.3-21 Distribution of benefits at various scales (Verma et al., 2015)*

### 5.3.20 Habitat for Species

Tiger reserves are designated areas to conserve natural ecosystems. They provide a suitable habitat or living space and food to wildlife. They also perform buffering functions that significantly contribute towards mitigation and adaptation in extreme weather events for wild animals. This crucial ecosystem service is considered for all tiger reserve sites selected for the study. On account of lack of site-specific studies for estimating the economic value of Habitat for Species function for wildlife, the method of benefits transfer is used[1]. Based on unit area values for Habitat for Species for different ecosystems from a global meta-analysis study[116], the economic value of this service has been derived for all tiger reserves. While the benefits of this service flow goes to local, regional as well as national scale, notified area i.e. the core and buffer areas of the tiger reserve is used for calculations.

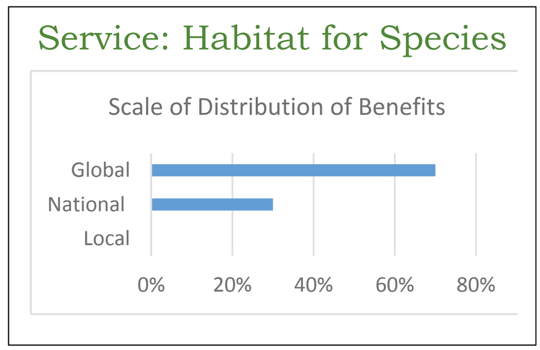


*Figure 5.3-22 Distribution of benefits at various scales (Verma et al., 2015)*

### 5.3.21 Cultural Heritage

The tribal settlements within the tiger reserve have a rich culture and heritage and an assortment of cultural values. Nature as ecosystems and local forests are deeply rooted in the lives of local communities, their culture and their social traditions. As per the Fourth Global Environment Outlook, "Biodiversity also incorporates human cultural diversity, which can be affected by the same drivers as biodiversity, and which has impacts on the diversity of genes, other species and ecosystems" (UNEP, 2008). The indigenous and local knowledge of biodiversity and ecosystem services helps in accentuating the intrinsic value of the ecosystems within these tiger reserves. Thus it is important to highlight the synergies between nature's contribution to the lives of local people by not only emphasizing the economic contribution but by also capturing its role in the culture and local traditions. On account of appropriate valuation methodologies for valuing such services, qualitative and quantification in terms of tribal population, endemism and other factors are used to reflect the cultural heritage value of the tiger reserves[1,106].

**Cultural values are important providing inspiration, motivation, historical values, aesthetic values, health enhancement, recreational, scientific and educational opportunities**

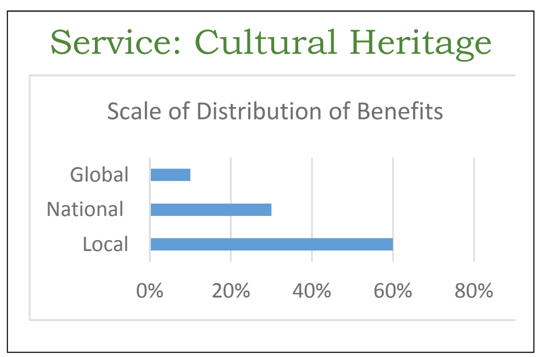


*Figure 5.3-23 Distribution of benefits at various scales (Verma et al., 2015)*

### 5.3.22 Recreation

Tiger reserves offer a wide ranging platform for recreational opportunities such as jungle safaris, nature walks, trekking, hiking, bird-watching, etc. Acknowledging that gate receipts do not adequately represent the utility derived by tourists. Therefore, consumer surplus derived using the Travel Cost Method (TCM) is opted to assess the same. While each tiger reserve offers substantial recreational value, on account of lack of primary data available for the calculation of consumer surplus by TCM, estimates from secondary studies have been used for selected tiger reserves. As major tourist attractions, tiger reserves generate revenue for the respective states while supporting local economy and impacting livelihoods of the local communities. The state governments receive tax income from the tourism sector directly in the form of sales tax and various other taxes and charges on tourist spending and indirectly through property, profits and income taxes.

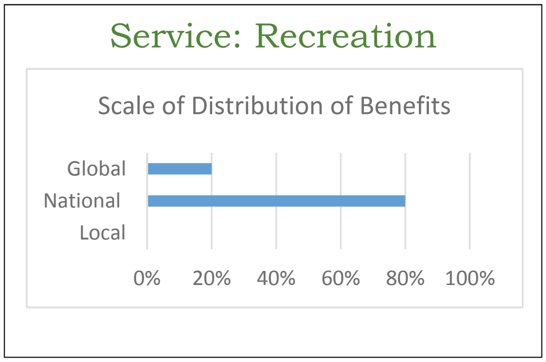


*Figure 5.3-24 Distribution of benefits at various scales (Verma et al., 2015)*

The tiger reserves earn revenue from various tourism-related activities such as gate receipts, taxes, camera fees, etc. To estimate the value of recreation from a tiger reserve, consumer surplus has been taken into account along with the total revenue generated from tourism activities. It may be noted that wherever consumer surplus value was not available, extrapolation of consumer surplus has been used. In cases where extrapolation was not possible due to lack of secondary studies in similar tiger reserves, the total revenue generation has been taken as the proxy value of recreation[1].

**Scared natural sites are probably the oldest form of nature conservation in many countries.**

In addition to the consumer surplus derived by tourists, local economy also gets impacted by the tourism activities of tiger reserves. There are many sectors which are directly or indirectly dependent on this tourism in adjoining villages/towns such as souvenir shops, photographers, transport, catering, etc. Due to insufficient data, the economic contribution of park tourism to these petty sectors is not estimated in this study[1].

### 5.3.23 Spiritual Tourism

Almost all world religions and spiritual traditions have a great respect for nature and regard for nature as a divine manifestation. They are often termed as sacred groves. Ecosystems, especially forests within a tiger reserve have deep associations with local myths, rituals, festivals and beliefs of local communities as well as for communities living at a distance from the reserve. Many places of pilgrimage and worship are located inside tiger reserves in India. While avoiding quantification of this service in monetary terms, the number of pilgrims visiting such places inside the reserve has been used to qualitatively represent this value[1,106].

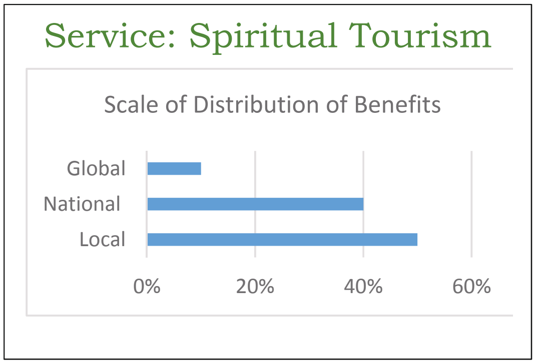


*Figure 5.3-25 Distribution of benefits at various scales (Verma et al., 2015)*

### 5.3.24 Research, Education and Nature Interpretation

Tiger reserves help in conserving natural ecosystems keeping them intact and relatively undisturbed. These ecosystems are like living laboratories of nature with preserved wilderness and long history of natural/ecological processes. On account of this, tiger reserves can be considered as hotspots for conducting research. Such studies help in improving our understanding of natural processes which is ultimately beneficial to mankind. Environmental challenges are intensifying; tiger reserves provide high option value for sustaining the natural fabric and facilitating research for future generations.

Due to limitations in available methodologies for estimating the value of this service in monetary terms, it has been qualitatively quantified through proxy indicators in terms of number of PhD Theses, MSc Theses, other research studies, technical papers, educational trips, study tours and/or visitation to interpretation centres wherever applicable[1,106].

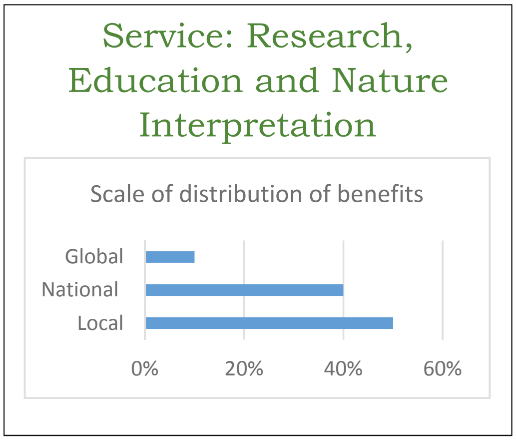


*Figure 5.3-26 Distribution of benefits at various scales (Verma et al., 2015)*

## 5.3.25 Gas Regulation

The role of forests and other natural ecosystems in regulating air quality and composition is widely known. Through various natural processes and ecological functions, the chemical composition of atmospheric gases such as oxygen, ozone, sulphur oxides, nitrogen oxides are regulated. On account of lack scarcity of site-specific studies for estimating the economic value of gas regulation function, the method of benefits transfer is used[1]. Based on unit area values for gas regulation for different ecosystems from a global meta-analysis study[116], the economic value of this service has been derived for all tiger reserves. While the benefits of this service flow goes to local, regional as well as national scale, the notified areas, i.e. the core and buffer areas of the tiger reserves are used for calculations.

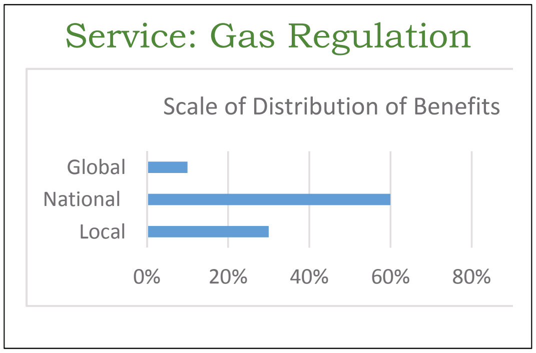


*Figure 5.3-27 Distribution of benefits at various scales (Verma et al., 2015)*

## 5.3.26 Waste Assimilation

Natural vegetation and biota within the tiger reserves break down xenic compounds and help in pollution control and detoxification similar to the case of water purification service (section 5.3.13). While all natural systems help in treating biological waste generated by an assimilation function, wherever relevant data was available, the economic value of the service has been estimated in this study using avoided cost approach. In this approach, the cost of establishing and operating a waste treatment plant is considered. In case of paucity of data for estimating the value, method of benefit transfer is used[1]. Based on unit area values for waste assimilation for different ecosystems from a global meta-analysis study[116], the economic value of this service have been derived for all tiger reserves. While the benefits of this service flow goes to local, regional as well as national scale, notified areas, i.e. the core and buffer areas of the tiger reserves are used for calculations.

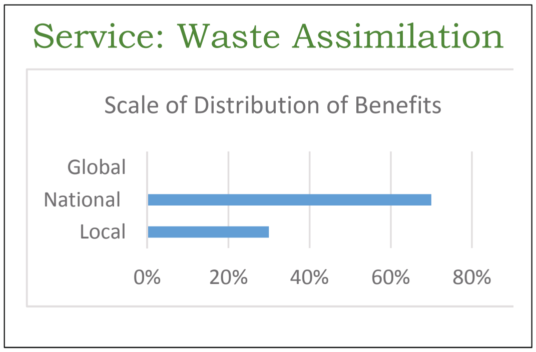


*Figure 5.3-28 Distribution of benefits at various scales (Verma et al., 2015)*

### 5.3.27 Climate Regulation

Natural ecosystems help in regulating the micro climate of the area within and near a particular tiger reserve. They also help in maintaining weather conditions as well as some climatic factors on a larger scale. In the context of present challenges like global warming and climate change, such a regulation function is crucial for sustaining living conditions. Owing to lack of site-specific studies, the method of benefit transfer is used to estimate the economic value of the service in this study[1]. Based on unit area values for climate regulation for different ecosystems from a global meta-analysis study[116], the economic value of this service has been derived for all tiger reserves. While the benefits of this service flow goes to local, regional as well as national scale, notified area i.e., the core and buffer areas of the tiger reserves are used for calculations.

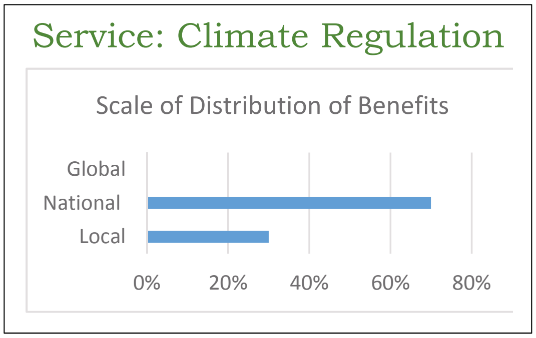


*Figure 5.3-29 Distribution of benefits at various scales (Verma et al., 2015)*

# 6 Chapter 6 Findings: Economic Valuation of Ecosystem Services from Tiger Reserves

## Anamalai Tiger Reserve

Anamalai Tiger Reserve (ATR) is one of the prominent reserves in the southern region of the Western Ghats providing a habitat for many endemic species and the presence of vast Shola forests.

**It is estimated that the Anamalai Tiger Reserve (ATR) provides flow benefits worth Rs. 97.77 billion per year (Rs. 0.56 million per hectare per year) and stock benefits of Rs. 461.50 billion. Critical ecosystem services from ATR include provisioning of water (Rs. 38.19 billion per year), climate regulation (Rs. 18.22 billion per year) and genepool protection (Rs. 15.79 billion per year).**

**Under the Total Economic Value (TEV) framework, the annual direct-, indirect- benefits and option values were Rs. 0.22 billion, Rs. 81.75 billion and Rs. 15.79 billion, respectively.**

As per the MA framework, the value of provisioning services was Rs. 0.12 billion per year, that of regulating services was Rs. 96.26 billion per year, for cultural services was Rs. 0.54 billion per year and supporting services was Rs. 0.84 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 0.12 billion and Rs. 559.14 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 38.23 billion), protection from disease (Rs. 0.18 billion), benign physical and chemical environment (Rs. 42.93 billion), socio-cultural fulfilment (Rs. 0.62 billion) and ecosystem assets (Rs. 477.29 billion). The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 177.23 billion per year. The investment multiplier for ATR was calculated as 3750.10.

# 6.1 Anamalai Tiger Reserve

## 6.1.1 Location and Landscape

Anamalai Tiger Reserve (ATR)-The largest tiger reserve of Tamil Nadu is situated at the heart of Anamalai range. Also known as the Elephant Hills, the Anamalai forms an integral part of the Western Ghats after the Palakkad gap. Earlier a wildlife sanctuary known for its diverse ecosystems and elephant population, ATR was declared as a tiger reserve in 2007.The diversity of Western Ghats is well represented in ATR, as the reserve supports diverse habitat types; endemism of vegetation is very rich which makes its floral diversity extraordinary. Some important ecosystems like the Kariyan Sholas, Grass Hills and Manjampatti Valley of Anamalai have been identified as world heritage sites by UNESCO. Spread over 1491 sq kms, the core area of 970.16 sq kms falls in six ranges of Coimbatore and Tirupur districts and the buffer area of 521.28 sq kms falls in Kodaikanal and Dindigul districts[150].

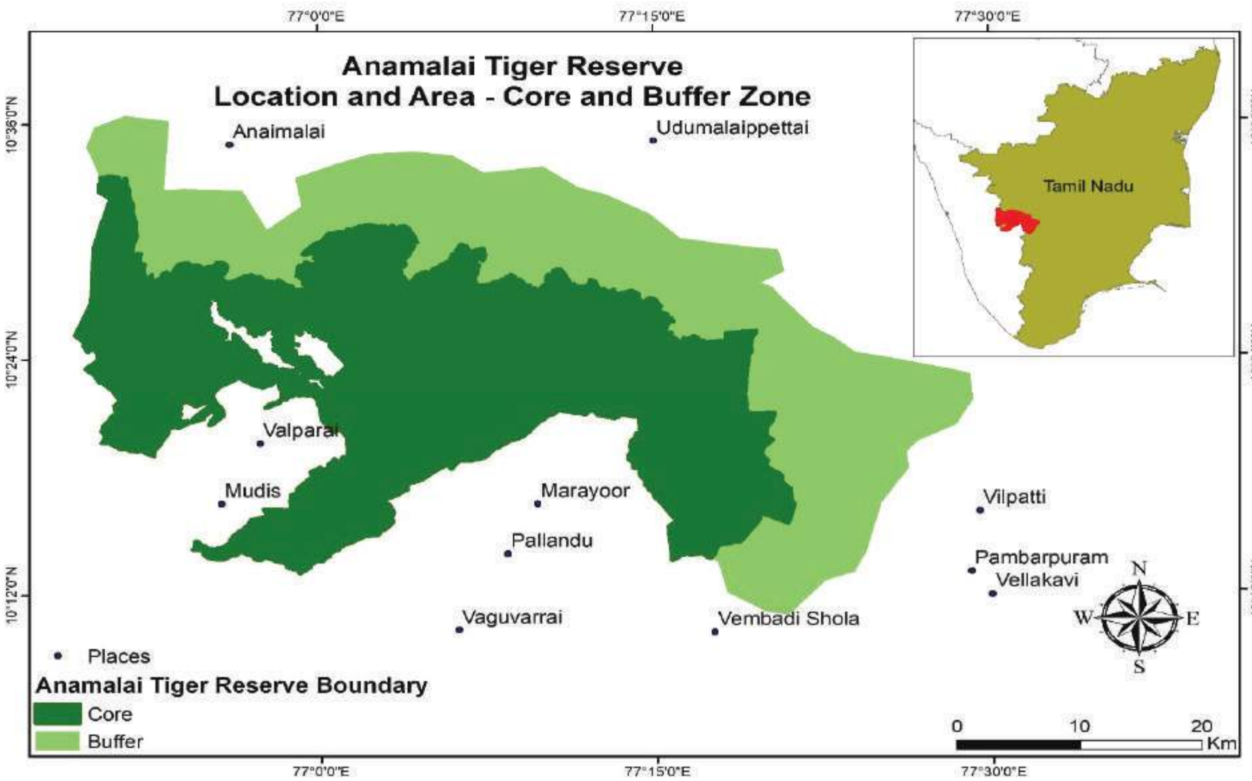


*Figure 6.1-1 Anamalai Tiger Reserve (Source: Forest Survey of India)*

Protected Areas bordering Kerala and Tamil Nadu surround the tiger reserve from the west, south and east. It shares the boundary with Parimbukulam Tiger Reserve on the east and Eravilkulam National Park and Chinnar Wildlife Sanctuary in the south-west. Once used by the British for timber, coffee and tea plantations, the ATR, is characterized by the interplay of perennial streams, grasslands, woodlands and multiple forest types. Moving from valleys to hills in the core area, the various stages of ecological succession becomes evident as the forest type changes from dry thorn forests in the plains to southern tropical dry deciduous forests at lower altitudes to tropical dry deciduous at mid-altitude. Further moving up the forest type changes to semi-evergreen to evergreen. At higher elevations near the mountain tops and folds the presence of undisturbed, pristine patches of mossy Shola forests and rainforests interspersed with rolling montane grasslands offers a breathtaking panoramic view of the entire landscape[150].

## 6.1.2 History

The ATR was part of the ancient Kogumandalam country; the old kingdom had maritime relations with Rome and was an essential part of the Vijaynagar dynasty for three centuries. After the downfall of Vijaynagar, Mysore and Madurai fought for the region. The British finally conquered it from Mysore in 1799. With the advancement of shipbuilding operations in the Bombay dockyard, the region came into focus of British interests. In 1820, the rich teak patches of Anamalai attracted British interests and in 1848, Major Cotton reported the significant presence of large trees suitable for making planks. This kick-started the exploitation of the region for timber, and the Coimbatore South Forest division became a modern forest division for Madras state[150].

In subsequent years until independence, the evergreen forest patches and deciduous forest patches of Anamalai were significantly exploited to meet the demand of timber for shipbuilding and construction of railway sleepers. Plantations of teak and eucalyptus were also established to replace natural moist deciduous and deciduous patches. Only the evergreen patch of Karian Sholas were relatively spared as it was critical for ensuring the water supply to Topslip[2]. Around 1896 vast patches of pristine evergreen forests (200 sq kms) were cleared for raising coffee, tea and cardamom plantations in the Valparai area. Large forest patches were also felled for establishing cinchona plantations in 1927. When the demand for quinine progressively fell after more powerful anti-malarial drugs were discovered post the Second World War, the Cinchona plantations were then replaced for planting fast-growing species for industrial raw material, *i.e. Eucalyptus grandis*. Large portions of cinchona plantations were also taken by the Tamil Nadu Tea Plantation Corporation (TAN TEA). Other exotic species like *Eucalyptus globulus*, *Eucalyptus tereticornis* and black wattle were also introduced. In 1976, the Coimbatore south division was declared as "Anamalai Wildlife Sanctuary". This led to a quantum shift by the 1980s as the focus of forestry operations shifted from timber harvest to forest conservation and wildlife management[150].

The early 1980s and declaration of the Coimbatore South Forest division into "Anamalai Wildlife Reserve" in late the 1970s led to the halting of further planting of eucalyptus and timber harvest. Consequently in 1987, the reserve was renamed "Indira Gandhi Wildlife Sanctuary". The sanctuary was declared as an elephant reserve in 2003 and tiger reserve in 2007. The conservation efforts since the 1980s are bearing fruitful results as the remaining evergreen patches of pristine evergreen forests and grasslands are intact and forests are rejuvenated[150].

### 6.1.3 Topography and Climate

Anamalai Tiger Reserve exhibits a mountainous terrain. This reserve lies in Anamalai Hills in Tamil Nadu with several peaks. ATR was named 'Anamalai' after the elephants found in this hill in abundance from time immemorial. The area coming under Anamalai-tract forms more than 90 percent of the total area of this tiger reserve. The main ranges of the Anamalai range have a general direction of north-west to south-east with an elevation from 800 metres (at Topslip) to 2200 metres (at Akkamalai and Thangachimalai). The minimum elevation within ATR is 175 metres while the maximum elevation is 2514.51 metres[150].

The northern slopes of Anamalai descend swiftly towards the cultivated plains of Pollachi and Udumalpet Taluk. On the western side, the range of Kuchimalai is separated from the Bolampetti hills by a 50 kilometre wide break in the Western Ghats and again rise abruptly towards the peak of Pandaravarai of the Unlandy range[150].

On the south-west, the gradient is gentle with undulating plateau with round hills. The area around Valparai has an elevation of 900 to 1500 metres and has now been entirely taken up for the cultivation of cardamom, tea and coffee. Generally, hills in Udumalpet and Amaravathi ranges are very lofty. The steep western portion of Ulandy and Valparai ranges draining westwards consists of low undulating hills and numerous streams. The lofty mountains of Amaravathi ranges such as Jambumalai, Vellingirimalai and part of Palani Hills abruptly fall down and drain towards the northern direction of the range. The plains area is restricted to a portion of the Kallapuram beat adjoining the Navalodai stream in the Amaravathi range and a portion of Pothamadai Ayerangal and Gudaravalli beats in the Pollachi range[150].

The varied topography and climate influence vegetation type and biodiversity. ATR also has wide variation in annual rainfall in its different parts. The reserve can be grouped into three different eco-zones based rainfall and altitudes, the low altitudes low rainfall areas in the plains, medium altitude medium rainfall areas and high altitude high rainfall areas in Grass Hills, Valparai and Manamboly. The monsoon corresponds to the seasonal winds blowing from Asia to the Indian Ocean in winter and from the Indian Ocean to Asia in summer. The winter winds are dry and do not bring about any rainfall, but the warmer winds of summer bring about torrential rainfall. ATR has south-west and north-east monsoons. The monsoon is generally between 5th June and 15th November[150].

Corresponding to altitude, the temperature and rainfall pattern also vary significantly. temperature during the day ranges from 23 °C to 40 °C at the foothills and night temperatures are between 18 °C to 30°C. At higher elevations,

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2 Topslip was a critical site for processing and transportation for timber harvested from Mount Stuart.

the temperature is naturally lower often dropping below the freezing point in the Grass Hills during winter. December and January are the coldest months of the year. Frost is experienced in the high altitudes during winter (November to February) in places like Grass Hills along the swampy areas[150].

### 6.1.4 Land Cover Classification

The land use and land cover has been sourced from the Forest Survey of India. The land cover of Anamalai Tiger Reserve can be broadly classified into forest, agriculture, wasteland, grassland and habitation (Figure 6.1-2).

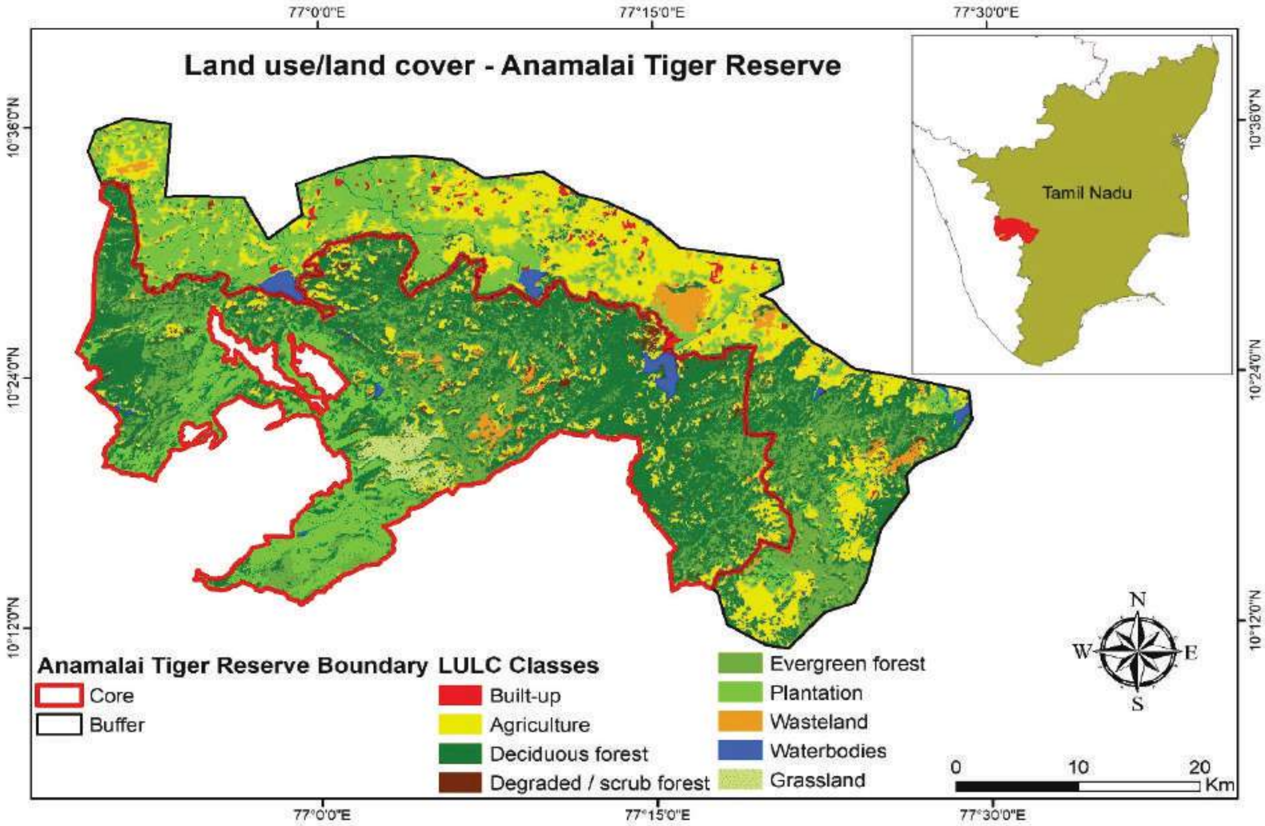



*Figure 6.1-2 Land Use/Land Cover: Anamalai Tiger Reserve (Source: Forest Survey of India, 2013-2014)*

The core and buffer area mainly consists of deciduous forest (36.6 percent), evergreen forest (17 percent), plantation (18.2 percent) and agriculture (20.8 percent) of the total tiger reserve. The area under each of these land cover classes in Anamalai Tiger Reserve is shown in the Table 6.1-1.

*Table 6.1-1 Land Cover Classes*

| LULC Class | Area (ha) |
|---|---|
| Agriculture | 36245.57 |
| Built-up | 1165.34 |
| Deciduous forest | 63835.16 |
| Degraded / scrub forest | 2370.19 |
| Evergreen forest | 29746.21 |
| Plantation | 31726.60 |
| Wasteland | 6438.21 |

| | |
|---|---|
| Water bodies | 2580.30 |

### 6.1.5 Rivers and Streams

ATR is blessed with many streams, tributaries, wetlands, reservoirs and rivers. There are about 15 rivers and 64 streams in the reserve. Most of these streams go dry during summer. The few significant perennial streams and rivers within ATR are Konalar, Varagaliar, Karuneerar, and Chinnar and Amaravathi. The presence of these perennial water sources greatly influences the distribution of wildlife[150].

The western range of Anamalai is drained by a number of streams and rivers such as Thorakadavu, Sholayar, Kallar, Italiyar and Aliyar. Aliyar descends from the hill through a narrow gorge near the Upper Aliyar dam. Power is generated at Navamalai situated at the base of the Upper Aliyar dam. Kallar, Sholayar, Italiyar, and a host of small tributaries originate in the Anamalais and meet in the Sholayar reservoir where part of the water is allowed to flow into Kerala after generating power, and a part of the water is pumped through a tunnel to Manampalli Power House to generatepower. Konalar River that has its origins in the Grass Hills joins the Thoracadavu River to form the Aliyar River. The eastern portion of the tract is drained by the Amaravathi River, which has its source from Travancore and Palani Hills. Many streams merge with the Amaravathi River at different stages of its course[150].

A series of reservoirs and weirs have been constructed in and around ATR under the multipurpose Parimbukulam Aliyar, Amaravathi and Kadamparai projects. These reservoirs supply water to Coimbatore and Tirrupur districts of Tamil Nadu and parts of Kerala and generate approximately 589 MW of electricity annually[150].

### 6.1.6 Biodiversity

The diverse natural habitats of ATR harbour extraordinary floral and faunal diversity well representative of the Western Ghats. The tiger reserve supports more than 2500 species of angiosperms and more than 39 species of rare, endangered and threatened plants are protected and distributed across the reserve. Along with tigers, ATR also protects more than 80 species of mammals, 120 species of reptiles, 140 species of fishes and amphibians and nearly 300 species of birds. Some extremely rare and endemic species like Nilgiri Thar, Nilgiri langur and Lion-tailed macaque are well represented in the reserve. The reserve has one of the highest densities of Gaur and supports the largest population of wild elephants. The Anamalais provide vital natural corridors for migration as it is connected and surrounded by multiple protected areas and reserve forests[150].

Anamalai Tiger Reserve has an assemblage of highly diverse habitats that possess assorted fauna and flora, well representative of the region. The tiger reserve supports diverse habitat types viz. wet evergreen forests, semi-evergreen forests, moist deciduous, dry deciduous, dry thorn and Shola forests. It has other unique habitats such as montane grasslands; savannah and marshy grasslands are also present[150].

### 6.1.7 Socio-Economic Profile

One of the principal occupations of the people in the villages is agriculture. The chief crops grown are paddy, maize, ragi, horse gram, groundnut, tapioca along with certain horticultural plants like coconut, citrus, banana, mango, etc and cash crops like banana and silk cotton. The irrigated areas are cultivated with paddy, whereas the other dry lands have groundnut and coconut. Agriculture in some parts is still done by traditional methods and equipment[150].

### 6.1.8 World Heritage Sites

ATR has two world heritage sites in the Western Ghats namely Grass Hills National Park and Karian Shola National Park. It comprises the Shola tropical forests and Shola grassland. These two spots are among the 39 serial sites notified in the list of World Heritage Sites during 2010. Apart from this, Grass Hills and Majampatthy Valley are also areas of biological importance[150].

### 6.1.9 Valuation Estimates for Anamalai Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES

#### 6.1.9.1 Employment Generation

Owing to paucity of data for physical estimation of Employment Generation on the basis of man-days generated, the service has been estimated on the basis of wage-expenditure done by the Tiger Reserve management on daily-wage labour, watchers and other support staff. As per the estimates provided by the tiger reserve management[151], Anamalai Tiger Reserve incurs an expenditure of around Rs. 7.94 crores or 79.4 million annually on staff wages. As an approximate value, this figure is taken as the monetary estimation for Employment Generation service in Anamalai Tiger Reserve.

#### 6.1.9.2 Fishing

In ATR, fishing from the buffer area is permitted, and the locals generally go fishing in the Aliyar reservoir. Fishes like *Catla*, *L. rohita*, *C. mrigala* and other edible species comprise the common catch. Due to local fishing practices and the unorganized market, there is a lack of documentation of the exact quantity of annual fish catch from the whole reserve. The tiger reserve management, however, has some recorded fishing data for the reservoir[151]. This amounts to approximately Rs. 10.1 million that has been taken as the value of fish harvesting benefits to the local people.

#### 6.1.9.3 Fuel Wood

Collection of fuel wood is strictly permitted from the buffer areas only. According to the estimates of the ATR management[151], the reserve provides approximately an annual Rs. 0.078 million worth of fuel wood to the local inhabitants.

#### 6.1.9.4 Fodder/Grazing

Using the total number of cattle in the buffer, given by the tiger reserve management[151], as equivalent cattle units, and assuming standard forage quantity at 22 kilograms per day per cattle unit[107], the total annual quantity of fodder harvested is equal to 16, 863 tons. Considering an average price of Re. 1 per kilogram of fodder the economic value of annual grazing benefits provided by ATR is approximately equal to Rs. 16.86 million.

#### 6.1.9.5 Standing Timber (Stock)

The standing stock of ATR has immense value. To estimate the economic value of the standing stock, growing estimates of timber species from the forest inventory database[108] of the Forest Survey of India (FSI) have been used as per the forest type to estimate the total stock of ATR. It is estimated that approximately 14.97 million cubic metres of standing stock of timber are contained in ATR. In monetary terms, using an average price of 25,000 per cubic metre after discounting transportation and maintenance cost, the standing stock has a value equal to 374.15 billion rupees. The detailed calculations are shown in Table 6.1-2:

*Table 6.1-2 Value of Timber Stock in the Forests of ATR*

| Forest Type | Forest Cover | Growing Stock (cubic m per ha) | Area (ha) | Total Growing Stock (in thousand cubic m) | Economic Value (in million rupees) |
|---|---|---|---|---|---|
| Tropical Wet Evergreen Forests | VDF | 211.56 | 10579.55 | 2238.22 | 55955.49 |
| Tropical Wet Evergreen Forests | MDF | 112.14 | 3576.59 | 401.09 | 10027.28 |
| Tropical Wet Evergreen Forests | OF | 143.94 | 3263.95 | 469.82 | 11745.38 |
| Tropical Semi-Evergreen Forests | VDF | 242.23 | 1043.54 | 252.78 | 6319.47 |
| Tropical Semi-Evergreen Forests | MDF | 121.12 | 1263.86 | 153.07 | 3826.84 |
| Tropical Semi-Evergreen Forests | OF | 60.56 | 366.62 | 22.20 | 555.04 |

| | | | | | |
|---|---|---|---|---|---|
| Tropical Moist Deciduous Forests | VDF | 135.81 | 10951.72 | 1487.38 | 37184.61 |
| Tropical Moist Deciduous Forests | MDF | 108.84 | 15386.41 | 1674.65 | 41866.16 |
| Tropical Moist Deciduous Forests | OF | 45.44 | 12201.64 | 554.40 | 13860.10 |
| Tropical Dry Deciduous Forests | VDF | 109.94 | 2444.60 | 268.77 | 6719.21 |
| Tropical Dry Deciduous Forests | MDF | 30.18 | 15095.60 | 455.59 | 11389.71 |
| Tropical Dry Deciduous Forests | OF | 62.98 | 12332.25 | 776.69 | 19417.19 |
| Subtropical Broadleaved Hill Forest | VDF | 134.08 | 3412.60 | 457.58 | 11439.47 |
| Subtropical Broadleaved Hill Forest | MDF | 67.04 | 832.23 | 55.79 | 1394.86 |
| Subtropical Broadleaved Hill Forest | OF | 33.52 | 765.51 | 25.66 | 641.52 |
| Montane Wet Temperate Forests | VDF | 149.67 | 2620.40 | 392.19 | 9804.65 |
| Montane Wet Temperate Forests | MDF | 74.83 | 521.35 | 39.01 | 975.36 |
| Montane Wet Temperate Forests | OF | 37.42 | 485.18 | 18.15 | 453.84 |
| Tropical Thorn Forests | VDF | 13.07 | 68.17 | 0.89 | 22.28 |
| Tropical Thorn Forests | MDF | 6.54 | 4900.10 | 32.03 | 800.81 |
| Tropical Thorn Forests | OF | 3.27 | 4197.51 | 13.72 | 342.99 |
| Plantation/TOF | - | 3.29 | 9165.78 | 30.17 | 754.22 |
| Non-Forest | - | 80.58 | 63862.3 | 5146.28 | 128657.04 |
| **Total** | | | | **14966.14** | **374153.53** |

For Anamalai Tiger Reserve growing stock estimates for Tropical Semi-Evergreen Forests of MDF and OF canopy class has been derived from the VDF estimates by taking 50 percent as MDF and 25 percent as OF. Similarly, for forest type Subtropical Broadleaved Hill MDF and OF estimates have been derived from VDF; for Montane Wet Temperate Forests MDF and OF estimates have been derived from VDF and for Tropical Thorn Forests MDF and OF estimates have been derived from VDF. There were no estimates available for Littoral and Swamp Forests (651.25 ha) and hence this forest type has not been included in calculations.

#### 6.1.9.6 Timber Flow

No timber harvesting takes place in ATR and hence the economic value of flow benefits from this service in ATR is zero.

#### 6.1.9.7 Bamboo

ATR has bamboo patches spread over 75 hectares of the reserve[151]. Locals harvest bamboo from buffer areas is used for making or repairing huts, and/or other traditional uses. According to the figures provided by the ATR, 10 tonnes of bamboo harvesting was done in the year 2015-16[151]. Taking a local market price of Rs. 4 per kg, bamboo harvesting worth Rs. 40 thousand is done which has been taken as the monetary value of this service.

#### 6.1.9.8 Non-Timber Forest Produce

Local inhabitants collect NTFP from the buffer areas of the reserve[151]. Major NTFP from ATR includes tamarind, tamarind seeds, broom grass, *amla* (Indian Gooseberry), honey, mango kernel and neem seed. Myrobalans are used for tanning skins and hides. Mango, *Phyllanthus emblica*, *Carrisa caranda,* etc. are used for the preparation of pickles. Tamarind fruits are used for culinary purposes. The annual worth of the NTFP collection is assessed as per the details given by the tiger reserve management[151]. Thus, the economic value of NTFP collection for the year 2015-16 is estimated to be around Rs. 0.6 million.

#### 6.1.9.9 Genepool Protection

The biota of this region is not only highly rich; it covers a distinctive range of biota with over 2000 species of plants and over 600 species of vertebrates. Major groups of plants that have rich diversity are Balsams, Crotalarias, Orchids and Kurinchi. There is rich diversity of wild genetic resources of crop plants like Mango, Jack, Banana, Ginger, Turmeric, Pepper, Cardamom, Solaipuli, Nutmeg, Cinnamon, Amla, Jasmine, Capparis, Nervilia, Bitter gourd, Snakegourd, Ivy gourd Drumstick, Yams, Elephant foot yam, Malabar Tamarind, Rice, Strawberry, Rose, Raspberry, Wild guava, Nilgiri lily, Carrisa, Ber. Elaeocarpus, Elaegnus etc. Highly threatened medicinal plants like *Utleria salicifolia, Decalepis hamiltonii* are well represented in the tiger reserve. One Medicinal Plant Conservation Area has also been established at Topslip where Rare and Endangered Medicinal Plants are raised and maintained for conservation and awareness purposes[150,151].

**Corridors and Connectivity**

ATR is an important Protected Area for many species of conservation importance including tiger and elephants. Both these species have a wide-range of dispersal, the ecological boundaries therefore extend much beyond the ATR's legal boundaries in adjoining Kerala and Tamil Nadu Forest areas, viz. Nemmara, Parambikulam Tiger Reserve, Vazhachal, Malayattur, Munnar, Eravikulam National Park, Chinnar Wildlife Reserve, Kodaikanal and Dindigul forest divisions. ATR is also a part of the recently declared Anamalai – Parambikulam Elephant Reserve.These corridors are significant to ensure gene-flow and hence continuity and conservation for various valuable species in the Western Ghats area which comes under one of the twenty-five globally rich biodiversity hot spots[150,151].

Owing to the lack of comprehensive primary data, the method of benefits-transfer has been used for the valuation of this service. Using estimates of economic value of gene-pool protection for tropical forests (Rs. 100122 per hectare per annum), grasslands (Rs. 80124 per hectare per annum) and cropland (Rs. 68772 per hectare per annum) from a global meta-analysis study[116], the annual economic value of this service from 127678.16 hectares of forests, 6438.21 hectares of grasslands and 36245.57 hectares of cropland in ATR is estimated to be Rs. 15.79 billion.

#### 6.1.9.10 Carbon Storage

The InVEST model used in this research estimates carbon storage according to regional carbon density profiles of different LULC. Outputs of the model are expressed as Mega-gram (Mg) of carbon per grid cell. Since no research exists on the quantity of carbon stored in various pools, estimates from the report of carbon stock in India's forests of the Forest Survey of India has been used. The estimated carbon stored in four major pools – above ground biomass (above ground biomass (AGB), below ground biomass (BGB), dead wood (DW), litter and soil organic matter (SOM) for major forest types of Tamil Nadu, shown in Table 6.1-3.

*Table 6.1-3 Carbon Stock in Anamalai Tiger Reserve*

| Vegetation class | | Carbon Stock in Various Pools(tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total carbon Stock (million tC) |
|---|---|---|---|---|---|---|---|---|
| | Forest Cover | AGB | BGB | SOM | DW (incl. litter) | | | |
| **Littoral and Swamp Forests** | **VDF** | 75.53 | 26.10 | 88.62 | 1.30 | 191.54 | 0.74 | 0.00 |
| **Littoral and Swamp Forests** | **MDF** | 16.15 | 5.59 | 56.85 | 0.78 | 79.38 | 509.75 | 0.04 |
| **Littoral and Swamp Forests** | **OF** | 8.68 | 2.99 | 33.02 | 0.89 | 45.58 | 140.77 | 0.01 |
| **Montane Wet Temperate Forests** | **VDF** | 69.11 | 17.45 | 87.09 | 4.70 | 178.35 | 2620.40 | 0.47 |
| **Montane Wet Temperate Forests** | **MDF** | 53.80 | 13.58 | 78.23 | 2.96 | 148.57 | 521.35 | 0.08 |
| **Montane Wet Temperate Forests** | **OF** | 24.97 | 6.31 | 64.99 | 2.16 | 98.43 | 485.18 | 0.05 |
| **Non Forest** | | 2.96 | 0.32 | 49.88 | 0.00 | 53.16 | 63862.29 | 3.39 |
| **Plantation/TOF** | **VDF** | 35.40 | 7.28 | 116.74 | 2.36 | 161.78 | 68.17 | 0.01 |
| **Plantation/TOF** | **MDF** | 33.86 | 6.96 | 114.02 | 3.06 | 157.90 | 4900.10 | 0.77 |
| **Plantation/TOF** | **OF** | 13.62 | 2.80 | 45.89 | 0.97 | 63.29 | 4197.51 | 0.27 |
| **Subtropical Broadleaved Hill For** | **VDF** | 48.57 | 19.07 | 89.02 | 2.17 | 158.83 | 3412.60 | 0.54 |
| **Subtropical Broadleaved Hill For** | **MDF** | 42.91 | 16.85 | 24.96 | 2.81 | 87.53 | 832.23 | 0.07 |
| **Subtropical Broadleaved Hill For** | **OF** | 20.49 | 8.04 | 17.11 | 0.66 | 46.30 | 765.51 | 0.04 |
| **Tropical Dry Deciduous Forests** | **VDF** | 64.02 | 25.14 | 36.22 | 8.51 | 133.89 | 2444.60 | 0.33 |
| **Tropical Dry Deciduous Forests** | **MDF** | 60.61 | 23.80 | 34.29 | 1.85 | 120.54 | 15095.60 | 1.82 |
| **Tropical Dry Deciduous Forests** | **OF** | 13.75 | 5.40 | 26.11 | 0.88 | 46.14 | 12332.25 | 0.57 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Tropical Moist Deciduous Forests** | **VDF** | 38.67 | 7.95 | 101.78 | 4.49 | 152.88 | 10951.72 | 1.67 |
| **Tropical Moist Deciduous Forests** | **MDF** | 31.95 | 6.57 | 54.91 | 4.48 | 97.91 | 15386.41 | 1.51 |
| **Tropical Moist Deciduous Forests** | **OF** | 14.62 | 3.01 | 45.65 | 2.37 | 65.64 | 12201.64 | 0.80 |
| **Tropical Semi-Evergreen Forests** | **VDF** | 57.62 | 11.85 | 165.93 | 11.50 | 246.90 | 1043.54 | 0.26 |
| **Tropical Semi-Evergreen Forests** | **MDF** | 29.54 | 6.08 | 46.16 | 4.45 | 86.23 | 1263.86 | 0.11 |
| **Tropical Semi-Evergreen Forests** | **OF** | 11.31 | 2.32 | 26.24 | 2.54 | 42.41 | 366.62 | 0.02 |
| **Tropical Thorn Forests** | **VDF** | 12.54 | 4.92 | 24.20 | 2.56 | 44.21 | 186.62 | 0.01 |
| **Tropical Thorn Forests** | **MDF** | 9.07 | 3.56 | 17.52 | 1.39 | 31.55 | 319.69 | 0.01 |
| **Tropical Thorn Forests** | **OF** | 6.25 | 2.46 | 15.97 | 1.15 | 25.83 | 51.76 | 0.00 |
| **Tropical Wet Evergreen Forests** | **VDF** | 58.30 | 20.17 | 107.23 | 9.85 | 195.55 | 10579.55 | 2.07 |
| **Tropical Wet Evergreen Forests** | **MDF** | 55.20 | 19.09 | 77.60 | 3.78 | 155.66 | 3576.59 | 0.56 |
| **Tropical Wet Evergreen Forests** | **OF** | 10.37 | 3.59 | 32.37 | 3.25 | 49.58 | 3263.95 | 0.16 |
| **Total** | | | | | | | | **15.62** |

It can be noted that the non-forest area comprises mostly agricultural land and since maize is one of the major crops of Anamalai Tiger Reserve, the value of maize has been considered for the AGB and BGB pool[152]. While to calculate the carbon density in the soil for the non-forest area, the values of Soil Organic Carbon (SOC) have been referred to as based on the agro-ecological region[153]. The carbon pool of water has been assumed to be zero. The InVEST model provides output in the form of a carbon spread map and a summary table. The Carbon Map in Figure 6.1-3 shows the areas of high and low carbon storage within a region. According to the model, Anamalai Tiger Reserve stores approximately 15.62 million tonnes of carbon.

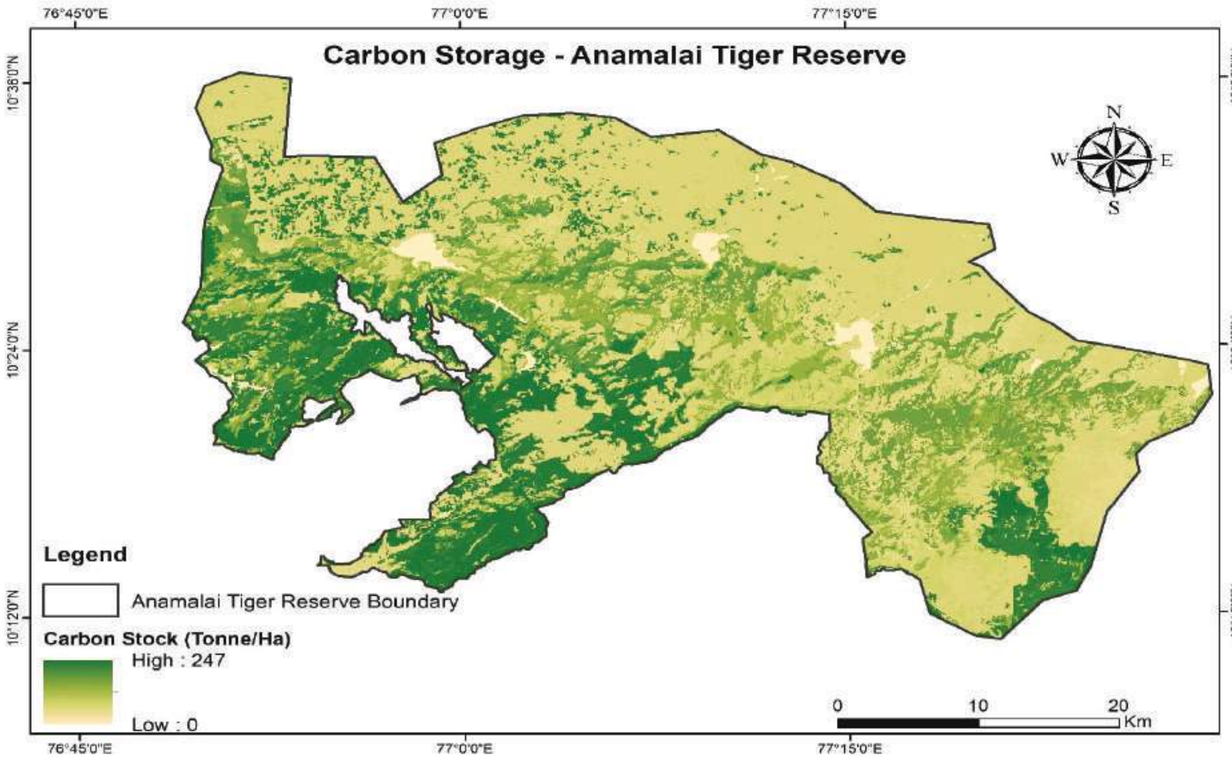



*Figure 6.1-3 Carbon Storage Map of Anamalai Tiger Reserve Created Using InVEST Model*

The estimates from the Carbon Stock model of InVEST as 15.62 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= Rs. 65 as the average for the year 2017-18, the economic value of carbon stock in ATR is calculated as Rs. 87.35 billion.

### 6.1.9.11 Carbon Sequestration

Apart from 15.62 million tonnes of carbon stock in the forests of Anamalai Tiger Reserve, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database. Based on total biomass per unit area, mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type[120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, the total carbon sequestered in the forests of Anamalai Tiger Reserve by aggregating estimates for each forest type is equal to 402.78 kilo tonnes annually. Detailed calculation is shown in Table 6.1-4.

*Table 6.1-4 Calculating Value of Carbon Sequestration from the Forests of ATR*

| Forest Type | Forest Cover | Total Biomass per unit area (tonnes/ha) | Mean Annual Increment per unit area (tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) | Total Value of Annual Carbon Sequestration (million Rs. per year) |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Tropical Wet Evergreen Forests | VDF | 509.86 | 19.65 | 10579.55 | 103918.79 | 4263.85 |
| Tropical Wet Evergreen Forests | MDF | 270.27 | 10.41 | 3576.59 | 18622.34 | 764.09 |
| Tropical Wet Evergreen Forests | OF | 346.90 | 13.37 | 3263.95 | 21813.16 | 895.01 |
| Tropical Semi-Evergreen Forests | VDF | 583.78 | 19.06 | 1043.54 | 9947.40 | 408.15 |
| Tropical Semi-Evergreen Forests | MDF | 291.89 | 9.53 | 1263.86 | 6023.78 | 247.16 |
| Tropical Semi-Evergreen Forests | OF | 145.95 | 4.77 | 366.62 | 873.68 | 35.85 |
| Tropical Moist Deciduous Forests | VDF | 327.31 | 10.33 | 10951.72 | 56584.72 | 2321.70 |
| Tropical Moist Deciduous Forests | MDF | 262.30 | 8.28 | 15386.41 | 63708.74 | 2614.01 |
| Tropical Moist Deciduous Forests | OF | 109.50 | 3.46 | 12201.64 | 21091.25 | 865.39 |
| Tropical Dry Deciduous Forests | VDF | 264.96 | 9.55 | 2444.60 | 11677.70 | 479.14 |
| Tropical Dry Deciduous Forests | MDF | 72.73 | 2.62 | 15095.60 | 19794.81 | 812.19 |
| Tropical Dry Deciduous Forests | OF | 151.78 | 5.47 | 12332.25 | 33746.23 | 1384.63 |
| Subtropical Broadleaved Hill Forest | VDF | 323.14 | 9.33 | 3412.60 | 15914.01 | 652.96 |
| Subtropical Broadleaved Hill Forest | MDF | 161.57 | 4.66 | 832.23 | 1940.46 | 79.62 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Subtropical Broadleaved Hill Forest | OF | 80.79 | 2.33 | 765.51 | 892.45 | 36.62 |
| Montane Wet Temperate Forests | VDF | 360.70 | 9.44 | 2620.40 | 12371.21 | 507.60 |
| Montane Wet Temperate Forests | MDF | 180.35 | 4.72 | 521.35 | 1230.67 | 50.50 |
| Montane Wet Temperate Forests | OF | 90.17 | 2.36 | 485.18 | 572.64 | 23.50 |
| Tropical Thorn Forests | VDF | 31.51 | 1.16 | 68.17 | 39.42 | 1.62 |
| Tropical Thorn Forests | MDF | 15.75 | 0.58 | 4900.10 | 1416.92 | 58.14 |
| Tropical Thorn Forests | OF | 7.88 | 0.29 | 4197.51 | 606.88 | 24.90 |
| **Total** | | | | **106309.36** | **402787.27** | **16526.60** |

The social cost of carbon for India as per the latest paper[117] the economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=Rs. 65, the total economic value of annual carbon sequestration in ATR is calculated at Rs. 16.52 billion.

#### 6.1.9.12 Water Provisioning

Parimbukulam - Aliyar Project and Amaravathi dam in the ATR plays a vital role in the regional economy by providing water and electricity. Agricultural prosperity of the plains in Pollachi, Udumalpet and the hilly taluk of Valparai, adjoining areas in Erode and Tirupur districts, are dependent on ATR for their water requirements. The dams under the Parimbukulam–Aliyar projects provide irrigation to the draught-prone areas of Coimbatore and Tirupur districts. Amaravathi reservoir provides irrigation facilities to Udumalpet and Dharapuran in Tirupur district[151].

The output of the InVEST model is very exhaustive. It provides raster and shapefile where various outputs can be spatially studied. It gives the estimated values of mean actual evapotranspiration, mean potential evapotranspiration, water yield volume, etc. The total water yield volume from ATR as well as its fringe areas amounts to 1372.2 million cubic metres as shown in Figure 6.1-4.

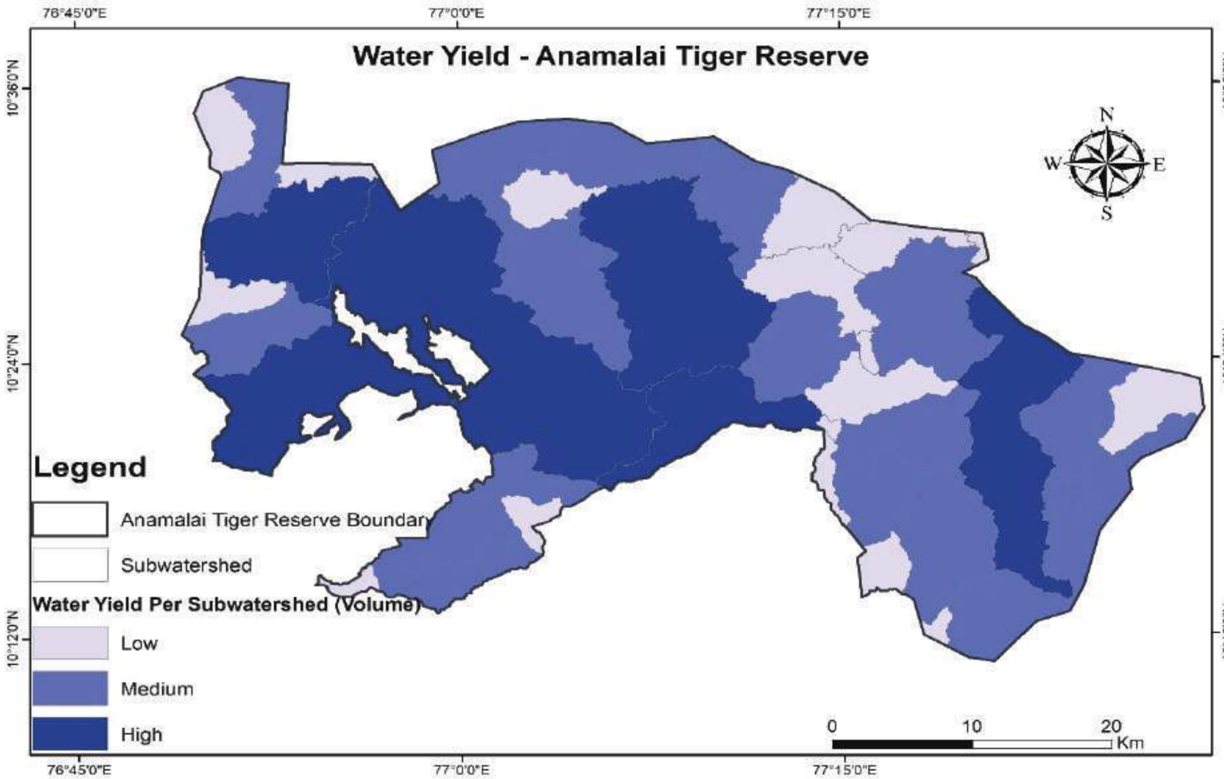



*Figure 6.1-4 Water Yield Output for Anamalai Tiger Reserve Created Using InVEST Model*

Using the monetary value of Rs. 18.43 per cubic metre[1], the economic value of water provisioning service from ATR given its water yield of 1372297857 cubic metres is estimated to be 25.29 billion per year.

In addition to providing water supply to the region, Parimbukulam-Aliyar project (Aliyar, Sholayar and Sarkarpathy Powerhouse), Amravathypoject, and Kadamparai project also generate electricity[151].. A detailed power generation by the dams in ATR is indicated in Table 6.1-5.

*Table 6.1-5 Total Power Generation by Various Damns in ATR* [151]

| Name of the Dam/ Powerhouse | Power Generation (in MW) |
|---|---|
| 1. Parimbukulam-Aliyar | |
| *Aliyar* | 60 |
| *Sholayar: From Unit 1* | 70 |
| *Sholayar: From Unit 2* | 25 |
| *Sarkarpathy Powerhouse* | 30 |
| 2. Amravathy Project | 4 |
| 3. Kadamparai Project | 400 |

The average annual electricity production through these dams/powerhouses collectively is around 589 MW[151]. Conservatively assuming an average price of 2.5 per kWh, the economic value of annual electricity produced through the water from ATR is approximately 12.9 billion per year. Thus, the total economic value of water yield and electricity generation from ATR is around 38.19 billion per year.

### 6.1.9.13 Water Purification

The population dependent on ATR for water supply is around 5200 in its core and buffer areas[150]. The daily minimum water requirement as per the Bureau of Indian Standards is 40 litres per capita is taken as the lower bound estimate to calculate the total domestic water requirement[130]. Using the total dependent population and per capita water requirement the total domestic water requirement is 75,920 kilolitres per annum. Only 10 percent of this estimate is used for valuation, as sufficient data was not available to map the beneficiaries and their exact water supply for drinking purpose for the whole year. Thus the annual drinking water requirement comes to around 7592 kilo litres. Using a lower bound estimate of average cost of treating water for domestic supply at Rs. 10 per cubic m based on estimates for different municipalities of India[131]. Since the people living in the core and buffer villages use water from ATR without any prior treatment, the avoided cost of water purification for drinking water is around Rs. 0.08 million per year.

### 6.1.9.14 Soil Conservation/Sediment Retention

The InVEST SDR model provides various data for spatial analysis of the area. Figure 6.1-5 provides spatial details of the total sediment exported to the stream per watershed in the study area. Here, the model generates the gradation of sediment export ranges from 1000 tons to 62700 tons per sub watershed. High sediment load is generated from the wasteland areas of ATR.

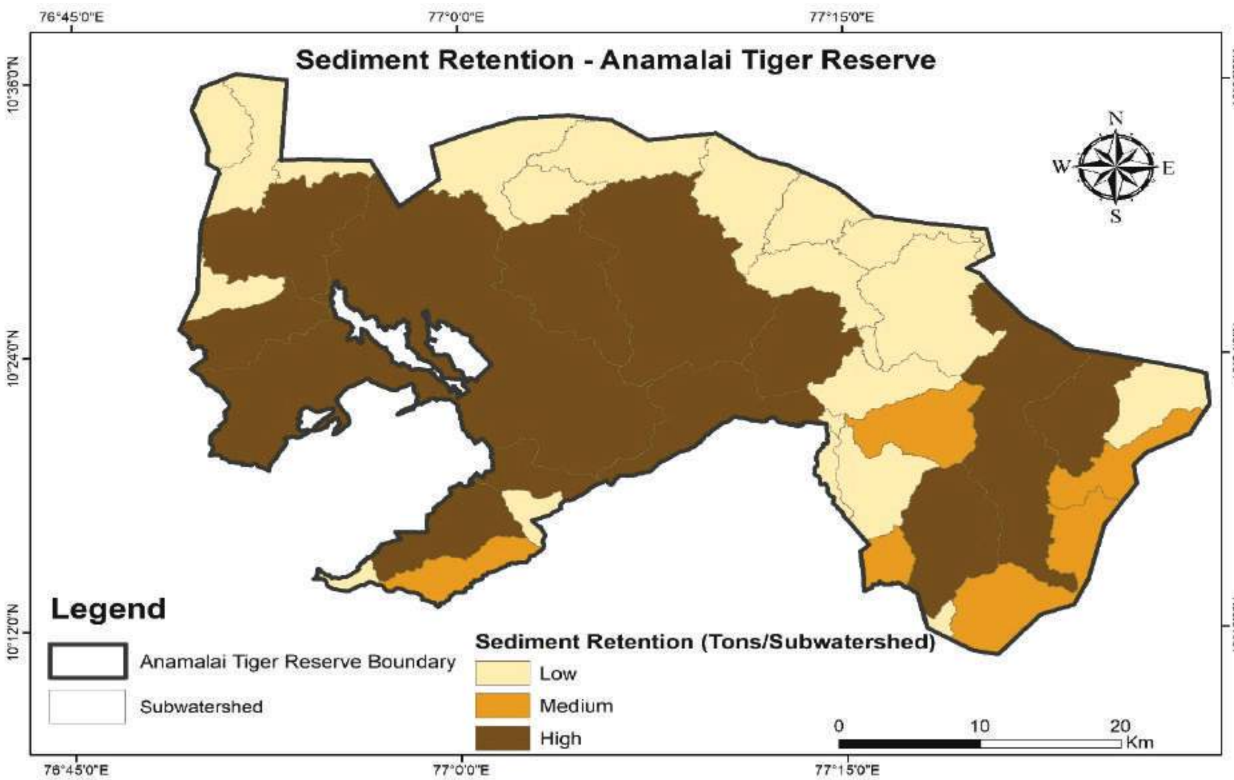



*Figure 6.1-5 Sediment Export from Anamalai Tiger Reserve Created Using InVEST Model*

The sediment retention output of the model supports the theory that forested areas help in controlling sediment flow in an area. The values of sediment retention range from 2000 tons to 79894536 tons per subwatershed. As shown in Figure 6.1-6 the sediment retention in the ATR landscape is high across all the highly forested subwatersheds. The sediment retention values are higher in the core area of ATR.

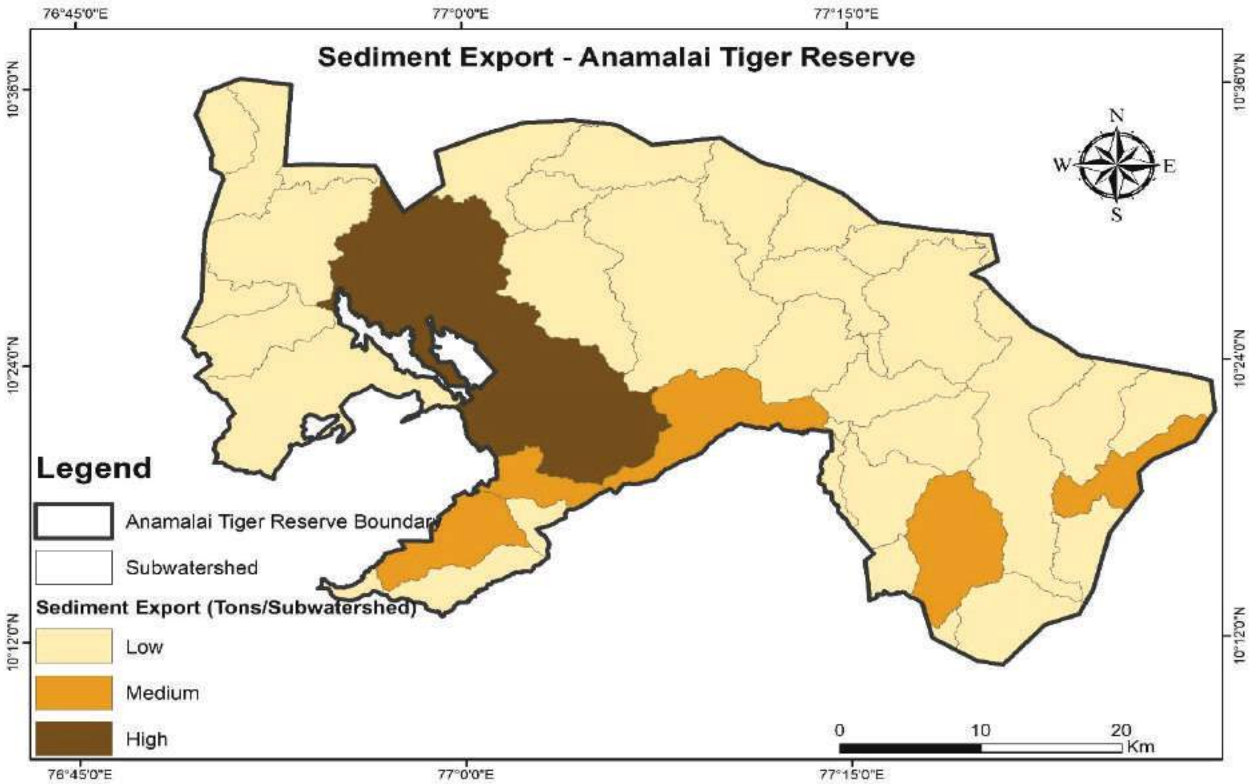



*Figure 6.1-6 Sediment Retention in Anamalai Tiger Reserve Created Using InVEST Model*

To estimate the economic value of soil loss avoided by the forests of ATR, the cost of dredging/de-siltation has been considered. Because of lack of site-specific data, a cost estimate of Rs. 60 per cubic metre [132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 2125.05 million.

### 6.1.9.15 Nutrient Retention

The total soil loss avoided from the InVEST Sediment Retention model of ATR is around 46.85 million tons. To calculate the amount of nutrients retained, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust[147] has been used because of lack of local estimates for the same. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations from Table 6.1-6, the total quantity of nutrients retained is approximately 98602.73 tonnes of N, 1870.05 tonnes of P and 350634.70 tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary value has been derived. The total value of nutrient loss prevented by the forests of ATR is equal to Rs. 4787.74 million annually.

*Table 6.1-6 Nutrient Retention in ATR*

| Nutrient | Soil Nutrient Concentration (g Per Kg) | Total Nutrient Loss Avoided (Tonnes Per Year) | Fertilizer (Substitute) Used for Valuation | Price of Fertilizer (Rs. Per Tonne) | Economic Value of Nutrient Retention (Million Rs. Per Year) |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 98602.73 | Urea | 5360 | 528.51 |
| Phosphorous (P) | 0.044 | 1870.05 | DAP | 20100 | 37.59 |
| Potassium (K) | 8.25 | 350634.70 | Muriate of Potash | 12040 | 4221.64 |

| | | | | | |
|---|---|---|---|---|---|
| **Total** | | **451107.48** | | | **4787.74** |

### 6.1.9.16 Biological Control

Using estimates of economic value of biological control for tropical forests (Rs. 726 per hectare per annum), grasslands (Rs. 2046 per hectare per annum) and cropland (Rs. 2178 per hectare per annum) from a global meta-analysis study[116] the economic value of biological control service from 127678.16 hectares of forests, 6438.21 hectares of grasslands and 36245.57 hectares of cropland in ATR is calculated equal to Rs. 184.80 million per annum.

### 6.1.9.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to ATR; hence, it is not included in the valuation of the ecosystem service of ATR in this study.

### 6.1.9.18 Pollination

Using estimates of economic value of pollination for tropical forests (Rs. 1980 per hectare per annum), grasslands (Rs. 2310 per hectare per annum) and cropland (Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 127678.16 hectares of forests, 6438.21 hectares of grasslands and 36245.57 hectares of cropland in ATR is calculated equal to Rs. 320.3 million per annum.

### 6.1.9.19 Nursery Function

Nursery function was not found relevant due to insufficient information and evident linkages to attribute this service to ATR. Hence, it is not included in the valuation of the ecosystem service of ATR in this study.

### 6.1.9.20 Habitat for Species

Using estimates of economic value of habitat service for tropical forests (Rs. 2574 per hectare per annum), grasslands (Rs. 80124 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 127678.16 hectares of forests and 6438.21 hectares of grasslands in ATR is calculated equal to Rs. 844.49 million.

*Key Habitat Areas of Anamalai Tiger Reserve (Source: Anamalai Tiger Reserve: Tiger Conservation Plan [150]).*

**Shola-Grassland Mosaics**: Unique habitat systems comprising pockets of evergreen Shola forest in a sheltered cool climate among grasslands on ridges, they support many endemic species. For example, Nilgiri langurs are fairly common in these pockets.

**Wet Evergreen Hill Forests**: Occurring at elevations from 800 to 1350 m, tropical wet evergreen forests have extremely dense canopy and numerous epiphytes, especially orchids, ferns, tree mosses, canes, creeping bamboo and palms. Lion-tailed macaque is commonly found in these areas.

**Vayals and Grassy Blanks**: The swampy areas are commonly known as 'Vayals' and are vital microhabitats for a variety of wildlife, especially amphibians.

**Cliffs and Rocky Outcrops**: The areas are critical habitat sites for Nilgiri Tahr.

**Caves:** They are important as they serve as significant sites for various nocturnal animals as well as reptiles. The caves are located at the foothills of the Anamalai in the southern thorn and dry deciduous forest areas.

**Riparian Areas**: Riparian areas are found along the stream and river courses, on shady slopes, and in sheltered places. The vegetation is mainly tall bamboo clumps with occasional trees in moist deciduous forests.

### 6.1.9.21 Cultural Heritage

ATR supports six indigenous tribes of people viz. Malasar, Malai Malasars, Kadars, Eravallars, Pulayars and Muduvars. These indigenous people protect several traditional varieties of crops like rice, ragi, tenai, grain amaranth etc. and distributed across the reserve. There are around 33 tribal settlements inhabited by over 5200 people[150,151].

ATR has several culturally and historically significant areas. Many temples of local and historical importance are found inside the tiger reserve as enclosures. In the eastern part of the Anamalai Tiger Reserve falling in Udumalpet, Amaravathi ranges, there are historic sites like ruins of forts of the Vijaynagar kings, Pandavarkuzhis (Mandavarkuzhi)[150,151].

### 6.1.9.22 Recreation

Anamalai Tiger Reserve, being near cities like Coimbatore, is becoming a popular tourist destination. It offers opportunities for wildlife viewing, trekking, owing to rich biological diversity and scenic beauty. The bulk of visitors are mainly daytime tourists flocking to places like Monkey Falls near Aliyar, Topslip, and Tirumurthi. ATR has many scenic spots like Topslip, Attakatti, Nallamudi, Pooncholai, Punganodai Viewpoint, Chinnakallar Waterfalls, Monkey Falls, etc. and important peaks like Pandaravarai, Kuchimalai, Perumkundru, Vellimudi, and Thanakamalai. Areas like Chinnar, Manjampatti, Valparai, Manamboly, Grass Hills, and Varagaliar are rich in aesthetic value and wildlife. Topslip is the very famous tourist attraction of ATR[150,151].

Maximum tourist inflow can be observed from April to June, i.e. during the summer holidays and also to some extent from September to December. Maximum footfall is noticed during the weekends[151].

*Table 6.1-7 Annual Tourist Visitation in ATR [151]*

| S. No. | Year | Total No. of Tourists Visited |
|---|---|---|
| 1 | 2011-12 | 673535 |
| 2 | 2012-13 | 386768 |
| 3 | 2013-14 | 583171 |
| 4 | 2014-15 | 538377 |
| 5 | 2015-16 | 583946 |

Revenue generated by the tiger reserve by tourism activities in the year 2015-16 is approximately Rs. 24.9 million[151]. This includes gate receipts, taxes, charges for safari, eco-tourism activities, forest-department owned lodges and resorts, camps and other tourism activities. A study, Surendran & Sekar (2010) estimates Willingness to Pay (WTP) fusing individual travel cost method for biodiversity conservation. The study reveals that an individual tourist is willing to pay Rs. 665 annually for conservation of ATR. This value of WTP was adjusted for inflation from 2010 to 2015-16 value[3]. Using this adjusted value (Rs. 885.6/annum) along with the number of tourist visitors in the year 2015-16 as 583946, the monetary value of recreation service is calculated on the basis of consumer surplus is equal to Rs. 517.14 million per annum. The value of consumer surplus along with the revenue generated is taken as the total value of recreation service, which is around Rs. 542.04 million.

### 6.1.9.23 Spiritual Tourism

There are many temples situated inside ATR such as Malai Perumalswami Koil, Gopalaswami Koil, Thadaganachi Amman Koil, Ponnalamman Temple, Tirumurthi Temple and Panchalingam, Panchalingam, Mamangathamman Koil, Bodinayakam Koil, Yelumalayan Venkatachalapathi Koil, Mukundappar Koil, Avarakodipallam Temple, Kamatchi Amman Koil, Athaliamman Koil, Kannimar Amman Koil, and Katalai Mariamman Koil[150,151]. The annual footfall in some of these temples is given in the Table 6.1-8 Annual Footfall in the Temples of ATR

*Table 6.1-8 Annual Footfall in the Temples of ATR[150,151]*

| S. No. | Name of Temple | No. of Devotees Visiting Per Year | Period of Visit |
|---|---|---|---|

[3] WPI based on 2004-05 as base year: 2010=130.8 and for 2016 (April)=177

| | | | |
|---|---|---|---|
| 1 | Tirumurthi Temple in Udumalpet division | 4 lakhs | Throughout the year |
| 2 | Yelumalayan Temple | 1 lakh | In the montsh of September and October |
| 3 | Kodanthur Temple in Udumalpet division | 60,000 | Three times a week |
| 4 | Athaliamman Temple in Valparai division | 16,000 | Throughout the year |

#### 6.1.9.24 Research, Education and Nature Interpretation

The diverse habitats of ATR, its faunal and floral associations and the matrix of cultural heritage and historical ruins provide ample research opportunities in the field of biology, ecology and anthropology. It also offers an ideal ecotourism experience and an ideal place for environmental education. ATR is part of a larger landscape covering the areas of adjoining Eravikulam NP, Parimbukulam Tiger Reserve and other forest divisions of Kerala State[150,151].

ATR is a well-chosen site for research studies in the field of species distribution, tribal settlements, climate change impact, corridor connectivity, ecological mapping, landscape genetics, habitat suitability, socio-economic conditions of the tribal villages, etc. In the last five years (2011-2016) a total of 62 studies have been carried out in ATR by various institutes including the Nature Conservation Foundation (NCF), National Centre for Biological Sciences (NCBS) Tata Institute of Fundamental Research, Ashoka Trust for Research in Ecology and the Environment (ATREE), Wildlife Institute of India (WII), World Wildlife Fund (WWF), Anthropological Survey of India and Bharathiar University[150,151]. A detailed year-wise distribution of studies carried out in ATR is given in Table 6.1-9.

*Table 6.1-9 Number of Studies Done in ATR [151]*

| Year | Number of Studies |
|---|---|
| 2011-12 | 9 |
| 2012-13 | 13 |
| 2013-14 | 19 |
| 2014-15 | 11 |
| 2015-16 | 10 |

The Anamalai Nature Information Centre established in 2007 by the Nature Conservation Foundation is situated at Iyerpadi. It is used for educating and building awareness about the importance of ATR amongst local stakeholders, school students, teachers, estate workers, media persons, tourists and the general public. The main objective is to engage local children in the Valparai region through interactive and experiential learning and to sensitize the public to promote and protect the rainforest fragments and its wildlife in the human-dominated landscape of the Anamalai Hills. Primary activities include nature walks, illustrated talks and screening of wildlife movies[150].

#### 6.1.9.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (Rs. 792 per hectare per annum) and grasslands (Rs. 594 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation from 127678.16 hectares of forests and 6438.21 hectares of grasslands in ATR is calculated equal to Rs. 104.94 million.

#### 6.1.9.26 Waste Assimilation

Due to inadequate information and evident linkages to ATR, the service has not been found relevant and hence is not included in the valuation of the ecosystem service of ATR in this study.

#### 6.1.9.27 Climate Regulation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 134904 per hectare per annum), grasslands (Rs. 2640 per hectare per annum) and cropland (Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 127678.16 hectares of forests, 6438.21 hectares of grasslands and 36245.57 hectare of cropland in ATR is calculated equal to Rs. 18.22 billion.

### 6.1.10 Spectrum of Values- Anamalai Tiger Reserve

ATR provides a variety of values that fall under economic, biological, ecological, conceptual, physical, scientific, educational, cultural, religious and historical values.

#### 6.1.10.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| **Summary of Ecosystem Services Based on TEV Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **227.05** | **Rs. Million/Year** |
| Fuel wood, Fodder, Non-Timber Forest Products, Fishing, Bamboo (Flow), Employment Generation<br>* - Timber (Flow) | | |
| **Indirect Use Value** | **81746.18** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>*- Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Option Value** | **15791.93** | **Rs. Million/Year** |
| Genepool Protection | | |

| **Summary of Ecosystem Services Based on MA Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **122.11** | **Rs. Million/Year** |
| Employment Generation, Fishing, Fodder, Fuel wood, Bamboo (Flow), NTFP<br>* - Timber (Flow) | | |
| **Regulating Services** | **96256.51** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool Protection<br>* - Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Cultural Services** | **542.04** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Supporting Services** | **844.50** | **Rs. Million/Year** |

| | | |
|---|---|---|
| Habitat for Species | | |

| Summary of Ecosystem Services Based on Stock and Flow Benefits | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Flow Benefits** | **97.77** | **Rs. Billion/Year** |
| Employment Generation, Fishing, Fodder, Bamboo (Flow), NTFP, Fuel wood, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - Timber (Flow), Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Stock Benefits** | **461.50** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| Summary of Ecosystem Services Based on Tangible/Intangible Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Tangible Benefits** | **122.11** | **Rs. Million/Year** |
| Employment Generation, Fishing, Fodder, Fuel wood, Bamboo (Flow), NTFP<br>* - Timber (Flow) | | |
| **Intangible Benefits** | **559143.94** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |

| Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **38233.26** | **Rs. Million/Year** |
| Fishing, Fodder, Fuel wood, Bamboo (Flow), NTFP, Water Provisioning<br>* - Timber (Flow) | | |
| **Protection from Disease/Predators/Parasites** | **184.81** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **42933.72** | **Rs. Million/Year** |
| Carbon Sequestration, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Climate Regulation, Habitat for Species | | |

| | | |
|---|---|---|
| * - Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Socio-Cultural Fulfilment** | **621.44** | **Rs. Million/Year** |
| Employment Generation, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Ecosystem Assets** | **477292.82** | **Rs. Million** |
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| **Summary of Ecosystem Services Based on EPA Effect Categories** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **558724.01** | **Rs. Million** |
| Employment Generation, Timber (Stock), Gene pool protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Soil Conservation/Sediment Retention, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Gas Regulation, Climate Regulation<br>* - Timber (Flow) | | |
| **EPA Effect Category 2** | **542.04** | **Rs. Million** |
| Recreation | | |
| **EPA Effect Category 3** | **62** | **Studies** |
| Research, Education and Nature Interpretation | | |
| **EPA Effect Category 4** | **6** | **Indigenous Tribes** |
| Cultural Heritage | | |
| **EPA Effect Category 5** | **More than 4 lakh** | **Devotees per year** |
| Spiritual Tourism | | |

#### 6.1.10.2 Linkages to Human Health

Anamalai Tiger Reserve emanates a range of ecosystem services vital for maintenance of human well-being. Amongst these, Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Biological Control, Pollination, Cultural Heritage, Recreation, Research, Education and Nature Interpretation, Gas Regulation, and Climate Regulation Services have a huge direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 177.23 billion.

#### 6.1.10.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Anamalai Tiger Reserve for the year 2016-17, was around Rs. 26.07 million. Based on the flow benefits of Rs. 97.77 billion per year, for every rupee spent on management costs in ATR, flow benefits of Rs. 3750.1 are realized within and outside the tiger reserve.

#### 6.1.10.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Anamalai Tiger Reserve is estimated at Rs. 0.56 million (Rs. 5.62 lakhs) per hectare.

#### 6.1.10.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 3.56 percent of flow benefits accrue at the local level, 14.69 percent at the national level and 81.75 percent at the global level.

## Unique Features: Anamalai Tiger Reserve[150,151]

Anamalai Tiger Reserve contains unique blend of habitats and forest types. The diversity is also reflected in the flora and fauna of the tiger reserve. Shola forests and grasslands are one of the most remarkable features of the reserve.

**1. GRASS HILLS NATIONAL PARK**

The Shola forest or Montane rainforest and grassland ecosystems are one of the most spectacularly beautiful and biologically unique landscapes of the Western Ghats. The area is dotted with characteristic picturesque rolling hills with dark pockets of verdant stunted mossy rainforest nestling amidst smooth grassland providing a stark contrast and steep rocky cliffs. Grass Hills National Park (GNP) nestled in the Anamalai Hills, marks the beginning of the Southern Western Ghats, which is recognized as a global hot spot for biodiversity. The Anamalai Hills were declared a wildlife sanctuary in 1976 and Grass Hills was upgraded to a National Park in 1989 owing to the requirement of higher protection levels to its sensitive habitat. The major portion of the area is covered with grasslands, within which are embedded numerous patches of the unique stunted Montane rainforest called Shola, typical of this region. GNP covers an area of approximately 3122.50 hectares with an average altitude of 2000 m above mean sea level. Annual rainfall varies between 3500-5000 mm annually. It is contiguous with the Eravikulam National Park (Kerala).

**2. KARIAN SHOLA NATIONAL PARK**

Karian Shola is also a part of the Anamalai hills which was upgraded to a National Park in 1989. The region, Karian Shola, represents a well-protected tract of low elevation tropical rainforest. The Karian Shola National Park (KNP) covers an area of 5 sq kms (503.25 hectares) with an average altitude of 740 m above mean sea level. The annual rainfall here varies between 1000-1500mm. The forests of Karian Shola National Park have been classified into three types as lowland evergreen forests in the broad Mesua – Cullenia – Palaquium type. The evergreen forests in the area are distributed at an altitudinal range of 700 – 1800 m above MSL. Above which are the high altitudinal grasslands and Shola forests. The moist deciduous forests have dominant species like *Lagastroemia microcarpa – Dillinia pentagyna* – and *Tectona grandis.* The dominant bamboo species are Bamboosa arundinaceae, with a 40-year rhizome.

Karian Shola National Park is also a Medicinal Plant Conservation Area (MPCA) Area with 161 herbs, 51 shrubs, 95 trees and 41 climbers with medicinal value. Apart from being rich in flora it is also highly rich in wildlife. Four Indian non-human primates, the Bonnet Macaque (*Macaca radiate*), Common langur *(Presbytis entellus*), Nilgiri Langur (*P.johnii)* and the Slender Loris *(Loris tardigradus)* are found. In addition, other mammals in the area include the Tiger (*Panthera tigris),* Leopard (*Panthera pardus*), Jungle Cat (*Felix Chaus*), Dhole (*Cuon alpinus*), Jackal (*Canis aureus*), Small Indian Civet (*Viverricola indica*), Palm Civet (*Paradoxus hermophroditus*), Elephant (*Elephas maximus*), Gaur (*Bos gaurus*), Barking Deer (Muntiacus muntjac), Mouse Deer (Tragulus meminna), Sambhar *(Cervus unicolor*), Nilgiri Tahr (*Hemitragus hylocrius*), Wild Pig (*Sus scorfa*), Sloth Bear (*Melusurus ursinus*), Mongoose (Herpestis Sp.), Indian Porcupine (Hystric indica), Pangolin (Manis crasicaudata), Indian hare (*Lepus negricolis*), and the Squirrels (*Ratufa and Petaurista spl*.). Twelve species of mammals (excluding bats, rodents and aquatic species) are endemic to this part of the Western Ghats. An extensive variety of birds and reptiles are also found in the area.

# Bandipur Tiger Reserve

Part of the Nilgiri Biosphere Reserve, the Bandipur Tiger Reserve (BTR) is recognized as Mega Biodiversity Area and is home to a large population of elephants in the country.

**It is estimated that the tiger reserve provides flow benefits worth Rs. 64.06 billion per year (Rs. 0.44 million per hectare) and stock benefits of Rs. 314.76 billion per year. Vital ecosystem services that arise from this reserve include provisioning of water (Rs. 20.66 billion per year), climate regulation (Rs. 14.43 billion per year) and genepool protection (Rs. 12.63 billion per year).**

**Under the Total Economic Value (TEV) framework, the annual direct-, indirect- benefits and option values were Rs. 0.56 billion, Rs. 50.85 billion and Rs. 12.63 billion, respectively.**

As per the MA framework, the value of provisioning services was Rs. 0.48 billion per year, that of regulating services was Rs. 63.23 billion per year, for cultural services it was Rs. 66.86 million per year and supporting services was Rs. 0.27 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 0.48 billion and Rs. 378.33 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 21.07 billion), protection from disease (Rs. 0.15 billion), benign physical and chemical environment (Rs. 30.04 billion), socio-cultural fulfilment (Rs. 0.15 billion) and ecosystem assets (Rs. 327.39 billion).

The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 149.66 billion per year. The investment multiplier for BTR was calculated as 716.34.

## 6.2 Bandipur Tiger Reserve

### 6.2.1 Location, Landscape and Significance

Bandipur Tiger Reserve (BTR) is a part of the Mudumalai, Sathyamangalam, Wayanad and Nagarhole landscape complex. The landscape spreads across three states, viz. Tamil Nadu (Mudumalai-Sathyamangalam), Kerala (Wayanad) and Karnataka (Bandipur-Nagarhole). It holds 1/8$^{th}$ of the worldwide tiger population (one-fourth of India's tiger population) and is home to the single largest Asian Elephant population in the world. It is also a part of the Mysore Elephant Reserve (MER)[155].

The Bandipur Tiger Reserve is a significant component of the 5520 sq km landscape, the first biosphere reserve in the country, i.e. the Nilgiri Biosphere reserve under the Man and Biosphere (MAB) programme of IUCN. The reserve is one of the Mega Biodiversity Areas in the country representing a Western Ghats Biogeographic Zone. It is surrounded by Mudumalai Tiger Reserve in the south and Wayanad Wildlife Sanctuary in the south-west. On the north-west side, Kabini reservoir separates Bandipur and Nagarhole Tiger Reserve. The northern side is surrounded by human-dominated habitation with villages and agricultural lands[155].

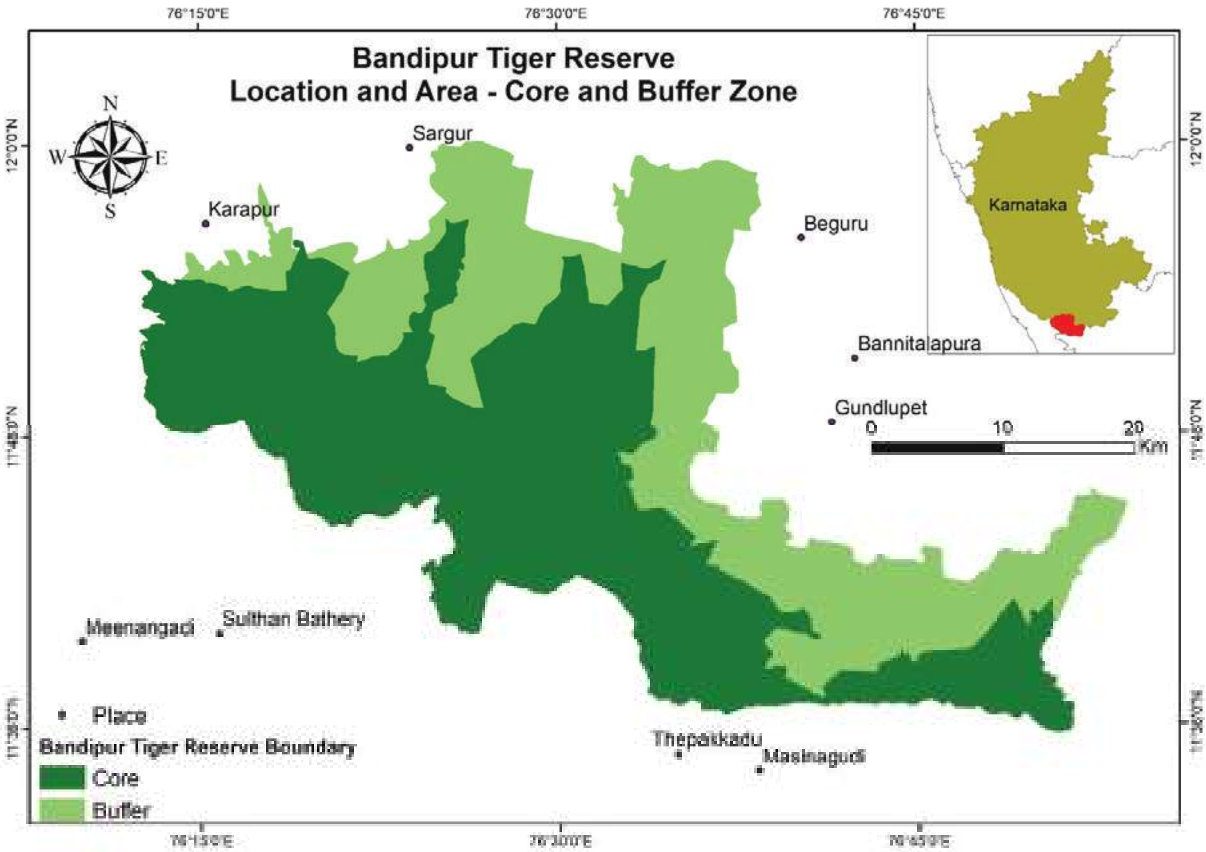



*Figure 6.2-1 Bandipur Tiger Reserve (Source: Forest Survey of India)*

Bandipur Tiger Reserve (BTR) formerly known as Bandipur National Park, lies in the contiguous landscape spread in two revenue districts of southern Karnataka namely Mysore (Nanjangud and H.D. Kote Taluks) and Chamarajanagar (Gundlupet Taluk). It is situated at the tri-junction area of the three states viz. Tamil Nadu, Karnataka and Kerala. The critical tiger habitat or the core area in the reserve is 872.24 sq kms with a buffer of 597.45 sq kms[155].

As recognized by the National Tiger Conservation Authority (NTCA)/Wildlife Institute of India (WII) (Status of tiger, co-predators and prey in India, 2010), there are three identified/delineated corridors at a macro level (circuitscape/least cost pathways) in the landscape comprising BTR[155]. They are:

**Bandipur-Cauvery Wildlife Sanctuary:** The corridor connects BTR to the Cauvery Wildlife Sanctuary through the buffer area of Mudumalai and Sathyamangalam TRs. In addition to that, it also connects to the BRT Tiger Reserve and the M.M. Hills Wildlife Sanctuary.

**Bandipur-Mudumalai Tiger Reserve:** The reserve has a common boundary of about 80 km with the Mudumalai TR

**Bandipur-Wayanad Wildlife Sanctuary: The** reserve has a common boundary with the Wayanad Wildlife Sanctuary and the Nagarhole TR. over a length of about 70 kms.

## 6.2.2 Land Cover Classification

The land use and land cover has been sourced from the Forest Survey of India. The land cover of Bandipur Tiger Reserve can be broadly classified into forest, agriculture, wasteland, grassland and habitation (Figure 6.2-2).

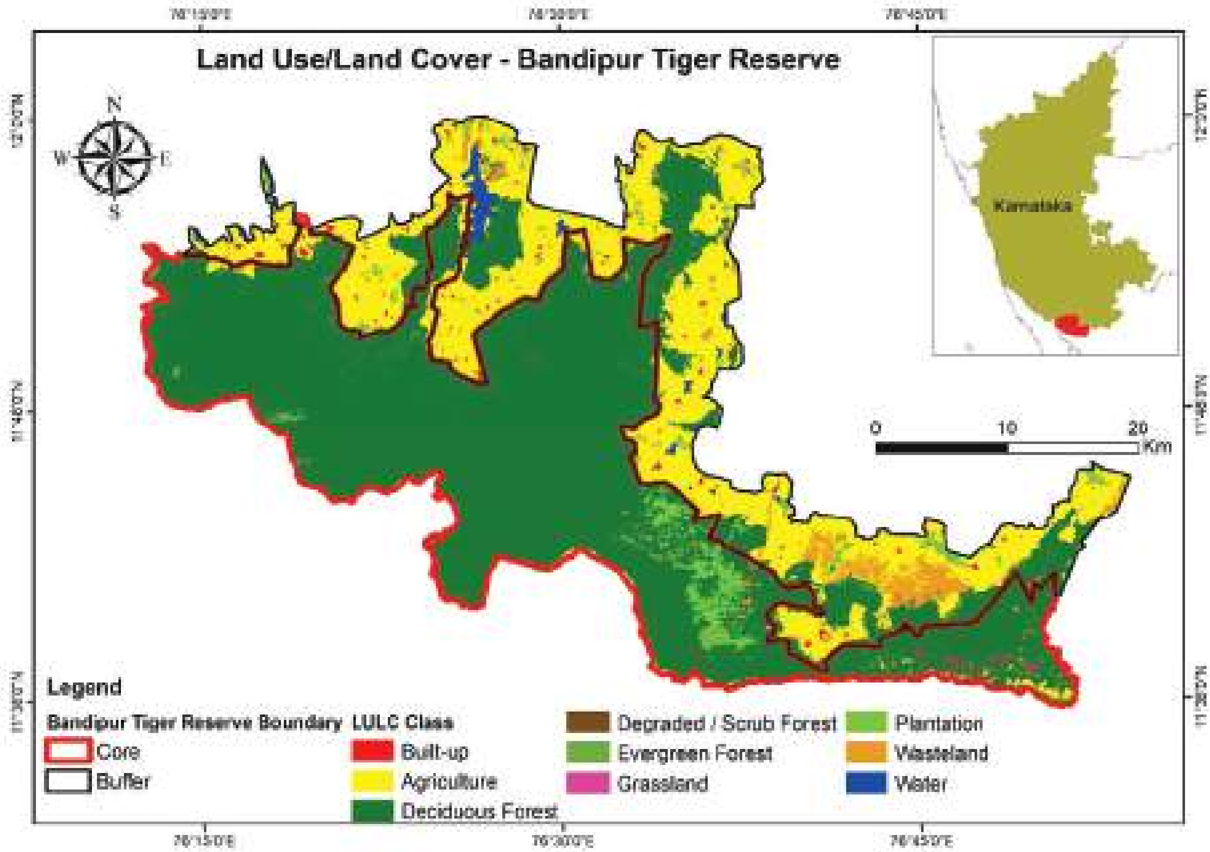



*Figure 6.2-2 Land Use/Land Cover: Bandipur Tiger Reserve (Source: Forest Survey of India, 2013-2014)*

The core area mainly consists of deciduous forest (64.21 percent) while the buffer area dominates with agriculture (27.09 percent). The area under each of these land cover classes in Bandipur Tiger Reserve is as shown in the Table 6.2-1.

*Table 6.2-1 Land Cover Classes*

| LULC class | Area (ha) |
|---|---|
| Agriculture | 39347.392 |
| Built-up | 1027.67 |
| Deciduous forest | 93242.37 |
| Evergreen forest | 1756.79 |
| Degraded / scrub forest | 538.14 |
| Grassland | 158.68 |
| Plantation | 3528.31 |
| Wasteland | 3787.66 |
| Waterbodies | 1813.86 |

### 6.2.3 History

In 1941, the princely state of Mysore declared an area of 90 sq kms as "Venugopala Wildlife Park" under the Mysore Game and Forest Preservation and Regulation Act, 1931. The area was increased to 800 sq km by addition of the adjoining forest areas in 1942. In 1973, an area of 683.52 sq km from this was brought under the Project Tiger as a potential tiger habitat and became one of the first nine tiger reserves in the country[155].

### 6.2.4 Topography and Climate

The general terrain of the reserve is gentle and undulating. The average elevation ranges from 960 m to 1450 m. Much of the Bandipur area is flat. *Himvad Gopalaswami Betta* is the highest peak (1454 m) in the reserve and a gorge nearly 100 m deep is found in the Moyar River on the southern side[155].

The temperature in the reserve ranges from about 30°C to 19°C. The overall climate is moderate and generally hot and dry in summer with occasional pre-monsoon showers in April and May. The cold season starts in November and lasts up to mid-February; the hot season then starts and stretches until mid-June. The coldest months are December and January; the hottest are March and April. The monsoon starts from June and lasts until September. The north-east monsoon starts from mid-October until mid-November. Rainfall varies from 1270 mm to 914 mm across the reserve[155].

### 6.2.5 Rivers and Hydrology

The reserve is located in the Wayanad plateau, characterized by the presence of several swamps and vayals. These are the essential sites for nurturing herbivores like sambar, wild boar and others. The central portion of the reserve is slightly elevated with intermittent hills of moderate height, interspersed with several seasonal streams and a few perennial water sources. It is an important catchment area for the Kabini, Nugu, Kannegala and Moyar rivers[155].

The Moyar River originating from the Nilgiri Mountain range near Pykara is one of the prominent water sources in the reserve for the wildlife as well as for the inhabitants living in and around the reserve. The river meanders through the reserve over a length of more than 20 kms along the boundary of the TR[155].

On the western part of the reserve bordering Wayanad (Kerala), Noolpuza River enters Karnataka state known as Nugu hole, traverses through the reserve for more than 30 kms and ends up in the backwaters of Nugu dam. There are other seasonal streams like Mavinahalla, Shikkatihalla, Bidarahalla, Hebballa, Kekkanahalla, Vaddattihole, Waranchihole and Mukkattihole[155].

### 6.2.6 Biodiversity

Vegetation in the reserve varies from scrub forests, dry deciduous to moist deciduous forests. The reserve is home to a rich variety of flora and fauna. It contains about 35 species of mammals, 227 species of birds, 34 species of reptiles, 21 species of amphibians and 25 species of fishes. BTR is part of the landscape complex that is known to have the highest density source population of wild tigers in the world. Its flagship species are Asiatic elephants and tigers. Asiatic wild dog (Dhole) is also one of the popular species[155].

Since the reserve acts as a corridor between the Eastern and Western Ghats landscapes by providing contiguity, it has a high connectivity value. The coexistence of sympatric carnivores like tiger, leopard and wild dog (dhole) is a unique feature of the tiger reserve. It also holds the ground for the assemblage of seven large ungulates and presence of rare species like four-horned antelopes. The occurrence of many species of primates like common langur (*Semnopithecus entellus*), bonnet macaque (*Macaca radiate*), tufted langur (*Semnopithecus priams*) and black-footed grey langur (*S. hypoleucos*) signifies the high habitat value of the TR. It is an abode for about 250 species of avian fauna of terrestrial woodlands and aquatic habitats[155].

### 6.2.7 Tourism

Since the inception of project tiger, eco-tourism activities are in operation. As the area of 82 sq km adjacent to national highway 67 on both sides is earmarked for ecotourism activities, tourists come to BTR throughout the year. BTR offers diverse values to people with different needs like recreation, peace of mind, education and research. It is quite popular among domestic and foreign- casual tourists, wildlife enthusiasts, photographers and students as well. Moyar gorge through which the Moyar river runs, separating Karnataka and Tamil Nadu state is one of the major tourist spots[155].

Moyar gorge is one of the striking features of the Bandipur landscape. It is about 100 m deep at certain places with near vertical cliffs. They face the Nilgiris and the Moyar River, plunges into the gorge below at Theppakadu (Mudumalai), and the picturesque Moyar falls. Apart from this, rolling-rocks on the banks of the Kekkanahalla stream is also one of the picturesque spots. Interestingly, its name is derived from the phenomenon that rocks roll down the turbulent stream in the rainy season. Bolgudda is a hillock having a watchtower is also popular among the people visiting BTR[155].

### 6.2.8 Socio-Economic Situation

Historically, the BTR has been home for many indigenous Dravidian adivasis such as the Yeravas, Paniyas, Jenu Kurubas, Betta Kurubas, Odigas and Soligas. They were primarily honey gatherers and hunt-gatherers. There is no human habitation in the core. There are 118 villages in the buffer area in the four taluks of Chamarajanagar, Gundlupet, H.D. Kote and Nanjangud. Seventy percent of the population depends on agriculture and allied activities like dairy farming. There are 22 eco-development committees and 7 village forest committees. The human population is around 135000 as per the 2011 census data. The percentage of population belonging to Scheduled Caste and Scheduled Tribe is approximately 45 percent[155].

### 6.2.9 Valuation Estimates for Bandipur Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES.

#### 6.2.9.1 Employment Generation

Employment Generation under plan and non-plan schemes have been considered to estimate the value of this service in Bandipur Tiger Reserve (BTR). As per the TR management[156], total man-days of employment generated from labour activities under those schemes are approximately 298433 days per year. Bandipur Tiger Reserve management incur an annual expenditure of Rs. 83.93 million on labour-wages. Due to paucity of information on the job-wise wage rate, the total wage-expenditure (labour component) is taken as the monetary value of this service.

#### 6.2.9.2 Fishing

On account of the scarcity of any recorded information this ecosystem service was not found applicable for BTR in this study.

#### 6.2.9.3 Fuelwood

The population in the villages in the buffer area of BTR is around 135000 as per Census of India (2011) [156]. Due to lack of sufficient information on actual fuelwood collection in BTR, extrapolation using per capita fuelwood requirement for the entire population is used for valuation of this service. As per the National Sample Survey Organisation survey (2001) estimates the per capita fuelwood requirement is 17.7 kg per capita per month for rural areas [157]. Assuming that locals collect fuelwood collection only for six months from the buffer area. The total fuelwood collection for BTR is calculated as 14.34 kilo tonnes approximately. Using a local market price of Rs. 2 per kg, the total economic value of the fuelwood collection from BTR is Rs. 28.67 million per year.

### 6.2.9.4 Fodder/Grazing

The pressure of grazing is high along the northern boundary of Bandipur The villages in Gundlupet and Chamarajanagar taluk lie in the high-density cattle population area[155]. Owing to insufficient information on dependent cattle units in BTR for forage requirements, estimates from Nagarhole Park[17] have been used to estimate the economic value of fodder/grazing benefits provided by BTR. As per the study, there are 6000 standard cattle units in Nagarhole[17]. To obtain conservative value, a basic assumption is made that only 50 percent of this estimate is applicable, i.e. 3000 standard cattle units are taken as dependent on BTR for forage requirement. Due to absence of data on stall feeding it is assumed that the cattle graze only for 200 days in a year. Using the standard forage quantity of 22 kg per cattle unit per day[107], the total fodder consumption comes to around 132 kilo tonnes. A minimum local market price of Re. 1 per kg is taken for valuation purposes. Thus the economic value of grazing service provided by BTR is calculated as Rs. 132 million per year.

### 6.2.9.5 Standing Timber (Stock)

The standing stock of BTR has immense value. To estimate the economic value of the standing stock, growing stock estimates of timber species from the forest inventory database[108] of the Forest Survey of India (FSI) have been used. It is estimated that approximately 9.11 million cubic metres of standing stock of timber is contained in BTR as shown in Table 6.2-2. In monetary terms, using an average price of Rs. 25000 per cubic metre after discounting for transportation and maintenance cost, the standing stock has a value equal to Rs. 227.81 billion.

*Table 6.2-2 Timber Stock in BTR*

| **Forest Type** | **Forest Cover** | **Growing Stock (cubic m per ha)** | **Area (ha)** | **Total Growing Stock (in thousand cubic m)** | **Economic Value (in million rupees)** |
|---|---|---|---|---|---|
| Tropical Semi-Evergreen Forests | VDF | 449.19 | 16.39 | 7.36 | 184.01 |
| Tropical Semi-Evergreen Forests | MDF | 224.60 | 241.76 | 54.30 | 1357.44 |
| Tropical Semi-Evergreen Forests | OF | 112.30 | 33.84 | 3.80 | 95.02 |
| Tropical Moist Deciduous Forests | VDF | 125.97 | 5799.79 | 730.59 | 18264.63 |
| Tropical Moist Deciduous Forests | MDF | 168.42 | 42007.76 | 7074.85 | 176871.21 |
| Tropical Moist Deciduous Forests | OF | 56.16 | 21062.98 | 1182.90 | 29572.43 |
| Tropical Dry Deciduous Forests | VDF | 3.00 | 15.61 | 0.05 | 1.17 |
| Tropical Dry Deciduous Forests | MDF | 1.50 | 4004.18 | 6.01 | 150.16 |
| Tropical Dry Deciduous Forests | OF | 0.75 | 26409.45 | 19.81 | 495.18 |
| Non-Forest | | | 42778.05 | 32.9391 | 823.4775 |
| **Total** | | | | **9112.59** | **227814.73** |

For Bandipur Tiger Reserve, growing stock estimates for Tropical Semi-Evergreen Forests- VDF and OF category have been derived from MDF by taking double the value for VDF and half the value for OF. Also, for forest type Tropical Dry Deciduous VDF and MDF have been derived from OF value using similar approach and scale. There were no estimates for growing stock available for Tropical Wet Evergreen Forests (152.28 ha), Plantation/TOF

(356.73 ha) and Littoral and Swamp Forests (1.19 ha) therefore these forest types have not been included in calculations.

### 6.2.9.6 Timber Flow

For the purpose of road widening and fire-line, trees from the roadside were auctioned for the timber value. The total revenue generated from such sale is 0.49 million[156].

### 6.2.9.7 Bamboo

Due to the scarcity of data and other relevant information to calculate the annual recorded bamboo collection, the economic value of this service has not been estimated in monetary terms in this study.

### 6.2.9.8 Non-Timber Forest Produce

On account of shortage of primary information on NTFP collection in BTR, estimates from (Ninan's Study) have been used. In Nagarhole National Park, local communities residing within and on the periphery used to collect NTFP such as fuelwood, bamboo, honey, wild edible fruits, nuts and tubers, bush meat, medicinal plants, etc. The study Ninan & Kontoleon (2016) mentions the economic value is estimated at Rs. 106.26 million (2013-14 prices) taking that 25 percent of the park area had access to the NTFP collection (alternate scenario) estimates of NTFP collection comes to around Rs. 0.16 million per hectare which is extrapolated to BTR area (1452 square km[4]). The economic value of NTFP collection thus derived is approximately Rs. 239.8 million per year.

### 6.2.9.9 Genepool Protection

Owing to lack of comprehensive primary data, the method of benefits-transfer has been used for valuation of this service. Using estimates of economic value of genepool protection for tropical forests (at Rs. 100122 per hectare per annum), grasslands (at Rs. 80124 per hectare per annum) and cropland (at Rs. 68772 per hectare per annum) from a global meta-analysis study[116], the annual economic value of this service from 99065.61 hectares of forests, 158.68 hectares of grasslands and 39347.39 hectares of cropland in BTR is estimated to be Rs. 12.64 billion.

### 6.2.9.10 Carbon Storage

The carbon storage for the Bandipur Tiger Reserve has been quantified and spatially mapped using InVEST modelling. Since no location-specific research and information exists for this reserve on the quantity of carbon stored in various pools, estimates from the report of carbon stock in India's forest, the Forest survey of India has been used. The estimated carbon stored in four major pools – above ground biomass (above ground biomass (AGB), below ground biomass (BGB), dead wood (DW), litter and soil organic matter (SOM) for major forest types in Karnataka is shown in the Table 6.2-3.

It can be noted that the non-forest area comprises mostly agriculture land and since maize is one of the major crop of Bandipur Tiger Reserve, the value of maize has been considered for the AGB and BGB pool[152]. While to calculate the carbon density in soil for the non-forest area the values of Soil Organic Carbon (SOC) has been referred based on the agro-ecological region[153]. The carbon pools of water have been assumed to be zero.

*Table 6.2-3 Carbon Stock in BTR*

| Vegetation Class | Forest Cover | Carbon Stock in Various Pools (tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total carbon Stock (million tC) |
|---|---|---|---|---|---|---|---|---|
| | | AGB | BGB | SOM | DW (incl. litter) | | | |
| Plantation/ TOF | MDF | 35.15 | 7.23 | 97.43 | 2.50 | 142.32 | 10.36 | 0.00 |
| Plantation/ TOF | OF | 8.26 | 1.70 | 47.33 | 0.61 | 57.89 | 346.37 | 0.02 |

[4] As per the Land Use and Land Cover Classification Map of BTR (Source: FSI)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 73.33 | 28.73 | 98.57 | 7.46 | 208.10 | 15.61 | 0.00 |
| Tropical Dry Deciduous Forests | MDF | 69.57 | 27.32 | 84.99 | 0.66 | 182.54 | 4004.18 | 0.73 |
| Tropical Dry Deciduous Forests | OF | 14.88 | 5.84 | 51.75 | 0.47 | 72.94 | 26409.45 | 1.93 |
| Tropical Moist Deciduous Forests | VDF | 58.42 | 12.01 | 102.30 | 4.86 | 177.59 | 5799.79 | 1.03 |
| Tropical Moist Deciduous Forests | MDF | 38.92 | 8.00 | 90.29 | 8.52 | 145.73 | 42007.76 | 6.12 |
| Tropical Moist Deciduous Forests | OF | 17.46 | 3.59 | 82.86 | 4.05 | 107.97 | 21062.98 | 2.27 |
| Tropical Semi-Evergreen Forests | VDF | 42.79 | 8.80 | 93.15 | 46.95 | 191.68 | 16.39 | 0.00 |
| Tropical Semi-Evergreen Forests | MDF | 40.59 | 8.35 | 85.62 | 14.33 | 148.90 | 241.76 | 0.04 |
| Tropical Semi-Evergreen Forests | OF | 25.35 | 5.21 | 82.70 | 17.72 | 130.98 | 33.84 | 0.00 |
| Tropical Wet Evergreen Forests | VDF | 64.71 | 22.38 | 91.28 | 8.33 | 186.70 | 34.33 | 0.01 |
| Tropical Wet Evergreen Forests | MDF | 43.86 | 15.17 | 90.13 | 3.43 | 152.58 | 117.95 | 0.02 |
| Non-Forest | | 2.96 | 0.32 | 75.68 | 0.00 | 78.96 | 42778.05 | 3.38 |

| | |
|---|---|
| **Total** | **15.55** |

The InVEST model provides output in the form of a carbon spread map and a summary table. According to the model, Bandipur Tiger Reserve stores approximately 15.55million tonnes of carbon. The other output is received in the form of a map where the stored carbon values are mapped spatially across the landscape (Figure 6.2-3).

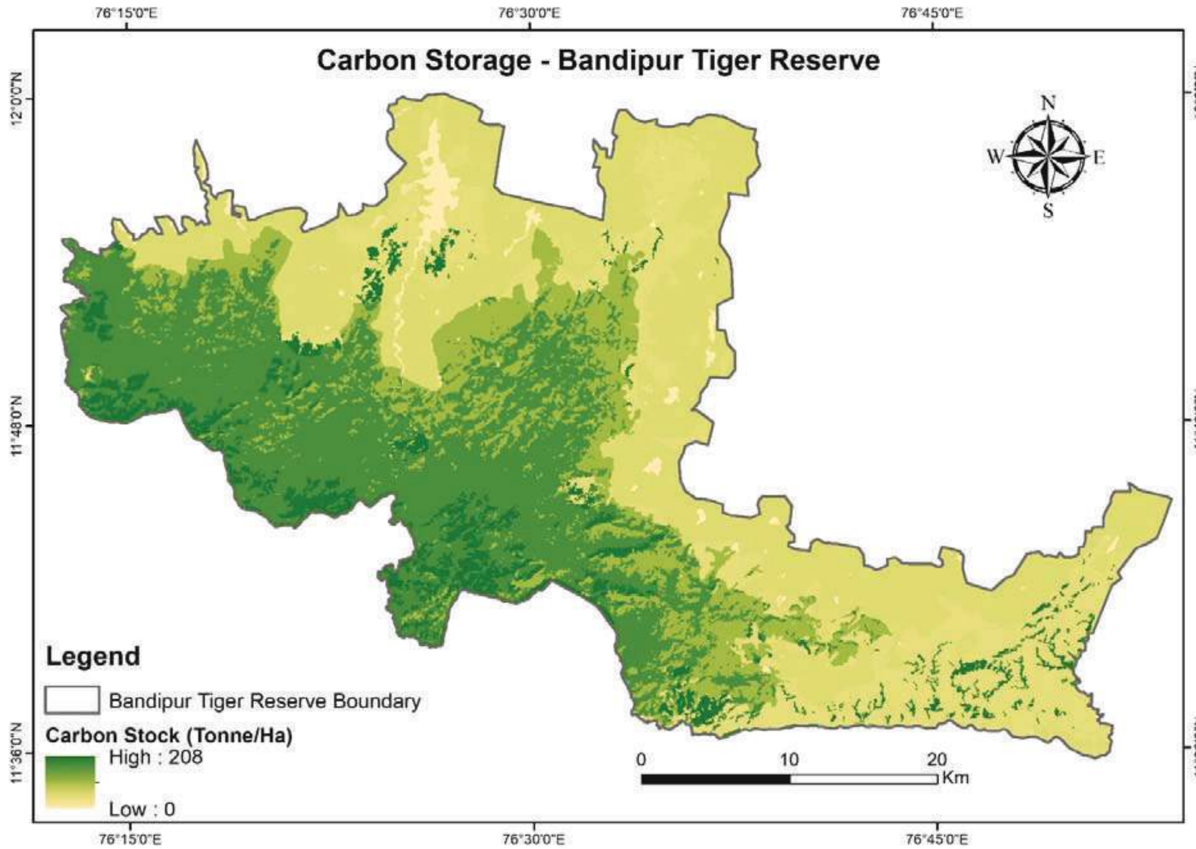



*Figure 6.2-3 Carbon Storage Map of Bandipur Tiger Reserve Created Using InVEST Model*

The estimates from the carbon stock model of InVEST as 15.55 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= Rs. 65as the average for the year 2017-18, the economic value of carbon stock in BTR is calculated as Rs. 86.95 billion.

### 6.2.9.11 Carbon Sequestration

Apart from 15.55 million tonnes of carbon stock in the forests, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database. Based on total biomass per unit area, mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type[120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, the total carbon sequestered in the forests of Bandipur Tiger Reserve by aggregating estimates for each forest type is equal to 345.64 kilo tonnes annually. Detailed calculation is shown in Table 6.2-4.

*Table 6.2-4 Carbon Sequestration in BTR*

| Forest Type | Forest Cover | Total Biomass Per Unit Area (tonnes/ha) | Mean Annual Increment Per Unit Area (tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) | Total Value of Annual Carbon Sequestration (million Rs. per year) |
|---|---|---|---|---|---|---|
| Tropical Semi-Evergreen Forests | VDF | 1082.56 | 35.35 | 16.39 | 289.65 | 11.88 |
| Tropical Semi-Evergreen Forests | MDF | 541.28 | 17.68 | 241.76 | 2136.73 | 87.67 |
| Tropical Semi-Evergreen Forests | OF | 270.64 | 8.84 | 33.84 | 149.56 | 6.14 |
| Tropical Moist Deciduous Forests | VDF | 303.58 | 9.58 | 5799.79 | 27793.73 | 1140.39 |
| Tropical Moist Deciduous Forests | MDF | 405.89 | 12.81 | 42007.76 | 269149.21 | 11043.35 |
| Tropical Moist Deciduous Forests | OF | 135.35 | 4.27 | 21062.98 | 45001.08 | 1846.42 |
| Tropical Dry Deciduous Forests | VDF | 7.23 | 0.26 | 15.61 | 2.03 | 0.08 |
| Tropical Dry Deciduous Forests | MDF | 3.62 | 0.13 | 4004.18 | 260.97 | 10.71 |
| Tropical Dry Deciduous Forests | OF | 1.81 | 0.07 | 26409.45 | 860.60 | 35.31 |
| **Total** | | | | | **345643.56** | **14181.96** |

The social cost of carbon for India as per the latest paper[117] on the economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=65 Rs., the total economic value of annual carbon sequestration in BTR is calculated to be Rs. 14.18 billion.

#### 6.2.9.12 Water Provisioning

Bandipur Tiger Reserve is a part of catchment areas for the rivers Kabini, Nugu and Moyar. There are two main dams in BTR namely the Nugu dam and Kabini dam. Nugu dam is located in Beerwal village under Heggadadevana Kote (H. D. Kote taluk) of Mysore district in Karnataka. The dam is constructed across the river Nugu flowing through the Kaveri basin. The reservoir was built to serve the purpose of irrigation and hydroelectricity generation. The construction of the dam was started in the year 1956-57 and was completed in the year 1959. Its reservoir has a length of 637.65 metres and a height of 43.58 metres above its deepest foundation. The total catchment area of the reservoir is 30.8 thousand hectares[155,156].

The Kabani dam is built on the River Kabini in the district of Mysore. The dam is 696 metres in length and was built in 1974. The dam is situated near village Beechanahally (Taluk) H. D. Kote. Catchment area of the dam is 2141.90 sq kms. It caters to the needs of around 22 villages and 14 hamlets. This dam also provides water to the combined system of Sagaredoddakere and Upper Nugu Dams. There is an arrangement of lifting and transfer of 28.00 TMC of water during the monsoon months from the Kabini dam to two other smaller dams. The dam is spread over an area of 55 hectares covering forests, rivers, lakes and valleys[155,156].

The InVEST model provides various outputs like modelled values of mean actual evapo-transpiration, mean potential evapo-transpiration, water yield volume, etc. The total water yield volume of the study area is around 1121.51 million cubic metres. (Figure 6.2-4).

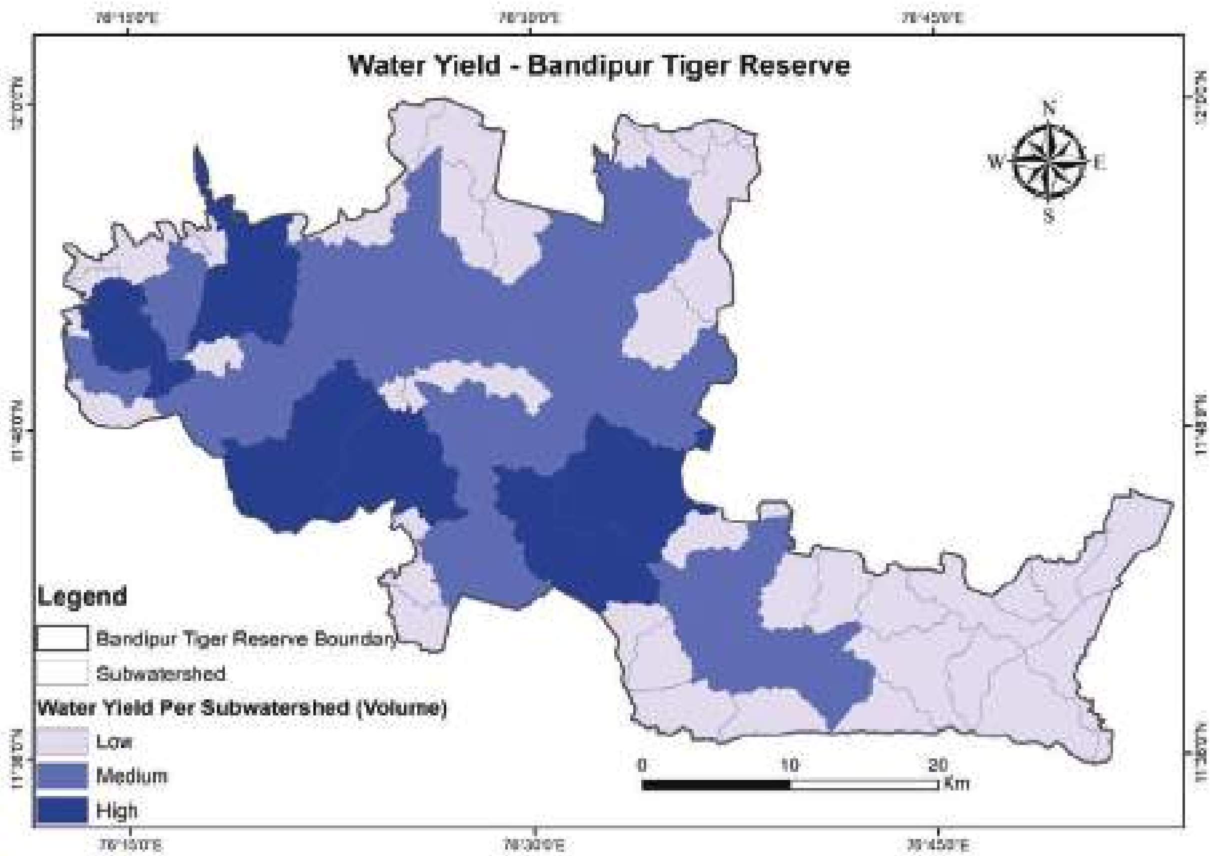



*Figure 6.2-4 Water Yield Output for Bandipur Tiger Reserve Created Using InVEST Model*

Using a monetary value of Rs. 18.43 per cubic metre[1], the economic value of the water provisioning service from BTR is estimated to be Rs. 20.67 billion per year.

### 6.2.9.13 Water Purification

On account of paucity of data on beneficiaries to establish attribution of this ecosystem service to BTR and insufficient information on water treatment facilities, this ecosystem service was not found relevant for BTR and therefore is not included for economic valuation in this study.

### 6.2.9.14 Soil Conservation/Sediment Retention

The InVEST model provides various outputs for spatial analysis of the BTR. Figure 6.2-5 provides spatial details of the total sediment exported to the stream per watershed in the study area. The values of sediment export ranges from 100 tons to 27357 tons per watershed.

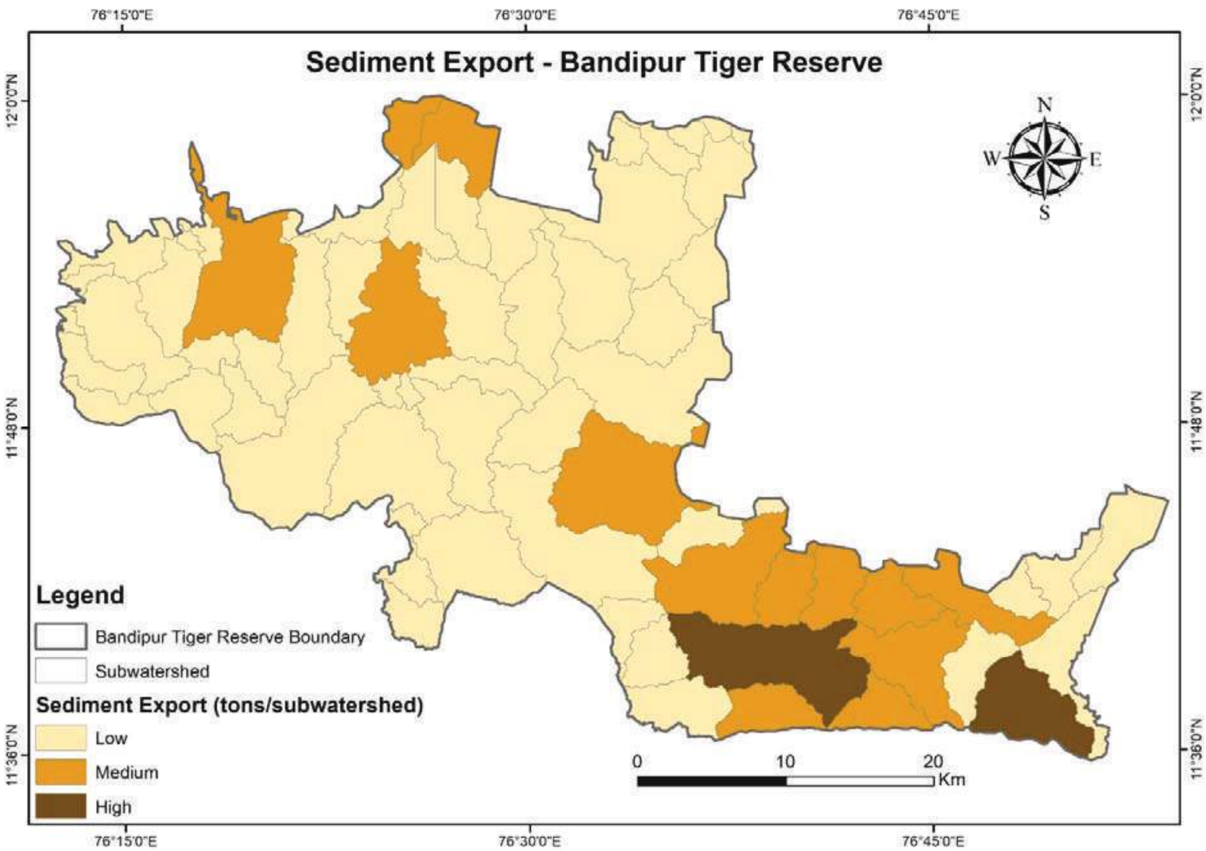



*Figure 6.2-5 Sediment Export from Bandipur Tiger Reserve Created Using InVEST Model*

As shown in Figure 6.2-6 the sediment retention in the BTR landscape is high mainly in the areas with dense forest. The sediment retention values ranges from 10000 tons to 5567900 tons per subwatershed. The sediment retention values are much higher compared to the sediment export values.

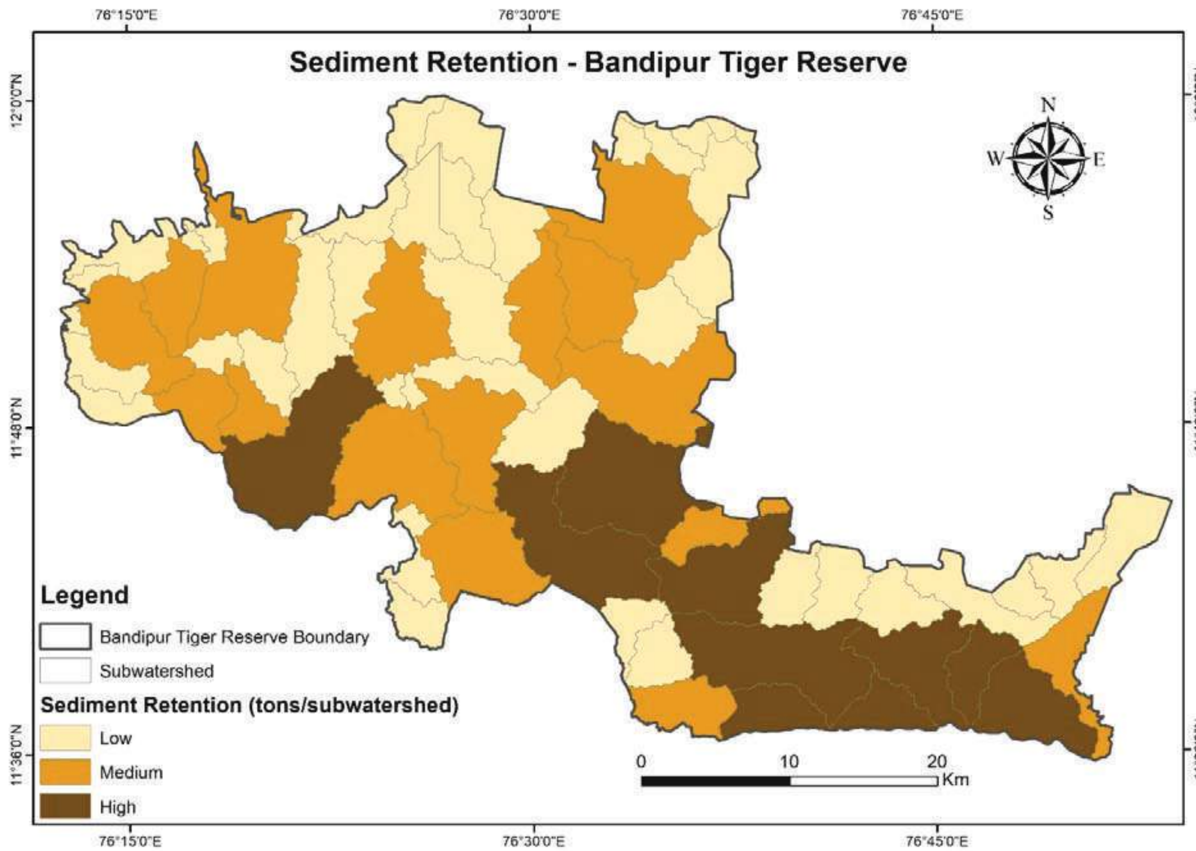



*Figure 6.2-6 Sediment Retention in BandipurTiger Reserve Created Using InVEST Model*

To estimate the economic value of soil loss avoided by the forests of BTR, the cost of dredging/de-siltation has been considered. Because of lack of site-specific data, a cost estimate of Rs. 60 per cubic metre[132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 253.92 million.

### 6.2.9.15 Nutrient Retention

The total soil loss avoided as estimated from the InVEST Sediment Retention model of BTR is around 5.6 million tons. To calculate the amount of nutrients retained, because of lack of local estimates for the same, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust[147] has been used. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations as shown in the Table 6.2-5, the total quantity of nutrients retained is approximately 11782.26 tonnes of N, 22.46 tonnes of P and 41898.12 tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary values have been derived. The total value of nutrient loss prevented by the forests of BTR is equal to Rs. 572 million annually.

*Table 6.2-5 Nutrient Retention in BTR*

| Nutrient | Soil Nutrient Concentration (g per kg) | Total Nutrient Loss Avoided (Tonnes per year) | Fertilizer (Substitute) Used for Valuation | Price of Fertilizer (Rs. per tonne) | Economic Value of Nutrient Retention (million Rs. per year) |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 11782.26 | Urea | 5360 | 63.15 |

| | | | | | |
|---|---|---|---|---|---|
| Phosphorous (P) | 0.044 | 223.46 | DAP | 20100 | 4.49 |
| Potassium (K) | 8.25 | 41898.12 | Muriate of Potash | 12040 | 504.45 |
| **Total** | | **53903.83** | | | **572.10** |

### 6.2.9.16 Biological Control

Using estimates of economic value of biological control for tropical forests (at Rs. 726 per hectare per annum), grasslands (at Rs. 2046 per hectare per annum) and cropland (at Rs. 2178 per hectare per annum) from a global meta-analysis study[116] the economic value of biological control service from 99065.61 hectares of forests, 158.68 hectares of grasslands and 39347.39 hectares of cropland in BTR is estimated to be Rs. 157.94 million per annum.

### 6.2.9.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to BTR; hence, it is not included in the valuation of the BTR ecosystem service in this study.

### 6.2.9.18 Pollination

Using estimates of economic value of pollination for tropical forests (at Rs. 1980 per hectare per annum), grasslands (at Rs. 2310 per hectare per annum) and cropland (at Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 99065.61 hectares of forests, 158.68 hectares of grasslands and 39347.39 hectares of cropland in BTR is estimated to be Rs. 253.65 million per annum.

### 6.2.9.19 Nursery Function

Nursery function was not relevant due to inadequate information and lack of supporting evident linkagesto attribute this service to BTR; hence, it is not included in the valuation of ecosystem service of BTR in this study.

### 6.2.9.20 Habitat for Species

Using estimates of economic value of habitat service for tropical forests (at Rs. 2574 per hectare per annum), grasslands (at Rs. 80124 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 99065.61 hectares of forests, 158.68 hectares of grasslands and 39347.39 hectares of cropland in BTR is estimated to be Rs. 267.71 million.

### 6.2.9.21 Cultural Heritage

BTR has many culturally and historically important areas such as the G.S. Betta and Beladkuppe Mahadeswara temples that are of local and historical importance. The Gopala Swami Betta or G.S. Betta temple is as old as 800 years and is located in the south-eastern portion of the reserve. The main entry gate to the temple is about 5 kms. from Hangala village located on the NH 67 connecting Gundlupet to Ooty. The temple is located at an elevation of 1454.40 metres. The sanctum sanctorum of the temple and its adjoining area spread over an area of 0.3 sq kms, which is earmarked for the temple administration. An annual fair is held during the months of February to March[155,156].

The Beladkuppe Mahadeswara Swami Temple is another major temple located in the reserve. It is in the northern portion of the reserve in the Hediyala Range. The temple has been in existence for about 100 years. It attracts many pilgrims from neighbouring villages and districts. An annual fair is held over a period of 2-3 days in the months of November-December. Other than these two, there is also a Basaveshwara Temple in the N. Begur Range that is also a major pilgrimage site for the local population. Other temples/dargas such as Ainurmarigudi, Gundre Darga, Kanivemallapa Temple etc. exist inside the reserve. However, the visitation by the devotees is observed only once or twice a year[155,156].

### 6.2.9.22 Recreation

BTR attracts many tourists round the year. Moyar gorge, Rolling-rocks and Bolgudda are major tourists spots. BTR is also famous among wildlife and tiger enthusiasts for tiger sighting. People from cities like Bangalore, Coimbatore, etc. are regular visitors. BTR also has luxury lodges like Dhole Resort, Jungle Lodges and Resort, etc. which offer many amenities for the incoming tourists[155,156]. The visitation influx for the last 5 years can be seen in Table 6.2-6. The total number of tourists who visited BTR in the year 2015-16 is equal to 165142 including 163812 Indian and 1330 foreign tourists[156].

*Table 6.2-6 Tourist Visitation in the Last Five Years in BTR*

| Sl. No. | Year | Indians | Foreigners |
|---|---|---|---|
| 1. | 2010-11 | 87784 | 3079 |
| 2. | 2011-12 | 49693 | 1024 |
| 3. | 2012-13 | 63203 | 2280 |
| 4. | 2013-14 | 99164 | 971 |
| 5. | 2014-15 | 76557 | 581 |
| 6. | 2015-16 | 163812 | 1330 |

Revenue generated by the tiger reserve from tourism activities in the year 2015-16 is approximately Rs. 66.86 million [156]. This includes gate receipts, taxes, charges for safari, eco-tourism activities, forest-department owned lodges and resorts, camps and other tourism activities.

To estimate the consumer surplus for BTR, the estimates from study[17] have been used. Nagarhole National Park is located in the Western Ghats biodiversity spot and so is Bandipur Tiger Reserve. Both of them are notified as critical tiger habitats. They study[17] mentions consumer surplus as Rs. 27 per visitor for domestic visitors and Rs. 384 per visitor for foreign visitors in terms of 2013–14 prices (with base year 1993–94=100). Using the same estimates for BTR, for 163812 Indian and 1330 foreign tourists respectively, the economic value of recreation service is around Rs. 4.93 million per annum.

The aggregate value of the revenue generated and recreation value via consumer surplus for BTR is equal to Rs. 71.8 million per year.

#### 6.2.9.23 Spiritual Tourism

The reserve has two major temples i.e. the Himvad Gopalaswami Betta (G.S. Betta) and the Beladkuppe Mahadeswara. Himvad Gopalaswami Betta temple has been in existence for more than 800 years and is located in the G.S. Betta range of the south-eastern portion of the reserve[156]. Located at an elevation of 1454 m, the sanctum sanctorum of the temple and its adjoining areas are spread over 0.3 sq kms, which is earmarked for the temple administration. The annual fair is held in the months of February and March[155].

Beladkuppe Mahadeswara Swami Temple is located in the northern portion of the reserve in the Hediyala Range. The temple is about 100 years old and attracts many pilgrims from neighbouring villages and districts during the annual fair held over a period of 2-3 days in the months of November-December. Another one, Basaveshwara Temple is located in Begur district. Visits to this temple are limited to two short periods per year[155,156]. Other than these two major temple, BTR has many other temples where locals visit during the year[155]. The annual footfall of all the temples[156] is given in Table 6.2-7.

*Table 6.2-7 Numbers of visitors in Temples of BTR each year*

| S. No | Name of the Site | No. of visitors /year |
|---|---|---|
| 1. | Himavad gopalaswamy temple | 25000-30000 |
| 2. | Beladakuppe Sri Mahadeshwaraswamy temple | 345000 |
| 3. | Parvadi betta temple | 6000 |
| 4. | Venkateshwara temple | 20000 |
| 5. | Kasagalapura maramma temple | 10000 |
| 6. | Gundre Maramma temple | 4000 |
| 7. | Thekkalswamy temple | 5000 |
| 8. | Huliyammana temple | 700-800 |

| | | |
|---|---|---|
| 9. | Somanathapura tempie | 5000-8000 |
| 10. | Kanivemallappana temple | 2000-3000 |
| 11. | Alaganchi maramma | 800 |
| 12. | Tavarakatte mahadeshwara temple | 25000 |
| 13. | Basaveshwara temple | 5000 |

### 6.2.9.24 Research, Education and Nature Interpretation

Schoolchildren in close proximity are brought to BTR in tiger reserve vehicles and are educated about its rich natural heritage. Nature education workshops are periodically conducted for 3-4 days at BTR. Nature orientation camps for both rural and urban students are conducted in collaboration with other local organizations. Many research projects are carried out in BTR by independent researchers, organizations and institutes. A total of 23 studies have been conducted in BTR from 2011-12 to 2015-16. Major studies focused on topics like wildlife meta-population analysis, climate change adaptation, lantana spread, biodiversity and ecology linkages (biodiversity hotspots), studies on elephants, studies on leopards and eco-tourism[155].

### 6.2.9.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (at Rs. 792 per hectare per annum) and grasslands (at Rs. 594 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation from 99065.61 hectares of forests, 158.68 hectares of grasslands and 39347.39 hectares of cropland in BTR is estimated to be Rs. 78.55 million.

### 6.2.9.26 Waste Assimilation

Waste Assimilation was not found relevant due to insufficient information and evident linkages to attribute this service to BTR; hence, it is not included in the valuation of the ecosystem service of BTR in this study.

### 6.2.9.27 Climate Regulation

Using estimates of economic value of climate regulation service for tropical forests (at Rs. 134904 per hectare per annum), grasslands (at Rs. 2640 per hectare per annum) and cropland (at Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 99065.61 hectares of forests, 158.68 hectares of grasslands and 39347.39 hectares of cropland in BTR is estimated to be Rs. 14.43 billion.

### 6.2.10 Spectrum of Values- Bandipur Tiger Reserve

BTR provides a variety of values that fall under economic, scientific, educational, cultural and recreational. The following section presents the values in various frameworks.

#### 6.2.10.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| Summary of Ecosystem Services Based on TEV Framework (Flow Benefits) | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **563.46** | **Rs. Million/Year** |
| Fuel wood, Fodder, Timber (Flow), Non-Timber Forest Products, Employment Generation<br>* - Fishing, Bamboo (Flow) | | |
| **Indirect Use Value** | **50855.71** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Option Value** | **12637.36** | **Rs. Million/Year** |
| Genepool Protection | | |

| Summary of Ecosystem Services Based on MA Framework (Flow Benefits) | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **484.90** | **Rs. Million/Year** |
| Employment Generation, Fodder, Timber (Flow), Fuel wood, NTFP<br>* - Fishing, Bamboo (Flow) | | |
| **Regulating Services** | **63237.05** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool Protection<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Cultural Services** | **66.86** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Supporting Services** | **267.71** | **Rs. Million/Year** |
| Habitat for Species | | |

| Summary of Ecosystem Services Based on Stock and Flow Benefits |
|---|

| Type of Value | Value | Unit |
|---|---|---|
| **Flow Benefits** | **64.06** | **Rs. Billion/Year** |
| Employment Generation, Fodder, Timber (Flow), NTFP, Fuel wood, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - Fishing, Bamboo (Flow), Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Stock Benefits** | **314.76** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| **Summary of Ecosystem Services Based on Tangible/Intangible Framework** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Tangible Benefits** | **484.90** | **Rs. Million/Year** |
| Employment Generation, Fodder, Timber (Flow), Fuel wood, NTFP<br>* - Fishing, Bamboo (Flow) | | |
| **Intangible Benefits** | **378333.12** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |

| **Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **21070.42** | **Rs. Million/Year** |
| Fodder, Timber (Flow), Fuel wood, NTFP, Water Provisioning<br>* - Fishing, Bamboo (Flow) | | |
| **Protection from Disease/Predators/Parasites** | **157.94** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **30040.00** | **Rs. Million/Year** |
| Carbon Sequestration, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Climate Regulation, Habitat for Species<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Socio-Cultural Fulfilment** | **150.79** | **Rs. Million/Year** |
| Employment Generation, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |

| | | |
|---|---|---|
| **Ecosystem Assets** | **327398.85** | **Rs. Million** |
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| **Summary Of Ecosystem Services Based on EPA Effect categories** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **378751.16** | **Rs. Million** |
| Employment Generation, Timber (Stock), Timber (Flow), Gene Pool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Soil Conservation/Sediment Retention, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Gas Regulation, Climate Regulation | | |
| **EPA Effect Category 2** | **66.86** | **Rs. Million** |
| Recreation | | |
| **EPA Effect Category 3** | | **Studies** |
| Research, Education And Nature Interpretation | | |
| **EPA Effect Category 4** | | **Major Temples** |
| Cultural Heritage | | |
| **EPA Effect Category 5** | | **Lakh Devotees Per Year** |
| Spiritual Tourism | | |

### 6.2.10.2 Linkages to Human Health

Bandipur Tiger Reserve emanates a range of ecosystem services vital for maintenance of human well-being. Amongst these, Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Biological Control, Pollination, Cultural Heritage, Recreation, Research, Education and Nature Interpretation, Gas Regulation, and Climate Regulation services have huge direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 149.66 billion.

### 6.2.10.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Bandipur Tiger Reserve for the year 2016-17, was about Rs. 71.78 million. Based on the flow benefits of Rs. 64.06 billion per year, for every rupee spent on management costs in BTR, flow benefits of Rs. 716.3 are realized within and outside the tiger reserve.

### 6.2.10.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Bandipur Tiger Reserve was estimated at Rs. 0.44 million (Rs. 4.41 lakhs) per hectare.

### 6.2.10.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 3.06 percent of flow benefits accrue at the local level, 16.01 percent at the national level and 80.93 percent at the global level.

# Dudhwa Tiger Reserve

Located on the Indo-Nepal border, Dudhwa Tiger Reserve (DTR) is a part of Shivalik Hills and Gangetic Plains tiger landscape complex in Uttar Pradesh that provides habitat for unique species including the endangered Rhinoceros and Bengal Florican.

**The tiger reserve generates flow benefits worth Rs. 50.95 billion per year (Rs. 0.53 million per hectare) and stock benefits of Rs. 561.06 billion per year. Key ecosystem services that arise from this reserve include provisioning of water (Rs. 16.43 billion per year), carbon sequestration (Rs. 14.19 billion per year) and climate regulation (Rs. 10.54 billion per year).**

**Under the Total Economic Value (TEV) framework, the annual direct, indirect-benefits and option values were Rs. 89.70 million, Rs. 42.21 billion and Rs. 8.64 billion, respectively**.

As per the MA framework, the value of provisioning services was Rs. 27.98 million per year, that of regulating services was Rs. 50.25 billion per year, cultural services were Rs. 4 million per year and supporting services was Rs. 0.66 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 27.98 million and Rs. 611.98 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 16.43 billion), protection from disease (Rs. 0.16 billion), benign physical and chemical environment (Rs. 25.67 billion), socio-cultural fulfilment (Rs. 25.12 million) and ecosystem assets (Rs. 569.71 billion).

The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 110.13 billion per year. The investment multiplier for DTR was calculated as 573.83.

## 6.3 Dudhwa Tiger Reserve

### 6.3.1 Location, Landscape and Significance

Dudhwa Tiger Reserve (DTR) situated in Uttar Pradesh, comprises three Protected Areas, viz., Dudhwa National Park, Katerniaghat Wildlife Sanctuary and Kishanpur Wild Life Sanctuary, and forest areas of North Kheri Forest Division and South Kheri Forest Division and Shahjahanpur Forest Division. The total inviolate core area spreads in around 1093.79 sq km and buffer area is around 1107.98 sq km. The total area of the reserve is 2201.77 sq km. It is an important part of the Shivalik Hills and Gangetic Plains and is representative of the Terai-Bhabhar bio-geographic subdivision of the Upper Gangetic Plains biogeographic province[158].

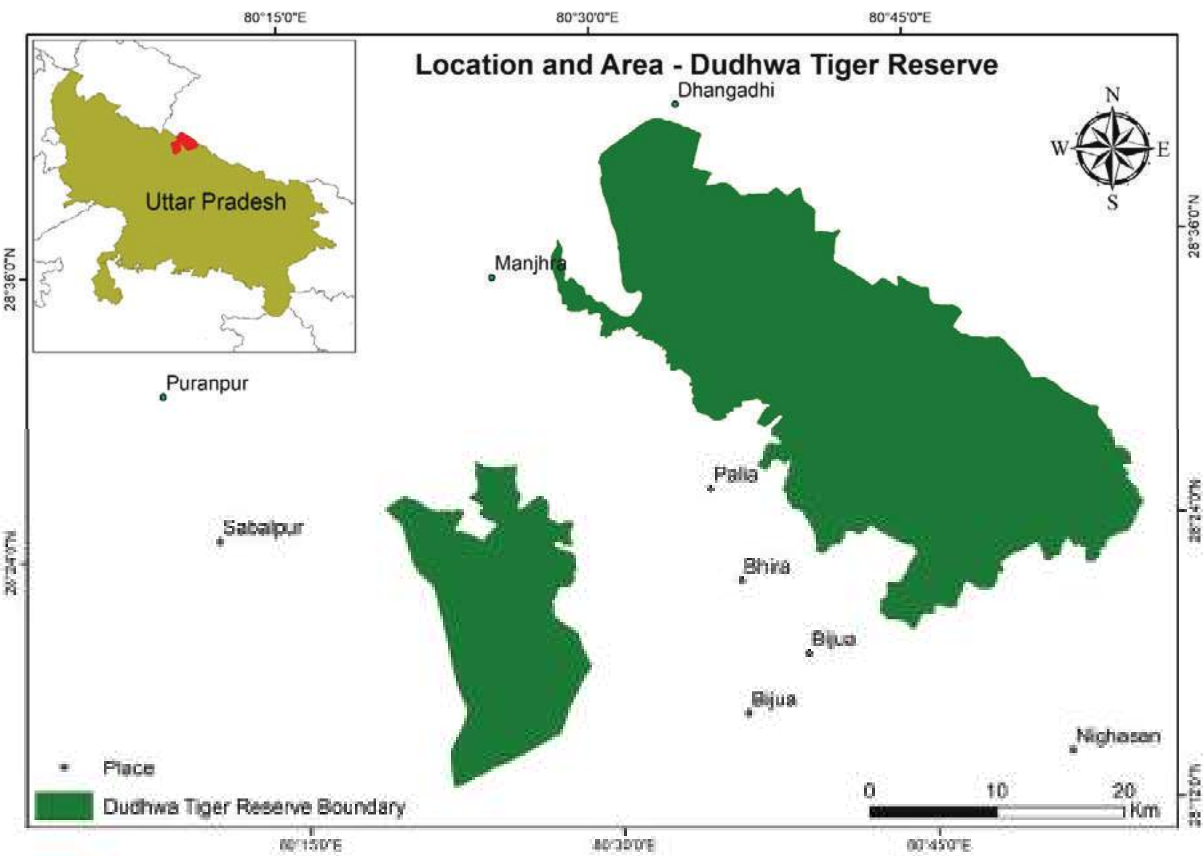



*Figure 6.3-1 Dudhwa Tiger Reserve (Source: Forest Survey of India)*

Terai with its characteristic complex of Sal forests, tall grasslands and swamps maintained by periodic flooding, is one of the threatened ecosystems in India. The vegetation of DTR is North Indian Moist Deciduous type and has one of the finest Sal forests in the country. A significant attribute of the Sal forest ecosystem is interspersed swamps, wet tall grasslands, and dry grasslands or 'phanta', variously dominated by *Saccharum spontaneum, Saccharum narenga, Sclerostachya fusca, Imperata cylindrica, and Vetiveria zizianiodes*. It is an important habitat area for holding a potentially viable population of the nominate sub-species of the swamp deer (*Rucervus duvaucelii duvaucelii* syn *Cervus duvaucelii duvaucelii)*. Of the seven species of deer found in the country, five occur in the reserve. It is also home to a sizeable tiger population. Some critically endangered species such as the Bengal Florican (*Hubaropsis bengalensis*) and Hispid Hare (*Caprolagus hispidus*) find a home here. The Great Indian One Horned Rhinoceros has been successfully reintroduced here [158].

Katerniaghat Wild Life Sanctuary of Dudhwa Tiger Reserve has a strong connectivity with the Bardia National Park, Nepal and Kishanpur Sanctuary has connectivity with the Pilibhit Tiger Reserve in the west. The Dudhwa-Pilibhit complex is one of the largest conservation matrix in the country and the largest in the entire Terai landscape [158].

### 6.3.2 History

Before 1861, most of the terai forests from Khairigarh pargana were under the control of the Raja of Khairigarh for hunting reserves and commercial uses. After 1861, most of them came under the control of the government and a

Conservator of Forests was appointed. Some forests were under private ownership of local "Zamindars". The reserved forests were divided into the North Kheri Forest Division (NKFD) and South Kheri Forest Division (SKFD) on respective sides of the Sharda River. Scientific management of these forests started in 1886 with the development of the first Forest Working Plan. Until 1968 all reserved forests in the region were managed for the commercial production of wood products and for the subsistence need of the local people.

In 1958, relatively small (16 sq km) Sonaripur Wildlife Sanctuary was established with the aim of protecting the population of the swamp deer *(Rucervus duvaucelii duvaucelii).* The area was increased in 1968 and named Dudhwa Wildlife Sanctuary. In 1977 more areas of the North Kheri Forest Division (NKFD) were added to the sanctuary and the enlarged area was declared as Dudhwa National Park (DNP) with designated core and buffer zones. Additional management forests of the North Kheri Forest Division were added to the buffer zone of Dudhwa National Park in 1991. To further protect swamp deer, part of the South Kheri Forest Division (SKFD) was declared as Kishanpur Wild Life Sanctuary (KWLS) in 1981. In 1987, DNP and KWLS were brought together under the 'Project Tiger' as Dudhwa Tiger Reserve (DTR)[158].

### 6.3.3 Topography and Climate

The general terrain description of DTR is given below:

**Dudhwa National Park:** The area of the National Park, in general, has vast alluvial plains scoured with the channels of numerous water courses, large and small. The surface of riverbeds and their high banks form a gentle undulating surface. This results in a series of fairly elevated plateaus formed which are separated by streams flowing from north-west to south-east and each bordered by low alluvial belts of varying width. The general slope of the area is from north-west to south-east. The altitude above mean sea level ranges from 182 m in the extreme north to 150 m in the farthest southeast [158].

**Kishanpur Wild Life Sanctuary:** The area is covered with alluvial soil and has a very gentle slope to south-east with an average elevation of 165 m above mean sea level. With Sarda river changing its course, the high-banks get dredged constantly. On account of the difference in elevation, the quality of the soil and the vegetation, three main divisions are easily distinguishable, viz. the high alluvium or *bangar, khera* or *damar;* the middle alluvium; and the low alluvium or *khadar* or *ganjar.* High alluvium is the oldest formation of the Sarda river; middle alluvium comes next and low alluvium is the most recent formation of the same river. The tract comprising the high and middle alluvium, particularly the latter, is traversed by a number of depressions and water-courses interlinked with each other and running in all directions. These depressions represent the silted up courses of former waterways[158].

**Katerniaghat Wildlife Sanctuary:** The sanctuary area is generally levelled with drainage running from north-west to south-west. Forests of Katerniaghat separate basins of Kauriala and Saryu rivers. The basin of the Kauriala river is intersected by numerous creeks, lakes and swamps which occupy the sites over of the river's earlier course. A larger portion of the WLS lies in the low alluvial plains and in the south, except for Babai block which is at a slightly higher elevation. The Saryu river enters from Nepal and winds along the eastern edge of the forests, showing the western limit that the river flowed at some former period. At most places it has receded for considerable distances towards the east from areas to which it is never likely to return, leaving behind an irregular belt of moist and fertile alluvium[158].

Monsoon in DTR generally begins in the middle of June and lasts up to September. The day and night temperature during the months of July/August is between 37.2°C and 19.8°C respectively. This period accounts for about 90 percent of total annual rainfall. The winters are cold and foggy. January is the coldest month in which the daily minimum temperature can go upto 6.6°C on an average. Dewfall and frost are common in the grasslands. May and June are the hottest months in summer with temperature ranging from 40-44°C [158].

### 6.3.4 Land Cover Classification

According to the land use land cover map obtained from the Forest Survey of India, the Dudhwa Tiger Reserve can be broadly classified into forest, agriculture, wasteland, grassland and habitation (Figure 6.3-2).

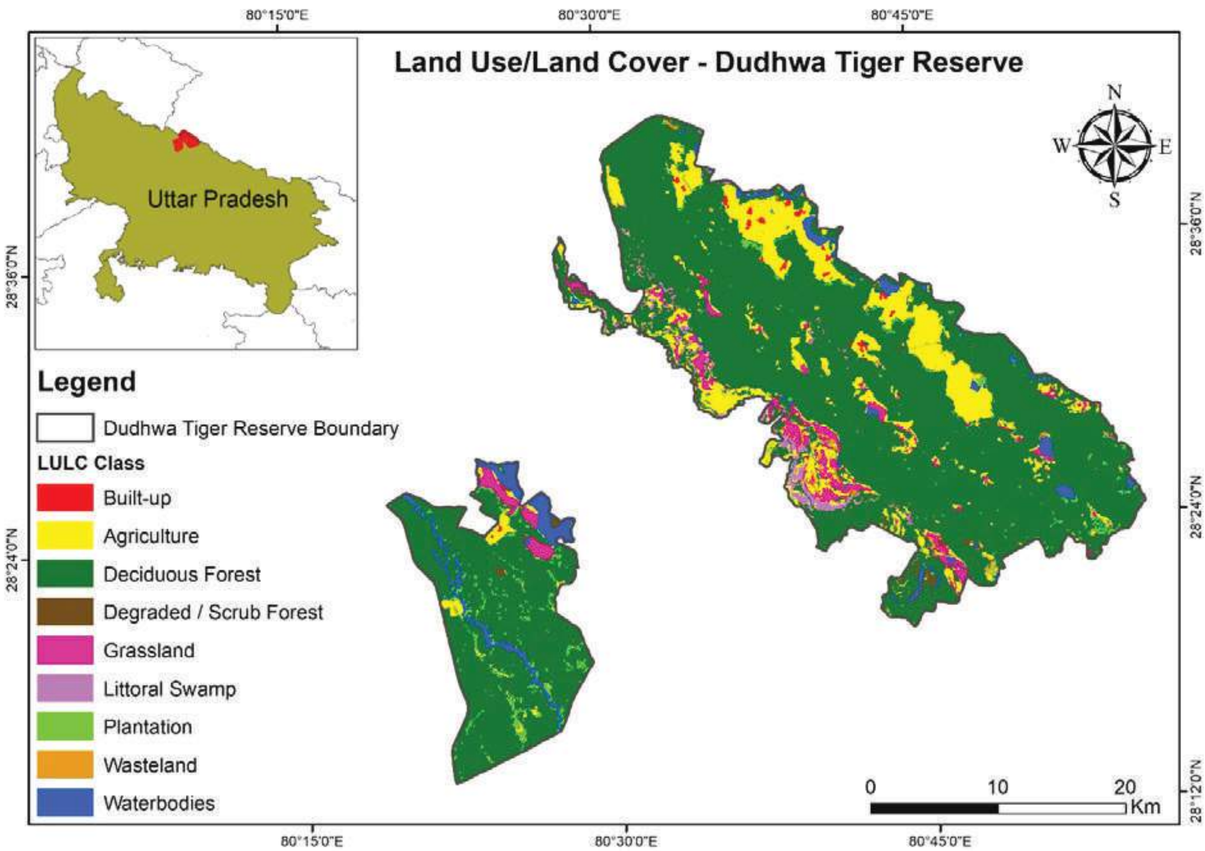



*Figure 6.3-2 Land Use/Land Cover: Dudhwa Tiger Reserve (Source: Forest Survey of India, 2013-2014)*

The area under each of these land cover classes in Dudhwa Tiger Reserve is as shown in the Table 6.3-1. The Tiger Reserve mainly dominates with 75.76 percent of deciduous forest and agriculture with 12.36 percent.

*Table 6.3-1 LULC Classes*

| LULC Class | Area (ha) |
|---|---|
| Agriculture | 11916.25 |
| Built-Up | 340.75 |
| Deciduous Forest | 73036.27 |
| Degraded / Scrub Forest | 885.95 |
| Grassland | 3381.49 |
| Littoral Swamp | 1192.61 |
| Plantation | 1464.09 |
| Wasteland | 605.05 |
| Waterbodies | 3574.72 |

### 6.3.5 Rivers and Hydrology

DTR has a number of rivers, canals and perennial water sources. The Tiger Reserve falls in the catchments area of the Ghagra-Saryu-Sarda rivers. In Dudhwa National Park (DNP) Suheli and Mohana rivers, Kauriala, Gerva, Ull, Barauchha, Joraha, Nagrol, Nakua and Newra nalas (streams), are the major sources of water supply. Suheli and Mohana rivers flow roughly along the southern and northern boundaries of the National Park. Two streams, i.e. Newra and Nagrol have their origins in Nepal. Nagrol further merges with Newra which ultimately merges with Suheli. Joraha flows for a considerable distance almost across the park[158].

There are also several perennial *taals* or lakes such as the Bankey, Kakraha, Chhedia, Bhandara, Chhapra, Amaha, Bhadi, Mutna, Churaila, Puraina, Laudaria, Nagra, Khajua, Chaitua, Dhanghari, Bhadraula, Terhia, etc. located inside the park[158]. In Kishanpur Wildlife Sanctuary, major rivers are Sharda (or Sarda) and Ull. Sharda river constitutes the northern boundary of the WLS, and Barauchha and Ull river pass through the sanctuary. Jhadi Taal is the most important lake in the sanctuary[158].

Katerniaghat Wildife Sanctuary, is blessed with numerous water sources. The major rivers of this WLS are Gerva, Kauriala, Ghagra and Saryu. Gerva river and Kauriala are two streams of river Karnali branching out, before entering India, in Nepal. Both these rivers intersect the forests and meet at Girijapuri barrage. Patalchuhi, a perennial nala, also drains into the convergence and this confluence of rivers forms the river Ghagra. The confluence has prominent aesthetic value but is also an important habitat for birds, including the migratory ones. The system incorporates a number of islands. The sizes of these islands vary according to seasons, and they constitute excellent habitats for animals like rhinos, tigers and elephants. The sanctuary has a good network of nalas ending eventually into one of the above rivers[158].

### 6.3.6 Biodiversity

DTR has a unique blend of habitats like Sal dominated forests, exquisite grasslands, swamps/wetlands and riverine ecosystem. According to Champion and Seth's revised classification of the Forest Types of India[158], the forests of the reserve can be broadly classified as under:

- Northern Semi-Evergreen Forests
- North Indian MoistDeciduous Forests
- Tropical Swamp Forests
- Northern Tropical Dry Deciduous Forests

The northern semi-evergreen forests have cane-breaks; North Indian Moist Deciduous Forests consist of luscious Sal Forests; Tropical Swamp Forests have Barringtonia Swamp Forests and Syzygium Cumini Swamp Forest and Northern Tropical Dry Deciduous Forests consist of dry plain Sal Forests and Sisoo Forests. Vegetation of Katerniaghat WLS has great diversity and varies from dense moist terai Sal forests to large open grasslands. The vegetation close to Gerva river and its tributaries is characterized by the presence of dense canebrakes. Other species occurring along with Sal are Haldu (*Adina cordifolora*), padal (*Stereospermum suaveolens, kusum* (*Schleichera oleosa*) and various species of figs and Ficus species[158].

Grasslands are one of the prominent features of DTR, having nearly one-fifth of the area under grasslands. They are generally located on the southern fringe of the park along the Suheli river. Grasslands of varied dimensions are dispersed throughout the Dudhwa National Park. The area around Jhadi Taal and some stretches along Ull river are the prominent grasslands of the Kishanpur Sanctuary. These grasslands have several endangered species such as Swamp Deer, Tiger, Hispid Hare, Swamp Partridge, the reintroduced Rhinos, Bengal Florican, Black Buck, Python, , etc. The grasslands can be broadly categorized into two, i.e. Naregnga Savannah type (upland areas) and Wet Savannah type (low lying areas). Upland grasslands cover most of the area and are the primary habitat of Swamp deer and Hog deer. Low lying grasslands are typically marshy and are colonized by *Phragmites karka, Arundo donax, Typha* and *Hydroryza*[158].

An important feature of the grasslands is their seasonal flooding and water logging. During the monsoon almost all the grasslands get covered by tall grasses. These are coarse and almost impenetrable due to which animals shift to buffer areas (farmlands). They habitat continuum in the form of paddy, wheat and sugar cane fields that provide food and cover akin to the grasslands of the reserve[158].

Wetlands in DTR are also a prominent habitat type. They include the rivers, streams, lakes and marshes. While many of the major wetlands are perennial, some dry up during summer. The wetlands provide a fairly diverse condition, as a result of which significant variations in vegetative types are found. The extent of area under water varies with the seasons. The wetlands have a diverse vegetation of free floating, suspended and submerged, anchored submerged, anchored with floating leaves, amphibious, and wetland hydrophytes[158].

DTR has a vast and varied heritage of fauna. The hills in the northern part of the Indo-Gangetic plains, innumerable large and small taals, rivers and nalas, vast grasslands, densely forested areas, open woodlands and mixed forests provide a unique admixture of shelter, food and habitat conditions for wildlife. Besides tigers, the most notable feature of the reserve is the existence of the last surviving major population of northern swamp deer (*Rucervus duvaucelii duvaucelii*) in association with four other species of deer, namely Spotted deer or Cheetal, Hog deer, Sambar and Barking deer. It is also home to certain critically endangered species such as the rediscovered Hispid hare, Bengal Florican and the reintroduced Great Indian One-Horned Rhinoceros. The taals, streams and rivers support a rich variety of turtle species (13 spp.), crocodile species (*Crocodylus palustris*), Ghariyal (*Gavialis gangeticus*) and the Gangetic Dolphin (*Plantanista gangetica*). DTR is also a vital habitat for avian fauna. Around 450 bird species including resident and migratory species can be found here like the Bengal floricans, Pied Bushchat, Scarlet Minivet, Citrine Wagtail, Emrald Dove, Paradise Flycatcher, Swamp Francolin, Black-necked Stork, Asian Openbill, Kingfisher, Ruddy Shelduck, Greylag Goose, Northern Shoveer, Gadwall, Red-Crested Pochard, Pintail, etc. Thirteen species of mammals, nine species of birds, eleven species of reptiles and amphibians found here are considered to be endangered and are listed in Schedule–1 of the Wildlife (Protection) Act, 1972[158].

### 6.3.7 Tourism

With its varied topography, diverse flora and fauna and the natural splendour of its lush green landscape dotted with taals (lakes) the stunning virgin beauty of Dudhwa is a veritable paradise for nature and wildlife enthusiasts. This forest of quiet flowing rivers and Sal-dappled glades is tiger and swamp deer country, where unexpected sights and sounds greet us at almost every turn. Dudhwa the one and only national park of Uttar Pradesh has its own charm. Its enchanting hues change from season to season. Starting from Sati Math (Sati monument) in Sathiana to the remnants of the Qila Fort in Bellraien entails the rich history of Dudhwa. Apart from this, the lifestyle of Tharus gives a glimpse of a traditional lifestyle to the tourists[158].

### 6.3.8 Socio-Economic Situation

The surrounds of DTR are cultivated fields. Agriculture is the mainstay of the local economy. Highly fertile soil and high water-table results in good yields. Most of the land holding is under private ownership (30-40 percent) and small land holdings are leased lands. While the average size of the land holding is small, the majority of the farmers having subsistence type of agriculture, a sizeable number of large well managed farms practising highly profitable agriculture on a commercial scale also exist. Major crops are sugarcane, paddy, wheat, pulses, maize and vegetables. Landless people work as labour in the large fields. A small percentage of the population is involved in local business and is employed in services in the government and private sector[158].

People keep a lot of livestock including mulch cattle, draught animals, goats, sheep, pigs and poultry. Economic strength lies with the big farmers. Dudhwa Tiger Reserve has *Tharu* tribals. They are settled cultivators, keep large herds of cattle, some sheep and goats. They have a distinct cultural identity. Most of their villages are enclosed in the northern buffer of the park. A few are located elsewhere in the landscape within close proximity of the tiger reserve. Major Tharu group includes Ranas, Dingoras and Katarias. In Katerniaghat WLS, there are four forest villages in the core area, namely- Bhawanipur, Bichhia, Tedhia and Dhekia constituting about 500 families. Palia is the nearest large township. Buffer has a total of 202 villages and core has 34 villages[158].

### 6.3.9 Valuation Estimates for Dudhwa Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES.

#### 6.3.9.1 Employment Generation

Dudhwa Tiger Reserve is a source of employment for many locals. DTR has around 65 naturalists and guides who work for 7 months when the tiger reserve is open for tourists (from Novermber 15 to June 15)[159]. The trip fee is around Rs. 450 per trip. Assuming that each naturalist/guide gets atleast 10 tripsduring the tourist season, the total days of labour are 650 man-days. DTR also has many fire watchers, daily wages and wireless operators. There are around 326 daily wage workers employed in the field[159]. These workers get wages at the rate of Rs. 175 per day[159]. Total employment generated is equal to 119640 man-days. The value of total employment generation from Dudhwa Tiger Reserve is approximately 21.12 million.

#### 6.3.9.2 Fishing

Fishing is not allowed in DTR and hence is not included for valuation in this study.

#### 6.3.9.3 Fuelwood

Around 500 families live in the villages of the buffer area of DTR[158,159]. Due to in sufficient information on actual fuelwood collection in DTR, extrapolation using per capita fuelwood requirement is used for valuation of this service. As per the National Sample Survey Organisation survey (2001) estimates the per capita fuelwood requirement is 17.7 kg per capita per month for rural areas[157]. For the sake of calculation, it is assumed that there is an average of four members in each family and fuelwood collection is only done for six months from the buffer area. The total fuelwood collection for DTR is calculated as 212.4 tonnes approximately. Using a local market price of Rs. 2 per kg, the total economic value of fuelwood collection from DTR is Rs. 0.428 million per year.

#### 6.3.9.4 Fodder/Grazing

Owing to inadequate information on dependent Adult Cattle Units in DTR, the same has been derived from Corbett Tiger Reserve (CTR). As per the Verma et al. (2015) study there were 2929 Adult Cattle Units (ACUs) in CTR[1]. To obtain a conservative estimate, it is assumed that DTR contains fifty percent of ACU as compared to CTR. Due to absence of data on stall feeding it is assumed that the cattle graze only for 200 days in a year. Using the standard forage quantity of 22 kg per cattle unit per day[107], the total fodder consumption comes to around 6.4 kilo tonnes. A minimum local market price of Re. 1 per kg is taken for valuation purposes. Thus the economic value of grazing service provided by DTR is calculated as Rs. 6.44 million per year.

#### 6.3.9.5 Standing Timber (Stock)

The standing stock of DTR has immense value. To estimate the economic value of the standing stock, growing estimates of timber species from the forest inventory database[108] of the Forest Survey of India (FSI) have been used. It is estimated that approximately 20.05 million cubic metres of standing stock of timber is contained in DTR as shown in Table 6.3-2. In monetary terms, using an average price of Rs. 25000 per cubic metre after discounting for transportation and maintenance cost, the standing stock has value equal to Rs. 501.13 billion.

*Table 6.3-2 Timber Stock in DTR*

| Forest Type | Forest Cover | Growing Stock (Cubic m per ha) | Area (ha) | Total Growing Stock(in thousand cubic m) | Economic Value (in million rupees) |
|---|---|---|---|---|---|
| Tropical Moist Deciduous Forests | VDF | 301.71 | 55096.86 | 16623.1 | 415577.90 |
| Tropical Moist Deciduous Forests | MDF | 172.20 | 6307.06 | 1086.1 | 27151.88 |
| Tropical Moist Deciduous Forests | OF | 154.80 | 3687.49 | 570.8 | 14270.59 |
| Littoral and Swamp Forests | VDF | 125.53 | 1261.51 | 158.4 | 3959.05 |
| Littoral and Swamp Forests | MDF | 62.77 | 812.32 | 51.0 | 1274.67 |
| Littoral and Swamp Forests | OF | 60.93 | 3311.16 | 201.7 | 5043.32 |
| Plantation/TOF | MDF | 96.28 | 2401.24 | 231.2 | 5779.82 |
| Non-Forest | | 53.22 | 21106.43 | 1123.3 | 28082.15 |
| **Total** | | | | **20045.6** | **501139.37** |

For Dudhwa Tiger Reserve, the growing stock estimates for Littoral and Swamp Forests- MDF category have been derived from VDF by taking 50 percent of its value.

#### 6.3.9.6 Timber Flow

No timber harvesting is recorded in DTR and hence the economic value of flow benefits from this service in DTR is zero.

#### 6.3.9.7 Bamboo

Owing to inadequate data and other relevant information to calculate the annual bamboo collection, the economic value of this service has not been estimated in monetary terms in this study.

#### 6.3.9.8 Non-Timber Forest Produce

Some villages and local communities are dependent on DTR for basic requirements like food, fodder, medicine, small timber for construction of huts and agricultural implements, handicrafts, social and religious ceremonies[158]. Due to shortage of data and other relevant information to calculate the annual NTFP collection, the economic value of this service has not been estimated in monetary terms in this study.

> **Dudhwa Tiger Reserve: Ecosystem and Fuana (Source: Dudhwa Tiger Reserve: Tiger Conservation Plan)**
>
> DTR comprises unique complex wood land–grassland–wetland ecosystem which harbours a variety of floral and faunal diversity, including several charismatic and obligate species, viz.,Tiger *(Panthera tigris tigris),* great one-horned rhinoceros *(Rhinoceros unicornis)*, Swamp deer *(Rucervus duvaucelii duvaucelii* syn *Cervus duvaucelii duvaucelii)*, Bengal Florican *(Hubaropsis bengalensis)* and Hispid Hare *( Caprolagus hispidus)*.Dudhwa National Park is the only place in the country to hold a potentially viable population of sub-species of swamp deer *(Rucervus duvaucelii duvaucelii* syn *Cervus duvaucelii* [158]

#### 6.3.9.9 Genepool Protection

Due to the lack of comprehensive primary data, the method of benefits-transfer has been used for valuation of this service. Using estimates of economic value of genepool protection for tropical forests (Rs. 100122 per hectare per annum), grasslands (Rs. 80124 per hectare per annum), wetlands (Rs. 68772 per hectare per annum) and cropland (Rs. 68772 per hectare per annum) from a global meta-analysis study[116], the annual economic value of this service from 75386.30 hectares of forests, 3381.49 hectare of grasslands, 1192.61 hectares of wetlands, and 11916.25 hectare of cropland in DTR is estimated to be Rs. 8.64 billion.

#### 6.3.9.10 Carbon Storage

The carbon storage for the Dudhwa Tiger reserve has been quantified and spatially mapped using InVEST modelling. Since no research exists on the quantity of carbon stored in various pools, estimates from the report of carbon stock in India's forests, the Forest Survey of India have been used. The estimated carbon stored in four major pools – above ground biomass (above ground biomass (AGB), below ground biomass (BGB), dead wood (DW), litter and soil organic matter (SOM) for major forest types of Uttar Pradesh is shown in **Error! Reference source not found.**.

| Vegetation class | Forest Cover | Carbon Stock in Various Pools(tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total carbon Stock (million tC) |
|---|---|---|---|---|---|---|---|---|
| | | AGB | BGB | SOM | DW (incl. litter) | | | |
| Littoral and Swamp Forests | VDF | 75.57 | 26.15 | 86.38 | 1.27 | 189.37 | 1261.51 | 0.24 |
| Littoral and Swamp Forests | MDF | 44.48 | 15.38 | 56.81 | 0.69 | 117.37 | 812.32 | 0.10 |
| Littoral and Swamp Forests | OF | 14.31 | 4.95 | 33.03 | 0.40 | 52.69 | 3311.16 | 0.17 |
| Non Forest | | 1.31 | 0.11 | 15.32 | 0.00 | 16.74 | 21106.43 | 0.35 |
| Plantation/TOF | VDF | 32.44 | 6.68 | 92.12 | 1.64 | 132.87 | 656.51 | 0.09 |
| Plantation/TOF | MDF | 28.51 | 5.86 | 65.67 | 1.84 | 101.88 | 912.97 | 0.09 |
| Plantation/TOF | OF | 10.08 | 2.07 | 38.92 | 0.62 | 51.69 | 831.77 | 0.04 |
| Tropical Dry Deciduous Forests | VDF | 63.18 | 24.81 | 53.49 | 7.77 | 149.25 | 236.62 | 0.04 |
| Tropical Dry Deciduous Forests | MDF | 59.84 | 23.50 | 39.33 | 0.85 | 123.52 | 524.70 | 0.06 |
| Tropical Dry Deciduous Forests | OF | 10.46 | 4.11 | 25.60 | 0.59 | 40.74 | 422.81 | 0.02 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tropical Moist Deciduous Forests | VDF | 73.84 | 15.19 | 60.75 | 3.97 | 153.73 | 55096.86 | 8.47 |
| Tropical Moist Deciduous Forests | MDF | 45.98 | 9.46 | 60.13 | 3.59 | 119.16 | 6307.06 | 0.75 |
| Tropical Moist Deciduous Forests | OF | 18.00 | 3.70 | 55.83 | 1.99 | 79.52 | 3687.49 | 0.29 |
| **Total** | | | | | | | | **10.72** |

It can be noted that the non-forest area comprises mostly agriculture land. The average values of major crops like wheat, black gram, pigeon pea and green gram have been taken to calculate the AGB and BGB carbon pools[152]. While to calculate the carbon density in soil for the non-forest area the values of Soil Organic Carbon (SOC) has been referred based on the agro-ecological region[153]. The carbon pools of water have been assumed to be 0.

The InVEST model provides output in the form of a carbon spread map and a summary table. According to the model, Dudhwa Tiger Reserve stores approximately 10.72 million tonnes of carbon. The other output is received in the form of a map where the stored carbon values are mapped spatially across the landscape(Figure 6.3-3).

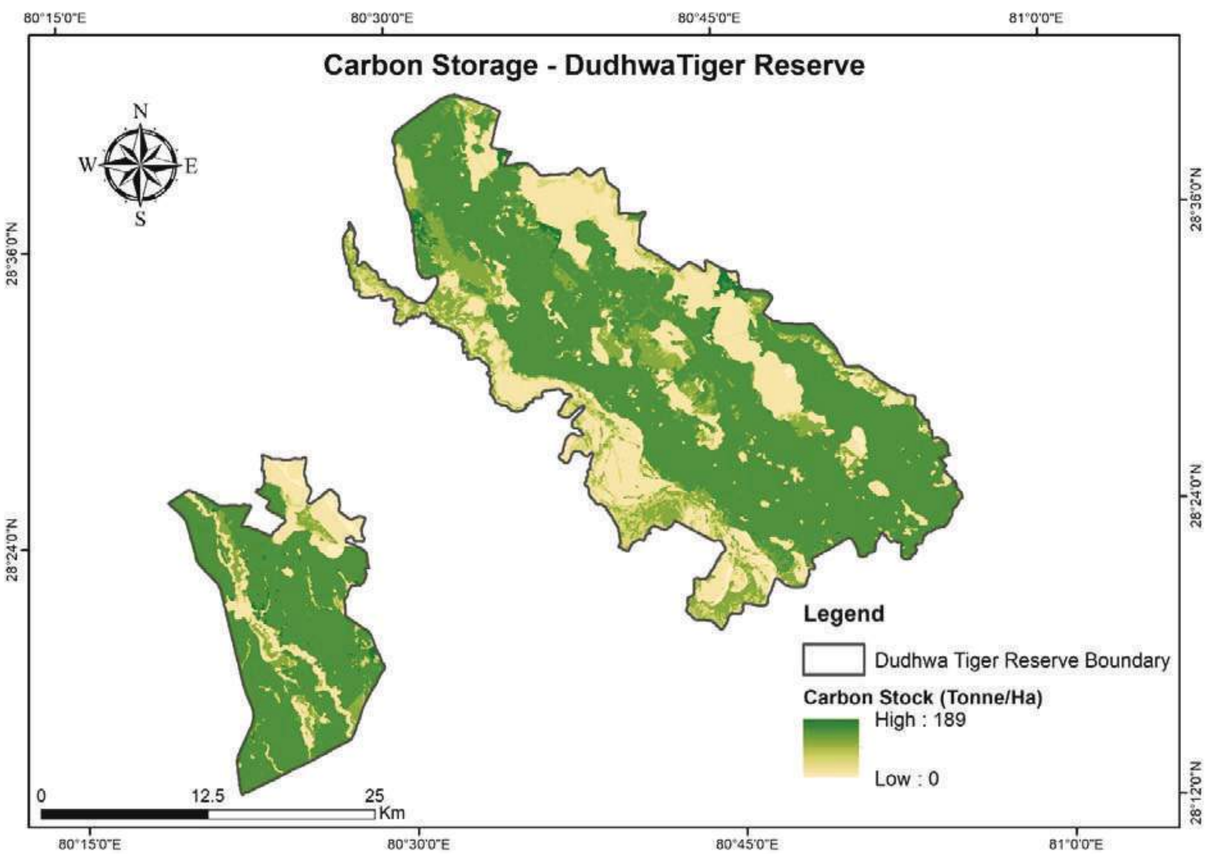



*Figure 6.3-3 Carbon Storage Map of Dudhwa Tiger Reserve Created Using InVEST Model*

The estimates from the Carbon Stock model of InVEST as 10.72 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= Rs. 65 as the average for the year 2017-18, the economic value of carbon stock in DTR is calculated as Rs. 59.92 billion.

### 6.3.9.11 Carbon Sequestration

Apart from 10.72 million tonnes of carbon stock in the forests of Dudhwa Tiger Reserve, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database. Based on total biomass per unit area, mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type[120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in the above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, the total carbon sequestered in the forests of Dudhwa Tiger Reserve by aggregating estimates for each forest type is equal to 345.96 kilo tonnes annually. Detailed calculation is shown in Table 6.3-3.

*Table 6.3-3 Carbon Sequestration in DTR*

| Forest Type | Forest Cover | Total Biomass Per Unit Area (Tonnes/ha) | Mean Annual Increment Per Unit Area (Tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) | Total Value of Annual Carbon Sequestration (Million Rs. per Year) |
|---|---|---|---|---|---|---|
| Tropical Semi-Evergreen Forests | VDF | 1082.56 | 39.73 | 16.39 | 325.49 | 13.35 |
| Tropical Semi-Evergreen Forests | MDF | 541.28 | 19.86 | 241.76 | 2401.12 | 98.52 |
| Tropical Semi-Evergreen Forests | OF | 270.64 | 9.93 | 33.84 | 168.07 | 6.90 |
| Tropical Moist Deciduous Forests | VDF | 303.58 | 9.58 | 5799.79 | 27793.73 | 1140.39 |
| Tropical Moist Deciduous Forests | MDF | 405.89 | 12.81 | 42007.76 | 269149.21 | 11043.35 |
| Tropical Moist Deciduous Forests | OF | 135.35 | 4.27 | 21062.98 | 45001.08 | 1846.42 |
| Tropical Dry Deciduous Forests | VDF | 7.23 | 0.26 | 15.61 | 2.03 | 0.08 |
| Tropical Dry Deciduous Forests | MDF | 3.62 | 0.13 | 4004.18 | 260.97 | 10.71 |
| Tropical Dry Deciduous Forests | OF | 1.81 | 0.07 | 26409.45 | 860.60 | 35.31 |
| **Total** | | | | **99591.77** | **345962.30** | **14195.04** |

The social cost of carbon for India is as per the latest paper[117]. The economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=Rs. 65, the total economic value of annual carbon sequestration in DTR is calculated to be Rs. 14.19 billion.

### 6.3.9.12 Water Provisioning

Dotted with a number of shallow lakes and taals, there are iverse perennial sources of freshwater in the reserve. The Sharda river flows by Kishanpur WLS, the Girwa river flows through Katerniaghat WLS and Suheli and Mohana rivers flow through Dudhwa National Park. Some of the importanttaals are Bankey, Kakraha, Amaha, Jhadi, Bhadi, Tiger taal and Bhadraula [158,159].

The InVEST model provides various outputs for spatial analysis of the area. It provides raster and shapefile where various outputs can be spatially studied. It also provides the estimated values of mean actual evapo-transpiration, mean potential evapo-transpiration, water yield volume, etc. The total water yield volume from DTR as well as its fringe areas amounts to 891.56million cubic metres. (Figure 6.3-4).

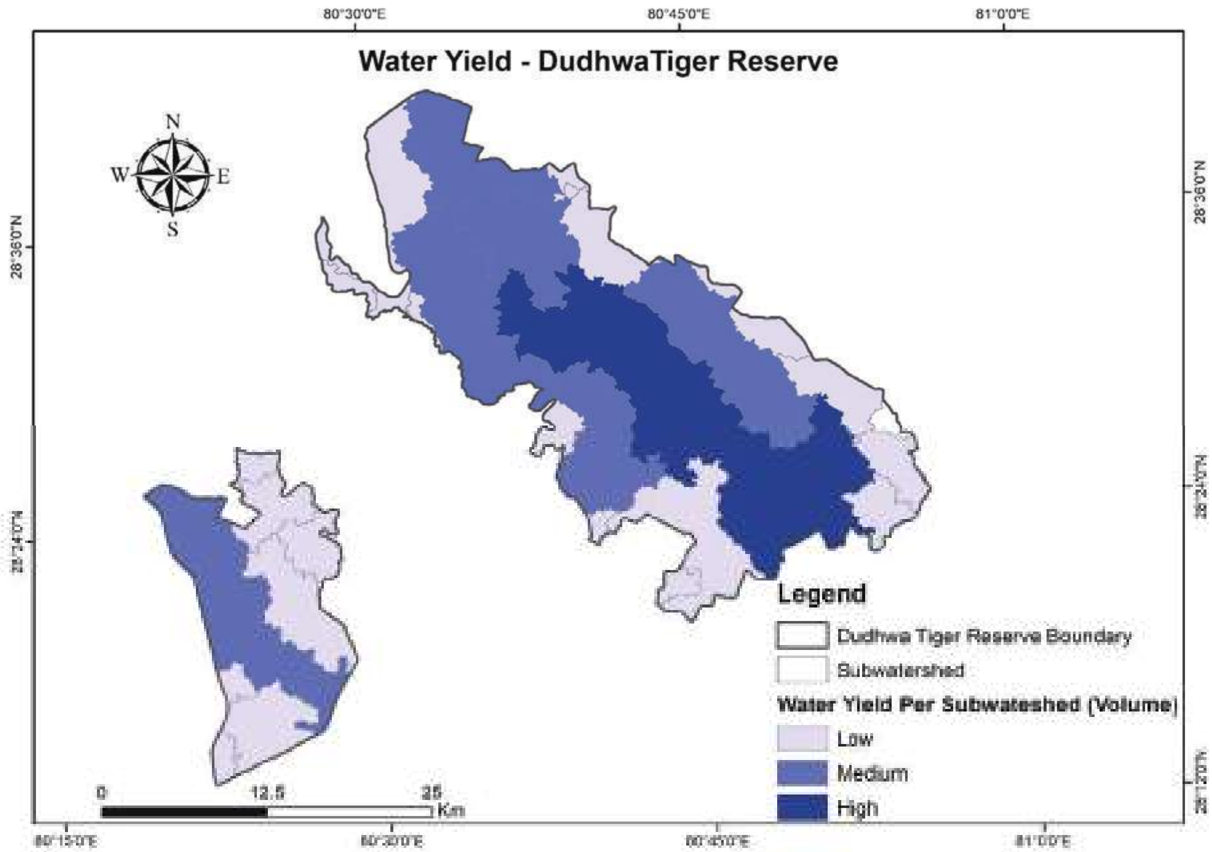



*Figure 6.3-4 Water Yield Output for Dudhwa Tiger Reserve Created Using InVEST Model*

Using the monetary value of Rs. 18.43 per cubic metre[1], the economic value of water provisioning service from DTR is estimated to be 16.43 billion per year.

### 6.3.9.13 Water Purification

On account of insufficient data on beneficiaries to establish attribution of this ecosystem service to DTR and lack of information on local water treatment facilities, this ecosystem service was not found relevant for DTR and therefore is not included for economic valuation in this study.

### 6.3.9.14 Soil Conservation/Sediment Retention

The model provides various outputs for spatial analysis of the area. Figure 6.3-5 provides spatial details of the total sediment exported to the stream per watershed in the study area. The value of sediment export ranges from 10 tons to 1930 tons per subwatershed.

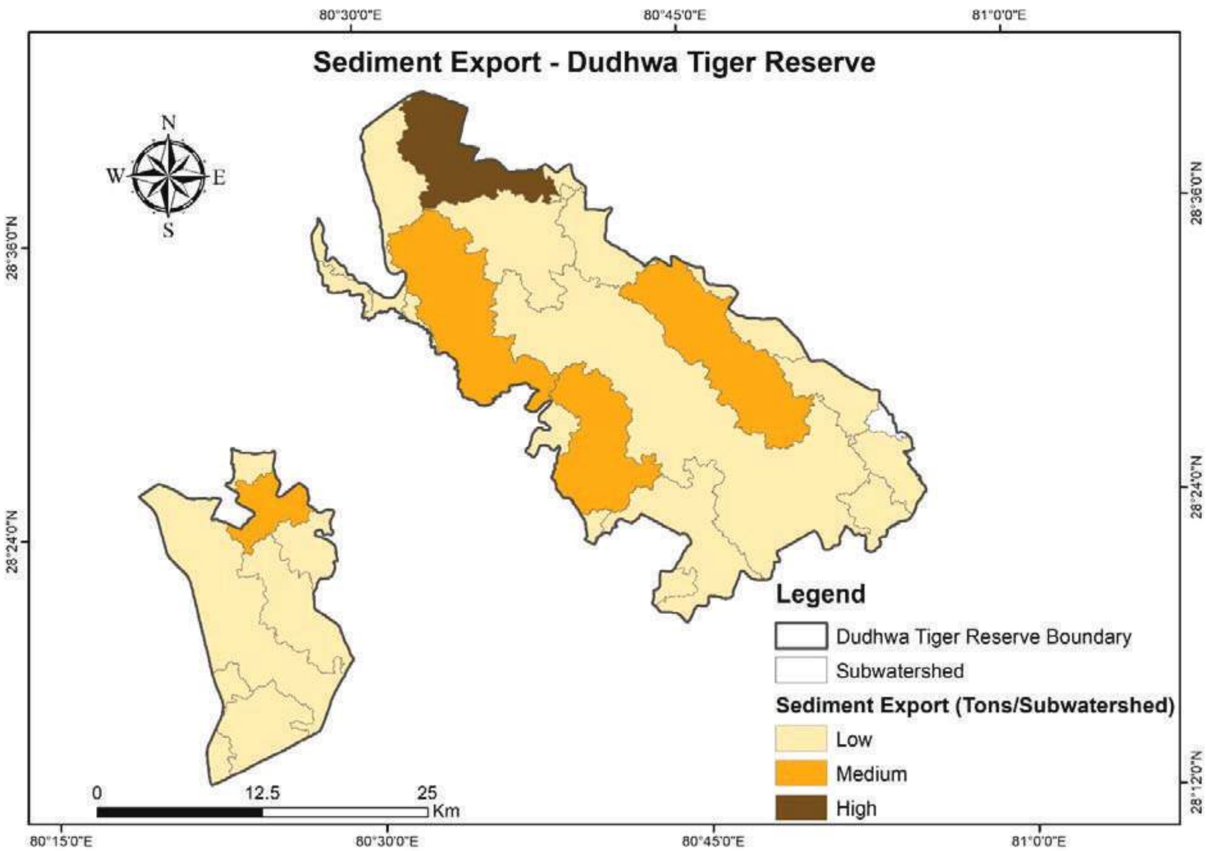



*Figure 6.3-5 Sediment Export from Dudhwa Tiger Reserve Created Using InVEST Model*

As shown in Figure 6.3-6 the sediment retention values in the DTR landscape are higher in the watersheds lying in highly forested areas. The values of sediment retention values range from 500 tons to 356800 tons per watershed.

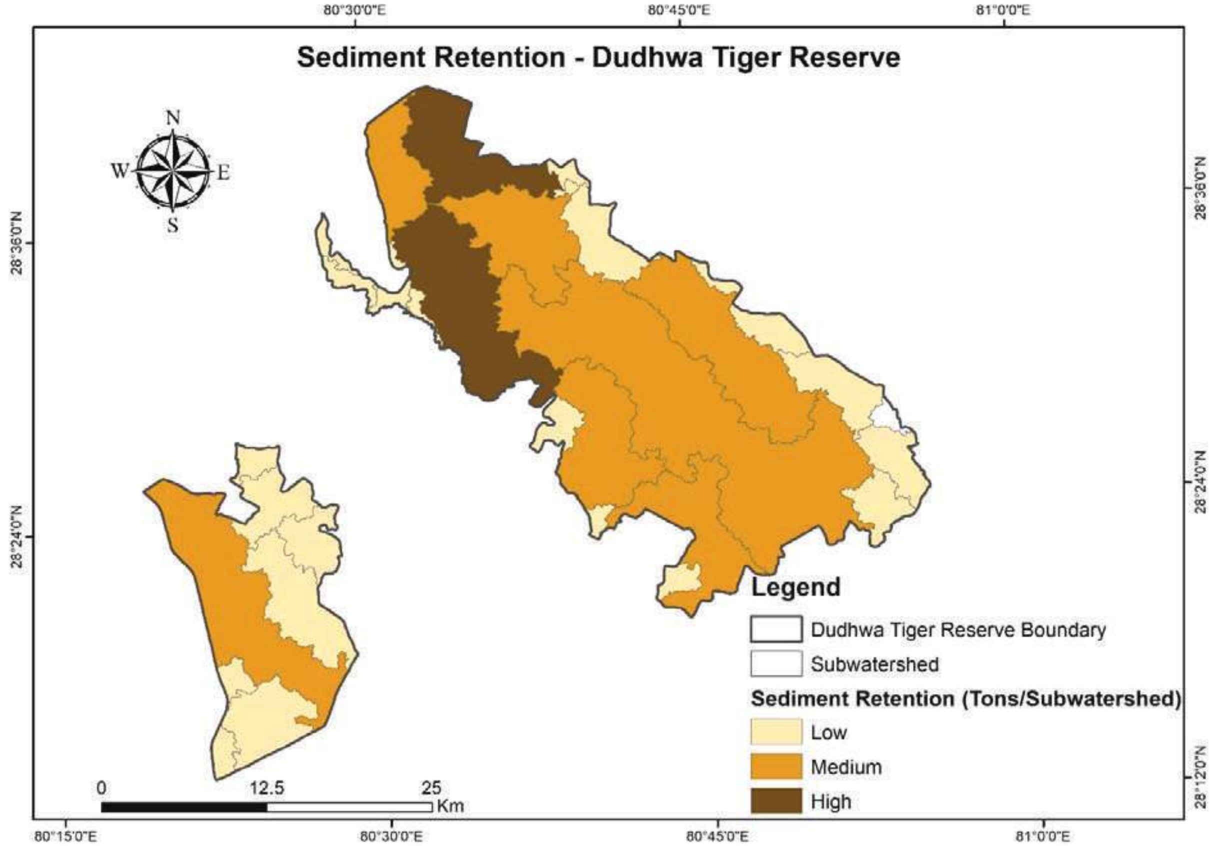



*Figure 6.3-6 Sediment Retention in Dudhwa Tiger Reserve Created Using InVEST Model*

To estimate the economic value of soil loss avoided by the forests of DTR, the cost of dredging/de-siltation has been considered. On account of lack of site-specific data, a cost estimate of Rs. 60 per cubic metre[132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 14.59 million.

### 6.3.9.15 Nutrient Retention

The total soil loss avoided from the InVEST Sediment Retention model of DTR is around 321699.5 tons. To calculate the amount of nutrient retained, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust [147] has been used on account of lack of local estimates for the same. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations from the Table 6.3-4**Error! Reference source not found.**, the total quantity of nutrients retained is approximately 677.07 tonnes of N, 12.84 tonnes of P and 2407.69 tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary value has been derived. The total value of nutrient loss prevented by the forests of DTR is equal to Rs. 32.88 million annually.

*Table 6.3-4 Nutrient Retention in DTR*

| Nutrient | Soil Nutrient Concentration (g Per Kg) | Total Nutrient Loss Avoided (Tonnes Per Year) | Fertilizer (Substitute) Used for Valuation | Price of Fertilizer (RS. Per Tonne) | Economic Value of Nutrient Retention (Million Rs. Per Year) |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 677.07 | Urea | 5360 | 3.63 |
| Phosphorous (P) | 0.044 | 12.84 | DAP | 20100 | 0.26 |
| Potassium (K) | 8.25 | 2407.69 | Muriate of Potash | 12040 | 28.99 |

| | | | | | |
|---|---|---|---|---|---|
| **Total** | | **3097.60** | | | **32.88** |

### 6.3.9.16 Biological Control

Using estimates of economic value of biological control for tropical forests (Rs. 726 per hectare per annum), grasslands (Rs. 2046 per hectare per annum), wetlands (Rs. 62568 per hectare per annum) and cropland (Rs. 2178 per hectare per annum) from a global meta-analysis study[116] the economic value of biological control service from 75386.30 hectares of forests, 3381.49 hectare of grasslands, 1192.61 hectare of wetlands, and 11916.25 hectares of cropland in DTR is estimated to be Rs. 162.22 million.

### 6.3.9.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to DTR, hence it is not included in the valuation of ecosystem service of DTR in this study.

### 6.3.9.18 Pollination

Using estimates of economic value of pollination for tropical forests (Rs. 1980 per hectare per annum), grasslands (Rs. 2310 per hectare per annum) and cropland (Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 75386.30 hectares of forests, 3381.49 hectares of grasslands and 11916.25 hectares of cropland in DTR is estimated to be Rs. 174.38 million.

### 6.3.9.19 Nursery Function

The nursery function was not found relevant due to shortage of information and evident linkages to attribute this service to DTR, hence it is not included in the valuation of the ecosystem service of DTR in this study.

### 6.3.9.20 Habitat for Species

Using estimates of economic value of habitat service for tropical forests (Rs. 2574 per hectare per annum), grasslands (Rs. 80124 per hectare per annum) and wetlands (Rs. 162030 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 75386.30 hectares of forests, 3381.49 hectares of grasslands and 1192.61 hectares of wetlands in DTR is estimated to be Rs. 658.22 million.

### 6.3.9.21 Cultural Heritage

Tharu tribals inhabit DTR. They are related to the Tharu in the Terai areas of Nepal. The major Tharu groups include the Ranas, Dingoras and Katharias. Once their habitations were forest villages but now most of these are revenue villages. The Tribal Area Development Schemes have benefitted these people. They have adopted modern farming techniques and have slowly shifted from subsistence level farming to raising cash crops[158].

### 6.3.9.22 Recreation

Dudhwa National Park along with Kishanpur WLS and Katerniaghat WLS represent best natural forests and grasslands of the Terai region of Uttar Pradesh. These three being the only habitats of tiger in the state have been jointly constituted as Dudhwa Tiger Reserve under Project Tiger. Although the 3 PAs are separate from each other they are linked by tracts of contiguous dense forests. These ecosystems in the Terai region are highly productive habitats of diverse flora and fauna. With its varied topography, lush green landscapes, exquisite wetlands and remarkable biodiversity, DTR is equivalent to a paradise for nature lovers and wildlife enthusiasts[158,159]. DTR is open for tourists from November 15 to June 15 every year [159]. The total number of tourists who visited in the year 2015-16 to DTR is equal to 21904 including 21820 Indian and 84 foreign tourists[159].

Revenue generated by the tiger reserve by tourism activities in the year 2015-16 is approximately Rs. 4 million. This includes gate receipts, taxes, charges for safari, eco-tourism activities, forest-department owned lodges and resorts, camps and other tourism activities. Due to paucity of information on WTP, the economic value of this service is taken as Rs. 4 million[159].

### 6.3.9.23 Spiritual Tourism

The reserve has many small temples and places of religious importance like Shiv Temple, Madha Baba Temple, Suheli Baba, Kila Shah Tomb, Goddess Kali Temple, Sati Math, and Karinga Kot Baba and Nauranga Baba. Many of these are very old temples. Some of them have an annual fair which is attended by local tribes. There is no recorded data on annual footfall on these sites [158,159].

### 6.3.9.24 Research, Education and Nature Interpretation

The unique ecosystem of DTR offers high potential for research studies. The blend of wetland, grassland, riverine and forest ecosystems provide ample topics for researchers to explore the wilderness. Due to inadequate recorded data on the number of research studies conducted in DTR, these have not been included in this study.

### 6.3.9.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (Rs. 792 per hectare per annum) and grasslands (Rs. 594 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation 75386.30 hectares of forests and 3381.49 hectares of grasslands in DTR is estimated to be Rs. 61.71 million.

### 6.3.9.26 Waste Assimilation

Waste assimilation was not found relevant due to scarcity of information and evident linkages to attribute this service to DTR. Hence it is not included in the valuation of ecosystem service of DTR in this study.

### 6.3.9.27 Climate Regulation

DTR plays an important role in the maintenance of water and climatic regime of the region and thereby sustaining agricultural productivity and overall well-being. Using estimates of economic value of climate regulation service for tropical forests (Rs. 134904 per hectare per annum), grasslands (Rs. 2640 per hectare per annum) wetlands (Rs. 32208 per hectare per annum) and cropland (Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 75386.30 hectares of forests, 3381.49 hectares of grasslands, 1192.61 hectares of wetlands, and 11916.25 hectare of cropland in DTR is estimated to be Rs. 105.4 billion.

## 6.3.10 Spectrum of Values- Dudhwa Tiger Reserve

DTR provides a variety of values that fall under economic, scientific, educational, cultural and recreational values. Global and National Values include the conservation of representative biodiversity and endangered species such as the Tiger, One-Horned Rhinoceros, Swamp Deer, Bengal Florican, Hispid Hare and Swamp Partridge. Regional and state significance includes the conservation of the Terai forest and grassland ecosystems, watershed and water conservation, endemic tribal peoples ('Tharu'), and ecotourism. Local values include wildlife conservation, ecotourism and related economic activities, non-wood and small timber products for local use and socio-culture religious values[158].

### 6.3.10.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| **Summary of Ecosystem Services Based on TEV Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **89.70** | **Rs. Million/Year** |
| Fuel wood, Fodder, Employment Generation<br>* - Non-Timber Forest Products, Fishing, Bamboo (Flow), Timber (Flow) | | |
| **Indirect Use Value** | **42213.39** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>*- Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Option Value** | **8646.06** | **Rs. Million/Year** |
| Genepool Protection | | |

| Summary of Ecosystem Services Based on MA Framework (Flow Benefits) | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **27.98** | **Rs. Million/Year** |
| Employment Generation, Fodder, Fuel wood<br>* - NTFP, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Regulating Services** | **50258.94** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool Protection<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Cultural Services** | **4.00** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Supporting Services** | **658.22** | **Rs. Million/Year** |
| Habitat for Species | | |

| Summary of Ecosystem Services Based on Stock and Flow Benefits | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Flow Benefits** | **50.95** | **Rs. Billion/Year** |
| Employment Generation, Fodder, Fuel wood, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - NTFP, Timber (Flow), Fishing, Bamboo (Flow), Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Stock Benefits** | **561.06** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| Summary of Ecosystem Services Based on Tangible/Intangible Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Tangible Benefits** | **27.98** | **Rs. Million/Year** |
| Employment Generation, Fodder, Fuel wood<br>* - NTFP, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Intangible Benefits** | **611984.29** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |

| Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **16438.43** | **Rs. Million/Year** |
| Fodder, Fuel wood, Water Provisioning<br>* - NTFP, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Protection from Disease/Predators/Parasites** | **162.22** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **25677.32** | **Rs. Million/Year** |
| Carbon Sequestration, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Climate Regulation, Habitat for Species<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Socio-Cultural Fulfilment** | **25.12** | **Rs. Million/Year** |
| Employment Generation, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Ecosystem Assets** | **569709.19** | **Rs. Million** |
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| Summary of Ecosystem Services Based on EPA Effect Categories | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **612008.27** | **Rs. Million** |
| Employment Generation, Timber (Stock), Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Soil Conservation/Sediment Retention, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Gas Regulation, Climate Regulation<br>* - Timber (Flow) | | |
| **EPA Effect Category 2** | **4.00** | **Rs. Million** |
| Recreation | | |
| **EPA Effect Category 3** | **-** | **Studies** |
| Research, Education and Nature Interpretation | | |
| **EPA Effect Category 4** | **Tharus** | **Main tribe** |
| Cultural heritage | | |
| **EPA Effect Category 5** | **-** | **Unrecorded** |
| Spiritual tourism | | |

#### 6.3.10.2 Linkages to Human Health

Dudhwa Tiger Reserve emanates a range of ecosystem services vital for maintenance of human well-being. Amongst these, Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Biological Control, Pollination, Cultural heritage, Recreation, Research, Education and Nature Interpretation, Gas Regulation, and Climate Regulation services have huge direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 110.14 billion.

#### 6.3.10.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Dudhwa Tiger Reserve for the year 2016-17, was around Rs. 73.72 million. Based on the flow benefits of Rs. 50.95 billion per year, for every rupee spent on management costs in DTR, flow benefits of Rs. 573.8 are realized within and outside the tiger reserve.

### 6.3.10.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Dudhwa Tiger Reserve was estimated at Rs. 0.53 million (Rs. 5.29 lakhs) per hectare.

### 6.3.10.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 1.37 percent of flow benefits accrue at the local level, 7.31 percent at the national level and 91.32percent at the global level.

# Melghat Tiger Reserve

Melghat Tiger Reserve (MTR) is a raptor's paradise with more than 260 species of birds. It is marked with large tracts of hills and ravines in the Satpura mountain ranges.

**The tiger reserve provides flow benefits worth Rs. 123.49 billion per year (Rs. 0.61 million per hectare) and stock benefits of Rs. 750.43 billion per year. Important ecosystem services that arise from this reserve include provisioning of water (Rs. 34.48 billion per year), carbon sequestration (Rs. 41.20 billion per year) and genepool protection (Rs. 19.84 billion per year).**

**Under the Total Economic Value (TEV) framework, the annual direct-, indirect- benefits and option values were Rs. 0.51 billion, Rs. 103.13 billion and Rs. 19.84 billion, respectively.**

As per the MA framework, the value of provisioning services was Rs. 0.36 billion per year, that of regulating services was Rs. 122.63 billion per year, for cultural services it was Rs. 3.10 million per year and supporting services were Rs. 0.49 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 0.36 billion and Rs. 873.56 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 34.84 billion), protection from disease (Rs. 0.16 billion), benign physical and chemical environment (Rs. 68.63 billion), socio-cultural fulfilment (Rs. 3.10 million) and ecosystem assets (Rs. 770.28 billion).

The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 253.80 billion per year. The investment multiplier for MTR was calculated as 346.73.

# 6.4 Melghat Tiger Reserve

## 6.4.1 Location, Landscape and Significance

Nestling in the Satpuda hill ranges of Central India, Melghat Tiger Reserve is one of the earliest Tiger Reserves established in India under Project Tiger. It came into being in 1974 and is also the first Tiger Reserve to be declared in the State of Maharashtra. Located in Maharashtra in the northern part of Amravathi District, it comes under the central highland province of Deccan Peninsula Bio-geographic region. Its critical tiger habitat extends over 1500.49 sq km. consisting of 5 protected areas namely, Gugamal National Park, Melghat Sanctuary, Narnala, Ambabarwa and Wan Sanctuaries. The area of Critical Tiger Habitat of the Melghat Tiger Reserve lies in Melghat forests of Amravati, Akola and Buldhana Districts of Vidarbha region of Maharashtra, bordering Madhya Pradesh in the north and east[160].

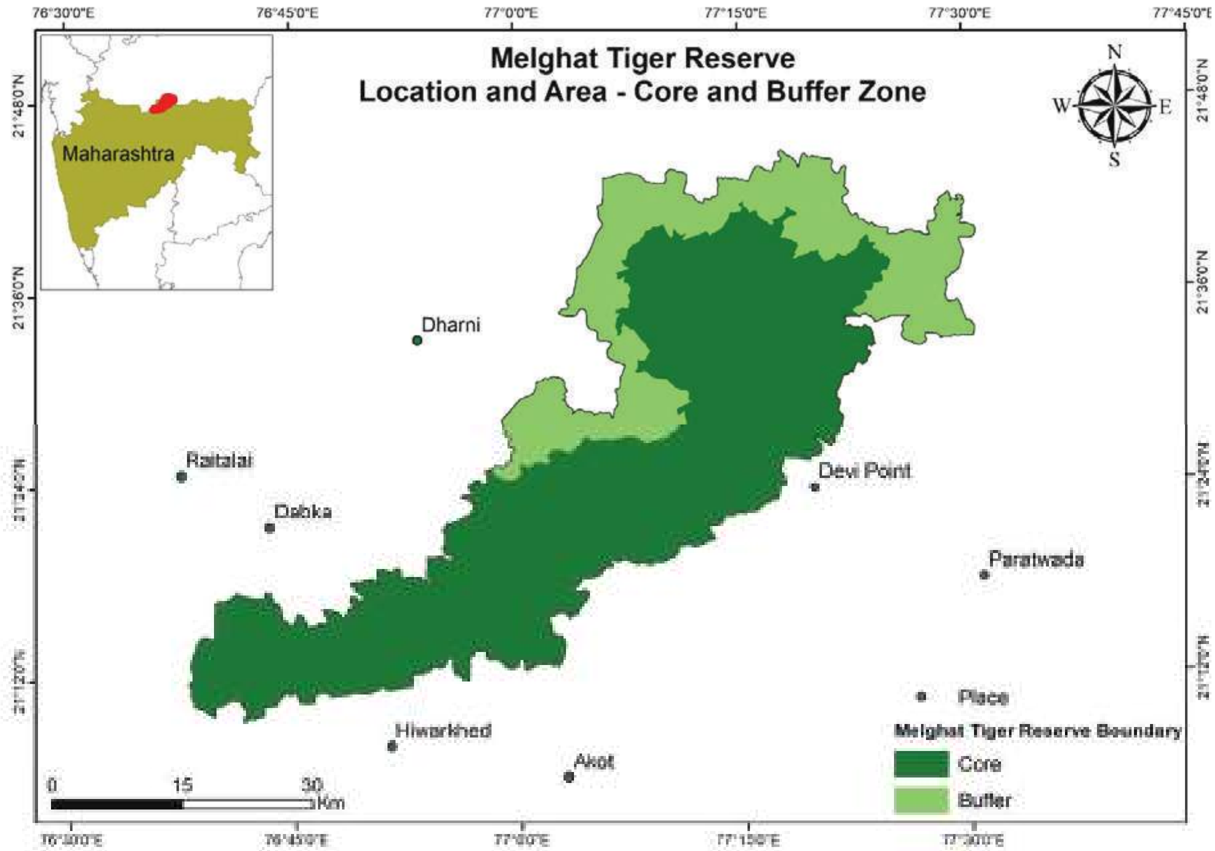



*Figure 6.4-1 Melghat Tiger Reserve (Source: Forest Survey of India)*

Containing a unique blending of multiple high hills and deep valleys with terrain and vegetation changing at close intervals, Melghat means where the hills meet. The reserve covers vast tracts of inviolate natural forests, consisting of unique and representative ecosystems with rich biodiversity and varied habitats offered by deep valleys (locally known as *khoras*) and high hills (locally known as *Ballas*). Punctuated with rivers and nallahs having water all the year round in the **'*doh*',** Melghat is also one of the largest Protected Areas of the country[160].

Ambabarwa Sanctuary situated at the foothills of the Satpuda ranges has a representative flora and fauna typical of the central highlands. It contains important corridor links between the forests of Maharashtra and MP. It has a rich repository of biodiversity with endangered mammals like Tiger, leopard, wild dog, chaushinga, ratel, etc. It is equally rich in birds, reptiles, insects and other invertebrates. The floral composition is extremely varied with representatives of Southern Tropical Dry deciduous forests[160].

Wan Sanctuary includes the outer slopes of Satpuda with all its floral and faunal attributes. It comes under the Satpuda Maikal range of the Deccan peninsula biogeographic zone and has representatives of Southern Tropical Dry deciduous forests. As an extension of Melghat Tiger Reserve, it provides an important corridor between Akola, Amravati and Buldhana districts. It connects Melghat Sanctuary with Narnala Sanctuary and Ambabarwa Sanctuary, providing a large contiguous stretch of protected areas. It has a rich repository of biodiversity with all the major animals of central highlands being found here[160].

Narnala Sanctuary is a continuation of the Gavilgarh range of Satpuda hills as a corridor between the Melghat Sanctuary and Wan Sanctuary. It is known as the Southern Gateway of Melghat. The hill of Narnala is situated at about 1000 metres above mean sea level. It has the historical fort of Narnala and contains valuable species like Sandal. Most of the major mammals which are sighted in Narnala include Tiger, Leopard, Sloth Bear, Sambar, Chital, etc. The list of avian fauna here includes large numbers of migratory waterfowl seen in the perennial waterbodies situated on the Narnala plateau and raptors are seen on the crags and cliffs[160].

### 6.4.2 History

Established on February 22, 1974, Melghat Tiger Reserve was one of the earliest tiger reserves established in India under Project Tiger[160].

### 6.4.3 Topography and Climate

The name Melghat itself signifies meeting of *ghats* and the reserve is located in a setting of rugged hills, steep cliffs and deep gorges. The highest ridge lies on the southern flank of the reserve. Average height ranges between 381 metres and 912 metres above mean sea level. These hills and valleys have constant abrupt variations in aspect and gradient. The general terrain of the reserve is undulating. Geologically the Melghat Tiger Reserve lies in the Deccan trap and underlying rock is basalt in one form or another[160].

The climate is tropical with December being the coldest month, when night temperature may go up to 5 $^{0}$C and May as the hottest month (47 $^{0}$C). Due to the variation in altitude and aspect, the climate inMelghat is varying and distinct seasons are experienced throughout the year. The rainfall in the area varies from 2250 mm to 1000 mm. The average no. of rainy days experienced is 65 to 90. Temperature varies considerably with the altitude. The plateau and the higher hills enjoy a pleasant climate throughout the year. While valleys become cold during winter, the valleys of Semadoh, Raipur, Harisal and parts of Akot range valleys experience heavy dew and occasional frost at times. The average mean maximum annual temperature is 46$^{0}$ c and the average mean minimum annual temperature is 4$^{0}$ C. Chikhaldara, Makhala plateau, Ghatang to Koktoo experience prolonged fog in the rainy and winter seasons[160].

### 6.4.4 Land Cover Classification

The land use and land cover have been sourced from the Forest Survey of India. The Melghat Tiger Reserve consists of mainly deciduous forests, both in core and buffer areas with an area around 184458 hectares.

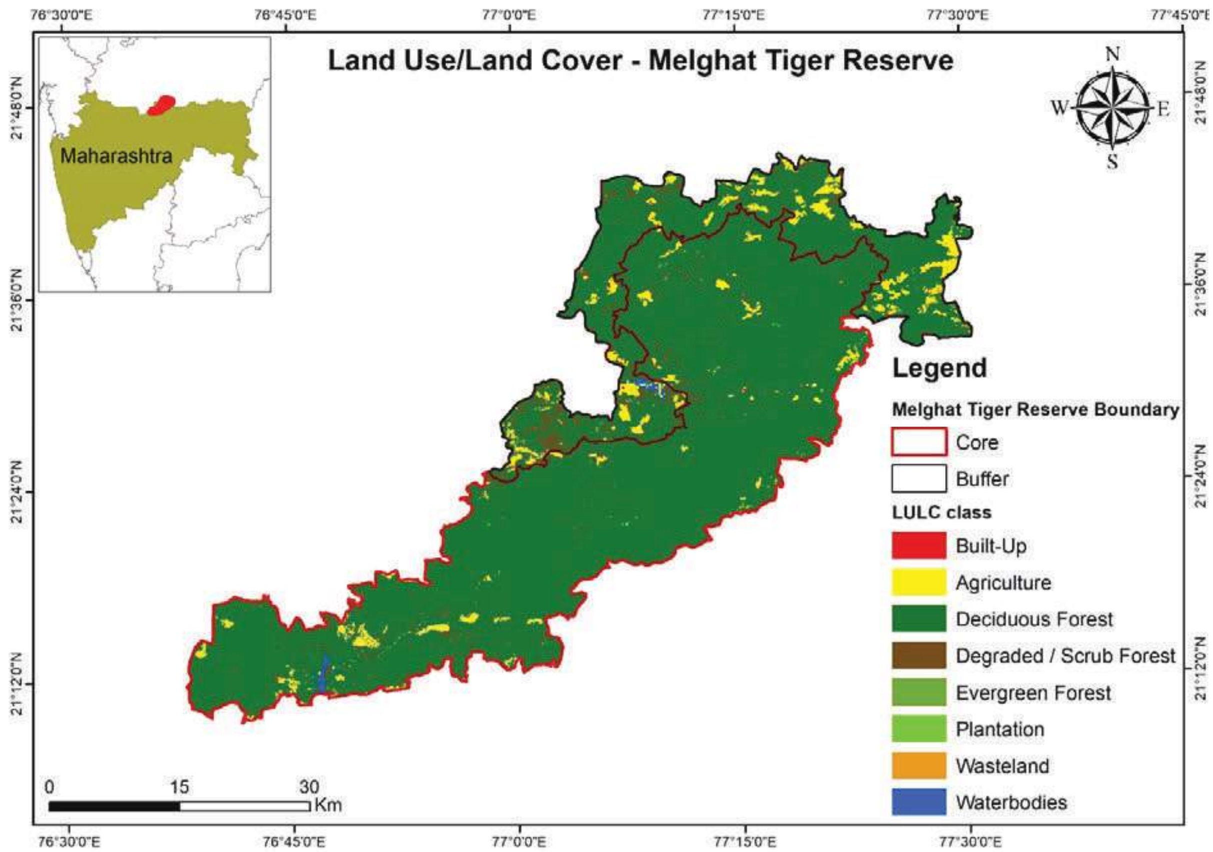



*Figure 6.4-2 Land Use/Land Cover: Melghat Tiger Reserve (Source: Forest Survey of India, 2013-2014)*

The core and buffer area mainly consists of deciduous forest (90.93 percent), agriculture (4.49 percent) and degraded forest (3.66 percent) of the total tiger reserve. The area under each of these land cover classes is shown in the Table 6.4-1.

*Table 6.4-1 Land Use and Land Cover Classes*

| LULC Class | Area (ha) |
|---|---|
| Agriculture | 9109.80 |
| Built-Up | 157.64 |
| Deciduous Forest | 184458.97 |
| Degraded / Scrub Forest | 7433.07 |
| Evergreen Forest | 43.28 |
| Plantation | 60.07 |
| Wasteland | 394.08 |
| Water Bodies | 1192.24 |

### 6.4.5 Rivers and Hydrology

The reserve forms a very important catchment to Tapi and Purna river systems with important tributaries like Dolar, Khandu, Sipna, Gadga, Khapra and Wan rivers. The Chandrabhaga river which originates from Chikhaldara has its watershed in the reserve. The main ridge of Gavilgarh Hills forms a water divide between Tapi and Purna rivers[160].

Gugamal National Park and Melghat Sanctuary area is well drained by many rivers. Most of the rivers are seasonal. The tract has five major drainage systems viz. Khandu, Khapra, Sipna, Gadga and Dolar. These rivers contribute as the important tributaries of Tapi river which is a perennial river and flows along the Western boundary of the reserve between Kund and Rangubeli for about 6 kms. Numerous depressions in river beds have accumulated water at places locally known as '*dohs*'. There are small numbers of springs which are of a perennial nature. Water pools in such *nalla* beds and depressions are supplemented by 15 anicuts at strategic places. A few artificial water bodies like tanks near Tarubanda, Kesarpur, Gullarghat, Malur, Chaurakund, Mehriaam, Chunkhadi and Ruipathar are significant additions to the surface water source because of their close vicinity to habitation[160].

The Wan Sanctuary area has only one major river draining the area namely, Wan River that flows from East to West. Another important surface water body in the protected area is the Wan river reservoir at Wari. In Ambabarwa Sanctuary there is no major river draining the area. In Narnala Sanctuary, old tanks on the plateau are an important source of water[160].

### 6.4.6 Biodiversity

Melghat Tiger Reserve forms an important extension of the Satpuda Hills into the West with its typical geological formations. Most of the area has the soil of trap origin. These soils are rich in mineral and have a high water holding capacity. They have a high rate of exchangeable calcium and ph varying from 6.5 to 7.5 thus supporting the best form of teak. Alluvial deposits along Tapti in Rangubeli and Dhakna support good teak forests along with bamboos. The places at *ballas* or on slopes, where the moisture condition deteriorates, the teak is soon replaced by Salai (*Boswellia serrata*) and Tiwas (*Ougeinia oogeinensis*)[160].

The major forest type in MTR is “Dry Deciduous Forests” as per Champion and Seth’s classification and fall under the sub-group “southern tropical dry deciduous forests.” Most dominant tree species is Teak. Other timber species are Tiwas, Bija, Haldu, Saja, Dhawda, Ain, Lendia, etc. Other important trees producing NTFP are Moha, Tendu, Achar, Amla, Behada, Bhilawa, Bor, Mango, Khair, Jamun, Apta, Bel, Kulu, etc. Melghat Tiger Reserve is very rich in medicinal plants and their traditional use by tribals and locals. Publications and technical bulletins identify and describe varied floristic details carried out in Melghat Tiger Reserve[160].

MTR has more than 769 plant species belonging to about 400 genera representing 97 families. It includes 90 tree species, 66 shrub species, 316 herb species, 56 climbers, 23 sedges and 99 grass species. The flora shows a combination of floristic elements from the Western Ghats and Satpuda, with many endemic species. Some of the Himalayan plant species like *Preistylus constrictus* are also reported here. The rare plants include *Convolvulus flavus*, *Utricularia striatula*, *Drosera indica* and many species of orchids like *Vanda tessellata* and *Aerides maculosum*. Some templerate flora is also present here *Peristylus constrictus, Apium graveolens, Morchella conica, Geranium mascatense, Senecio chryanthemoides* are such examples. Species with extremely restricted distribution, *Achyranthes coynei* or the species *Ceropegia oculata* which is endemic to Maharashtra and is also endangered are speaking examples of the rich and varied habitat this reserve provides to various plant species. The forests also provide a niche to insectivorous plant species like *Drosera indica*, rare species like *Sruithia bigemia*, medicinally important plants like *Habenaria* and *Senecio spp*. A varied and interesting orchid flora also inhabits forests of this reserve like *Vanda tessellata, Aerides Macculosum, Habenaria grandifloriformis, H. roxburghii, H. plantaginea*[160].

It harbours a viable population of Tiger (*Panthera tigris)* and of the endangered Gaur *(*Bos *gaurus).* It also harbours a number of other faunal species some of which figure in the IUCN Red Data List. These are Wild dogs (*Cuon alpinus),* Jackals*, (Vulpes bengalensis),* Sloth bears *(Melurus ursinus),* Leopards *(Panthera pardus),* Caracals *(Felis caracal)* and Ratels (*Mellivora capensis)*. Other than these, the common Langur, Rhesus monkey, Gaur, Panther, Jungle Cat, Hyena, Jackal, Fox, Wild Pig, Hare, Porcupine, Mongoose, Otter, Sambar, Chital, Barking deer, Blue bull, Four Horned Antelope are common here. There are 37 species of mammals and several species of reptiles, butterflies and insects. The reserve is also very rich in avifauna with 265 species of birds including the recently rediscovered Forest Spotted Owlet (*Athene blewitii)*[160].

More than 769 naturalized species are listed in the flora of Melghat belonging to about 400 genera representing 97 families. It includes 90 tree species, 66 shrub species, 316 herb species, 56 climbers, 23 sedges and 99 grass species. The flora shows a combination of floristic elements from the Western Ghats and Satpuda, with many endemic species. Some of the Himalayan plant species like *Preistylus constrictus* are also reported here. The rare plants include *Convolvulus flavus, Utricularia striatula, Drosera indica* and many species of orchids like *Vanda tesselata* and *Aerides maculosum*[160].

The area has a diverse population of avian fauna with 265 species. MTR is categorized prominently under the Global Important Bird Area (IBA). Species like Lesser Kestrel, Forest Owlet, Green Munia, White Backed Vulture and Long Billed Vulture are reported from here. The congregative bird species include Blossom-Headed Parakeet and Rose-

Ringed Parakeet. Biome Restricted species conforming to the Biome-Indian Peninsula Tropical Moist Forest include Crimson Fronted Barbet and Malabar Whistling Thrush whereas the Biome-Indo Malayan Dry Zone includes 39 bird species[160].

There are many species of reptiles, butterflies, insects and fishes inhabiting this reserve. Ecologically sensitive animals like Flying Squirrel are abundantly seen here. Inhabitation by Grey Hornbills also supports this authentication. Pied Hornbill is also reported in the area. Forest Owlet, once considered to be extinct, has reappeared here in one of the prominent forests of the reserve. The embankments of Tapi, Khapra and some '*doh*' in 'Koktu' valley are also reported to have crocodiles and otters[160].

In Ambarwada Sanctuary the major species is teak and its associates while bamboo forms the understory and the ground is covered by a large number of herbs and shrubs. Some of the rare and endangered carnivores seen in Wan Sanctuary are tiger, leopard, wild dog, sloth bear, leopard cat, rusty spotted cat, desert cat, ratel, etc. The common herbivores include chausinga, sambar, chital, nilgai, wild pigs and barking deer. It is also home to a plethora of birds, reptiles, insects, other invertebrates and aquatic species. The list of aquatic avifauna includes many resident as well as migratory species like Brahminy Ducks, White Necked Storks, White ibis, Spotbills, Common Teals, etc. The Rosha grass occurs in abundance in the area[160].

Key vegetation complexes of MTR include Vad-Umbar-Arjun Plant Community which is a typical riparian habitat found along the perennial water source near Pur historical temple. The vegetation is lush green and quite distinct from the dry-deciduous vegetation existing all around. Another is the Teak-Ain-Dhavda Plant Community which represents the majority of the vegetation of MTR. The third is the Teak-Bherra-Movai Plant Community which common occurrence in the fire-prone areas. The fourth is the Palas-Salai-Khair Plant Community[160].

### 6.4.7 Tourism

Melghat has many popular tourist spots and areas of interests. The reserve not only offers scenic natural beauty but also a glimpse of the historical splendour of the area. Chikhaldara plateau is a fine hill station in Amravati district which is a major tourist attraction, especially during summer holidays. Chikhaldhara falls are also quite popular among tourists. About 2.5 km. to the south-west to Chikhaldara lies the Gavilgad Fort built in 1426 AD by Ahmed Shah, the Bahamani ruler of Deccan for strengthening his northern frontier in order to prevent roads during his southern wars[160].

Another popular tourist spot is the Vairat Point, also known as the Sunset Point, located at a distance of about ten kilometres and is the highest of all the Chikhaldara Hills. The place is associated with ancient Indian mythology and is considered to be the ruling seat of king Virat with whom the Pandavas were supposed to have resided during the period of their exile. Chandrabhaga river rises just below the Vairat plateau[160].

The Makhala Road and Kolkaz also offer beautiful scenic views particularly during monsoon season. Shegaon is also a tourist spot in Vidarbha region. The frequency of tourists visiting Shegaon is huge owing to its pilgrimage value and picnic spot[160].

The Gavilgarh Fort and Vairat points in the vicinity of Chikhaldara hill station have important historical significance and are popular among tourists. The Narnala Fort situated in the Narnala Sanctuary is an ancient fortress in the hills north of Akot taluk. People from all over the state of Maharashtra visit the Narnala Fort. The fort is easily accessible throughout the year. The area has an excellent rain water harvesting and drainage system built on the fort plateau which is worth admiring. Crevices in valleys and forts offer good hiding spaces for wildlife. The fort consists of 3 separate forts of Jaffrabad in the East, Narnala in the centre and Telyagarh in the west. The fort covers 392 acres of land with a wall perimetre of 24 miles (36 Kms). It is said to have 22 gates and 36 buruj towers or bastions. The area has an excellent rain water harvesting and drainage system built on the fort plateau which is worth admiration. A total of 22 large tank and numerous smaller tanks are connected in such a manner that the overflow of water from tanks situated at a higher elevation goes into tanks at lower elevation and so on, thus ensuring that no drop of rain water is allowed to go waste[160].

### 6.4.8 Socio-Economic Situation

The area of buffer zone of Melghat Tiger Reserve consists of the Multiple Use Area which has the status of Reserve Forest. The buffer zone lies around the critical tiger habitat having 118 villages. The total human population of the villages is around 80265 (Census, 2011) and cattle population is 50747. The population mainly consists of local tribes. The major communities in Melghat are Korku, Gond, Nihals, Balai, Rathiya and Gaoli. In Buldana division besides these communities Kunbis, Marathas, Andhs, Mali, Banjaras are inhabitants of the area. The inhabitants are dependent on income from agriculture, forestry work and collection of non-wood products[160].

The non-forest area in the buffer zone is mainly use for agricultural purpose. The main crops are Jawar, Bajara, Soyabean, Tur, Kodo, Kutki, Jagani, etc. Agriculture is the principal activity of the tribal and non-tribal people in this area, which is included in Integrated Tribal Development Project (ITDP) area. Agriculture in tribal blocks of Dharni and Chikhaldara has a cropping pattern where rice, and jowar are the main crops. Wheat, pulses, gram, sesame (*Til*), horticulture crops and sunflower are grown on a smaller scale[160].

In east and west Melghat division villages as well as the buffer of Melghat Tiger Reserve the landholdings are small. All the people do practice subsistence level of agriculture. In hilly areas where light soils prevail, lesser millets like *Kodo*, *Kutki*, *Sawa*, *Gadmal* and *Jagni*, an oil seed, are grown and gram, jawar and Wheat on clayey soil. Cultivation of cotton is rare in the buffer area of Buldhana divisions, the crops taken are jawar, wheat, rice, bajara, soyabean, gram, til, etc. Mixed cropping is followed as an assurance against an unpredictable monsoon[160].

### 6.4.9 Valuation Estimates for Melghat Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES.

#### 6.4.9.1 Employment Generation

Due to insufficient data on the number of employment days generated, the economic value of this service has not been estimated in monetary terms in this study.

#### 6.4.9.2 Fishing

Owing to lack of data and other relevant information to calculate the annual recorded fish catch, the economic value of this service has not been estimated in monetary terms in this study.

#### 6.4.9.3 Fuelwood

Approximately 29322 people live in the villages of the buffer area of MTR[160,161]. Due to lack of sufficient information/record on actual fuelwood collection in MTR, extrapolation using per capita fuelwood requirement is used for valuation of this ecosystem service. As per the National Sample Survey Organisation survey (2001) estimates the per capita fuelwood requirement is 17.7 kg per capita per month for rural areas[157]. For the sake of calculation, it is assumed fuelwood collection is only done for six months from the buffer areas. The total fuelwood collection for MTR is calculated as 3.1 kilo tonnes approximately. Using a local market price of Rs. 2 per kg, the total economic value of fuelwood collection from MTR is Rs. 6.23 million per year.

#### 6.4.9.4 Fodder/Grazing

The total estimated number of Cattle Units dependent on tiger reserve in Sipna division, Gugamal division, in Akola wildlife division Katepurna and Dnyanganga Sanctuary, and cattle out of sanctuary is 44151 cattle[160,161]. Assuming this as Adult Cattle Units and taking a standard forage quantity of 22 kg per day per adult cattle unit[107] the total forage requirement is equal to 354532 tonnes. Taking a local market price of Re. 1 per kg for fodder, the monetary value of fodder/grazing service provided by MTR is approximately Rs. 354 million.

#### 6.4.9.5 Standing Timber (Stock)

The standing stock of MTR has immense value. To estimate the economic value of the standing stock, growing estimates of timber species from the forest inventory database[108] of the Forest Survey of India (FSI) have been used. It is estimated that approximately 24.76 million cubic metres of standing stock of timber are contained in MTR as shown in Table 6.4-2. In monetary terms, using an average price of 25000 per cubic metre after discounting for transportation and maintenance cost, the standing stock has value equal to Rs. 619.03 billion.

*Table 6.4-2 Timber Stock in the Forests of MTR*

| Forest Type | Forest Cover | Growing Stock (Cubic m Per ha) | Area (ha) | Total Growing Stock(in Thousand Cubic m) | Economic Value (in Million Rupees) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 161.27 | 45733.33 | 7375.20 | 184379.90 |
| Tropical Dry Deciduous Forests | MDF | 113.59 | 96173.14 | 10924.62 | 273115.51 |
| Tropical Dry Deciduous Forests | OF | 107.69 | 44695.72 | 4813.46 | 120336.47 |
| Non-Forest | | 103.67 | 15895.34 | 1647.87 | 41196.74 |
| **Total** | | | | **24761.14** | **619029** |

**MTR:** For Melghat Tiger Reserve, the growing stock estimated for forest type Non-Forest and category MDF and VDF have been derived from OF values by taking double the OF value as MDF and quadruple as VDF.

### 6.4.9.6 Timber Flow

No timber harvesting is recorded in MTR and hence the economic value of flow benefits from this service is zero.

### 6.4.9.7 Bamboo

Bamboo collection is not permitted from MTR and hence this ecosystem services is not included for valuation in this study.

### 6.4.9.8 Non-Timber Forest Produce

Major NTFPs present in MTR are Moha, Gum, Lac, Honey, Tendu leaves, Herbs, Roots, etc. which are collected by locals for food and medicinal purposes[160,161]. Owing to lack of exact estimation of NTFP collection, estimates from Bhattacharya & Patra (2007) have been used to derive the same. The study mentions that locals obtain an income of Rs. 122.62 per household per season. The total population of MTR is given as 80265. It is assumed that each household has an average of four persons and only 50 percent of these households are in proximity for collecting NTFP from buffer areas. Thus, the total value of the NTFP collection from MTR is approximately Rs. 1.23 million per year.

### 6.4.9.9 Genepool Protection

Due to lack of comprehensive primary data, the method of benefits-transfer has been used for valuation of this service. Using estimates of economic value of genepool protection for tropical forests (Rs. 100122 per hectare per annum) and cropland (Rs. 68772 per hectare per annum) from a global meta-analysis study[116], the annual economic value of this service from 191995.39 hectares of forests and 9109.8 hectares of cropland in MTR is estimated to be Rs. 19.85 billion.

**Melghat Tiger Reserve: Repository of Medcinal Plants[160]:**

MTR has a rich repository of medicinal plants, as per Ethnobotanical account by Khaire and Giri (1992) MTR contains information on 215 plants being used as medicine by local people. These contain 64 trees, 27 shrubs, 29 climbers, 2 grasses and one bamboo. Some of the medicinal plants found here are safed musli, and shatawari. Apart from this, MTR also has stores of wild-cultivars of many crops like Ran Soyabin, Ran Mug, Ran Jwar, Ran Tur.

**Flora and Fauna of Melghat Tiger Reserve: A Snapshot[160]**

More than 769 species of plants, 265 species of birds, 37 species of mammals, several species of reptiles, insects, butterflies, etc. Refuge to 45-50 Tigers (30 per cent of the total Tiger population of Maharashtra)

**Flagship species:** Tiger, Leopard, Sloth Bear, Gaur and Flying Squirrel.

**IUCN Red Data List species:** *Panthera tigris, Panthera pardus, Cuon alpinus. Vulpes bengalensis, Melurus ursinus, Felis caracal* and *Mellivcora capensis.*

**IUCN global IBA (Important Bird Area) category bird species:** Lesser Kestrel, Forest Owlet Crimson Fronted Barbet, Malabar Whistling Thrush, White Backed Vulture and Long Billed Vulture.

**Temperate species:** *Geranium mascatense, Senecio chrysanthemoides, Peristyluys constrictus, Apium graveolens.*

**Endemic species***: Achyranthes coynei, Ceropegia oculata Aquatic species. Ceratophyllum demersum, Hydrilla verticillata, Aeschynomene indica, Sesbania bispinosa, Smithia conferta.*

**Orchids:** *Vanda tessellata, Aerides Maculosum, Habenaria grandifloriformis, H. roxburghii, H. plantaginea.*

**Rare Species:** Convolvulus flavus, Utricularia striatula, Drosera indica.

### 6.4.9.10 Carbon storage

The large tracts of forested landscape of Melghat Tiger Reserve are storehouses of carbon. The main particular forest type: Tropical Dry deciduous forest, found in Melghat Tiger reserve. Based on Forest Survey of India report titled Carbon Stock in India's Forests published in 2011, carbon stock has been estimated for Tropical Dry Deciduous forest type to quantify and map the carbon storage.

*Table 6.4-3 Carbon Stock in MTR*

| Vegetation class | Forest Cover | Carbon Stock in Various Pools(tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total carbon Stock (million tC) |
|---|---|---|---|---|---|---|---|---|
| | | AGB | BGB | SOM | DW (incl. litter) | | | |
| Non Forest | | 1.31 | 0.11 | 22.26 | 0.00 | 23.68 | 15895.34 | 0.38 |
| Tropical Dry Deciduous Forests | VDF | 58.98 | 23.16 | 55.72 | 0.89 | 138.75 | 96173.14 | 13.34 |
| Tropical Dry Deciduous Forests | MDF | 11.86 | 4.66 | 45.79 | 0.45 | 62.76 | 44695.72 | 2.81 |
| Tropical Dry Deciduous Forests | OF | 62.30 | 24.46 | 58.87 | 7.12 | 152.75 | 45733.33 | 6.99 |
| Total | | | | | | | | 23.51 |

It is noted that the non-forest area comprises mostly agriculture land. The average values of major crops like wheat, black gram, pigeon pea and green gram have been taken to calculate the AGB and BGB carbon pools[152]. While to calculate the carbon density in soil for the non-forest area the values of Soil Organic Carbon (SOC) has been referred to based on the agro-ecological region[153]. The carbon pools of water have been assumed to be 0. As shown in Table 6.4-3 above, carbon stock of more than 23.51 million tonnes is stored in Melghat Tiger Reserve. The stock has immense economic value in terms of avoiding the perilous effects of climate change.

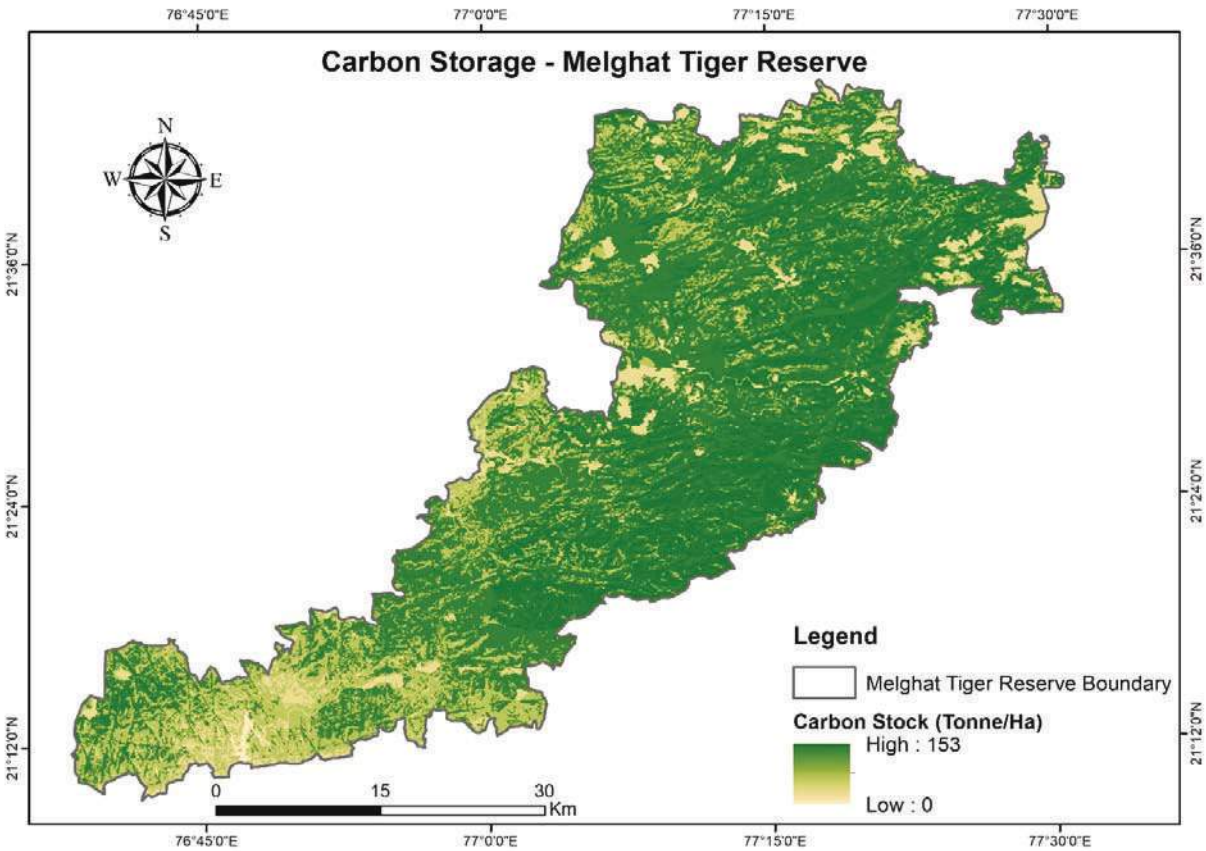



*Figure 6.4-3 Carbon Storage Map of Melghat Tiger Reserve Created Using InVEST Model*

The estimates from the Carbon Stock model of InVEST as 23.51 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= 65 Rs. as the average for the year 2017-18, the economic value of carbon stock in MTR is calculated as Rs. 131.4 billion.

### 6.4.9.11 Carbon Sequestration

Apart from 23.51 million tonnes of carbon stock in the forests of Melghat Tiger Reserve, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the The Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database. Based on total biomass per unit area, the mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type [120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, total carbon sequestered in the forests of Melghat Tiger Reserve by aggregating estimates for each forest type is equal to 1004.24 kilo tonnes annually. Detailed calculation is indicated in Table 6.4-4.

*Table 6.4-4 Carbon Sequestration in MTR*

| Forest Type | Forest Cover | Total Biomass Per Unit Area (Tonnes/ha) | Mean Annual Increment Per Unit Area (tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) | Total Value of Annual Carbon Sequestration (Million Rs. Per Year) |
|---|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 388.65 | 14.01 | 45733.33 | 320444.13 | 13148.01 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | MDF | 273.76 | 9.87 | 96173.14 | 474662.71 | 19475.70 |
| Tropical Dry Deciduous Forests | OF | 259.54 | 9.36 | 44695.72 | 209139.47 | 8581.12 |
| **Total** | | | | **186602.20** | **1004246.32** | **41204.83** |

The social cost of carbon for India as per the latest paper[117] the economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=Rs. 65, the total economic value of annual carbon sequestration in MTR is calculated to be Rs. 41.20 billion.

### 6.4.9.12 Water Provisioning

The reserve forms catchment to Tapi and Purna river systems with major tributaries like Dolar, Khandu, Sipna, Gadga, Khapra and Wan rivers. The Chandrabhaga river which originates from Chikhaldara has its watershed in the reserve. The area forms a major catchment of Wan river and has assumed greater significance since the construction of Wan Dam at Wari. The basic life support systems that the area beholds in terms of conserving soil, water and clean air, it serves as the life-line for the people of Amravati and Akola districts[160,161].

The model provides various outputs like modelled values of mean actual evapo-transpiration, mean potential evapo-transpiration, water yield volume, etc. The total water yield volume of the study area is around 1871.21 million cubic metres (Figure 6.4-4).

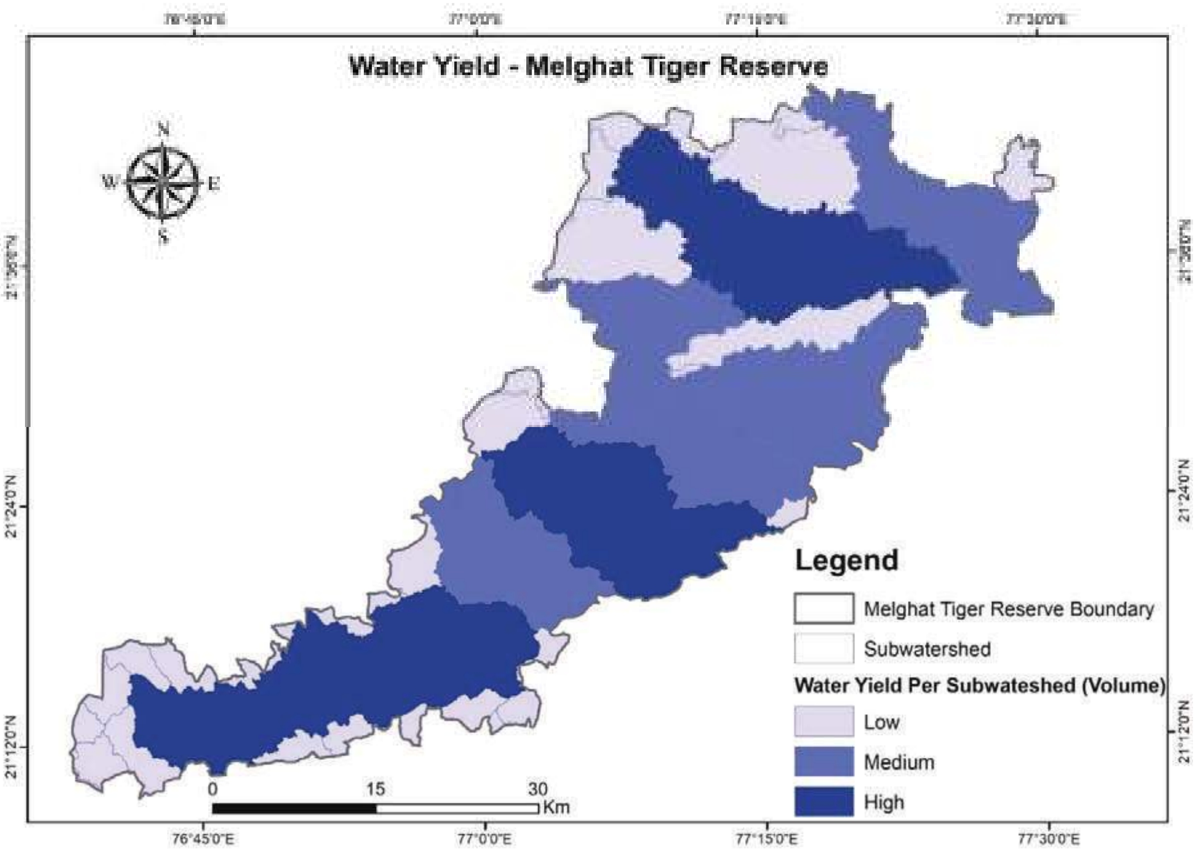



*Figure 6.4-4 Water Yield output for Melghat Tiger reserve Created Using InVEST Model*

Using the monetary value of Rs. 18.43 per cubic metres[1], the economic value of water provisioning service from MTR is estimated to be 34.48 billion per year.

### 6.4.9.13 Water Purification

Wan Dam ensures water supply for Akot city and Shegaon. Drinking water is supplied to 24 villages[160,161]. The population in Akot and Shegaon is 92637 and 59672 respectively (Census Data). The daily minimum water requirement as per the Bureau of Indian Standards is 40 litres per capita is taken as the lower bound estimate to calculate the total domestic water requirement[130]. Based on the total dependent population 152309and per capita water requirement, the total domestic water requirement is 2223711.4 kilo litres per annum. Only 10 percent of this estimate is used for valuation as sufficient data was not available to map the beneficiaries and their exact water supply for drinking purpose for the whole year, the annual drinking water requirement comes to around 222371.14 kilo litres. Using a lower bound estimate of average cost of treating water for domestic supply at Rs. 10/cubic m based on estimates for different municipalities of India[131], the avoided cost of water purification for drinking water is around Rs. 2.2 million per year.

### 6.4.9.14 Soil Conservation/Sediment Retention

The model provides various outputs for spatial analysis of the area. Figure 6.4-5 provides spatial details of the total sediment exported to the stream per watershed in the study area. The values of sediment export ranges from 200 tons to 10260 tons per subwatershed.

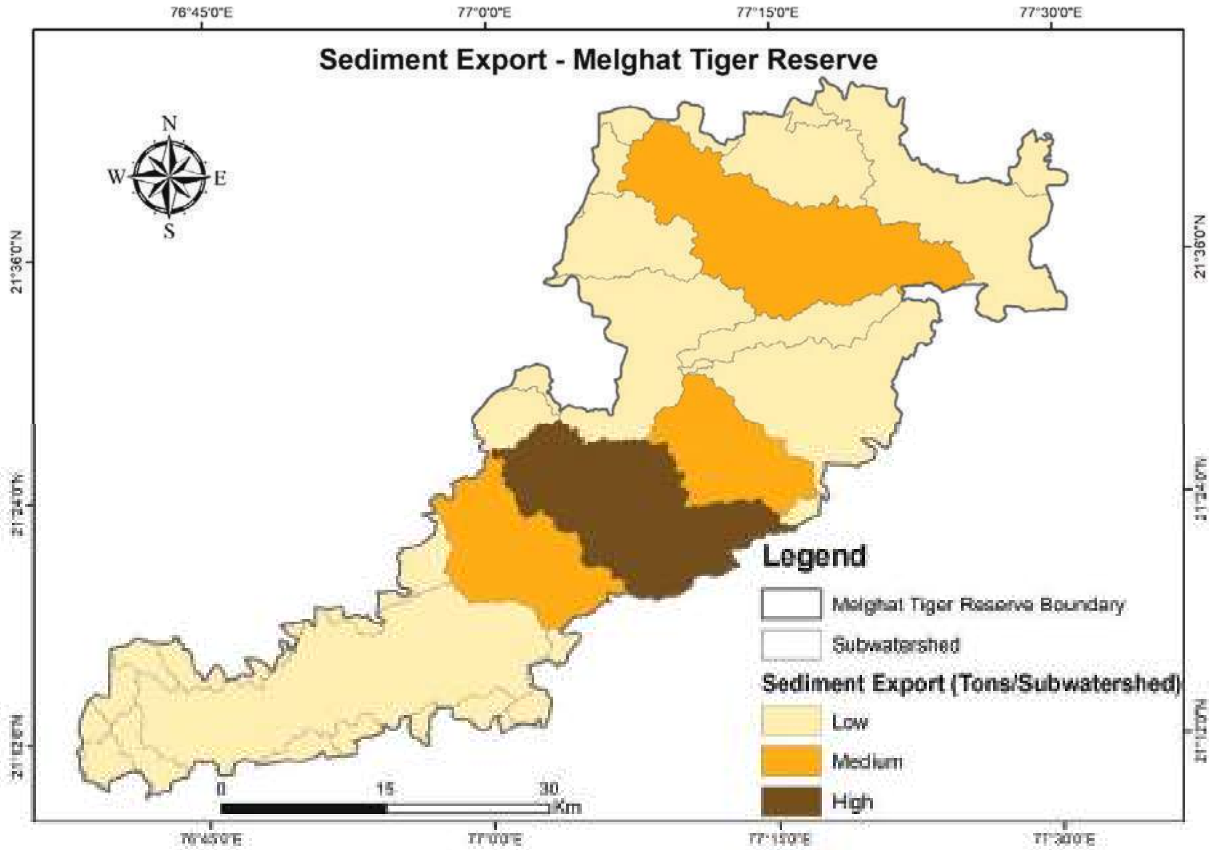



*Figure 6.4-5 Sediment Export from Melghat Tiger Reserve Created Using InVEST Model*

As shown in Figure 6.4-6 the sediment retention in the MTR landscape is higher across all the subwatersheds lying in both core and buffer areas of MTR. The values of sediment retention ranges from 247534 tons to 17752556 tons per subwatershed.

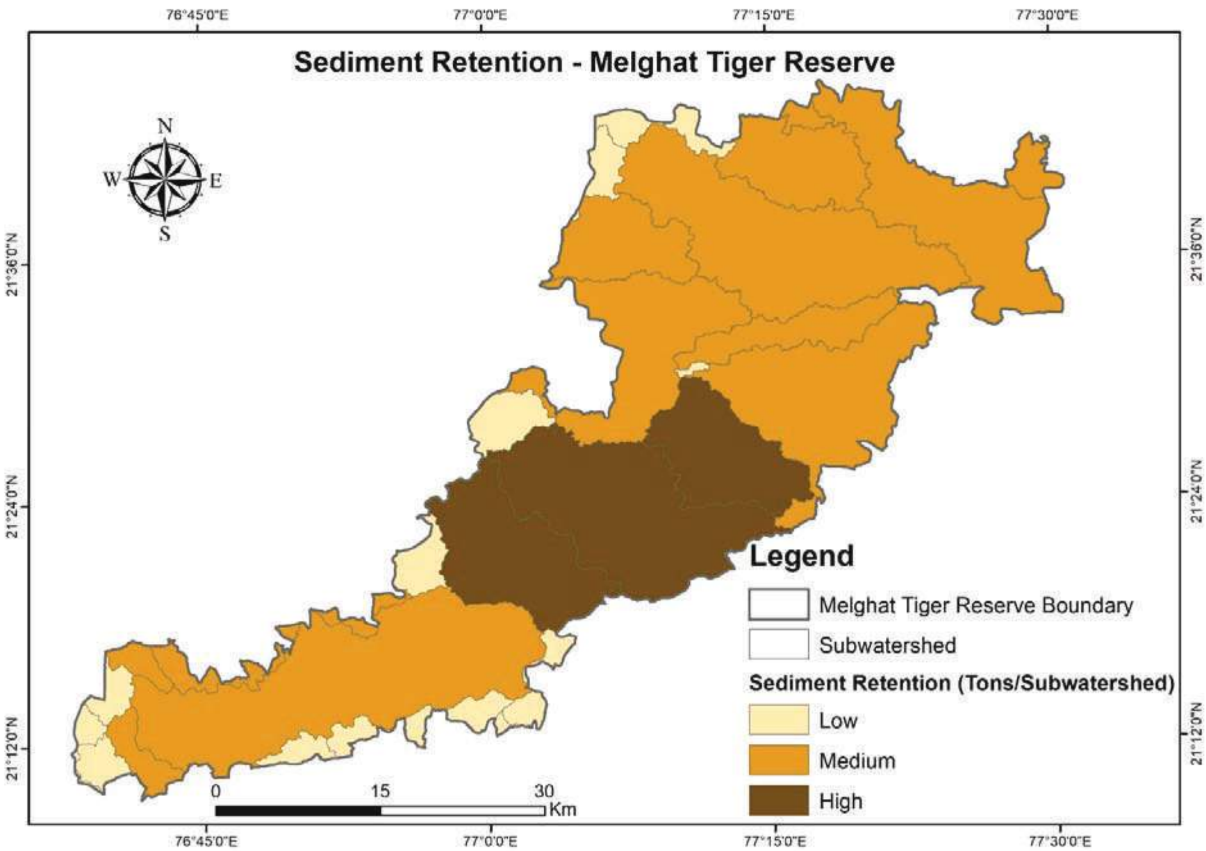



*Figure 6.4-6 Sediment Retention in Melghat Tiger Reserve Created Using InVEST Model*

To estimate the economic value of soil loss avoided by the forests of MTR, the cost of dredging/de-siltation has been considered. On account of lack of site-specific data, the cost estimate of Rs. 60 per cubic metre[132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 73.30 million annually.

### 6.4.9.15 Nutrient Retention

The total soil loss avoided from the InVEST Sediment Retention model of MTR is around 1.62 million tons. To calculate the amount of nutrient retained, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust[147] has been used on account of lack of local estimates for the same. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations from Table 6.4-5, the total quantity of nutrients retained is approximately 3401.40 tonnes of N, 64.51 tonnes of P and 12095.50 tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary value has been derived. The total value of nutrient loss prevented by the forests of MTR is equal to Rs. 165.16 million annually.

*Table 6.4-5 Nutrient Retention in MTR*

| **Nutrient** | **Soil Nutrient Concentration (g Per Kg)** | **Total Nutrient Loss Avoided (Tonnes Per Year)** | **Fertilizer (Substitute) Used for Valuation** | **Price of Fertilizer (Rs. Per Tonne)** | **Economic Value of Nutrient Retention (Million Rs. Per Year)** |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 3401.40 | Urea | 5360 | 18.23 |
| Phosphorous (P) | 0.044 | 64.51 | DAP | 20100 | 1.30 |

| | | | | | |
|---|---|---|---|---|---|
| Potassium (K) | 8.25 | 12095.50 | Muriate of Potash | 12040 | 145.63 |
| **Total** | | **15561.42** | | | **165.16** |

### 6.4.9.16 Biological Control

Using estimates of economic value of biological control for tropical forests (Rs. 726 per hectare per annum) and cropland (Rs. 2178 per hectare per annum) from a global meta-analysis study [116] the economic value of biological control service from 191995.39 hectares of forests and 9109.8 hectares of cropland in MTR is estimated to be Rs. 159.23 million per annum.

### 6.4.9.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to MTR. Hence it is not included in the valuation of the ecosystem service of MTR in this study.

### 6.4.9.18 Pollination

Using estimates of economic value of pollination for tropical forests (Rs. 1980 per hectare per annum) and cropland (Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 191995.39 hectares of forests and 9109.8 hectares of cropland in MTR is estimated to be 393.38 million Rs. per annum.

### 6.4.9.19 Nursery Function

The nursery function was not found relevant due to insufficient information and evident linkages to attribute this service to MTR. Hence it is not included in the valuation of the ecosystem service of MTR in this study.

### 6.4.9.20 Habitat for Species

Using estimates of economic value of habitat service for tropical forests (Rs. 2574 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 191995.39 hectares of forests in MTR is estimated to be Rs. 494.19 million.

### 6.4.9.21 Cultural Heritage

The tribal population inhabiting Melghat have a diverse and rich cultural heritage which has its coexistence with the flora and fauna of the surrounding forests. MTR is home to more than 27000 tribals. Inhabitants are mostly Scheduled Tribes and include Korku, Gonds and Nihal.  Balai is a Scheduled Caste community of Melghat. The remaining population consists of the traditional grazier community, the Gaolis.  The communities are dependent on agricultural produce and also they are traditional forest dwellers. The Korkus, Nihals and Gaolis have a repository of indigenous ethnobotanical knowledge[160,161].

MTR provides a unique opportunity to get an insight into the tribal culture and their nature-oriented lifestyle. The forests of Melghat are mainly inhabited by Korku tribes.  The Korkus are one of the few tribes who worship the tiger as God which explains their sense of belongingness to these forests. The Gotras (family names) of Korkus claim to have been named after trees, e.g. Jamunkar, Semalkar, etc[160].

### 6.4.9.22 Recreation

The fascinating landscape, its enchanting beauty and richness attract tourists and leave everlasting imprints on people visiting the area.  Owing to an easy approach and access, MTR has high recreation value with its lush green vegetation, diverse fauna and hilly and rugged terrain.  The area is visited by a number of tourists from various parts of the country who try to fathom the enticing realms of these pristine forests.  MTR also attracts researchers and enthusiasts in the fields of ethno botany, birds and butterfly identification, nature photography, wilderness experience and nature awareness[160].

Recreational activities offered in MTR are trekking, nature trails, scenic landscapes, wilderness experience, bird watching, observing wild animal and nature photography. People also come here to observe the unique culture of tribal people. It is one of the important tourist destinations of Maharashtra.  It is visited by more than 30,000 Indian and foreign visitors every year.  Chikhaldhara is an important tourist spot of MTR[160].

MTR is also famous for its historical structures like Narnala Fort, Gavilgarh Fort and rest houses of the British era like Rangubeli, Chunkhadi, Tarubanda, Dhargad, Dhakna etc. The area has been visited by famous naturalists like Dunbar Brander and Captain J. Forsyth who made important observations about wild animal behaviour like reporting herds of up to 40 wild dogs, explanation of biological control of langur population , etc[160,161]. Revenue generated by the tiger reserve through tourism activities in the year 2015-16 is approximately Rs. 3.1 million[161]. This includes gate receipts, taxes, charges for safari, eco-tourism activities, forest-department owned lodges and resorts, camps and other tourism activities. In FY 2015-16 around 45918 tourists visited MTR [161]. The annual tourist inflow of the last five years is given in Table 6.4-6**:**

*Table 6.4-6 Tourist Visitation Rates of Last Five Years [161]*

| Sr. No. | Year | No. of Tourists |
|---|---|---|
| 1 | 2012-13 | 26277 |
| 2 | 2013-14 | 33882 |
| 3 | 2014-15 | 37647 |
| 4 | 2015-16 | 45918 |
| 5 | 2016-17 | 57451 |

### 6.4.9.23 Spiritual Tourism

Wan Sanctuary area has a large number of unique geological and religious features. The Mahadev cave temple at Dhargad is a unique geological structure that has assumed religious importance over the years. It is the scene of a massive pilgrimage during the Shrawan mas. Apart from this, there are many spots in Gugamal wildlife division and Khandribaba where local tribes offer their prayers to the natural forces and other deities. These places observe a footfall of over 25,000 visitors per year[161].

### 6.4.9.24 Research, Education and Nature Interpretation

MTR holds huge potential in recreation as well as education in its lush green vegetation, diverse fauna and hilly and rugged terrain. The forests of MTR offer scope for research on rare and medicinal plants, wild animals, the inter-relationships, pre-predator relationship, ecological dynamic, etc. There are 61 vegetation monitoring plots in the area. Apart from this, 23 technical bulletins are published Four Nature interpretation centres at Semadoh, Amravati, Harisal and Gullarghat are there with different themes, conservation awareness and education, ethno botany with tremendous scope for compilation of Indigenous technical knowledge (ITK)[160,161].

The Semadoh Nature Interpretation Centre was the first such centre established under Project Tiger. It is about 25 kms from Chikhaldara and about 50 kms from Paratwada. Wildlife viewing in the tourist zone in vehicle safari and the Project Tiger Museum are some of the attractions at Semadoh from the nature interpretation and ecotourism point of view. The Interpretation centre at Harisal attracts tourists from MP and Dharni area of Maharashtra. Interpretation centre at Gullarghat is helps in creating awareness of local medicinal plants. Interpretation Centre at Amravati is there for meeting the needs of nature education for the urban population and as a gateway to Melghat[160,161].

From 2014-17, 28 studies have been conducted in MTR. The main topics of these studies were socio-economic analysis of local village communities, genetic variation of floral species, rehabilitation, bio-diversity assessments, ethno-botany, status and trends in prey-predator, and many species-specific studies[161].

### 6.4.9.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (Rs. 792 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation from 191995.39 hectares of forests in MTR is estimated to be Rs. 152.06 million.

### 6.4.9.26 Waste Assimilation

Waste assimilation was not relevant due to inadequate information and lack of supporting evident linkagesto attribute this service to MTR. Hence it is not included in the valuation of the ecosystem service of MTR in this study.

#### 6.4.9.27 Climate Regulation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 134904 per hectare per annum) and cropland (Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 191995.39 hectares of forests and 9109.8 hectares of cropland in MTR is estimated to be Rs. 26.15 billion.

### 6.4.10 Spectrum of Values- Melghat Tiger Reserve

MTR provides a variety of values that fall under economic, scientific, educational, historical, cultural and recreational values.

#### 6.4.10.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| **Summary of Ecosystem Services Based on TEV Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **514.05** | **Rs. Million/Year** |
| Fuel wood, Fodder, Non-Timber Forest Products<br>* - Employment Generation, Fishing, Bamboo (Flow), Timber (Flow) | | |
| **Indirect Use Value** | **103129.92** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>*- Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Option Value** | **19849.46** | **Rs. Million/Year** |
| Genepool Protection | | |

| **Summary of Ecosystem Services Based on MA Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **361.99** | **Rs. Million/Year** |
| Fodder, Fuel wood, NTFP<br>* - Employment Generation, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Regulating Services** | **122634.14** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool Protection<br>* - Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Cultural Services** | **3.10** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Supporting Services** | **494.20** | **Rs. Million/Year** |
| Habitat for Species | | |

| **Summary of Ecosystem Services Based on Stock and Flow Benefits** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |

| | | |
|---|---|---|
| **Flow Benefits** | **123.49** | **Rs. Billion/Year** |
| Fodder, NTFP, Fuel wood, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - Employment Generation, Timber (Flow), Fishing, Bamboo (Flow), Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Stock Benefits** | **750.43** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| **Summary of Ecosystem Services Based on Tangible/Intangible Framework** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Tangible Benefits** | **361.99** | **Rs. Million/Year** |
| Fodder, Fuel wood, NTFP<br>* - Employment Generation, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Intangible Benefits** | **873564.74** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |

| **Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **34848.43** | **Rs. Million/Year** |
| Fodder, Fuel wood, NTFP, Water Provisioning<br>* - Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Protection from Disease/Predators/Parasites** | **159.23** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **68633.21** | **Rs. Million/Year** |
| Carbon Sequestration, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Climate Regulation, Habitat for Species<br>* - Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Socio-Cultural Fulfilment** | **3.10** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Employment Generation | | |
| **Ecosystem Assets** | **770282.76** | **Rs. Million** |

| | | |
|---|---|---|
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| Summary of Ecosystem Services Based on EPA Effect Categories | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **873923.63** | **Rs. Million** |
| Timber (Stock), Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Soil Conservation/Sediment Retention, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Gas Regulation, Climate Regulation<br>* - Employment Generation, Timber (Flow) | | |
| **EPA Effect Category 2** | **3.10** | **Rs. Million** |
| Recreation | | |
| **EPA Effect Category 3** | **28** | **Studies from 2014-17** |
| Research, Education and Nature Interpretation | | |
| **EPA Effect Category 4** | **27000** | **Tribal Population** |
| Cultural Heritage | | |
| **EPA Effect Category 5** | **25000** | **Devotees Per Year** |
| Spiritual Tourism | | |

#### 6.4.10.2 Linkages to Human Health

Melghat Tiger Reserve emanates a range of ecosystem services vital for maintenance of human well-being. Amongst these, Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Biological Control, Pollination, Cultural Heritage, Recreation, Research, Education and Nature Interpretation, Gas Regulation, and Climate Regulation services have huge direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 253.80 billion.

#### 6.4.10.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Melghat Tiger Reserve for the year 2016-17, was around Rs. 356.17 million. Based on the flow benefits of Rs. 123.49 billion per year, for every rupee spent on management costs in MTR, flow benefits of Rs. 346.7 are realized within and outside the tiger reserve.

#### 6.4.10.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Melghat Tiger Reserve was estimated at Rs. 0.61 million (Rs. 6.09 lakhs) per hectare.

#### 6.4.10.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 2.18 percent of flow benefits accrue at the local level, 11.68 percent at the national level and 86.14 percent at the global level.

# Nagarjunasagar Srisailam Tiger Reserve

One of the largest tiger reserve in the country in terms of area notified, Nagarjunasagar-Srisailam Tiger Reserve (NSTR) features undulating terrain, subterranean valleys and steep cliffs comprising *Hardwickia* forest and mixed dry deciduous forest. The tiger reserve home to ruins of past dynasties, now provides a prime habitat for many endangered species.

**The tiger reserve provides flow benefits worth Rs. 162.02 billion per year (Rs. 0.43 million per hectare) and stock benefits of Rs. 501.30 billion per year. Main ecosystem services that arise from this reserve include provisioning of water (Rs. 50.55 billion per year), carbon sequestration (Rs. 20.50 billion per year), climate regulation (Rs. 43.01 billion per year) and waste assimilation (Rs. 3.25 billion per year).**

**Under the Total Economic Value (TEV) framework, the annual direct-, indirect- benefits and option values were Rs. 1.01 billion, Rs. 128.83 billion and Rs. 32.16 billion, respectively.**

As per the MA framework, the value of provisioning services was Rs. 0.76 billion per year, that of regulating services was Rs. 160.41 billion per year, for cultural services it was Rs. 17.40 million per year and supporting services were Rs. 0.82 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 0.76 billion and Rs. 662.54 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 51.28 billion), protection from disease (Rs. 0.24 billion), benign physical and chemical environment (Rs. 78.27 billion), socio-cultural fulfilment (Rs. 47.43 million) and ecosystem assets (Rs. 533.45 billion).

The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 345.92 billion per year. The investment multiplier for NSTR was calculated as 7488.59.

# 6.5 Nagarjunasagar Srisailam Tiger Reserve

## 6.5.1 Location, Landscape and Significance

Nagarjunasagar Srisailam Tiger Reserve (NSTR) is situated in the Nallamala, an extention of the Southern Eastern Ghats of Andhra Pradesh (AP). It is speread over an area of 3727 sq km. Two Wildlife Sanctuaries, viz. Rajiv Gandhi WLS and Gundla Brahmeswaram (GBM) WLS together constitute the tiger reserve area. Hilly terrain with plateaus, ridges, gorges and deep valleys which support tropical mixed dry deciduous and moist deciduous forests ornate the reserve. Having a typical Deccan plateau species of flora and fauna, NSTR is positioned between the latitudes and longitudes of 15.5728 – 79.3131 (N), 15.3997 – 78.8188 (S), 16.0245 – 78.2874 (E) and 16.0369 – 78.4820 (W). The critical tiger habitat/inviolate area is spread over 2444 km., south of Hyderabad on the southern side of the banks of the river Krishna. It spreads over in parts of three districts, *i.e.* Kurnool, Prakasham and Guntur[163].

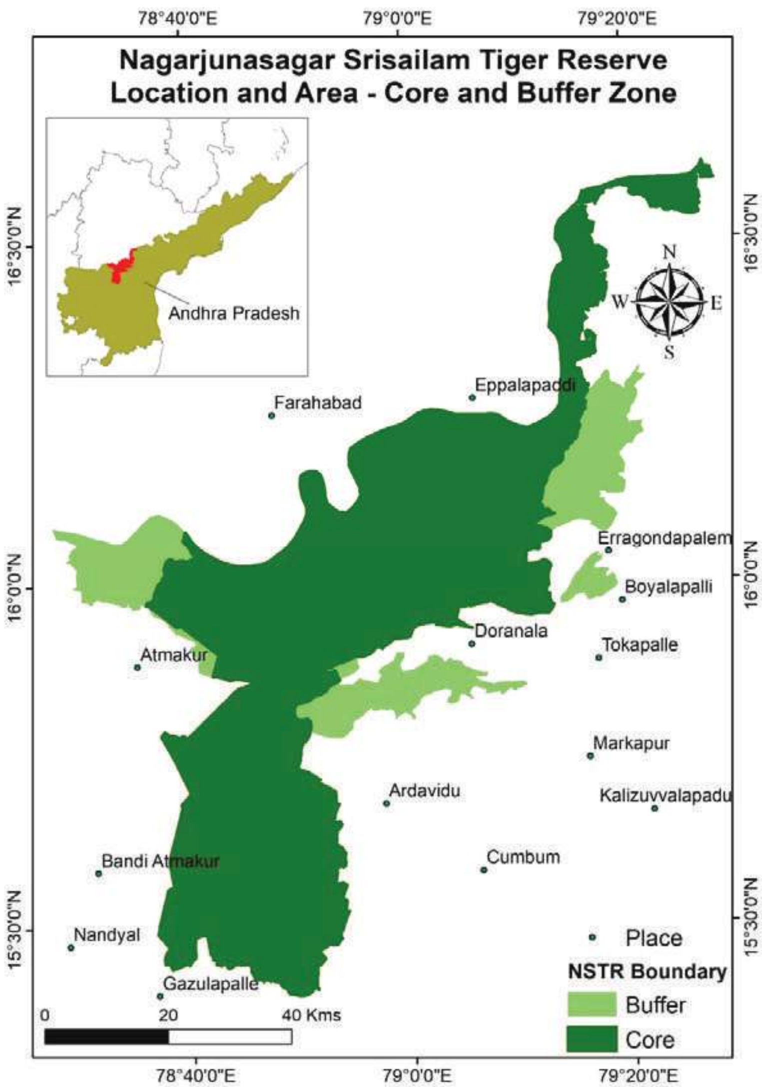



*Figure 6.5-1 Nagarjunasagar Srisailam Tiger Reserve (Source: Forest Survey of India)*

A large and representative example of Nallamala scarp eco-system with geological, biological, cultural, religious and scenic attributes can be seen along the side of river Krishna which flows across the core area and forms the northern boundary of the core area. NSTR is the abode of many springs, cave temples, sacred groves, mesic sites, ancient rock formations, etc[163].

## 6.5.2 Topography and Climate

The general terrain of NSTR is undulating, the Nallamalas in the core area feature unbroken, rugged and rather steep hill ranges. A series of folds from the main ridge runs in a westerly direction, descending into the plains of

Atmakur. The hills descend towards the north into the plateaus of Peddacheruvu, Sivapuram and Srisailam, which further abruptly descends precipitously into the Krishna valley. In the hilly portion nearly 1 percent of the total area occurs at an elevation of 900 m, 10 percent of the area lies between 700 - 800 m, 13 percent of area lies between 300 - 500 m, and 76 percent of the area is less than 200 m above mean sea level. Durgamkonda in Markapur Reserve Forest, Prakasam District is the highest peak (917 m above mean sea level) and the Krishna River area has the lowest elevation (100 m above mean sea level)[163].

Most of the rainfall is received from the south-west monsoon that generally sets during the second half of June and continues up to the first week of October. The eastern half encompassing the V.P. South Range (Markapur Division) in Guntur District and Markapur Wildlife Division and Giddalur Wildlife Division in Prakasham District receive rains from the north-east monsoon which is active in November and the first half of December. The average annual rainfall for the last decade is approximately 676 mm[163].

The climate is extreme with a maximum temperature of about 43°C in summer and minimum temperature of 16°C during winter nights. Summer is from March to May and winter from the end of November to mid-February[163].

### 6.5.3 Land Cover Classification

According to the land use land cover map obtained from the Forest Survey of India, the Nagarjunasagar Srisailam Tiger Reserve (NSTR) can be broadly classified into forest, agriculture, wasteland, degraded forest and habitation (Figure 6.5-2).

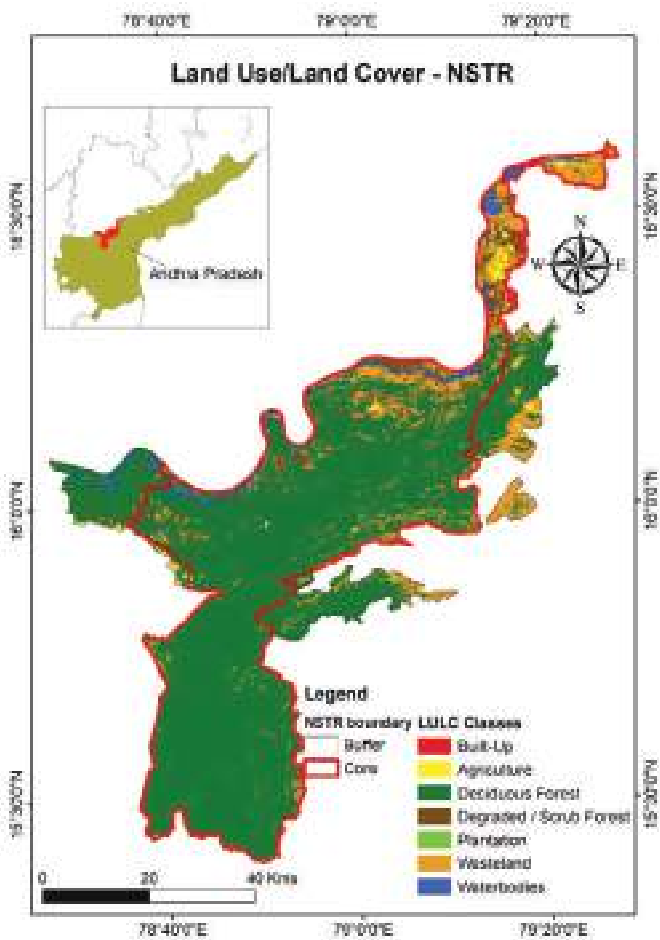



*Figure 6.5-2 Land Use/Land Cover: NSTR (Source: Forest Survey of India, 2013-2014)*

The NSTR consists of mainly deciduous forest both in core and buffer areas with an area around 300174 hectares, which is approximately 79.4 percent of total tiger reserve. The area under each of these land cover classes as shown in the Table 6.5-1.

*Table 6.5-1 LULC Classes NSTR*

| LULC Class | Area (ha) |
|---|---|
| Agriculture | 4933.77 |
| Built-Up | 534.77 |
| Deciduous Forest | 300174.85 |
| Degraded / Scrub Forest | 17449.78 |
| Plantation | 213.24 |
| Wasteland | 44545.77 |
| Waterbodies | 9983.34 |

### 6.5.4 Rivers and Hydrology

The reserve has numerous small and big streams most of which join the river Krishna ultimately. River Krishna forms the main drainage of the catchment and buffer area of NSTR, running mainly from west to east and then to north. The total length of the streams in the core and buffer area is estimated to be 10394.05 Km. Most of these streams are dry throughout the year except for a few months of the rainy season (July-November). Streams like Nekkantivagu, Kamakshmmavagu, Dwarapusarivagu, Maddulsarivagu, Jeerivagu, Gandivagu, Chamavagu and Nippulagundamvagu in Markapur R.F. and Bhimuni Kolanuvagu, Munimaduguleru, Amudalapentavagu and Pangdivagu in Nandikotkur R.F. contains perennial water sources flow even in summer[163].

The distinctive topography of the tiger reserve functions both as a catchment and a multiple watershed. Gundlakamma river rises in the heart of the core of NSTR and the Cumbum tank is formed by bund across this river in the plains. It is a major drinking water source for Ongole and many towns and villages of Prakasam District. Many perennial springs are located at the origin of hill streams in Nallamala. There are also numerous waterfalls, seasonal and perennial, scattered across the tiger reserve. Some of them are Ethipothals falls on the river Chandravanka and Jendapenta falls on Jarrivagu in Guntur District; and Palanka falls on Palankavagu in Prakasam District[163].

Srisailam Reservoir is located within the core area. The length of the Srisailam dam is 512 m and maximum height of 144 m from the deepest foundation level. The dam has a storage capacity of 8723Mm$^3$ (308 TMC) at Full Reservoir Level. It has a discharging capacity of 37384 cum/sec (1320000 cusec). The deepest portion of the reservoir has a depth of 60m to 90m for an extent of 250 sq km. The shallow reservoir area with depth below 30m is 365 sq km. The depth of the reservoir at the dam site is 118m[163].

A significant characteristic of the Srisailam Reservoir is that the reservoir flows between deep gorges with steeply rising hill ranges on either side, and the depth is more than the width. It varies from 60m to 90m in this portion and the reservoir from Siddheswaram spreads out into a wide but shallow portion where the depth is between 9m and 15m and is surrounded by thick and verdant forest vegetation of NSTR[163].

### 6.5.5 Biodiversity

NSTR is part of one of the four eco-floristic zones found in Andhra Pradesh types ("Eco-floristic zones map of Tropical Asia" FAO, 1989). The core area comes under the the biotic provinces of zone (6) of the Deccan peninsula, i.e. 6D and 6E and has its representative bio-geographic features. The forests are mostly southern tropical dry deciduous miscellaneous type as per the Champion and Seth classification. The forests in core area consists mostly of a mixture of *Hardwickia, Chlorxylon* or *Albizzia* communities. They can be further sub-divided into Teak, Miscellaneous, Nallamaddi, Yepi and Anogeissus types depending on species preponderance[163].

Moist Deciduous forests occur mainly in the northern zone along the permanent small streams. *Mangnifera indica* occurs along the streams. The wet parts are occupied by *Costus speciosus*, *Clerodendron serratum*, , etc., *Barleria strigosa* forms a dense population near the small river falls. *Entada pursaetha* and *Bauhinia vahlii* form huge climbers. Other than these, *Piper attenuatum*, *P. hymenophyllum, P. nigrum* species are also present in this reserve. On the banks of the streams and at moist places *Ficus hispida, Trema orientalis, Glochidion zeylanica, Suregada lanceolatum* are common. Occurrence of *Barringtonia racemosa* can be observed on the slopes of the bank of river Krishna[163].

Near the fringes of tanks *Dendrocalamus strictus* forms a dense forest. *Murraya koenigii* is confined to the Eastern Nallamala where aridity is evident. Thorny scrub near the very dry localities, especially Peddachama, has a population of *Acacia catechu* var. chudra, *A. horrida, A. leucophleoa, A. nilotica, Aegle marmelos, Capparis divaricata, Dichrostachys cinerea, Delmonia acidissima etc., Albizzia lebbeck, A. ordoratissima, Ailanthus excelsa, Balanites aegyptiaca, Ochna obtusata*, and many species of *Grewia*. Some of the old trees commonly found are Ficus, Terminalias, Hardwickia, Bombax, Tamarindus, Syzygium, Pterocarpus, and Albizzia species[163].

The diversity of geo-morphology and vegetation gives rise to a multitude of habitats and ecological niches that support rich wildlife. Extensive forest areas along the river allow the development of genetically viable populations. NSTR is home to over 80 species of mammals, 303 species of birds, 54 species of reptiles, 20 amphibians, 55 fishes, 101 species of butterflies, 57 species of moths, 45 species of coleopteran, 30 species of *Odonata* and numerous other forms of insects some of which are very rare and important species of arachnids like Emperor Scorpion, Tarantula Spider, Whip Scorpion and Whip Spider. This tiger reserve constitutes significant piscine fauna comprising 55 species of 36 genera under 20 families. The water bodies like ponds, puddles, foot hills, hill streams rivulets form suitable habitat for these species[163].

The main faunal species include Tiger, Panther, Sloth Bear and typical dry land predators – Wild Dog, Hyena and Jackal; prey species like Sambar, Chital, Chowsingha, Nilgai, Mouse Deer, Wild Boar and Chinkara. The river Krishna has Mugger, Otters and Turtle populations. Among the birds found here are Grey Hornbill, Malabar Whistling Thrush and Paradise Fly Catcher[163].

### 6.5.6 Tourism

NSTR offers wholesome package of natural beauty, recreational activities, historical structures and religious hermitage. Its tourism zone constitutes around 8 percent of the total inviolate area of tiger reserve and 5.4 percent of the total geographic area of the tiger reserve. It has three tourism zones[163] details of which are given in the Table 6.5-2.

*Table 6.5-2 Tourism Zones in NSTR* [163]

| Name of the Zone | Area (Km$^2$) | Important Tourist Locations |
|---|---|---|
| Vijayapuri North Tourism Block | 26.94 | The Nagarjunasagar Dam, Nellikal Reserve Forest |
| Vijayapuri South Tourism Block | 14 | The Relics of the Nagarjuna Buddhist University |
| Ethipothala Tourism | 2.42 | Chandaravanka Waterfall |

The Srisailam (overlapping) zone spread in an area of 18.25 sq km, envelopes Srisailam Project Colony – Sikharam, Ishta Kameswari Temple along Srisailam-Dornal Road up to Tummalabailu. This is an overlapping zone on research, environmental education, interpretation, adventure and aquatic sports region[163].

The famous temples such as Srisaila Mallikarjuna Swamy Temple, Akkamahadevi Temple, Nagaluty Veerabhadra Swamy Temple, Rudrakoteswara Swamy Temple and Ishtakameshwari Temple are located in the core area of NSTR. Among these temples, Srisailam Temple is visited by many pilgrims throughout the entire year. This temple is visited by lakhs of pilgrims (approximately 5 lakh pilgrims) during Mahasivarathri and Ugadi festivals. About 2-3 lakh pilgrims visit the temple during festival time by walking through the tiger reserve[163].

The ruins of the Nagarjuna University can be seen at Nagarjunakonda. Nagarjuna Acharya, the great Buddhist scholar of the Mahayana cult, started this ancient seat of learning in 150 AD. He is known for his treatise on alchemy and *mritha sanjeevani* (the recipe for eternal life)[163].

The Srisailam Mallikarjuna Swamy is an important Hindu pilgrimage centre established since the thirteenth century AD. Within the Srisailam Temple complex stand the *'Trifala Vriksham',* three species of Ficus springing forth as if from a single stem-under which Adi Sankaracharyya, a great saint of medieval India, was believed to have meditated for 365 days. There are also several rock temples and cave shelters lying scattered in the reserve. The Ettipothala waterfalls, which is a tourist attraction, is located within the reserve[163].

### 6.5.7 Socio-Economic Situation

About 85 villages with a population of about 1.70 lakhs live in and around, within 2 km from NSTR. The Primitive tribe group - “Chenchus" and “Lambada” - tribes live in these villages. There are 16 villages in core area. About 557 families with a population of 3285 live in these villages. People of these nearby villages depend on the forests for their food requirements, day-to-day needs NWFP, fodder for cattle, fuelwood and land for agriculture. The Lambadas earn their livelihood by raising cattle and selling milk products besides practising agriculture. As per a PRA exercise conducted by the forest department, collection of NWFP like Tuniki leaves and honey, is one of the primary sources of income accounting for 45 percent. Overall collection of NWFP contributes upto 6-45 percent of household income. Employment opportunities such as agricultural labour are limited[163].

As most of the region is rain-fed, dry land crops are being raised by the farmers. The total area under cultivation is estimated to be around 65,752 hectares. The main cereal crops are paddy, sorghum and maize. Pulse crops include black gram, green gram, horse gram and Bengal gram and the principal oilseeds are groundnut, castor and sunflower. Some areas also have cash crops like cotton, chillie, tobacco and to a lesser extent soyabean. Farmers vary their crop rotations according to the onset of the monsoons. Kharif crop as mainly paddy and later sorghum, sunflower, groundnut, Bengal gram follow this[163].

Apart from this, fishing, carpentry or making of agriculture implements, and bamboo basket making are also prevailing sources of livelihood. Fishing is regulated and done as per the prescriptions of the Field Offices[163].

### 6.5.8 Valuation Estimates- Nagarjunasagar Srisailam Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES

#### 6.5.8.1 Employment Generation

NSTR provides employment opportunities to locals in the form of working at base camp, in strike force or anti-poaching quad, check posts and as fire watchers and maintenance workers. The total number of man-days of employment generated in the year 2015-16 is around 101590 (270 workers for 12 months and 20 workers for 5 months)[164]. Total monetary value of employment generation from NSTR is around Rs. 30.04 million per annum. Detailed job-wise calculation can be seen in Table 6.5-3.

*Table 6.5-3 Employment Generation in NSTR*

| Type of Job | Number of Workers | Period of Engagement (Months) | Wage Rate (Per Month) | Total Employment Generated (Rs.) |
|---|---|---|---|---|
| Helpers at Base Camp | 235 | 12 | 9232 | 26034240 |
| Strike Forces/ Anti-poaching Squad | 25 | 12 | 7932 | 2379600 |
| At Check-Points | 10 | 12 | 7932 | 951840 |
| Fire Watchers | 20 | 5 | 6700 | 670000 |
| **Total** | | | | **30035680** |

#### 6.5.8.2 Fishing

Fishing is done in the local streams and reservoirs which is regulated by the field offices and EDCs. According to the estimates of the NSTR management[164], about the reserve provide approximately 1514 tonnes of fish is caught annually. Taking species-wise catch and rate, total estimated value of fish harvesting benefits is around Rs. 227.1 million per annum.

#### 6.5.8.3 Fuelwood

Fuelwood collection is done by the people of settlements inside and near the reserve. Firewood is mainly used for cooking, water heating and keeping houses warm during the winter in the villages. According to the estimates of the NSTR management[164], about the reserve provide approximately annual RS. 11.86 million worth of fuelwood to local people.

### 6.5.8.4 Fodder/Grazing

Livestock of nearby settlements and villages is dependent on the reserve for the forage requirements. Taking the equivalent cattle units of the total cattle population in the core and buffer, given by the tiger reserve management[164], and assuming standard forage quantity at 22 kilograms per cattle unit per day per cattle unit[107], the total annual quantity of fodder harvested from the reserve is equal to 258942 tonnes. Assuming an average price of Re. 1 per kilogram of fodder the economic value of annual grazing benefits provided by NSTR is approximately equal to Rs. 258.94 million.

### 6.5.8.5 Standing Timber (Stock)

The standing stock of NSTR has immense value. To estimate the economic value of the standing stock, growing estimates of timber from the forest inventory database[108] of the Forest Survey of India (FSI) have been used. It is estimated that approximately 12.24 million cubic metres of standing stock of timber is contained in NSTR as shown in Table 6.5-4. In monetary terms, using an average price of 25000 per cubic metre after discounting for transportation and maintenance cost, the standing stock has value equal to 306.03 billion.

*Table 6.5-4 Timber Stock in the Forests of NSTR*

| Forest Type | Forest Cover | Growing Stock (Cubic m Per ha) | Area (ha) | Total Growing Stock(in Thousand Cubic m) | Economic Value (in Million Rupees) |
|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 41.70 | 29673.37 | 1237.3795 | 30934 |
| Tropical Dry Deciduous Forests | MDF | 41.44 | 186231.05 | 7716.53149 | 192913 |
| Tropical Dry Deciduous Forests | OF | 25.15 | 98640.49 | 2480.91321 | 62023 |
| Tropical Thorn Forests | VDF | 54 | 0.66 | 0.03548446 | 1 |
| Tropical Thorn Forests | MDF | 27.00 | 1517.82 | 40.9812453 | 1025 |
| Tropical Thorn Forests | OF | 13.50 | 2006.95 | 27.0938802 | 677 |
| Non-Forest | - | 15.15 | 48736.69 | 738.430451 | 18461 |
| **Total** | | | | **12241.3653** | **306034** |

For Nagarjunasagar Srisailam Tiger Reserve, the growing stock estimated for Tropical Thorn Forests VDF and MDF category have been derived from OF value by taking quadruple and double value respectively. For Plantation/TOF (4.94 ha), there were no growing stock estimates available and hence it has been excluded from calculations.

### 6.5.8.6 Timber Flow

No timber harvesting takes place in NSTR and hence the economic value of flow benefits from this service is zero[164].

### 6.5.8.7 Bamboo

Bamboo is used for making baskets which is one of the main sources of income for the villagers of Vadlaramapuram and Sundipenta. They make Chandrikas *(*baskets for rearing silkworms) and sell them in the Atmakur market and export to Karnataka[163,164]. According to the figures given by the tiger reserve management[164], bamboo harvesting worth Rs. 4.32 million is done annually which is taken as the economic value of this service from NSTR.

### 6.5.8.8 Non-Timber Forest Produce

Collection of NTFP like mahua, chiranji, honey, gum, amla, and medicinal plants is mostly carried out in the reserve forest of the buffer area. Apart from this, chenchu collect honey from tall trees and rock cliffs. Collection of honey and collection of Tuniki leaves is also done by the local people during the months of April and May[163,164]. Total economic value of the NTFP collection as per species-wise rates of local market (Table 6.5-5) is estimated approximately as Rs. 19.5 million in the year 2015-16.

*Table 6.5-5 NTFP Collection from NSTR[164]*

| S.No. | Name of the NTFP | Qty | Value (in Million Rs.) |
|---|---|---|---|
| 1 | Gum Karaya | 5885 Kgs | 1.03275 |
| 2 | Gum Thiruman | 2050 Kgs | 0.3075 |
| 3 | Gum Kondagogu | 1640 Kgs | 0.246027 |
| 4 | Myrabolans | 1125 Kgs | 0.10625 |
| 5 | Nuxvomica | 8160 Kgs | 0.8226 |
| 6 | Seeded Tamarind | 14810 Kgs | 0.37025 |
| 7 | Deseeded Tamarind | 2400 Kgs | 0.154 |
| 8 | Flower Tamarind | 1000 Kgs | 0.07 |
| 9 | Tamarind Seed | 4200 Kgs | 0.089 |
| 10 | Pongamia | 3687 Kgs | 0.058566 |
| 11 | Mohuva Seed | 1350 Kgs | 0.079 |
| 12 | Mohuva Flower | 150 Kgs | 0.009 |
| 13 | Honey | 17298 Kgs | 6.3894 |
| 14 | Sheekakai | 5000 Kgs | 0.3 |
| 15 | Soapnuts | 12761.85 Kgs | 0.3827 |
| 16 | Wild Brooms | 4200 Bundles | 0.13 |
| 17 | Hill Brooms | 2300 Bundles | 0.056 |
| 18 | Adda Leaf | 22250 Kgs | 0.3423 |
| 19 | Maredugeddalu | 5800 Kgs | 0.696 |
| 20 | Wax | 1000 Kgs | 0.6 |
| 21 | Dry Amla | 12550 Kgs | 0.251 |
| 22 | Rella Bark | 5 Kgs | 0.0003 |
| 23 | Others ( Green Amla) | 10600 Kgs | 1.6048 |
| 25 | Beedi-Leaves | 500 kg | 0.2 |
| 26 | Medicinal Herbs | 2000 Kgs | 0.04 |
| 27 | Sughandapaleru | 25540 Kgs | 4.2178 |
| 28 | Usiri | 520 Kgs | 0.0326 |
| 29 | Velaga | 17600 Kgs | 0.88 |
| 30 | Karaka | 600 Kgs | 0.03 |

| | Grand Total | | 19.498 |
|---|---|---|---|

### 6.5.8.9 Genepool Protection

NSTR has a rich repository of biological information and genepool. It also shares connectivity with SV National Park via corridors to Seshachalam Hills[163,164]. Using estimates of economic value of genepool protection for tropical forests (Rs. 100122 per hectare per annum) and cropland (Rs. 68772 per hectare per annum) from a global meta-analysis study[116], the annual economic value of this service from 317837.88 hectares of forests and 4933.77 hectares of cropland in NSTR is estimated to be Rs. 32.16 billion.

### 6.5.8.10 Carbon Storage

The model maps carbon storage densities to forest type raster which include types such as Tropical Dry Deciduous Forests, Tropical Thorn Forests, Plantation and Non Forest. The model summarizes results into raster outputs of storage, value, as well as aggregate totals. The carbon model provides summary in a table and a map of current carbon storage. Figure 6.5-3 shows the spatial distribution in carbon storage throughout NSTR.

**Medicinal Plants of NSTR [164]**

According to a Rapid Assessment Survey carried out during 1998 to assess the potential of medicinal plant resources of NSTR, about 353 species in 88 families are known to have medicinal properties. The ethno-botanical knowledge from local tribes related to 88 families of medicinal plants was also documented. The following plant families contain recorded species and the number of plants is shown in brackets:
Fabaceae (26), Rubiaceae (19), Euphorbiaceae (18), Mimosaceae (18), Caesalpinaceae (15), Acanthaceae (11), Asclepiadaceae (11), Asteraceae (11), Cucurbitacea (10), Solanaceae (10) share the larger proportion of medicinal plant species. A critical analysis of the status of medicinal plant wealth of NSTR reveals that 10 species are critically endangered; 21 species are endangered; and 27 species come under Vulnerable category.

*Table 6.5-6 Carbon Stock in NSTR*

| Vegetation Class | Forest Cover | Carbon Stock in Various Pools(tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total Carbon Stock (Million tC) |
|---|---|---|---|---|---|---|---|---|
| | | AGB | BGB | SOM | DW (Incl. Litter) | | | |
| Tropical Dry Deciduous Forests | VDF | 62.71 | 24.63 | 63.63 | 8.84 | 159.81 | 29673.37 | 4.74 |
| Tropical Dry Deciduous Forests | MDF | 59.36 | 23.31 | 42.50 | 1.30 | 126.48 | 186231.05 | 23.55 |
| Tropical Dry Deciduous Forests | OF | 11.69 | 4.59 | 30.73 | 0.83 | 47.84 | 98640.49 | 4.72 |
| Tropical Thorn Forests | VDF | 20.34 | 7.97 | 54.92 | 2.54 | 85.76 | 0.66 | 0.00 |
| Tropical Thorn Forests | MDF | 20.39 | 8.01 | 55.05 | 1.82 | 85.27 | 1517.82 | 0.13 |
| Tropical Thorn Forests | OF | 4.54 | 1.78 | 36.61 | 1.09 | 44.02 | 2006.95 | 0.09 |
| Non Forest | | 1.31 | 0.11 | 33.33 | 0.00 | 34.76 | 48736.69 | 1.69 |
| Plantation/TOF | OF | 3.11 | 0.64 | 68.41 | 1.66 | 73.81 | 4.94 | 0.00 |

| | |
|---|---|
| Total | 34.93 |

It is noted that the non-forest area comprise mostly agriculture land. The average values of major crops like wheat, black gram, pigeon pea and green gram have been taken to calculate the AGB and BGB carbon pools [152]. While to calculate the carbon density in soil for the non-forest area the values of Soil Organic Carbon (SOC) has been referred based on the agro-ecological region [153]. The carbon pools of water have been assumed to be 0. As shown in the table above, carbon stock of more than 34.93 million tonnes are stored in Nagarjunasagar Srisailam Tiger Reserve.

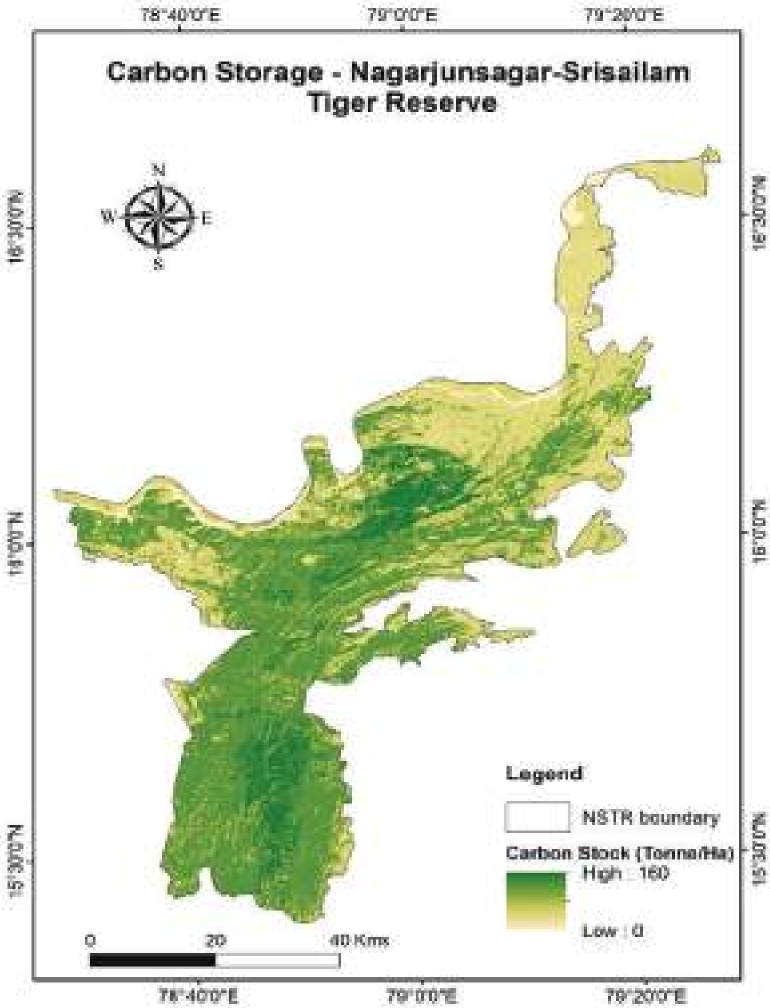



*Figure 6.5-3 Carbon Storage Map of NSTR Created Using InVEST Model*

The estimates from the Carbon Stock model of InVEST as 34.93 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= Rs. 65 as the average for the year 2017-18, the economic value of carbon stock in NSTR is calculated as Rs. 195.26billion.

### 6.5.8.11 Carbon Sequestration

Apart from 34.93 million tonnes of carbon stock in the forests of Nagarjunasagar Srisailam Tiger Reserve, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database[108]. Based on total biomass per unit area, mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type[120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in the above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, the total carbon sequestered in the forests of Nagarjunasagar Srisailam Tiger Reserve by aggregating estimates for each forest type is equal to 499.84 kilo tonnes annually. Detailed calculation is shown in Table 6.5-7.

*Table 6.5-7 Carbon Sequestration from NSTR*

| Forest Type | Forest Cover | Total Biomass Per Unit Area (Tonnes/ha) | Mean Annual Increment Per Unit Area (Tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) | Total Value of Annual Carbon Sequestration (Million RS. Per Year) |
|---|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 100.50 | 3.62 | 29673.37 | 53762.78 | 2205.92 |
| Tropical Dry Deciduous Forests | MDF | 99.86 | 3.60 | 186231.05 | 335274.79 | 13756.53 |
| Tropical Dry Deciduous Forests | OF | 60.61 | 2.19 | 98640.49 | 107792.94 | 4422.81 |
| Tropical Thorn Forests | VDF | 130.14 | 4.78 | 0.66 | 1.57 | 0.06 |
| Tropical Thorn Forests | MDF | 65.07 | 2.39 | 1517.82 | 1812.76 | 74.38 |
| Tropical Thorn Forests | OF | 32.54 | 1.19 | 2006.95 | 1198.47 | 49.17 |
| **Total** | | | | **318070.35** | **499843.30** | **20508.87** |

The social cost of carbon for India as per the latest paper[117], the economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=Rs.65, the total economic value of annual carbon sequestration in NSTR is calculated to be Rs. 20.50 billion.

### 6.5.8.12 Water Provisioning

The model provides various for spatial analysis of the area. It provides with raster and shapefile where various outputs can be spatially studied. The model estimated the total water yield volume for NS Tiger Reserve at 1985.54 million cubic metres. Figure 6.5-4 shows the spatial distribution in water yield throughout NSTR.

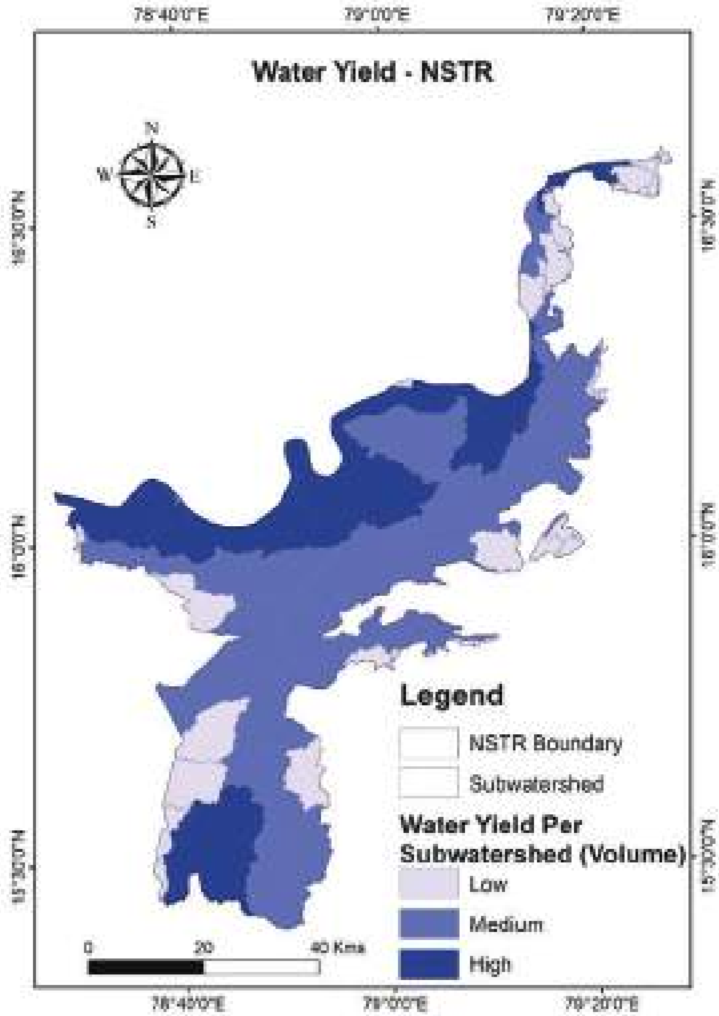



*Figure 6.5-4 Water Yield Output for NSTR Created Using InVEST Model*

Using the monetary value of Rs. 18.43 per cubic metre[1], the economic value of water provisioning service from NSTR is estimated to be 49.77 billion per year. In addition to this, 770 Megawatt of power is generated per day from the dam generators. During 2015-16, the power generated was 174.55 million units. Taking the average of domestic rate, of Rs. 2 per unit and commercial rate of Rs. 7 per unit, as Rs. 4.5 per unit, the economic value of electricity production is equal to Rs. 785.45 million for the year 2015-16.

Thus the total economic value of the water provisioning service from NSTR is approximately 50552.4 million rupees per year.

### 6.5.8.13 Water Purification

The storage capacity of Srisailam Dam is 885 ft (215.81 TMC) with water spread area of 615 sq km. Around 84.02 TMC of flood water is released for irrigation and drinking water. Drinking is water supplied to nearby cities; and back waters stored in upstream of river Krishna is supplied to cities like Chennai through Telugu Ganga Canal (Quantity: 0.95 TMC). Around 1 lakh population is dependent on water supply from the dam in the tiger reserve and about 12 lakh gallons of purified water is supplied per day to nearby Srisailam town[164]. Taking the local rate of purification of water as Rs. 16/- per 1000 gallons, in conjunction with the total purified water suppled as 12 lakh gallons[164], the economic value of water purification service provided by NSTR is approximately 7 million annually.

### 6.5.8.14 Soil Conservation/Sediment Retention

The InVEST model has great potential to quantify the sediment retention service. Outputs from the sediment model include the sediment load delivered to the stream at an annual time scale, as well as the amount of sediment eroded in the catchment and retained by vegetation and topographic features. The sediment load (or export, as it is called in the model results) from a given pixel, is the amount of sediment eroded from that pixel that actually reaches the stream. The values of sediment export ranges from 1000 tons to 630890 tons per subwatershed (Figure 6.5-5).

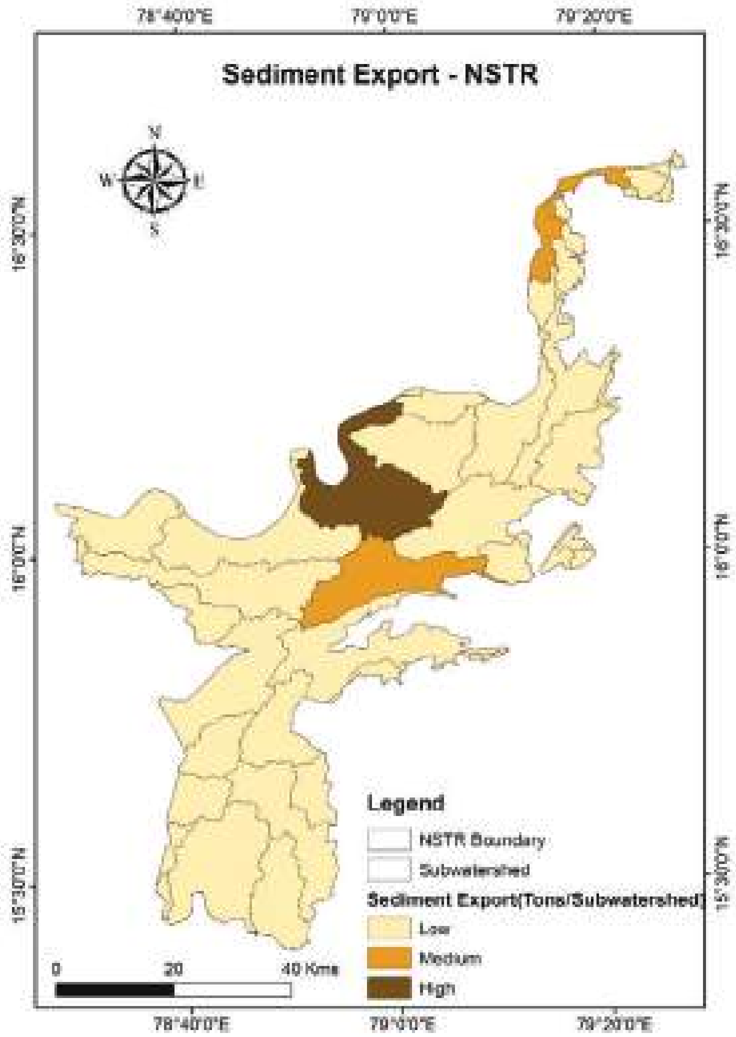



*Figure 6.5-5 Sediment Export from NSTR Created Using InVEST Model*

As indicated in Figure 6.5-6 the sediment retention in the NSTR landscape is moderately higher mostly in all the subwatersheds. The sediment retention values vary from 10000 tons to 34426092 tons per subwatershed.

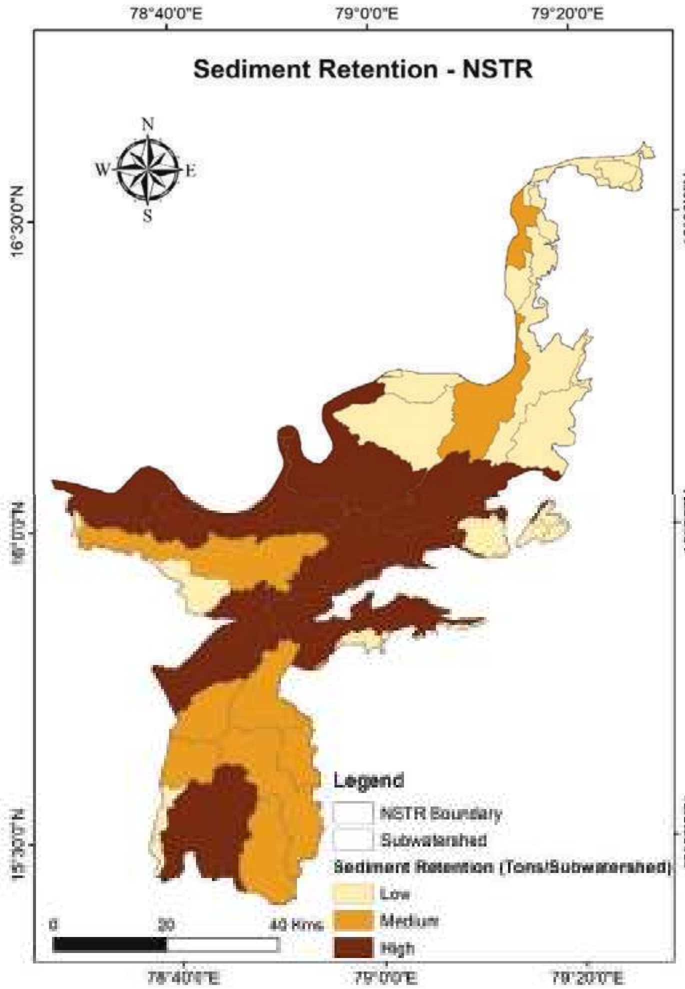



*Figure 6.5-6 Sediment Retention in NSTR Created Using InVEST Model*

To estimate the economic value of soil loss avoided by the forests of NSTR, the cost of dredging/de-siltation has been considered. On account of lack of site-specific data, the cost estimate of Rs. 60 per cubic metre[132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 3009.17 million per year.

### 6.5.8.15 Nutrient Retention

The total soil loss avoided from the InVEST Sediment Retention model of NSTR is around 66.34 million tons. To calculate the amount of nutrient retained, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust[147] has been used on account of lack of local estimates for the same. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations from Table 6.5-8, the total quantity of nutrients retained is approximately 139625.87 tonnes of N, 2648.08 tonnes of P and 496514.40 tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary value has been derived. The total value of nutrient loss prevented by the forests of NSTR is equal to Rs. 6779.65 million annually.

*Table 6.5-8 Nutrient Retention in NSTR*

| Nutrient | Soil Nutrient Concentration (g Per Kg) | Total Nutrient Loss Avoided (Tonnes Per Year) | Fertilizer (Substitute) Used for Valuation | Price of Fertilizer (Rs. Per Tonne) | Economic Value of Nutrient Retention (Million Rs. per Year) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 139625.87 | Urea | 5360 | 748.39 |
| Phosphorous (P) | 0.044 | 2648.08 | DAP | 20100 | 53.23 |
| Potassium (K) | 8.25 | 496514.40 | Muriate of Potash | 12040 | 5978.03 |
| **Total** | | **638788.35** | | | **6779.65** |

### 6.5.8.16 Biological Control

Using estimates of economic value of biological control for tropical forests (Rs. 726 per hectare per annum) and cropland (Rs. 2178 per hectare per annum) from a global meta-analysis study[116] the economic value of biological control service from 317837.88 hectares of forests and 4933.77 hectares of cropland in NSTR is estimated to be Rs. 241.5 million per annum.

### 6.5.8.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to NSTR. Hence it is not included in the valuation of the ecosystem service of NSTR in this study.

### 6.5.8.18 Pollination

Using estimates of economic value of pollination for tropical forests (Rs. 1980 per hectare per annum) and cropland (Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 317837.88 hectares of forests and 4933.77 hectares of cropland in NSTR is estimated to be Rs. 636.48 million per annum.

### 6.5.8.19 Nursery Function

The nursery function was not found relevant due to insufficient information and evident linkages to attribute this service to NSTR. Hence it is not included in the valuation of the ecosystem service of NSTR in this study.

### 6.5.8.20 Habitat for Species

The diversity of geo-morphology and vegetation of NSTR gives rise to a multitude of habitats and ecological niches that support rich wildlife. Extensive forest areas along the river allow the development of genetically viable populations. The steep vertical scarps are home to numerous raptors like Crested Serpent Eagle, Honey Buzzard, Black Eagle and Hawks. These forests also have Grey Jungle Fowl. Presence of numerous streams, dense foliage, wild flowers, woodland edges and damp patches attract numerous colourful butterflies including large Oak Blue, Black rajah, Great Egg Fly, Blue Pancy, etc. river Krishna flowing through the buffer area part of NSTR provides a good aquatic habitat for residential as well as migratory birds. It is a good habitat for Mugger Crocodile, Smooth Indian Otter and many varieties of fishes and amphibians. Flocks of Demoiselle Cranes and Bar-Headed Geese can be seen along the River Krishna. On the south of river Krishna - Pecheruvu and Guttalachenu plateaus have ideal ecotones for wild animals. The transitional zones between dry deciduous forest and thorn forests provide ecotone zones and harbour deer, antelopes and gazelles[163,164].

**NSTR Habitat features**[163]

The Nallamala Hill ranges in the core area of NSTR are dotted with valleys, cliffs, ledges caves and gorges forming an ideal habitat for a variety of fauna especially carnivores and small mammals. Such areas are common along riverbanks of Krishna. River Krishna with the Srisailam and Nagarjunasagar Reservoirs and large tanks like Pecheruvu provide a good aquatic habitat for residential as well as migratory birds. Krishna river is the habitat for Mugger Crocodile, smooth Indian Otter and many varieties of fishes and amphibians. Among avian fauna, flocks of Demoiselle Cranes and Bar-Headed Geese are seen near Nagarjunasagar during January.

Using estimates of economic value of habitat service for tropical forests (Rs. 2574 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 317837.88 hectares of forests in NSTR is estimated to be 818.11 million Rs.

### 6.5.8.21 Cultural Heritage

NSTR has tribal groups like Chenchus and Lambadas. Chenchus are an aboriginal tribe of the central hill ranges of Andhra Pradesh. Chenchus are classified under the most Primitive Tribal Groups in the state because of their subsistence, way of life and dependence on the forests for food gathering, hunting and collection of NWFP, their pre-agricultural level of economy and their symbiotic relationship with forests. They specialize in collecting forest products for sale to non-tribal people or Girijan Cooperative Corporation. They are dark complexioned and mostly short and lean in physical appearance. The male members carry bows and arrows for self-protection and for hunting small animals. They live in small circular huts of 10 feet diametre, made of bamboo and grass[163,164].

The other primitive tribe group Lambadas live in these villages. The Lambadas earn their livelihood by raising cattle and selling the milk products besides practicing agriculture. The Lambadas' original home is considered to be Rajasthan. The present-day Lambadas represent the complete transition from pastoral nomads to settled cultivation and many have turned to agriculture for sustenance. They are generally adept at cattle breeding and subsist on milk and milk products[163,164].

Other than Chenchus and Lambadas, the local communities include Scheduled Caste and Backward Classes. Prominent among them are Yadavas and Vadderas who mostly depend on forest produce like bamboo, NWFP, timber and smallwood[163] .

There are three types of settlements[163]:

(a) *Pentas*: Very small, highly scattered habitation having territory forest comprising only a few families. Each habitation has its own territory for the exploitation of forest resources.

(b) *Gudems*: Typically set up near the streams and comprising 3-30 families, many of whom have lands within the forest enclosures but which are not cultivated on a sustained basis.

*(c)* *Small Hamlets:* On the periphery of the area where families are engaged in continuous agriculture including cash crops such as cotton and gingelly.

### 6.5.8.22 Recreation

NSTR is located in the Nallamala Ranges of the Eastern Ghats. The scenic escarpments, with deep and vertical gorges along the streams and distant rolling mountainous plateau and grasslands of NSTR are a treat to the visitor's eye. NSTR has a full package to offer to the tourists. NSTR has an eco-tourism centre at Bairluty. Activities like jungle safari, jungle camp, nature trails, trekking, bird and butterfly watching, archery, heritage walks, etc are available here. NSTR gets many visitors throughout the year[163].

Rollapadu is a Wildlife Sanctuary in Nandikotkur (Kurnool District). Its main attraction is the Great Indian Bustard and Lesser Florican. It also has rolling grasslands and unique bird dirversity. It is one of the largest roosting sites of Harriers in South India during November to January. Heritage walks are through the teak plantation raised during 1906 by an Imperial Forest Service Officer H. F. A. Wood. It has traditional water harvesting structures and resting mandapams developed by the Vijayanagar rulers to facilitate pilgrims to Srisailam[163].

A total of 972301 tourist inflow has been reported in the year 2016-17. Revenue generated from tourism in NSTR in the year 2016-17 was Rs. 17.398 million.

### 6.5.8.23 Spiritual Tourism

NSTR has a number of of places of religious importace. It has a total of 31 temples[163,164]. Hatakeswaram, Paladarapanchadra, Istakameswari Temple, Nagaluty, Rudrakodur, Gundla Brahmeswaram Temple, Bairavakona, Bayanna Sela, Naramamidicheruvu Ankalamma Temple and Srisailam Mallikarjunaswamy Temple are the main temples of NSTR. Locals visit these throughout the year and on special occasions. There are a number of rituals, traditions and beliefs associated with them. NSTR has around 80 Choultries for the stay of pilgrims which have a total of about 5000 Rooms. The Srisailam temple attracts more than one crore pilgrims each year[163]. Apart from that a total of 2766050 pilgrims were also reported in 2015-16[164]. A detailed breakup of temple wise footfall is given in Table 6.5-9.

*Table 6.5-9 Annual Footfall in the Temples in NSTR [164]*

| Sl. No. | Name of the Division | Name of the Range | Name of the Temple/Sacred Grove | No. of Visitors / Year |
|---|---|---|---|---|
| A | Srisailam Mallikarjunaswamy | | | More than 1 crore |
| B | Atmakur Division | Atmakur Range | Kolanu Bharathi | 60000 |
| | | | Ankalamma Kota | 10000 |
| | | | Sangameswaram | 80000 |
| | | Nagaluty Range | Nagaluty Temple | 200000 |
| | | | Gummitham Temple | 800 |
| | | | Dharga | 50000 |
| | | Velgode Range | Yoganandham | 200 |
| | | | Gantalingamaiah | 50 |
| | | Bairluty Range | Rudracode Temple | 30000 |
| | | Srisailam Range | Paladhara Panchadhara | 350000 |
| | | | Sakshi Ganapathi | 550000 |
| | | | Bhimunikolanu | 550000 |
| | | | Shikharam | 250000 |
| C | **Markapur Division** | Dornal Range | Anjaneya Swamy Temple | 20000 |
| | | | Baiyanna Swamy Temple | 20000 |
| | | | Pedamanthanalamma | 5000 |
| | | | Ankalamma Temple | 500 |
| | | | Pedhamma Temple | 500 |
| | | | Sri Pathabirama Temple | 5000 |
| | | Y. Palem Range | Anjaneya Swamy Temple | 500 |
| | | G.V. Pally | Istakameswaramma Temple | 25000 |
| | | | Verabadhraswamy Tepmle | 5000 |
| | | V.P. South Range | Dhathatreya Swamy Temple | 123000 |
| | | | Siva Temple | 400 |
| | | | Maisamma Temple | 100 |
| D | **Nandyal Division** | Bandi Atmakur Range | Gundla Bramheswaram Temple | 20000 |
| | | | Omkaram Temple | 100000 |
| | | | Mahanandhi | 100000 |
| | | | Krishnanandhi | 10000 |
| E | **Giddalur Division** | Gundlakamma Range | Nemaligundla Ranga Swamy Temple | 200000 |
| | **Total** | **(A+B+C+D+E)** | | **2766050** |

#### 6.5.8.24 Research, Education and Nature Interpretation

NSTR has tremendous potential for research owing to the undisturbed forest patches and rich cultural heritage. Till date many brief studies and 16 research papers have been published on the natural and cultural wealth of NSTR[164]. It also has two interpretation centres. The Ecological Knowledge Park and the Biodiversity Research Centre are used as places for interpretation of wildlife and their conservation. Though these two centres are located in the core area, interpretation about the wildlife conservation of both core and buffer areas is being given. Awareness and education about the core and buffer area of NSTR is imparted to students, NGOs, conservationists, law makers and public by regularly organizing nature camps, awareness trainings, and workshops through these centres[163].

Ecological Knowledge Park located at Sundipenta is established for imparting the knowledge of evolutionary processes and ecological processes to visitors, especially students from colleges and schools. It depicts different eras and their process of evolution via models. Different stages of evolutionary processes from the origin of life in the ocean to dynasty of dinosaurs to rule of land by mammals are arranged in sequences to explain in a nutshell the gist of evolutionary and ecological aspects. The Ecological Knowledge Park, the first of its kind in a tiger reserve in India, has been developed with eco-friendly materials[163].

Biodiversity Research Centre is an ecological research and monitoring lab set up at Sundipenta. It has a collection of zoological specimens with different taxa like fishes, amphibian, reptilian species and mammalian species[163].

#### 6.5.8.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (Rs. 792 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation from 317837.88 hectares of forests in NSTR is estimated to be Rs. 251.73 million.

#### 6.5.8.26 Waste Assimilation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 7920 per hectare per annum), water body (Rs. 60588 per hectare per annum) and cropland (Rs. 26202 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 317837.88 hectares of forests, 9983.34 hectares of water bodies and 4933.77 hectares of cropland in NSTR is estimated to be Rs. 3.25 billion per annum.

#### 6.5.8.27 Climate Regulation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 134904 per hectare per annum) and cropland (Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 317837.88 hectares of forests and 4933.77 hectares of cropland in NSTR is estimated to be Rs. 43.01 billion.

### 6.5.9 Spectrum of Values- Nagarjunasagar Srisailam Tiger Reserve

NSTR provides a variety of values that fall under economic, scientific, educational, historical, cultural and recreational values.

#### 6.5.9.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| **Summary of Ecosystem Services Based on TEV Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **1018.72** | **Rs. Million/Year** |
| Fuel wood, Fodder, Non-Timber Forest Products, Fishing, Bamboo (Flow), Employment Generation<br>* - Timber (Flow) | | |
| **Indirect Use Value** | **128833.46** | **Rs. Million/Year** |

| | | |
|---|---|---|
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Waste Assimilation, Climate Regulation<br>*- Moderation of Extreme Events, Nursery Function | | |
| **Option Value** | **32161.87** | **Rs. Million/Year** |
| Genepool Protection | | |

| **Summary of Ecosystem Services Based on MA Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **766.99** | **Rs. Million/Year** |
| Employment Generation, Fishing, Fodder, Fuel wood, Bamboo (Flow), NTFP<br>* - Timber (Flow) | | |
| **Regulating Services** | **160411.54** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Waste Assimilation, Climate Regulation, Gene pool Protection<br>*- Moderation of Extreme Events, Nursery Function | | |
| **Cultural Services** | **17.40** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Supporting Services** | **818.11** | **Rs. Million/Year** |
| Habitat for Species | | |

| **Summary of Ecosystem Services Based on Stock and Flow Benefits** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Flow Benefits** | **162.02** | **Rs. Billion/Year** |
| Employment Generation, Fishing, Fodder, Bamboo (Flow), NTFP, Fuel wood, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Waste Assimilation, Climate Regulation<br>* - Timber (Flow), Moderation of Extreme Events, Nursery Function | | |
| **Stock Benefits** | **501.30** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| **Summary of Ecosystem Services Based on Tangible/Intangible Framework** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |

| | | |
|---|---:|---|
| **Tangible Benefits** | **766.99** | **Rs. Million/Year** |
| Employment Generation, Fishing, Fodder, Fuel wood, Bamboo (Flow), NTFP<br>* - Timber (Flow) | | |
| **Intangible Benefits** | **662544.42** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Waste Assimilation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>*- Moderation of Extreme Events, Nursery Function | | |

| **Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework** | | |
|---|---:|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **51289.36** | **Rs. Million/Year** |
| Fishing, Fodder, Fuel wood, Bamboo (Flow), NTFP, Water Provisioning<br>* - Timber (Flow) | | |
| **Protection from Disease/Predators/Parasites** | **241.50** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **78273.89** | **Rs. Million/Year** |
| Carbon Sequestration, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Waste Assimilation, Climate Regulation, Habitat for Species<br>*- Moderation of Extreme Events, Nursery Function | | |
| **Socio-Cultural Fulfilment** | **47.43** | **Rs. Million/Year** |
| Employment Generation, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Ecosystem Assets** | **533459.24** | **Rs. Million** |
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| **Summary of Ecosystem Services Based on EPA Effect Categories** | | |
|---|---:|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **663294.02** | **Rs. Million** |
| Employment Generation, Timber (Stock), Genepool protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Soil Conservation/Sediment Retention, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Gas regulation, Climate Regulation<br>* - Timber (Flow) | | |
| **EPA Effect Category 2** | **17.40** | **Rs. Million** |
| Recreation | | |
| **EPA Effect Category 3** | **16** | **Research Studies till 2015** |

| | | |
|---|---|---|
| Research, Education and Nature Interpretation | | |
| **EPA Effect Category 4** | **Chenchus and Lambadas** | **Main Tribe-Group** |
| Cultural Heritage | | |
| **EPA Effect Category 5** | **More than 1 crore** | **Devotees Per Year** |
| Spiritual Tourism | | |

### 6.5.9.2 Linkages to Human Health

Nagarjunasagar Srisailam Tiger Reserve emanates a range of ecosystem services vital for maintenance of human well-being. Amongst these, Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Biological Control, Pollination, Cultural Heritage, Recreation, Research, Education and Nature Interpretation, Gas Regulation, and Climate Regulation services have huge direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 345.92 billion.

### 6.5.9.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Nagarjunasagar Srisailam Tiger Reserve for the year 2016-17, was around Rs. 17.34 million. Based on the flow benefits of Rs. 162.02 billion per year, for every rupee spent on management costs in NSTR, flow benefits of Rs. 7488.6 are realized within and outside the tiger reserve.

### 6.5.9.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Nagarjunasagar Srisailam Tiger Reserve was estimated at Rs. 0.43 million (Rs. 4.29 lakhs) per hectare.

### 6.5.9.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 5.03 percent of flow benefits accrue at the local level, 22.89 percent at the national level and 72.07 percent at the global level.

# Pakke Tiger Reserve

Pakke Tiger Reserve (PKTR) located in the foothills of the Eastern Himalayas is home to four species of hornbills. Evergreen and broadleaved forests provide a key habitat for Clouded Leopard among numerous other faunal species.

**The tiger reserve generates flow benefits worth Rs. 87.22 billion per year (Rs. 0.58 million per hectare) and stock benefits of Rs. 322.01 billion per year. Vital ecosystem services that emanate from this reserve include provisioning of water (Rs. 36.74 billion per year), carbon sequestration (Rs. 11.68 billion per year) and climate regulation (Rs. 20.01 billion per year).**

**Under the Total Economic Value (TEV) framework, the annual direct-, indirect- benefits and option values were Rs. 0.20 billion, Rs. 72.14 billion and Rs. 14.87 billion, respectively.**

As per the MA framework, the value of provisioning services was Rs. 86.13 million per year, regulating services were Rs. 86.75 billion per year and supporting services was Rs. 0.38 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 86.13 million and Rs. 409.14 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 36.82 billion), protection from disease (Rs. 0.10 billion), benign physical and chemical environment (Rs. 35.41 billion) and ecosystem assets (Rs. 336.88 billion).

The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 208.49 billion per year. The investment multiplier for PKTR was calculated as 1946.49.

## 6.6 Pakke Tiger Reserve

### 6.6.1 Location, Landscape and Significance

The forests of North-East India are recognized as a 'Global Biodiversity Hotspot' and 'Endemic Bird Area' owing to the rich flora and fauna. The landscape forms a transition zone between the Indian and Malayan eco-regions and has high endemicity. Pakke Tiger Reserve is located in the East Kameng district of Arunachal Pradesh towards north of the river Brahmaputra in the transition zone between the Assam plains and the hilly forests of Arunachal Pradesh. Pakke Tiger Reserve is surrounded by forests on all sides and bound by the Kameng river in the west, Pakke river in the east and on the southern part of the reserve lies the Nameri National Park and Tiger Reserve, Assam[165].

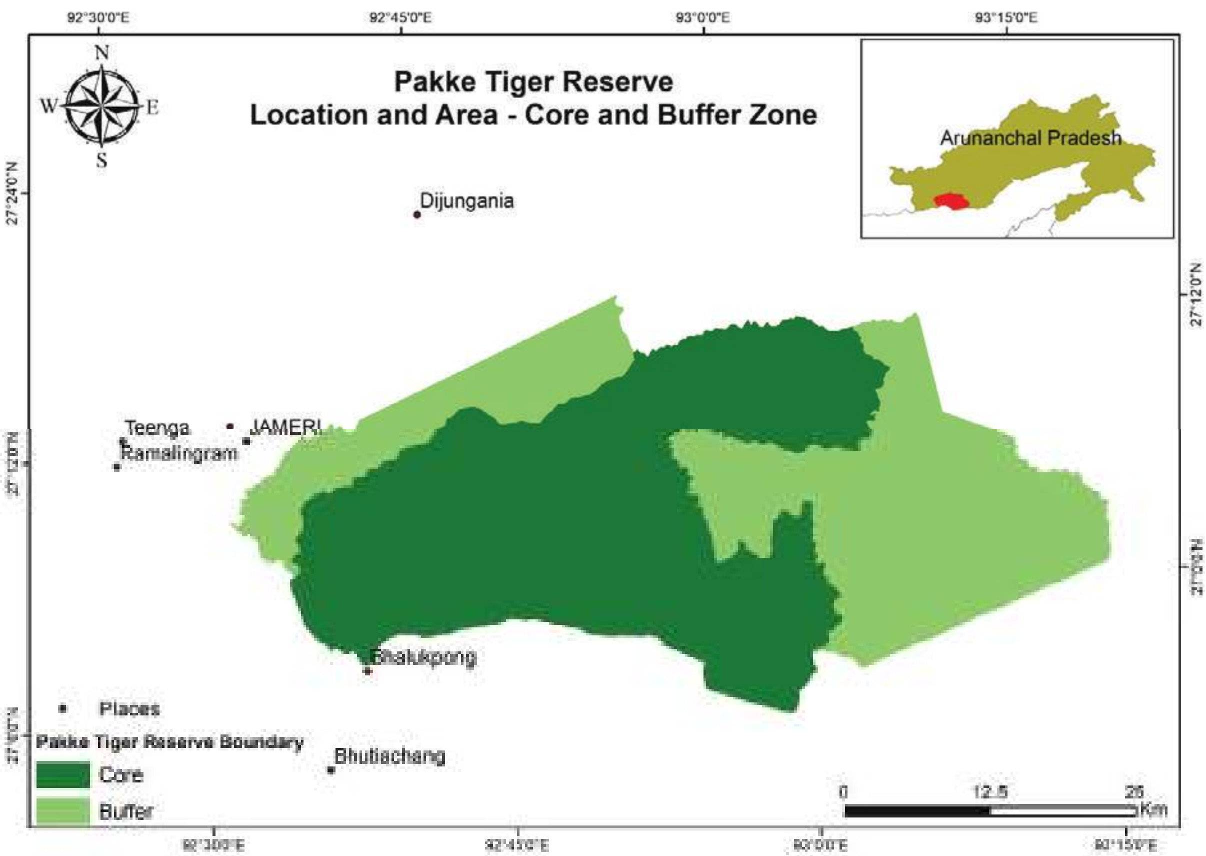



*Figure 6.6-1 Pakke Tiger Reserve (Source: Forest Survey of India)*

Pakke along with Nameri Tiger Reserve form one of the largest blocks of semi-evergreen and evergreen forests in the North-East. They have high significance for ensuring contiguity within the North-East Indian Forests. On the west, they connect with Sonai-Rupai Wildlife Sanctuary through Sessa Orchid Wildlife Sanctuary and Eaglenest Wildlife Sanctuary, on the South with Kaziranga Tiger Reserve and Karbi-Anglong Hills, and towards the north, they are contiguous with Tale Valley and Lower Subansiri forests, which are contiguous with East – Siang and further into Namdapha Tiger Reserve in Changlang District in eastern Arunachal Pradesh[165].

Pakke Tiger Reserve occupies about 20percent of the total geographical area of the East Kameng District and its altitude ranges from 100 m along the southern boundary to 2400 m. The core area of Pakke Tiger Reserve (861.95 sq km) which includes tourism zone (82.5 sq km). The tiger reserve has mainly evergreen and semi-evergreen forest types and some grassland and coniferous vegetation type on some patches. Amongst the 103 mammal species found in PKTR, 6 are endangered: Hog Deer, Asian Elephant, Tiger, Fishing Cat, Wild Dog and Chinese Pangolin. PKTR is home to 296 bird species including the Critically Endangered White Rumped-Vulture, the Endangered White-Winged Wood Duck and the Vulnerable Rufous-Necked Hornbill[165].

### 6.6.2 Topography and Climate

The topography of PKTR is hilly with the elevation ranging from 100 m to 2400 m. The average rainfall fluctuates from 1778.3 mm 1997 to 4174 mm in 2003. PKTR gets both the south-west and north-east monsoon. Most of the rainfall occurs between June and September (south-west monsoon), with some winter rain from December to February. March to May is hot and some thunderstorms and showers occur in April-May. The mean temperature ranges from 20°C to 29°C and humidity of 77 percent with March and June again[165].

### 6.6.3 Land cover Classification

The land use and land cover has been sourced from the Forest Survey of India. The core area of Pakke Tiger Reserve primarily consists of Evergreen and Deciduous forests while the buffer area has mainly Evergreen forest (Figure 6.6-2).

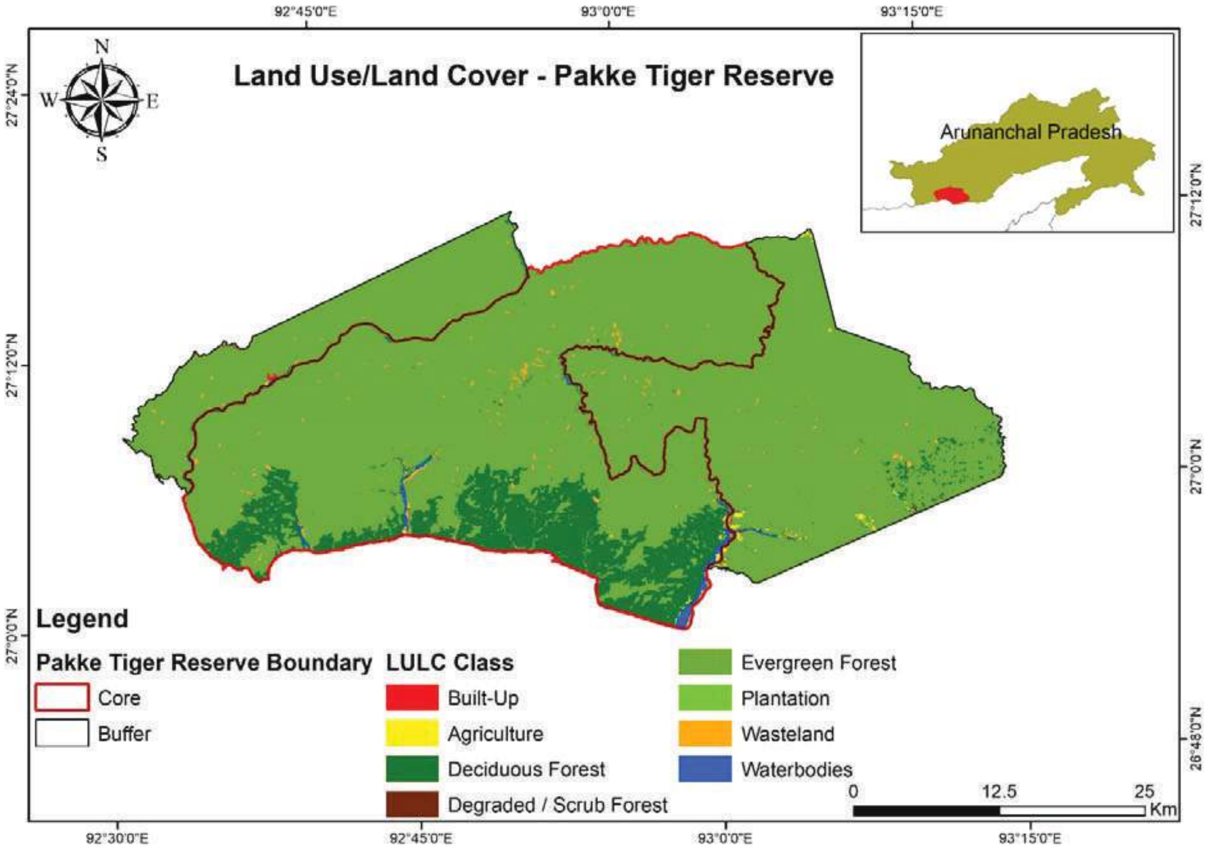



*Figure 6.6-2 Land Use/Land Cover: Pakke Tiger Reserve (Source: Forest Survey of India, 2013-2014)*

The core and buffer area mainly consists of Evergreen forest (87.31 percent) and Deciduous forest, around 10 percent of the total reserves in the core area. The area under each of these land cover classes as shown in the Table 6.6-1.

*Table 6.6-1 LULC Classes PKTR*

| LULC Class | Area (ha) |
|---|---|
| Agriculture | 344.09 |
| Built-Up | 65.97 |
| Deciduous Forest | 16555.00 |
| Degraded / Scrub Forest | 83.21 |
| Evergreen Forest | 131646.34 |
| Plantation | 7.20 |
| Wasteland | 867.05 |
| Water Bodies | 1202.63 |

## 6.6.4 Rivers and Hydrology

PKTR is well drained by many water sources most of which drain into Pakke and Kameng rivers. These rivers also form the boundary of PKTR with Kameng river in the west and Pakke river in the east. It has several perennial rivers and streams such as Khari, Lalung, Upper Dekorai, Doigurung, Nameri, Diji, Denai and Mithun nala on the southern part and Deling, Dera, Paori, Tasum-so in the Northern part. Many *nalas* in the south-eastern part form the Pakke river system. The north-eastern part of the park has several streams which originate in the reserve and drain into the Papu river. Also, many *nalas* originating in the hills in the North-Western region form a part of Kameng river system. Apart from this, there are plenty of other small nalas which have water only during monsoon. Khari Lake (approximately 1.2 ha) is one of the several water bodies used by wildlife like species of waterfowl including the endangered white-winged wood duck[165].

## 6.6.5 Biodiversity

PKTR vegetation can be classified as Assam Valley tropical semi-evergreen forest 2B/C1 according to Champion and Seth 1968 classification. There is evergreen and semi-evergreen vegetation which merge in some patches. Evergreen forests account for 82 percent in Pakke Tiger Reserve, this forest type is distributed throughout the reserve. Semi-evergreen forests occupy around 14 percent of Pakke Wildlife Sanctuary and covers an area of 116 sq km. This forest type is distributed in the southern region of the reserve. Grasslands are spread mainly along riverbanks and floodplains and occupy an area of about 62 sq km. Coniferous vegetation type is mostly found in the higher elevation zone and occupies around 2 percent of the reserve (around 193 sq km)[165].

The multi-storeyed dense forest has an abundance and diversity of epiphytic flora and woody lianas. Layered structures are quite visible in the forests and major emergent species are *Tetrameles nudiflora,Ailanthus grandis* and *Altingia excels*. Along the lower plains and foothills, the vegetation of tropical semi-evergreen dominated by species like *Polyalthia simiarum, Pterospermum acerifolium, Sterculia alata, Stereospermum chelonioides*, *Ailanthus grandis* and *Duabanga grandiflora*. The hill tops and higher slope regions are mostly dominated by subtropical broadleaved forests of the Fagaceae and Lauraceae and hill slopes have mainly species like *Mesua ferrea* and *Castanopsi*[165].

Cane, bamboo and palms are found extensively in the moist areas. Bamboo occurs in the gullies, in areas previously under settlements or subjected to some form of disturbance on the hill slopes. Eight species of bamboo occur and seven common species of cane including *Livistona jenkinsiana,* a species used extensively by locals for thatching roofs is found in the area. Patches of tall grasslands occur along the large perennial streams which give way to lowland moist forests with *Dillenia indica* and *Talauma hodgsonii.* Isolated trees species like *Bombax ceiba* and two species of *Albizzia* are common along the larger rivers[165].

There has been no systematic survey/exploration of the entire floral diversity of Pakke Tiger Reserve, although numerous research studies and extensive documentation have been done. A total of 29 species of ferns and fern-allies belonging to 15 families have been documented (11 species: Padmawathe et al. 2004, 18 species: A. Datta, *pers. obs.*). However, more systematic documentation is required. Among monocots, two species of palms, seven cane species (Arecaceae), and several bamboos and grasses (Poaceae) are recorded. A list of 67 other monocot species from 5 families has been recorded from various observations, including 43 species of orchids (Appendix XXVII (A). Thirty-four climber/liana species have also been identified (seven species: Padmawathe et al. 2004; rest: A. Datta, *pers. obs.*), however many more species are likely to occur[165].

***Tree Species Composition, Density and Structure***

In a study in 1995-96, 235 (of which 30 could not be identified) species of woody plants (angiosperms) were enumerated, from the lowland areas of the tiger reserve, with a high representation of species from the Euphorbiaceae and Lauraceae families (Datta and Goyal 1997), but at least 1500 species of vascular plants are expected from Pakke Tiger Reserve, of which 500 species would be woody (G.S. Rawat, *pers. comm.*). Fifty-eight dicot families were represented in plots. The families with maximum representation were Lauraceae (23 species), Euphorbiaceae (19), Meliaceae (12), Sterculiaceae (8), and Myrtaceae (7). A total of 2789 individual trees in 198 plots (10 m radius) were measured for various structural characteristics. The total area sampled was 5.914 ha; 1.76 ha in unlogged forest (Tipi), 2.074 ha in logged forest (Doimara RF), 0.82 ha in old logged forest (Seijusa), 1.26 ha in semi-disturbed forest (Khari) and 0.314 ha in plantation (Monai, Papum RF)[165].

There are 59 documented species of mammals in PKTR. However, this does not include most rodents and chiropterans. Based on other mammal lists and species distribution accounts for North-East India, 103 species of mammals listed can be found in Pakke. Based on the IUCN red list, PKTR has six species of endangered mammals : Hog Deer (*Axis porcinus*), Asian Elephant (*Elephas maximus*), Tiger (*Panthera tigris*), Fishing Cat (*Prionailurus viverrinus*), Wild Dog (*Cuon alpinus*) and the Chinese Pangolin (*Manis pentadactyla*), 10 vulnerable species: Gaur (*Bos gaurus* ), Sambar (*Rusa unicolor*), Capped Langur (*Trachypithecus pileatus*), Slow Loris (*Nycticebus bengalensis*), Clouded Leopard (*Neofelis nebulosa*), Marbled Cat (*Pardofelis marmorata*), Himalayan Black Bear (*Ursus thibetanus*), Binturong (*Arctictis binturong*), Oriental Small-Clawed Otter (*Aonyx cinerea*) and Smooth-Coated Otter (*Lutrogale perspicillata*)[165].

PKTR is rich in avifauna and has 296 documented bird species. The major avifaunal groups are forest birds such as three species of hornbills: The Great Hornbill (*Buceros bicornis*), Wreathed Hornbill (*Aceros undulatus*) and the Oriental Pied Hornbill (*Anthracoceros albirostris)*. More than 45-50 species of major frugivorous/granivorous birds occur here and apart from this, broadbills, cuckoos, the Red-Headed Trogon (*Harpactes erythrocephalus*), two leaf bird (*Chloropsis*) species, Fairy blue bird (*Irena puella*), two oriole species (*Oriolus*), and four species of flowerpeckers (*Dicaeum*) were also recorded. The avifauna includes at least 6 globally threatened species such as the Great Hornbill, Rufous-Necked Hornbill, White-Winged Wood Duck, Pallas's Fish Eagle and the White-Cheeked Hill Partridge. Rare species like Amur Falcon, Green Cochoa, Great Cormorant, Black Stork and the White-Browed Shortwing; and threatened and rare birds are the Wreathed Hornbill, Mountain Scops Owl and the Asian Brown Flycatcher are also recorded here. There are accounts of the rare Oriental Bay Owl, a first record from Western Arunachal Pradesh in PKTR[165].

There are 31 documented species of amphibians in PKTR. Forty-five reptile species have been recorded with 16 lizard species including the Monitor Lizard (*Varanus benghalensis*), Tokkay Gecko (*Gekko gecko*) and the Spotted Forest Skink (*Sphenomorphus maculatus*). It has 23 snake species including the locally threatened Burmese Python (*Python molurus bivittatus*) and six turtle species including three endangered/vulnerable species - the Keeled Box Turtle (*Pyxidea mouhotii*), Assam Roofed Turtle (*Pangshura sylhetensis*), Indian Peacock Softshell Turtle (*Nilssonia hurum*) (Datta 1998c) and the Indian Black Turtle (*Melanochelys trijuga*). PKTR has around 30 documented species of fish, at least two species of eels and two species of catfish sound. PKTR has over 200-300 estimated species of butterfly out of which 85 are recorded. About twenty-one species of dragonflies (13), damselflies (8), 26 genera of spiders and 2 species of scorpions have been recorded from PKTR[165].

### 6.6.6 Tourism

Tourism is low in the PKTR owing to its difficult accessibility, local weather and insurgent conditions[18]. However, PKTR does attract a number of local visitors for picnics and recreation along the river banks in the summer season[165].

### 6.6.7 Socio-Economic Situation

The tiger reserve management and local people have set up EDCs for promoting and managing ecotourism activities. A community managed Pakke jungle camp has been set up recently by Ghora-Aabhe (local NGO) and forest department. The community also plays an important role in conservation and awareness activities. There are total 43 villages in PKTR[165].

### 6.6.8 Valuation Estimates for Pakke Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES.

#### 6.6.8.1 Employment Generation

Owing to scarcity of data on number of employment days generated, the economic value of this service has not been estimated in monetary terms in this study.

#### 6.6.8.2 Fishing

Fishing is done in the streams and Kameng river by the local inhabitants. Estimates of fish catch are derived here by talking to the locals. As per the Focused Group Discussions (FGDs) conducted with the locals it was found that fishing is done throughout the year from the water bodies. It was also found that the total quantity of fish catch from Pakke Tiger Reserve is equal to 1.09 kilo tonnes a year (Consumption is 1.75 kg of fish per week for one person). Assuming a local average market price of Rs. 25 per kg, the economic value of fish catch from PKTR is equal to Rs. 27.29 million annually.

### 6.6.8.3 Fuelwood

Fuelwood is used by locals as a source of energy for cooking food and for maintaining temperatures in cooler weather. Estimates of fuelwood collection are taken after discussion with local groups. Taking a general estimate of 25 kg of fuelwood usage per household per week, the total fuelwood usage is around 2.99 kilo tonne per year. Taking a rate of Rs. 5 per kg, the economic value of fuelwood collection from PKTR is approximately Rs. 15 million annually.

### 6.6.8.4 Fodder/Grazing

Cattle of nearby and buffer villages of PKTR are dependent on PKTR for their forage requirements. Total livestock dependent on PKTR, as obtained from the PKTR management[166], converted to Adult Cattle Units (ACU) using appropriate weights for each category. Total Cattle Units dependent on PKTR are 2800.54. Taking the standard forage quanity of 22 kg per day per ACU[107], the annual forage requirement of 22.48 kilo tonnes is met from the forests of PKTR. Assuming a nominal rate of Re 1 per kg of fodder, the total economic value of forage service provided by the forests of PKTR is equal to Rs. 22.5 million per year.

### 6.6.8.5 Standing Timber (Stock)

The standing stock of PKTR has immense value. To estimate the economic value of the standing stock, growing estimates of timber species from the forest inventory database[108] of the Forest Survey of India (FSI) have been used. It is estimated that approximately 7.89 million cubic metres of standing stock of timber are contained in PKTR as shown in Table 6.6-2. In monetary terms, using an average price of 25000 per cubic metre after discounting for transportation and maintenance cost, the standing stock has value equal to Rs. 197.35 billion.

*Table 6.6-2 Timber Stock in the Forests of PKTR*

| Forest Type | Forest Cover | Growing Stock (Cubic m Per ha) | Area (ha) | Total Growing Stock(in Thousand Cubic m) | Economic Value (in Million Rupees) |
|---|---|---|---|---|---|
| Tropical Semi-Evergreen Forests | VDF | 100.55 | 11657.95 | 1172.21 | 29305.18 |
| Tropical Semi-Evergreen Forests | MDF | 66.34667 | 45390.18 | 3011.49 | 75287.18 |
| Tropical Semi-Evergreen Forests | OF | 68.13333 | 9388.28 | 639.65 | 15991.37 |
| Himalayan Moist Temperate Forests | VDF | 16.33571 | 26498.07 | 432.86 | 10821.62 |
| Himalayan Moist Temperate Forests | MDF | 27.43636 | 28725.41 | 788.12 | 19703.02 |
| Himalayan Moist Temperate Forests | OF | 21.68571 | 11865.48 | 257.31 | 6432.79 |
| Subtropical Broadleaved Hill Forests | VDF | 196.9333 | 4392.98 | 865.12 | 21628.10 |
| Subtropical Broadleaved Hill Forests | MDF | 98.46667 | 6891.44 | 678.58 | 16964.42 |
| Subtropical Broadleaved Hill Forests | OF | 49.23333 | 988.36 | 48.66 | 1216.50 |
| **Total** | | | | **7894.01** | **197350.19** |

For Pakke Tiger Reserve, the growing stocks estimated for Subtropical Broadleaved Hill Forest VDF and OF category have been derived from MDF estimates by taking double and half of its value respectively. There were no growing stock estimates for Tropical Wet Evergreen Forests (626.57 ha) and hence this forest type is excluded from calculations.

### 6.6.8.6 Timber Flow

No timber flow is recorded from the Pakke Tiger Reserve and thus this service has not been included in calculations.

### 6.6.8.7 Bamboo

Locals collect bamboo for domestic usage like making or repairing huts, thatching roofs, use as walking sticks, and making of furniture, baskets, etc. As per the discussion with local communities, a household uses 250 bamboos on an average per 3 years for repairing huts and making fences, and around 500 bamboos per household for making huts. Assuming an average life of 8 years for a bamboo hut, and a rate of Rs. 50 per bamboo piece (15-20 ft long), the economic value of bamboo collection from PKTR is estimated to be Rs. 16.78 million per year.

### 6.6.8.8 Non-timber Forest Produce

Locals collect forest produce from the buffer areas of PKTR. Tokko leaves (*Livistona jenkinsiana*) are collected from the forests and it is the main NTFP apart from Dhuna, which is a kind of resin from *Canarium* and cane. These leaves are mainly used for thatching the roofs of bamboo huts. As per the discussion with local groups, it is estimated that around 70-100 leaves are collected for 3 years by each household from PKTR. Assuming a local rate of Rs. 30 per leaf, the economic value of Tokko leaves collection from PKTR is estimated to be Rs. 4.6 million per year.

### 6.6.8.9 Genepool Protection

Pakke Tiger Reserve has 103 mammal species among which 6 are endangered: hog deer, Asian elephant, tiger, fishing cat, wild dog and Chinese pangolin, 296 bird species including the Critically Endangered White rumped-vulture, the Endangered White-winged wood duck and the Vulnerable Rufous-necked hornbill[165].

PTR also has 31 species of amphibians including Pterorana khare which is the first record from an area other than its type locality since its description in 1986 and 45 reptile species (13 lizard species, 26 snake species and 6 turtle species)[165].

**Pakke Tiger Reserve: Corridors and Connectivity[165]**

The forests of the North-East India are recognized as a 'Global Biodiversity Hotspot' and 'Endemic Bird Area' due to their richness in floral and faunal species. The landscape has high species diversity and endemicity as it forms the transition zone between the Indian and Malayan eco-regions. The two important parts of the North-East Indian tiger landscape are the Brahmaputra flood plains and the North-East Indian hills.

Pakke and Nameri Tiger Reserves are situated north of the river Brahmaputra in the transition zone between the Assam plains and the hilly forests of Arunachal Pradesh. Together, they form one of the largest blocks of semi-evergreen and evergreen forests in the North-East. They are extremely important in maintaining contiguity within the North-East Indian forests and are centrally located within the Western Assam and Arunachal forests. On the West, they are connected with the Sonai-Rupai Wildlife Sanctuary through the Sessa Orchid Wildlife Sanctuary and Eaglenest Wildlife Sanctuary, on the South with Kaziranga Tiger Reserve and Karbi-Anglong Hills, and towards the north, they are contiguous with Tale Valley and Lower Subansiri forests, which are contiguous with East – Siang and further into Namdapha Tiger Reserve in Changlang district in eastern Arunachal Pradesh.

This protected area is among the largest continuous block of tropical forests in the country and is extremely important in maintaining contiguity within the North-East Indian forests and has a vital role in maintenance of water and climatic regime of the region.

Due to lack of comprehensive primary data, the method of benefits-transfer has been used for valuation of this service. Using estimates of economic value of genepool protection for tropical forests (Rs. 100122 per hectare per annum) and cropland (Rs. 68772 per hectare per annum) from a global meta-analysis study[116], the annual economic value of this service from 148291.75 hectares of forests and 344.1 hectares of cropland in PKTR is estimated to be Rs. 14.87 billion.

### 6.6.8.10 Carbon Storage

The carbon stock of various forest types have been worked out from the FSI report titled Carbon Stock in India's Forests published in 2011 which has been used here to estimate the carbon storage of Pakke tiger reserve. The Montane moist temperate forest and Tropical semi-evergreen forest predominantly found in the tiger reserve with areas 670 sq km and 664 sq km respectively.

*Table 6.6-3 Carbon Stock in PKTR*

| Vegetation class | Forest Cover | Carbon Stock in Various Pools(tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total carbon Stock (million tC) |
|---|---|---|---|---|---|---|---|---|
| | | AGB | BGB | SOM | DW (incl. Litter) | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Himalayan Moist Temperate Forests | VDF | 63.77 | 16.10 | 113.16 | 4.70 | 197.72 | 26498.07 | 5.24 |
| Himalayan Moist Temperate Forests | MDF | 34.81 | 8.79 | 85.44 | 2.79 | 131.83 | 28725.41 | 3.79 |
| Himalayan Moist Temperate Forests | OF | 21.02 | 5.31 | 87.56 | 2.38 | 116.25 | 11865.48 | 1.38 |
| Tropical Wet Evergreen Forests | VDF | 42.56 | 14.72 | 137.00 | 3.62 | 197.91 | 284.08 | 0.06 |
| Tropical Wet Evergreen Forests | MDF | 26.88 | 9.30 | 126.69 | 5.29 | 168.15 | 246.24 | 0.04 |
| Tropical Wet Evergreen Forests | OF | 14.94 | 5.17 | 106.45 | 3.90 | 130.45 | 96.25 | 0.01 |
| Tropical Semi-Evergreen Forests | VDF | 60.92 | 12.53 | 136.33 | 4.19 | 213.98 | 11657.95 | 2.49 |
| Tropical Semi-Evergreen Forests | MDF | 35.53 | 7.31 | 99.74 | 3.14 | 145.71 | 45390.18 | 6.61 |
| Tropical Semi-Evergreen Forests | OF | 14.00 | 2.88 | 88.06 | 2.64 | 107.58 | 9388.28 | 1.01 |
| Subtropical Broad Leaved Hill Forests | VDF | 40.17 | 15.77 | 95.36 | 1.47 | 152.76 | 4392.98 | 0.67 |
| Subtropical Broad Leaved Hill Forests | MDF | 36.95 | 14.51 | 77.53 | 0.79 | 129.78 | 6891.44 | 0.89 |
| Subtropical Broad Leaved Hill Forests | OF | 27.49 | 10.79 | 64.92 | 0.53 | 103.74 | 988.36 | 0.10 |
| Total | | | | | | | | 22.30 |

It should be noted that the non-forest area comprises mostly agriculture land. The average values of major crops like wheat, black gram, pigeon pea and green gram have been taken to calculate the AGB and BGB carbon pools[152]. While to calculate the carbon density in soil for the non-forest area the values of Soil Organic Carbon (SOC) has been referred based on the agro-ecological region[153]. The carbon pools of water have been assumed to be 0.

The InVEST model provides output in the form of a carbon spread map and a summary table. Using these estimates in conjunction with carbon stock in various carbon pools as shown in the Table 6.6-3, the total carbon stored in

Pakke Tiger Reserve is approximately equal to 22.30 million tonnes. It can be seen from the output that carbon sock is higher across the whole landscape of Pakke Tiger Reserve (Figure 6.6-3). The other output received is in the form of a map where the stored carbon values are mapped spatially across the landscape.

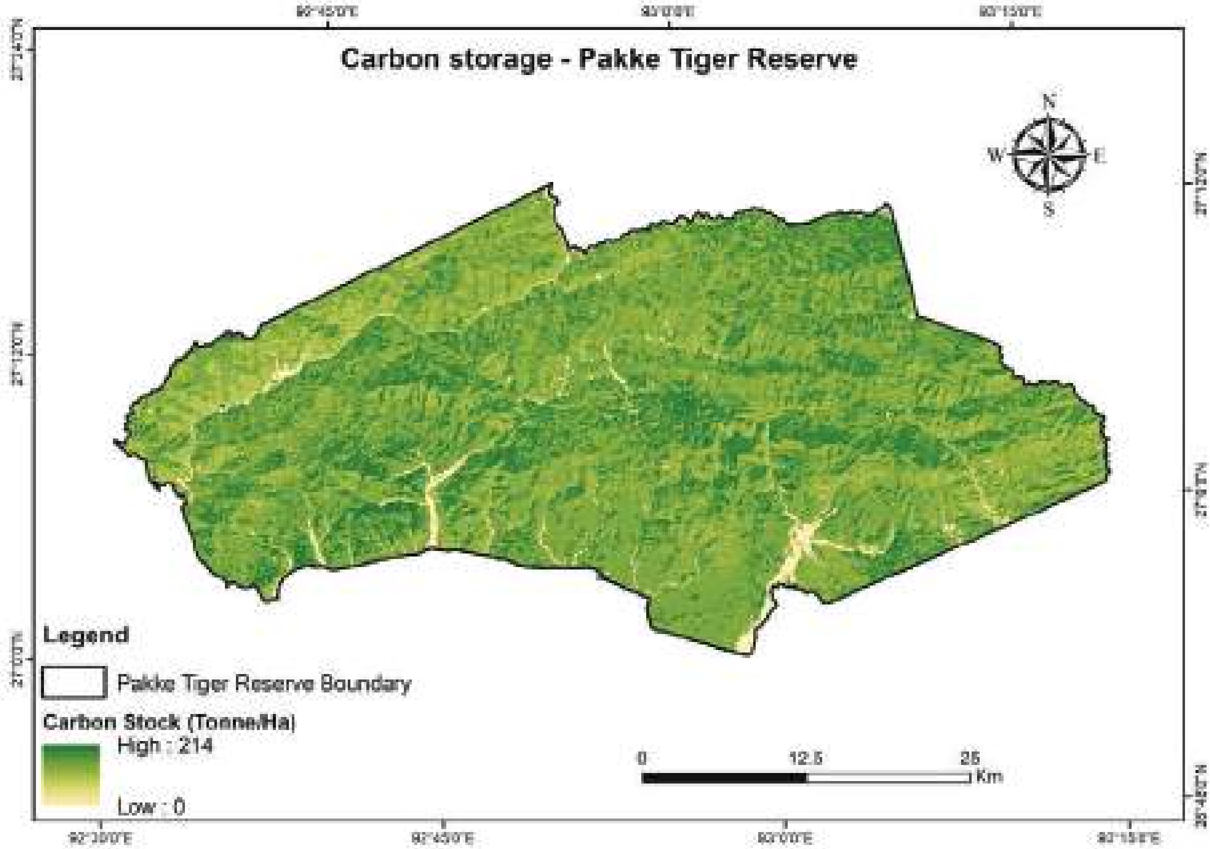



*Figure 6.6-3 Carbon Storage Map of Pakke Tiger Reserve Created Using InVEST Model*

The estimates from the Carbon Stock model of InVEST as 22.3 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= Rs. 65 as the average for the year 2017-18, the economic value of carbon stock in PKTR is calculated as Rs. 124.66billion.

### 6.6.8.11 Carbon Sequestration

Apart from 22.3 million tonnes of carbon stock in the forests of Pakke Tiger Reserve, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database. Based on total biomass per unit area, the mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type [120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, the total carbon sequestered in the forests of Pakke Tiger Reserve by aggregating estimates for each forest type is equal to 284.69 kilo tonnes annually. Detailed calculation is shown in Table 6.6-4.

*Table 6.6-4 Carbon Sequestration in PKTR*

| Forest Type | Forest Cover | Total Biomass Per Unit Area (Tonnes/ha) | Mean Annual Increment Per Unit Area (Tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) | Total Value of Annual Carbon Sequestration (Million RS. Per Year) |
|---|---|---|---|---|---|---|
| Tropical Semi-Evergreen Forests | VDF | 242.33 | 7.62 | 11657.95 | 44397.86 | 1821.67 |
| Tropical Semi-Evergreen Forests | MDF | 159.90 | 5.03 | 45390.18 | 114061.40 | 4680.01 |
| Tropical Semi-Evergreen Forests | OF | 164.20 | 5.16 | 9388.28 | 24227.21 | 994.06 |
| Himalayan Moist Temperate Forests | VDF | 39.37 | 1.03 | 26498.07 | 13654.40 | 560.25 |
| Himalayan Moist Temperate Forests | MDF | 66.12 | 1.73 | 28725.41 | 24860.67 | 1020.05 |
| Himalayan Moist Temperate Forests | OF | 52.26 | 1.37 | 11865.48 | 8116.70 | 333.03 |
| Subtropical Broad Leaved Hill Forests | VDF | 474.61 | 13.70 | 4392.98 | 30087.91 | 1234.53 |
| Subtropical Broad Leaved Hill Forests | MDF | 237.30 | 6.85 | 6891.44 | 23600.04 | 968.32 |
| Subtropical Broad Leaved Hill Forests | OF | 118.65 | 3.42 | 988.36 | 1692.34 | 69.44 |
| **Total** | | | | **145798.16** | **284698.52** | **11681.35** |

According to the social cost of carbon for India as per the latest paper[117], the economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=Rs. 65, the total economic value of annual carbon sequestration in PKTR is calculated to be Rs. 11.68 billion.

### 6.6.8.12 Water Provisioning

The model provides various outputs like modelled values of mean actual evapo-transpiration, mean potential evapo-transpiration, water yield volume, etc. The total water yield volume from Pakke Tiger Reserve as well as its fringe areas amounts to 1993.49 million cubic metres. (Figure 6.6-4).

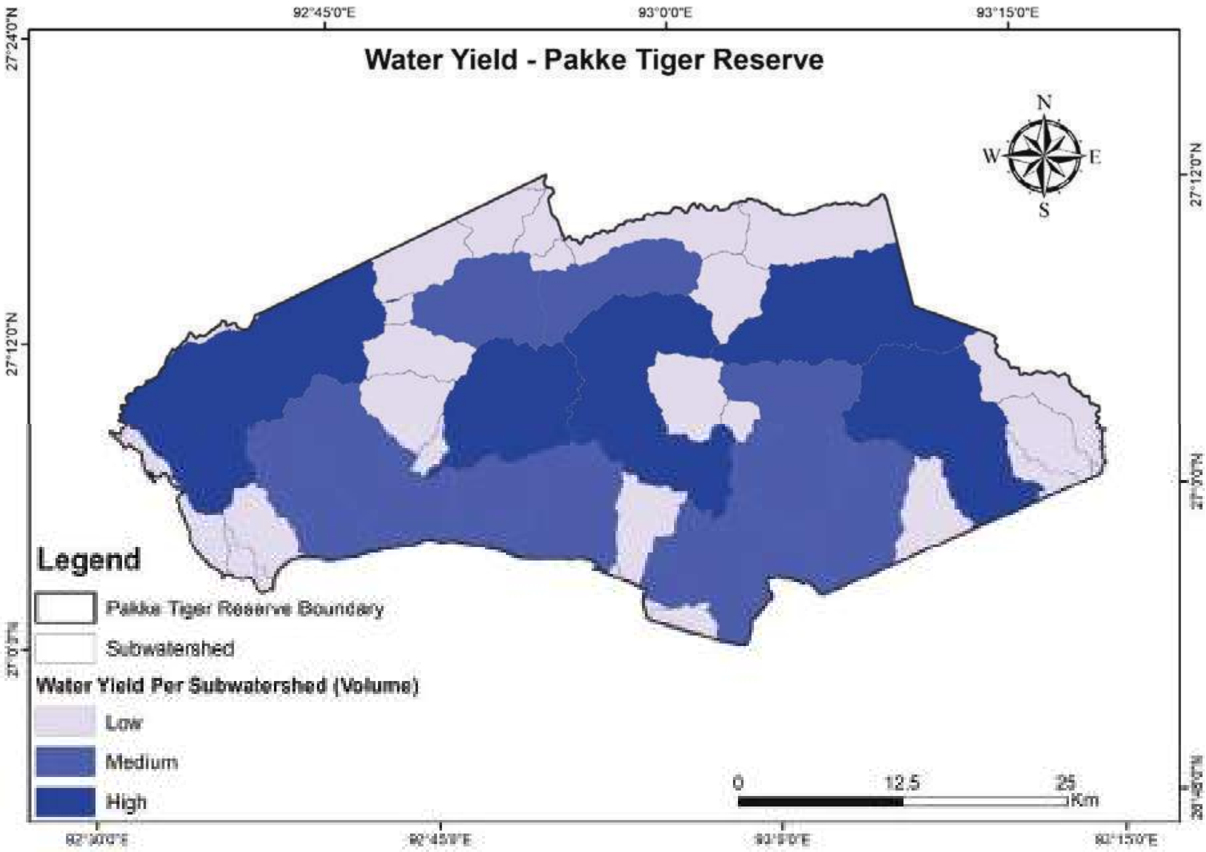



*Figure 6.6-4 Water Yield Output for Pakke Tiger reserve Created Using InVEST Model*

Using the monetary value of Rs. 18.43 per cubic metre[1], the economic value of water provisioning service from PKTR is estimated to be 36.74 billion per year.

### 6.6.8.13 Water Purification

Owing to insufficient data on beneficiaries to establish attribution of this ecosystem service to PKTR and lack of information on local water treatment facilities, this ecosystem service was not found relevant for PKTR and therefore is not included for economic valuation in this study.

### 6.6.8.14 Soil Conservation/Sediment Retention

The output of the model is very exhaustive. Figure 6.6-5 provides the values for the total amount of sediment exported in each subwatershed calculated modelled using InVEST SDR. The output suggests that there is overall low sediment loss found in the Pakke Tiger Reserve. The values of sediment export ranges from 200 tons to 187345 tons per subwatershed.

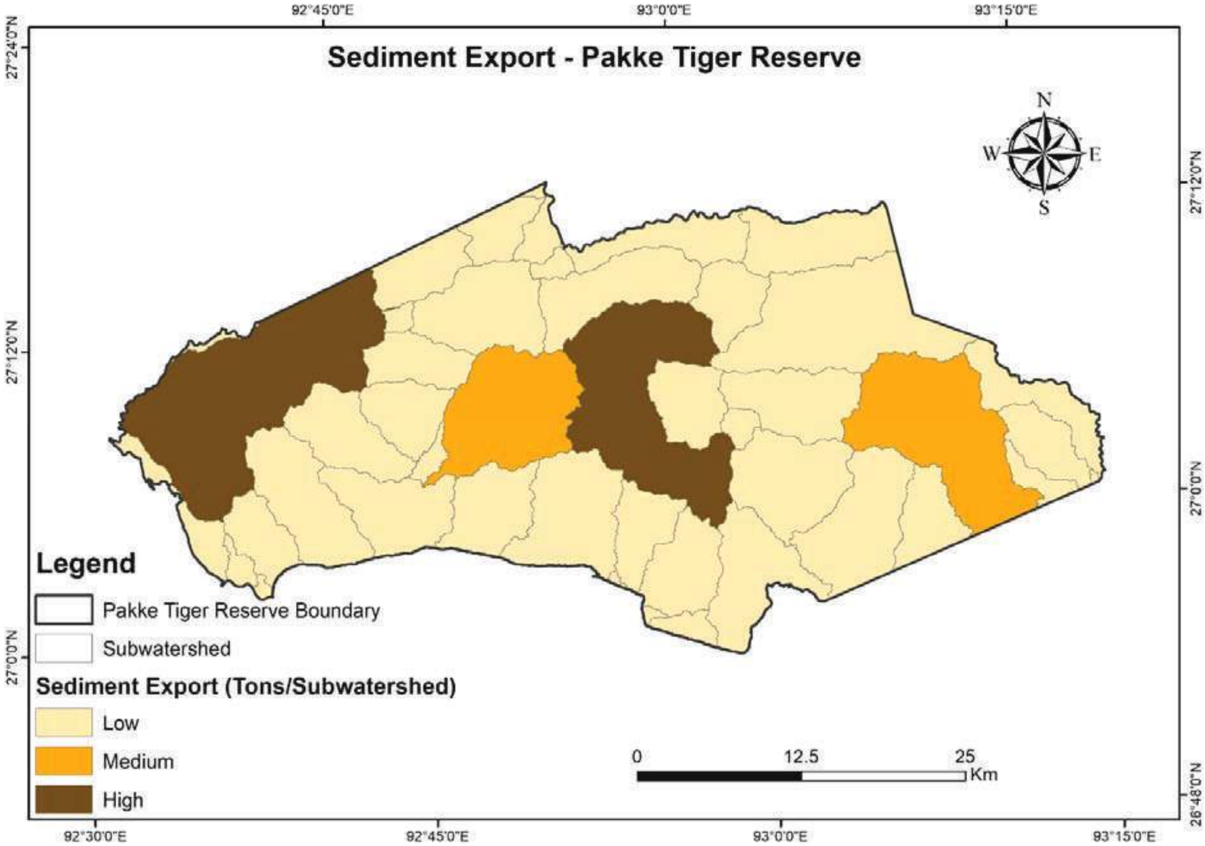



*Figure 6.6-5 Sediment Export from Pakke Tiger Reserve Created Using InVEST Model*

As shown in Figure 6.6-6 the sediment retention in the Pakke Tiger Reserve landscape is medium across the watersheds with fewer higher retention watersheds lying both inside and outside the core area of Pakke Tiger Reserve. The values of sediment retention varies from 58975 tons to 133590136 tons per subwatershed.

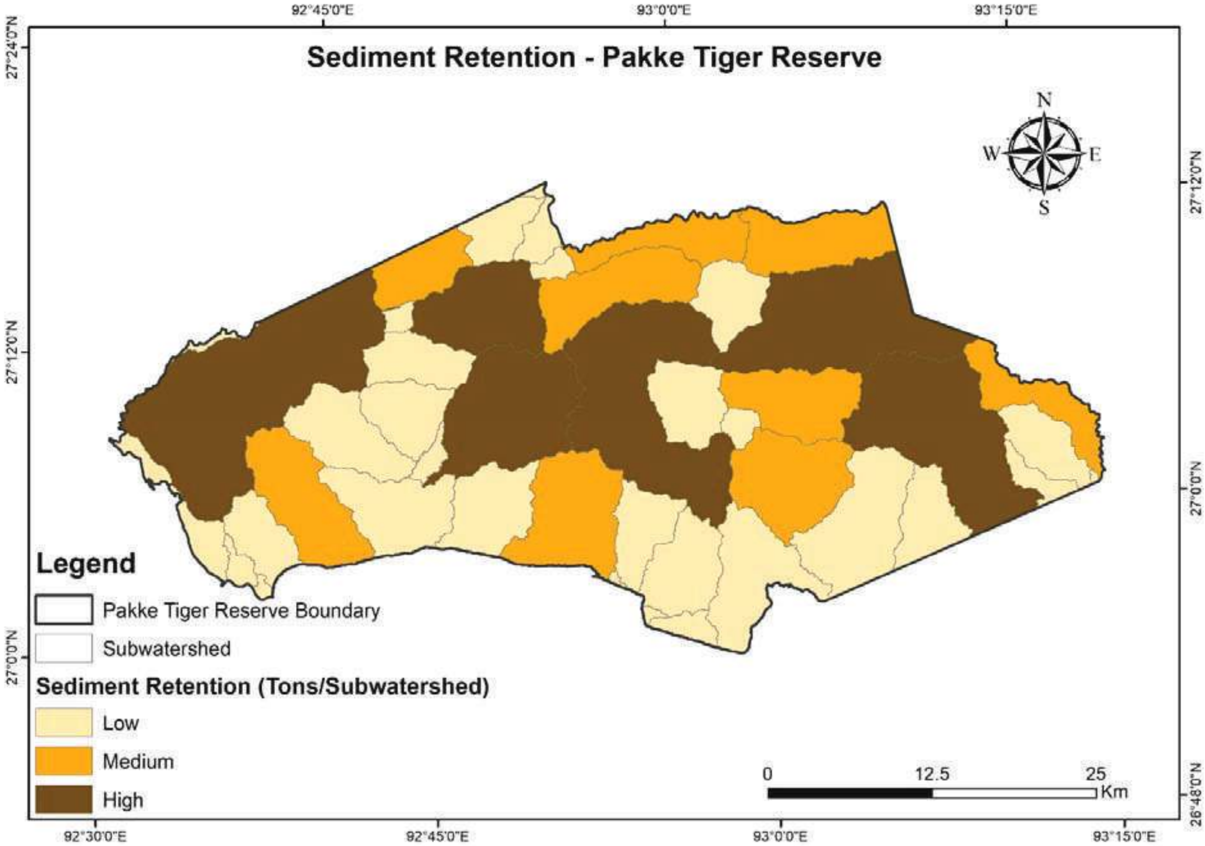



*Figure 6.6-6 Sediment Retention in Pakke Tiger Reserve Created Using InVEST Model*

To estimate the economic value of soil loss avoided by the forests of PKTR, the cost of dredging/de-siltation has been considered. On account of lack of site-specific data, the cost estimate of Rs. 60 per cubic metre [132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 899.88 million annually.

### 6.6.8.15 Nutrient Retention

The total soil loss avoided from the InVEST Sediment Retention model of PKTR is around 19.84 million tons. To calculate the amount of nutrients retained, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust[147] has been used on account of lack of local estimates for the same. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations from Table 6.6-5, the total quantity of nutrients retained is approximately 41754.21 tonnes of N, 791.89 tonnes of P and 148479.42 tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary value has been derived. The total value of nutrient loss prevented by the forests of PKTR is equal to Rs. 2027.41 million annually.

*Table 6.6-5 Nutrient Retention PKTR*

| Nutrient | Soil Nutrient Concentration (g Per Kg) | Total Nutrient Loss Avoided (Tonnes Per Year) | Fertilizer (Substitute) Used for Valuation | Price of Fertilizer (Rs. Per Tonne) | Economic Value of Nutrient Retention (Million Rs. per year) |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 41754.21 | Urea | 5360 | 223.80 |
| Phosphorous (P) | 0.044 | 791.89 | DAP | 20100 | 15.92 |

| | | | | | |
|---|---|---|---|---|---|
| Potassium (K) | 8.25 | 148479.42 | Muriate of Potash | 12040 | 1787.69 |
| **Total** | | **191025.52** | | | **2027.41** |

### 6.6.8.16 Biological Control

Using estimates of economic value of biological control for tropical forests (Rs. 726 per hectare per annum) and cropland (Rs. 2178 per hectare per annum) from a global meta-analysis study[116] the economic value of biological control service from 148291.75 hectares of forests and 344.1 hectares of cropland in PKTR is estimated to be Rs. 108.41 million per annum.

### 6.6.8.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to PKTR, hence it is not included in the valuation of the ecosystem service of PKTR in this study.

### 6.6.8.18 Pollination

Using estimates of economic value of pollination for tropical forests (Rs. 1980 per hectare per annum) and cropland (Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 148291.75 hectares of forests and 344.1 hectares of cropland in PKTR is estimated to be Rs. 294.11 million per annum.

### 6.6.8.19 Nursery Function

Nursery function was not relevant due to inadequate information and lack of supporting evident linkagesto attribute this service to PKTR, hence it is not included in the valuation of ecosystem service of PKTR in this study.

### 6.6.8.20 Habitat for Species

Using estimates of economic value of habitat service for tropical forests (Rs. 2574 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 148291.75 hectares of forests in PKTR is estimated to be Rs. 381.70 million.

### 6.6.8.21 Cultural Heritage

PKTR contains some sacred groves within its inviolate area. These areas are culturally important for the local inhabitants[165]. Owing to insufficient further information on these groves, the same has not been included in the study.

### 6.6.8.22 Recreation

Tourism in PKTR is at a very low scale at the moment mainly due to lack of connectivity and accessibility to the area. It gets around 300 visitors annually[18]. Apart from this many locals visit PKTR for riverside camping and picnics.

### 6.6.8.23 Spiritual Tourism

No information is available on annual footfall to the sacred/religious places inside the tiger reserve.

### 6.6.8.24 Research, Education and Nature interpretation:

PKTR is a hub for conversationalists and researchers. There are many research and conservation projects undertaken by several research scholars, government (WII, NCBS, IISER) and non-governmental organizations (NCF, WTI, WWF, WCT). There are more than 30 published research papers with numerous communication blogs, notes, articles PhDs and reports for PKTR[165]. It gives nature scientists many opportunities to observe and study nature in its pristine form. A variety of interesting studies have come out of work in Pakke Tiger Reserve. The major areas under study have been: abundance estimation, tree phenology, seed dispersal, human-animal conflict, conservation issues and documentation of flora and fauna. Hornbills is one of the most researched species of the area[165,166].

#### 6.6.8.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (Rs. 792 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation from 148291.75 hectares of forests in PKTR is estimated to be Rs. 117.45 million.

#### 6.6.8.26 Waste Assimilation

Waste assimilation was not found relevant due inadequate information and insufficient evident linkages to attribute this service to PKTR. Hence it is not included in the valuation of the ecosystem service of PKTR in this study.

#### 6.6.8.27 Climate Regulation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 134904 per hectare per annum) and cropland (Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 148291.75 hectares of forests and 344.1 hectares of cropland in PKTR is estimated to be Rs. 20.01 billion.

### 6.6.9 Spectrum of Values- Pakke Tiger Reserve

PKTR provides a variety of values that fall under economic, scientific, educational, historical, cultural and recreational values.

#### 6.6.9.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| **Summary of Ecosystem Services Based on TEV Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **203.58** | **Rs. Million/Year** |
| Fuel wood, Fodder, Timber (Flow), Non-Timber Forest Products, Bamboo (Flow), Fishing<br>* - Employment Generation | | |
| **Indirect Use Value** | **72147.46** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>*- Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Option Value** | **14870.93** | **Rs. Million/Year** |
| Genepool Protection | | |

| **Summary of Ecosystem Services Based on MA Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **86.13** | **Rs. Million/Year** |
| Fishing, Fodder, Timber (Flow), Fuel wood, Bamboo (Flow), NTFP<br>* - Employment Generation | | |
| **Regulating Services** | **86754.13** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool Protection | | |

| | | |
|---|---|---|
| * - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Cultural Services** | **0.00** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Supporting Services** | **381.70** | **Rs. Million/Year** |
| Habitat for Species | | |

| **Summary of Ecosystem Services Based on Stock and Flow Benefits** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Flow Benefits** | **87.22** | **Rs. Billion/Year** |
| Fishing, Fodder, Timber (Flow), Bamboo (Flow), NTFP, Fuel wood, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - Employment Generation, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Stock Benefits** | **322.01** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| **Summary of Ecosystem Services Based on Tangible/Intangible Framework** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Tangible Benefits** | **86.13** | **Rs. Million/Year** |
| Fishing, Fodder, Timber (Flow), Fuel wood, Bamboo (Flow), NTFP<br>* - Employment Generation | | |
| **Intangible Benefits** | **409147.70** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |

| **Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **36826.24** | **Rs. Million/Year** |
| Fishing, Fodder, Timber (Flow), Fuel wood, Bamboo (Flow), NTFP, Water Provisioning | | |
| **Protection from Disease/Predators/Parasites** | **108.41** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **35416.39** | **Rs. Million/Year** |

| | | |
|---|---|---|
| Carbon Sequestration, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Climate Regulation, Habitat for Species<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Socio-Cultural Fulfilment** | | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Employment Generation | | |
| **Ecosystem Assets** | **336882.79** | **Rs. Million** |
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| **Summary of Ecosystem Services Based on EPA Effect Categories** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **409233.83** | **Rs. Million** |
| Timber (Stock), Timber (Flow), Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Soil Conservation/Sediment Retention, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Gas Regulation, Climate Regulation<br>* - Employment Generation | | |
| **EPA Effect Category 2** | **No Data** | **Rs. Million** |
| Recreation | | |
| **EPA Effect Category 3** | **More than 30** | **Studies till 2015** |
| Research, Education and Nature Interpretation | | |
| **EPA Effect Category 4** | **-** | |
| Cultural Heritage | | |
| **EPA Effect Category 5** | **-** | |
| Spiritual Tourism | | |

### 6.6.9.2 Linkages to Human Health

Pakke Tiger Reserve emanates a range of ecosystem services vital for maintenance of human well-being. Amongst these, Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Biological Control, Pollination, Cultural Heritage, Recreation, Research, Education and Nature Interpretation, Gas regulation, and Climate Regulation services have a vast direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 208.49 billion.

### 6.6.9.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Pakke Tiger Reserve for the year 2016-17, was around Rs. 37.17 million. Based on the flow benefits of Rs. 87.22 billion per year, for every rupee spent on management costs in PKTR, flow benefits of Rs. 1946.5 are realized within and outside the tiger reserve.

### 6.6.9.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Pakke Tiger Reserve was estimated at Rs. 0.58 million (Rs. 5.79 lakhs) per hectare.

### 6.6.9.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 4.47 percent of flow benefits accrue at the local level, 21.61 percent at the national level and 73.92 percent at the global level.

# Palamau Tiger Reserve

The only tiger reserve in the state of Jharkhand, Palamau Tiger Reserve (PLTR) was formerly used for cattle grazing and camping. The Sal *(Shorea robusta)* forests, mixed deciduous forest and bamboo groves make up the landscape delivering diverse ecosystem services.

**The tiger reserve provides flow benefits worth Rs. 129.54 billion per year (Rs. 0.65 million per hectare) and stock benefits of Rs. 967.45 billion per year. Major ecosystem services that arise from this reserve include carbon sequestration (Rs. 59.79 billion per year), provisioning of water (Rs. 28.53 billion per year), and climate regulation (Rs. 21.14 billion per year).**

**Under the Total Economic Value framework (TEV), the annual direct-, indirect- benefits and option values were Rs. 0.46 billion, Rs. 111.23 billion and Rs. 17.85 billion, respectively.**

As per the MA framework, the value of provisioning services was Rs. 0.34 billion per year, that of regulating services was Rs. 128.81 billion per year, cultural services were Rs. 7.72 million per year and supporting services were Rs. 0.38 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 0.34 billion and Rs. 1096.64 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 28.88 billion), protection from disease (Rs. 0.20 billion), benign physical and chemical environment (Rs. 82.60 billion), socio-cultural fulfilment (Rs. 7.72 million) and ecosystem assets (Rs. 985.29 billion).

The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 231.01 billion per year. The investment multiplier for PLTR was calculated as 3450.55.

## 6.7 Palamau Tiger Reserve

### 6.7.1 Location, Landscape and Significance

One of India's first nine tiger reserves established under Project Tiger, Palamau Tiger Reserve was notified in 1974. Located in the state of Jharkhand, in the western part of Chhotanagpur plateau the reserve is spread over the districts of Latehar and Garhwa. It spans over an area of 1129.93 sq km comprising the Palamau Wildlife Sanctuary (979.27 sq km) and Betla National Park (226.32 sq km). The river North Koel runs along its western boundary and river Aurang along the northern[167].

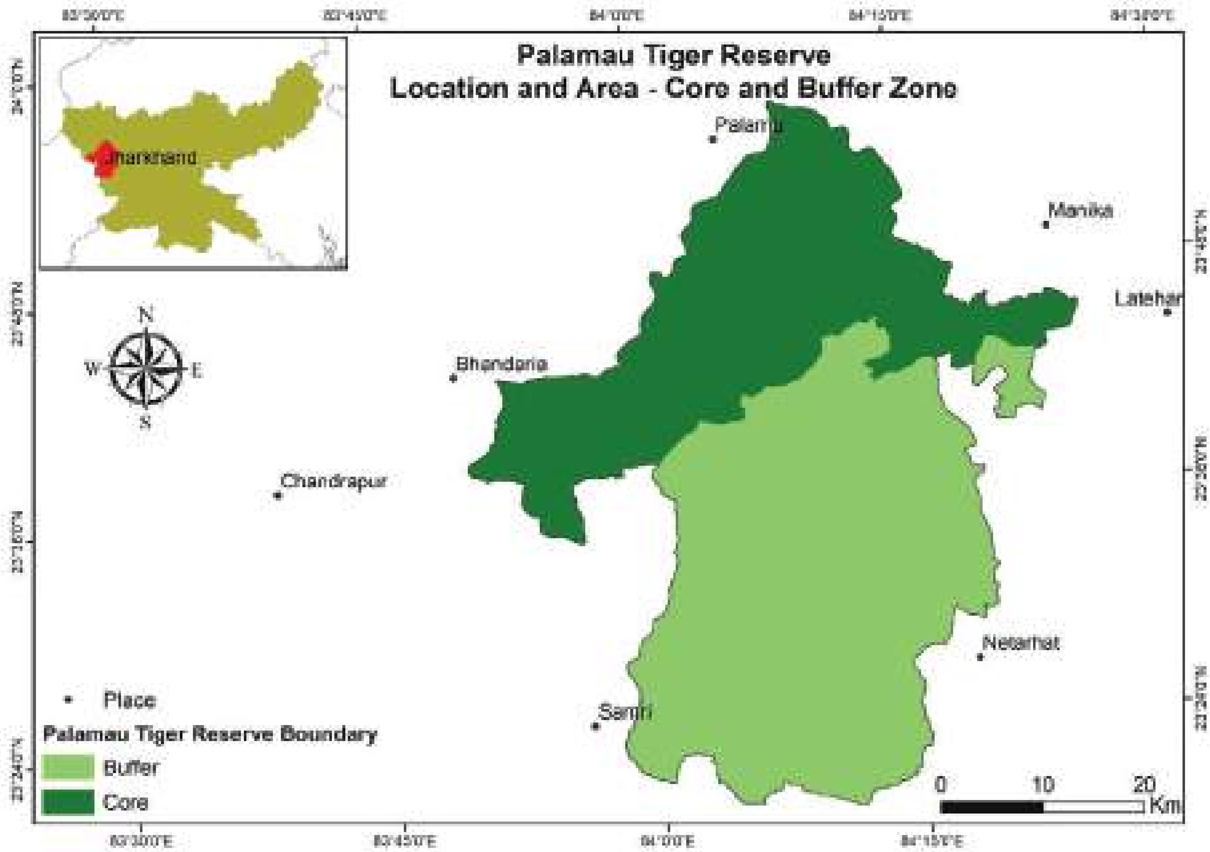



*Figure 6.7-1 Palamau Tiger Reserve (Source: Forest Survey of India)*

It is a part of the Central Indian Landscape Complex and its habitat contiguity extends to Sanjay-Dubri Tiger Reserve, through Guru Ghasidas NP, all the way to Bandhavgarh Tiger Reserve. This makes it a part of the 25000 sq km of Bandhavgarh-Sanjay-Guru Ghasidas-Palamau Landscape. It is also connected to the Achanakmar-Kanha tiger landscape through Jashpur and Mahan forests of Chhattisgarh. To its north-east, it is weakly connected to the Gautam Buddha Wildlife Sanctuary and Koderma Wildlife Sanctuary along the border with Bihar through Lawalong Wildlife Sanctuary in Chatra district as well as the Hazaribagh Wildlife Sanctuary. Towards the south, it is connected to the Saranda/Odisha landscape through the forests of Simdega and Palkot WLS in Gumla district, Chhattisgarh. The reserve has also connectivity to adjoining landscapes like Mahuadanr range forests including Mahuadanr Wolf Sanctuary, forests of Bhandaria and Ranka East ranges of Garhwa, which are contiguous with Sarguja Forest Division of Chhattisgarh, Latehar Forest Division in the west and Medininagar Forest Division in the north-western part[167].

Owing to its contiguity, the area forms one of the largest contiguous tiger habitats in Central India and hence has vast potential to be revived into a source population that supports a stable meta population of tigers across landscapes and revitalizes them with tigers and other wildlife in future[167].

### 6.7.2 Topography and Climate

The altitude increases from 200 m to 1000 m while traversing from north to south. The reserve has undulating terrain with spurs and valleys in the core area. This helps in formation of many primary and secondary level streams in the area. The elevation decreases in the northern part from 800 m to 200 m approximately. The highest peak of the core area is Huluk which is about 800m. The buffer area has an elevation range of 200 m to 1700 m. The major hills of the area are Sarwat, Netarhat, Orsa, Barichattan and Aksi. These major hills along with other small hills form valleys and gorges providing a trophic niche for biodiversity[167].

The major area is covered with denuded hills. The part of Saidup and Amwatikar is represented by structural hills and other areas have pediplain dissected residual hills. The moisture content and water table is high from the north to southern parts[167].

The area experiences tropical climate with extreme hot summers and cold winters. It primarily observes four seasons, viz. winter, summer, rains and autumn. Winters are generally quite cold especially at night. Frost can be seen from late December to early January usually every year but is not severe. The effect of frost is more evident in valleys. The temperature dips to as low as 4°C in valleys of the core. Summers are hot and dry and the temperature can reach 45°C in the northern part of reserve. However, the southern areas are at a higher altitude and denser forest cover, temperatures are comparatively moderate. The monsoon comes mostly with the south-west monsoon. Mean annual rainfall is 1075 mm. Periodic draughts have been noticed with recurring period of about 5 years. Severe hot winds blow during the summer[167].

### 6.7.3 Land Cover Classification

The land use and land cover map of Palamau Tiger Reserve has been sourced from the Forest Survey of India. The land cover of Palamau is broadly categorized into deciduous forest, agriculture, and degraded forest with other minor land uses (Figure 6.7-2).

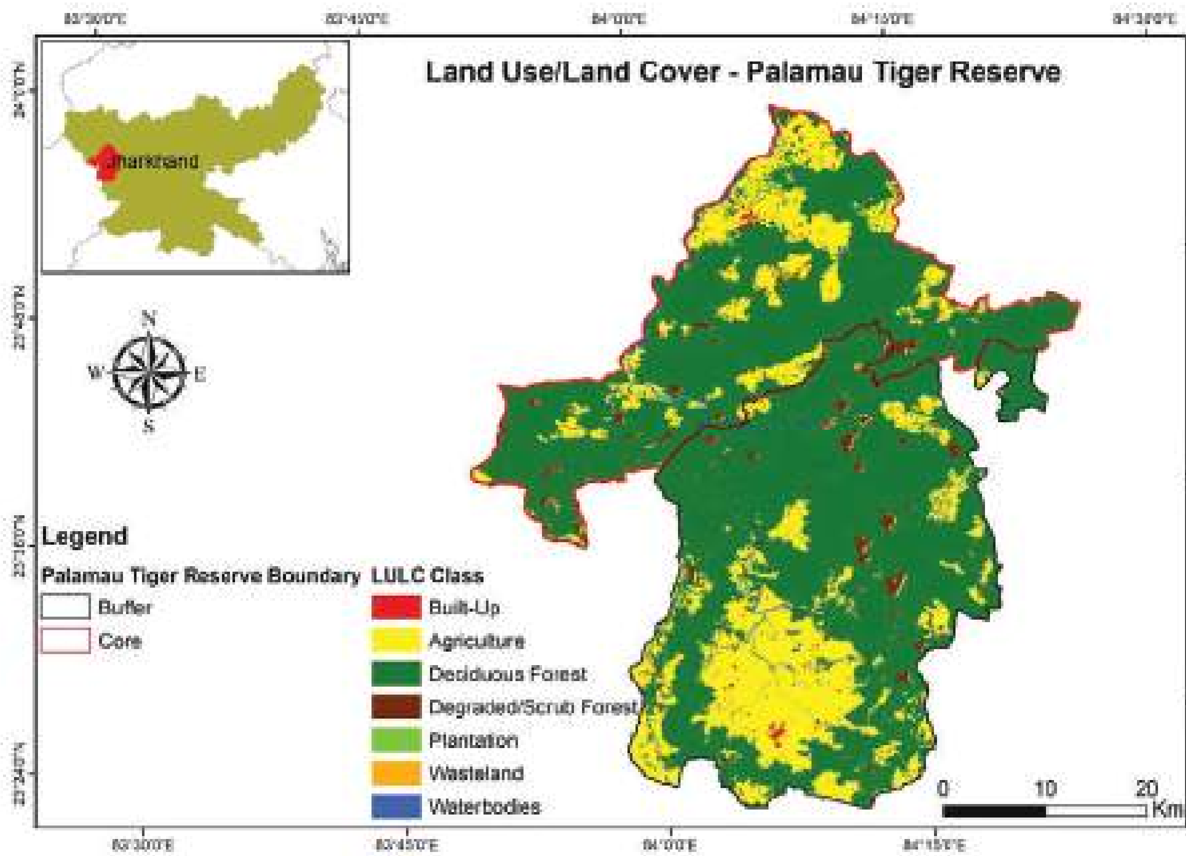



*Figure 6.7-2 Land Use/Land Cover: Palamau Tiger Reserve (Source: Forest Survey of India, 2013-2014)*

The core and buffer area mainly consists of deciduous forest (72.55 percent), agriculture (22.4 percent) and degraded forest (2.05 percent) of the total tiger reserve. The area under each of these land cover classes as shown in the Table 6.7-1.

*Table 6.7-1 LULC Classes PLTR*

| LULC Class | Area (ha) |
|---|---|
| Agriculture | 44371.60 |
| Built-Up | 1216.21 |
| Deciduous Forest | 143711.19 |
| Degraded / Scrub Forest | 4066.93 |
| Plantation | 26.88 |
| Wasteland | 2051.94 |
| Waterbodies | 2619.57 |

### 6.7.4 Rivers and Hydrology

The reserve falls under the region-Ganges, basin-lower Ganges and catchment-Son with sub-catchment of North Koel. It forms the watershed for Auranga, Charu, Burha and upper North Koel streams. There are 12 micro watersheds covering the area. The major drainages are Jawa river and Jalma river. The perennial river Burha meets North Koel in Bagechampa forming a valley[167].

Palamau Tiger Reserve is in a draught-prone area. Three perennial rivers flowing across the reserve, viz. North Koel that cuts across south to north and forms an external boundary of buffer area in the north; and Burha river on the western side. These two along with their tributaries are the major source of water supply. Auranga river is another perennial river flowing in the eastern part. Apart from the rivers there are many streams, *nallahs* and *chuans* (local word for aquifers). Other important streams are Aksi, Surkumi, Kotam, Chopat, Chipru, Jawa, Charu, Satnadia, Pandra, Panchnadia and Kohborwa. It receives less rainfall the northern part and the southern part has several hills and valleys forming drainages for three perennial rivers in the buffer area. The reserve has a sulphur hot spring near Barwadih[167].

### 6.7.5 Biodiversity

The habitat of Palamau Tiger Reserve offers a diverse mix of rich flora and fauna, dominated by Northern Tropical Dry Deciduous Sal (*Shorea robusta*) and its associates. Other forest types like Northern Tropical Moist Deciduous forests are also found in small pockets along with five other sub-types like Moist Peninsular Sal, Dry Peninsular Sal, Northern Dry Mixed Deciduous, Aegle Forest and Dry Bamboo Brake as per Champion and Seth's classification of forest types. The recorded plant diversity includes 97 species of seed-bearing plants, 49 species of shrubs and herbs, 30 species of climbers, semi-parasites and orchids, and 18 species of grasses. There are 114 species of recorded medicinal plants used by the local communities[167].

The core of PLTR has high level Sal to open grasslands and also riverine beds formed by the North Koel and Burha rivers. The spurs and valleys have different types of forests and have different distribution in wildlife. The riverine beds and the neighbouring areas offer good grassland and waterbodies. The grasslands are spread over an area of 485 ha and there are about 40 waterbodies that are frequently used by wildlife. PLTR well represents the trophic niches in its core areas[167].

The higher elevation areas are the home of Sloth Bear and Wolf breeding dens apart from other wildlife. It also has Orchids and 10 species out of 11 of *Dendrobium* are found here. Keystone wildlife species include Tiger (*Panthera tigris*), Asiatic Elephant (*Elephas maximus*), Leopard (*Panthera pardus*), Grey Wolf (*Canis lupus pallipes*), Wild Dog (*Cuon alpines*), Gaur (*Bos gaurus*), Sloth Bear (*Melursus ursinus*), Four Horned Antelope (*Tetracerus quadricornis*), Indian Ratel, Indian Otter, etc. Overall, a total of 39 species of mammals, 205 species of birds, 28 species of amphibians and reptiles are found here. In terms of flora, there are 97 species of seed-bearing plants, 49 species of shrubs and herbs, 30 species of climbers, semi-parasites and orchids, and 18 species of grasses[167].

### 6.7.6 Tourism

No tourism is allowed in the core area. An area of 37.7 sq km is demarcated as the tourism zone in Betla and neighbouring forest compartments. All tourism is confined only to this zone. The major attractions that Palamau offers are Palamau Fort, Kechki, Tatha, Mandal, Kutku, Maromar, Aksi, Rud, Bijaypur and Mundu [167].

### 6.7.7 Socio-Economic Situation

There are eight villages surrounded by the core area namely, Latu, Kujurm, Bijaypur, Ghutuwa, Gopkhanr, Pandra and Ramandag. Agriculture is the main occupation for the villagers. Most of them are small and marginal farmers. The main crops are paddy, maduwa, maize, lentils, etc. The productivity is low and the inhabitants are engaged in labour work as supplemental employment. Most of these villages are below the poverty line and they depend on subsistence agriculture, livestock rearing, gathering of forest produce, etc. apart from occasional labour work. Among NTFPs, mahua flower and seeds, medicinal plants like satavari, msuli, aswagandha and sarpgandha, mushrooms, oil seeds and honey are collected in the lean agricultural season[167].

The population is almost entirely tribal and hence tribal customs are dominant. The major tribes are Oraon, Birjia, Korwa, Kherwar, etc. The tribal women collect phoenix leaves and prepare carpets and bamboo items, which are sold through the EDC[167].

### 6.7.8 Valuation Estimates for Palamau Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES.

#### 6.7.8.1 Employment Generation

Due to scarcity of data like number of employment days generated and their respective job rates, the economic value of this service has not been estimated in monetary terms in this study.

#### 6.7.8.2 Fishing

In the local streams and rivers people practise fishing. But due to paucity of further information to calculate the total annual fish catch, economic value of this service has not been estimated in monetary terms here.

#### 6.7.8.3 Fuelwood

Fuelwood collection is done mainly from the buffer areas. The estimated per household requirement of fuelwood is 1.2 tonnes per year[167]. Total annual fuelwood collection amounts to 604.8 tonnes. This estimate is valued at the local market price of Rs. 5 per kg. Thus, the economic value of fuelwood collection from PLTR is estimated as 3.024 million per year.

#### 6.7.8.4 Fodder/Grazing

Livestock of villages inside and neighbouring villages are dependent on the forests of PLTR for the forage requirements. For the purpose of estimation of economic value of forage service provided by PLTR, only the cattle population in the eight villages inside PLTR[167] is used. The total number of cattle population is 2520 in these villages, taking that as equivalent cattle units and standard forage quantity at 22 kilograms per day per cattle unit [107]. The total annual quantity of fodder harvested is equal to 20235 tonnes in a year. Assuming an average local market price of Re. 1 per kilogram of fodder the economic value of annual grazing benefits provided by PLTR are approximately equal to Rs. 20.23 million.

#### 6.7.8.5 Standing Timber (Stock)

The standing stock of PLTR has immense value. To estimate the economic value of the standing stock, growing estimates of timber species from the forest inventory database[108] of the Forest Survey of India (FSI) have been used to as per the forest type to estimate the total stock of PLTR. It is estimated that approximately 34.59 million cubic metres of standing stock of timber are contained in PLTR as shown in Table 6.7-2. In monetary terms, using an average price of 25000 per cubic metres after discounting for transportation and maintenance cost, the standing stock has value equal to 864.76 billion rupees.

*Table 6.7-2 Timber Stock in the Forests of PLTR*

| Forest Type | Forest Cover | Growing Stock (Cubic m Per ha) | Area (ha) | Total Growing Stock(in Thousand Cubic m) | Economic Value (in Million Rupees) |
|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 331.67 | 43117.06 | 14300.70 | 357517.39 |
| Tropical Dry Deciduous Forests | MDF | 200.49 | 67428.46 | 13518.91 | 337972.67 |

| | | | | | |
|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | OF | 206.37 | 27726.39 | 5721.97 | 143049.29 |
| Non-Forest | - | 20.22276131 | 51869.89 | 1048.95 | 26223.81 |
| **Total** | | | | **34590.53** | **864763.16** |

For Palamau Tiger Reserve, the growing stock estimated for the Non-Forest-VDF category has been derived from MDF value by taking double of its value as VDF. There were no growing stock estimates available for Tropical Moist Deciduous Forests (3247.32 ha) and Plantation/TOF (2394.20 ha) and hence these have been excluded from timber stock calculations.

#### 6.7.8.6 Timber Flow

No timber flow is recorded from Palamau Tiger Reserve and thus this service has not been included in calculations.

#### 6.7.8.7 Bamboo

Due to lack of any recorded information, this ecosystem service was not found applicable for PLTR in this study.

#### 6.7.8.8 Non-Timber Forest Produce

Locals collect NTFP as a source of alternative livelihood. Major NTFP from PLTR include honey, mushrooms, mahua flowers, karanj seeds, chiraugi, mahulan leaves, kendu leaves, etc. They also collect wild fruits like wild bel, karjhani, indra jaw, bantulsi, etc. Apart from this, medicinal plants like roots of satavari, musli, aswagandha and sarpganda are also collected[167]. As per the TCP, nearly Rs. 320 million worth of NTFP is sold to the wholesale markets of Daltonganj through local traders per year[167]. Owing to lack of other primary studies and secondary estimates, this value is taken to be the economic value of NTFP collection from PLTR.

**Medicinal Plants: Palmau Tiger Reserve**[167]

There are 114 species of recorded medicinal plants used by the local communities.

#### 6.7.8.9 Genepool Protection

Owing to insufficient comprehensive primary data, the method of benefits-transfer has been used for valuation of this service. Using estimates of economic value of genepool protection for tropical forests (Rs. 100122 per hectare per annum) and cropland (Rs. 68772 per hectare per annum) from a global meta-analysis study [116], the annual economic value of this service from 147805 hectares of forests and 44371.60 hectares of cropland in PLTR is estimated to be Rs. 17.85 billion.

**Corridors and Connectivity**[167]

PLTR is part of the central Indian landscape and its connectivity extends to Similpal Tiger Reserve in Odisha through Patalkot WLS-Simdega-Porahat-Saranda (West) and Singhbhum (East) Forests. It has corridors through Semarsot WLS- Temorpingla- Guru Ghasidas NP- Sanjay NP- Bandhavgarh TR. The connectivity also extends to Bihar and West Bengal forests through Lawalong WLS- Gautam Buddha WLS- Hazaribagh WLS, Koderna WLS and Dalma WLS forests. The major corridors between Palamau Tiger Reserve and five other Tiger Reserves in the Central Indian Tiger Landscape are:

1. Bandhavgarh Tiger Reserve in Madhya Pradesh
2. Sanjay-Dubri Tiger Reserve in Madhya Pradesh
3. Achanakmar Tiger Reserve in Chhattisgarh
4. Kanha-Pench Tiger Reserve in Madhya Pradesh
5. Similipal Tiger Reserve in Odisha

### 6.7.8.10 Carbon Storage

InVEST model estimate carbon stock as a function of land use/land cover. Carbon storage indicates the mass of carbon in an ecosystem at a given point of time. The InVEST model output summary provides a table and a map of current carbon storage.

*Table 6.7-3 Carbon Stock in PLTR*

| Vegetation class | Forest Cover | Carbon Stock in Various Pools(tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total carbon Stock (million tC) |
|---|---|---|---|---|---|---|---|---|
| | | AGB | BGB | SOM | DW (incl. litter) | | | |
| Plantation/TOF | VDF | 10.00 | 0.00 | 20.00 | 0.00 | 30.00 | 13.02 | 0.00 |
| Plantation/TOF | MDF | 11.69 | 2.40 | 18.50 | 1.79 | 34.38 | 535.91 | 0.02 |
| Plantation/TOF | OF | 10.72 | 2.20 | 16.46 | 0.59 | 29.97 | 1845.27 | 0.06 |
| Tropical Dry Deciduous Forests | VDF | 62.32 | 24.47 | 64.67 | 1.15 | 152.62 | 43117.06 | 6.58 |
| Tropical Dry Deciduous Forests | MDF | 59.00 | 23.17 | 59.38 | 0.66 | 142.20 | 67428.46 | 9.59 |
| Tropical Dry Deciduous Forests | OF | 13.98 | 5.49 | 26.56 | 0.55 | 46.58 | 27726.39 | 1.29 |
| Tropical Moist Deciduous Forests | VDF | 34.78 | 7.15 | 62.77 | 3.53 | 108.23 | 159.96 | 0.02 |
| Tropical Moist Deciduous Forests | MDF | 26.64 | 5.48 | 55.53 | 3.27 | 90.92 | 1789.92 | 0.16 |
| Tropical Moist Deciduous Forests | OF | 16.23 | 3.34 | 29.23 | 1.70 | 50.49 | 1297.44 | 0.07 |
| Non Forest | | 1.31 | 0.11 | 9.93 | 0.00 | 11.36 | 51869.89 | 0.59 |
| Total | | | | | | | | 18.37 |

It should be noted that the non-forest areas comprise mostly agriculture land. The average values of major crops like wheat, black gram, pigeon pea and green gram have been taken to calculate the AGB and BGB carbon pools[152]. While to calculate the carbon density in soil for the non-forest area the values of Soil Organic Carbon (SOC) has been referred based on the agro-ecological region[153]. The carbon pools of water have been assumed to be zero. With the available data the model outputs have been obtained. The first was a summary tab, which communicated the biophysical results. The model provided that approximately 18.37 million tonnes of carbon are stored in Palamau Tiger Reserve (Figure 6.7-3).

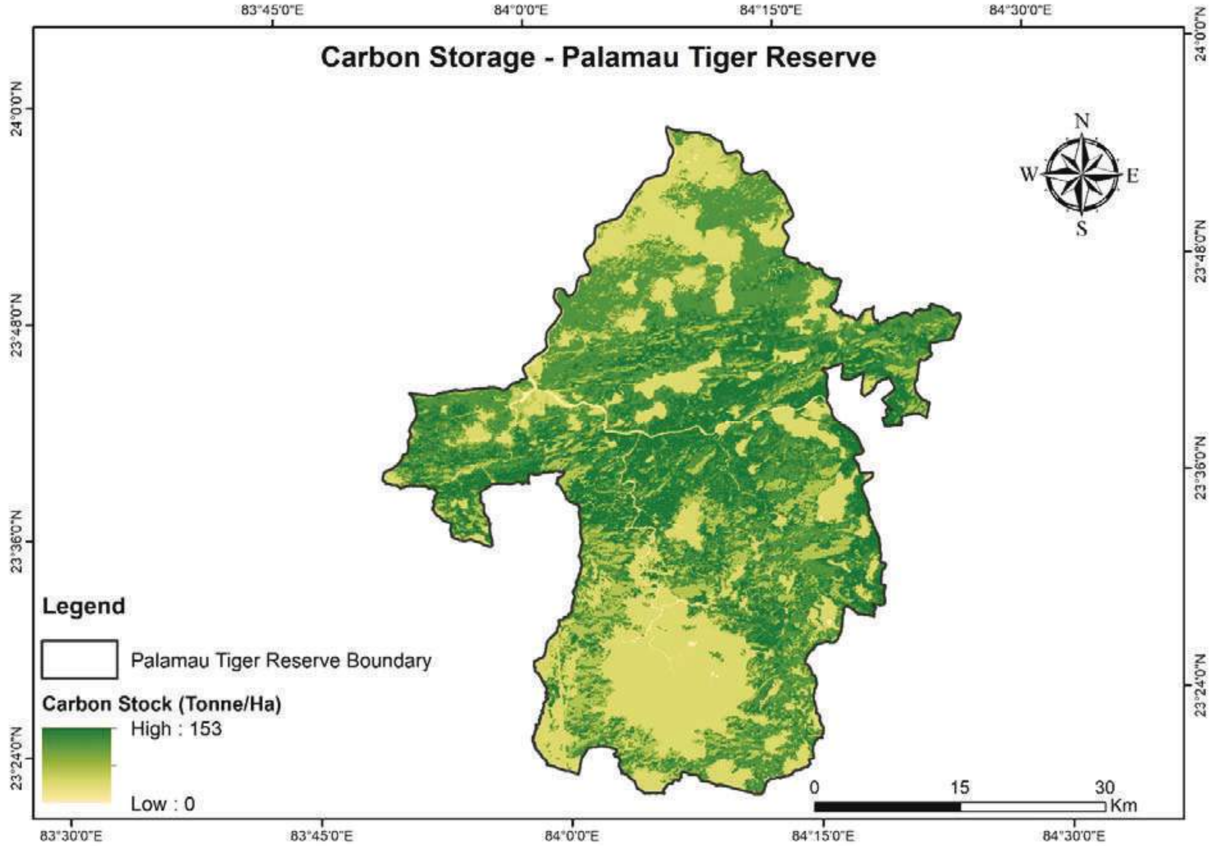



*Figure 6.7-3 Carbon Storage Map of Palamau Tiger Reserve Created Using InVEST Model*

The estimates from the Carbon Stock model of InVEST as 18.37 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= Rs. 65 as the average for the year 2017-18, the economic value of carbon stock in PLTR is calculated as Rs. 102.68 billion.

### 6.7.8.11 Carbon Sequestration

Apart from 18.37 million tonnes of carbon stock in the forests of Palamau Tiger Reserve, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database. Based on total biomass per unit area, the mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type[120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, the total carbon sequestered in the forests of Palamau Tiger Reserve by aggregating estimates for each forest type is equal to 1457.34 kilo tonnes annually. Detailed calculation is shown in Table 6.7-4.

*Table 6.7-4 Carbon Sequestration PLTR*

| Forest Type | Forest Cover | Total Biomass Per Unit Area (Tonnes/ha) | Mean Annual Increment Per Unit Area (Tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) | Total Value of Annual Carbon Sequestration (Million Rs. Per Year) |
|---|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 799.33 | 28.82 | 43117.06 | 621349.46 | 25494.34 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | MDF | 483.19 | 17.42 | 67428.46 | 587381.61 | 24100.62 |
| Tropical Dry Deciduous Forests | OF | 497.36 | 17.93 | 27726.39 | 248613.35 | 10200.76 |
| **Total** | | | | **138271.9** | **1457344.4** | **59795.7** |

The social cost of carbon for India as per the latest paper[117] and the economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=Rs. 65, the total economic value of annual carbon sequestration in PLTR is calculated to be Rs. 59.78 billion.

### 6.7.8.12 Water Provisioning

The altitude ranges from 200m to 1000m and increases from north to south. The area of this reserve falls under sub-catchment of river North Koel and catchment of river Son forming the major tributaries of river Ganga. These two along streams like Burha, Auranga, Kohborwa, Aksi, Pandra, Panchnadia, Satnadia and Jawa form the drainage network. However, the Palamau division falls under the drought-prone area[167].

The output of the Water yield model is very exhaustive and is provided with raster and shapefile where various outputs can be spatially studied. It provides the estimated values of mean actual evapo-transpiration, mean potential evapo-transpiration, water yield volume, etc. The total water yield volume from Palamau Tiger Reserve as well as its fringe areas amounts to 1548.47 million cubic metres (Figure 6.7-4).

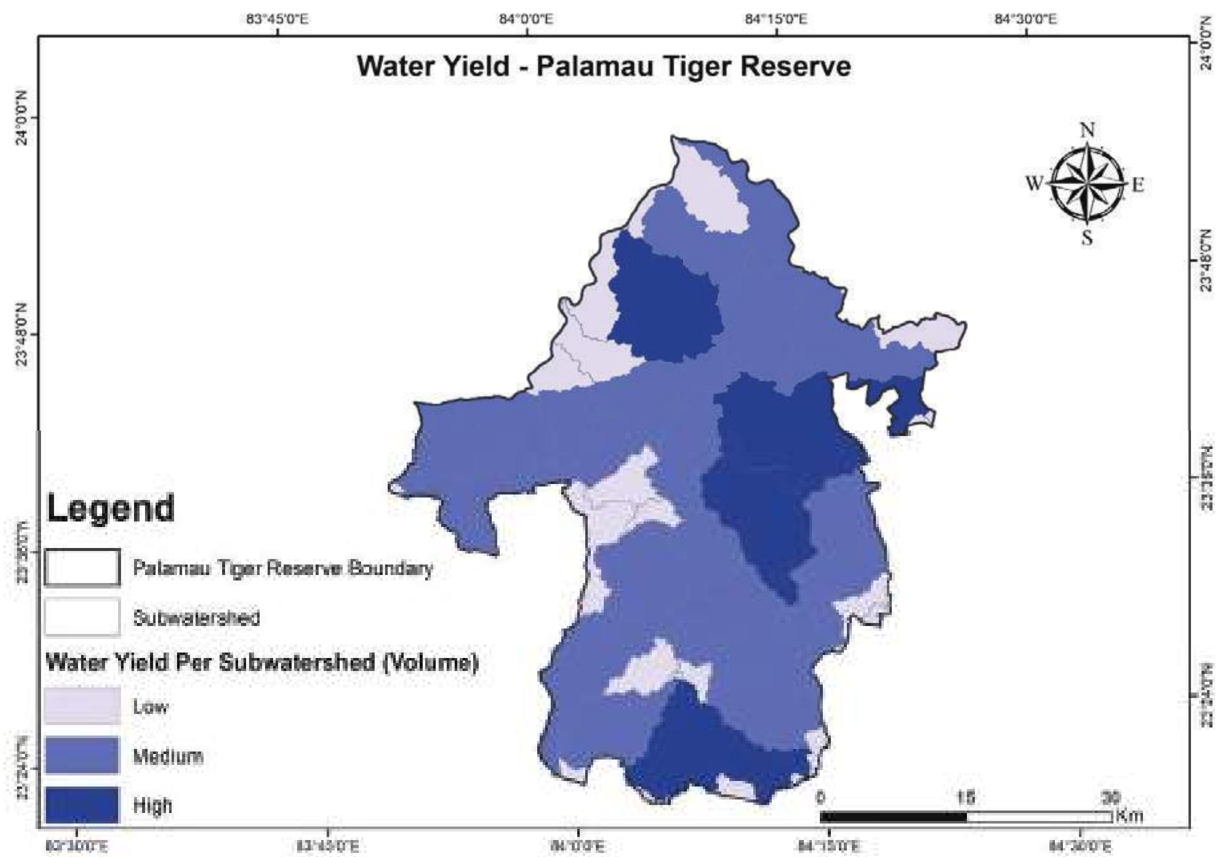



*Figure 6.7-4 Water Yield Output for Palamau Tiger Reserve Created Using InVEST Model*

Using the monetary value of Rs. 18.43 per cubic metre[1], the economic value of water provisioning service from PLTR is estimated to be 28.54 billion per year.

### 6.7.8.13 Water Purification

Owing to insufficient data on beneficiaries to establish attribution of this ecosystem service to PLTR and lack of information on local water treatment facilities, this ecosystem service was not found relevant for PLTR and therefore is not included for economic valuation in this study.

### 6.7.8.14 Soil Conservation/Sediment Retention

The output of the model is very exhaustive. Figure 6.7-5 provides the values for the total amount of sediment exported in each subwatershed calculated modelled using InVEST SDR. The output suggests that there is overall low sediment loss found in the core area of Palamau Tiger Reserve. The higher sediment loss is concentrated in the buffer area with more agriculture land. The value of sediment export varies from 50 tons to 18945 tons per subwatershed.

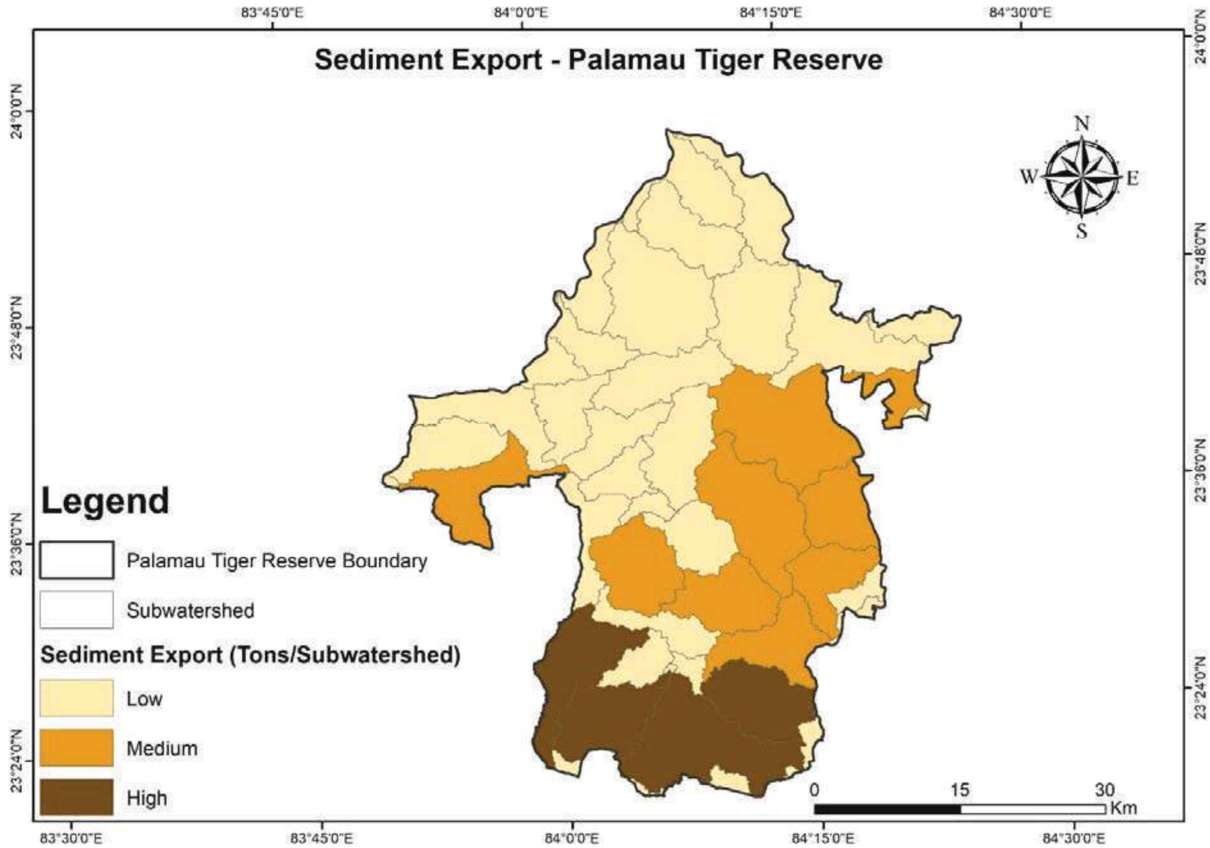



*Figure 6.7-5 Sediment Export from Palamau Tiger Reserve Created Using InVEST Model*

As shown in Figure 6.7-6, it is mainly higher sediment retention watersheds that overlap with the denser forest areas. The value of sediment retention varies from 2000 tons to 14792500 tons per subwatershed.

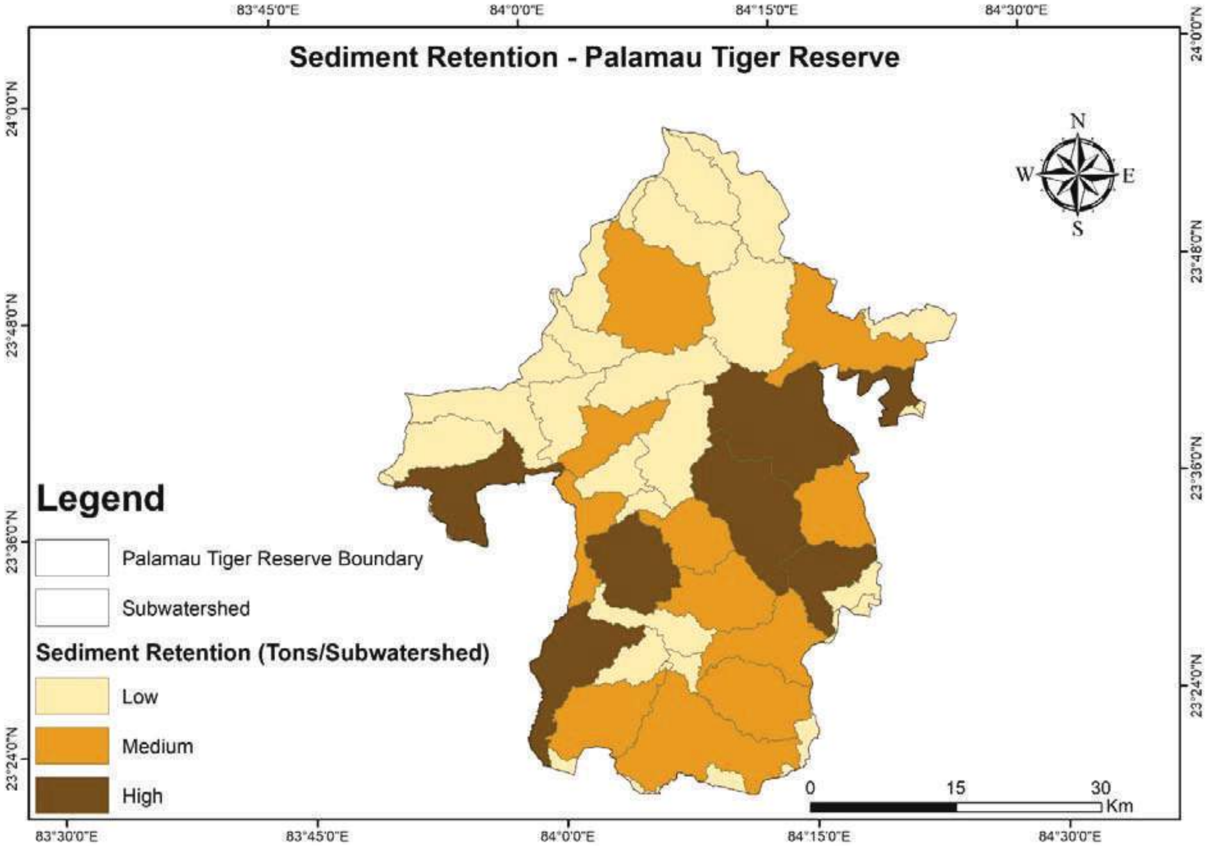



*Figure 6.7-6 Sediment Retention in Palamau Tiger Reserve Created Using InVEST Model*

To estimate the economic value of soil loss avoided by the forests of ---TR, the cost of dredging/de-siltation has been considered. On account of insufficient site-specific data, the cost estimate of Rs. 60 per cubic metre [132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 248.21 million per year.

### 6.7.8.15 Nutrient Retention

The total soil loss avoided from the InVEST Sediment Retention model of PLTR is around 5.47 million tons. To calculate the amount of nutrient retained, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust[147] has been used on account of lack of local estimates for the same. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations from Table 6.7-5, the total quantity of nutrients retained is approximately 11516.89 tonnes of N, 218.42 tonnes of P and 40954.45 tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary value has been derived. The total value of nutrient loss prevented by the forests of PLTR is equal to Rs. 559.21 million annually.

*Table 6.7-5 Nutrient Retention in PLTR*

| Nutrient | Soil Nutrient Concentration (g Per Kg) | Total Nutrient Loss Avoided (Tonnes Per Year) | Fertilizer (Substitute) Used for Valuation | Price of Fertilizer (Rs. Per Tonne) | Economic Value of Nutrient Retention (Million Rs. Per Year) |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 11516.89 | Urea | 5360 | 61.73 |
| Phosphorous (P) | 0.044 | 218.42 | DAP | 20100 | 4.39 |

| | | | | | |
|---|---|---|---|---|---|
| Potassium (K) | 8.25 | 40954.45 | Muriate of Potash | 12040 | 493.09 |
| **Total** | | **52689.76** | | | **559.21** |

### 6.7.8.16 Biological Control

Using estimates of economic value of biological control for tropical forests (Rs. 726 per hectare per annum) and cropland (Rs. 2178 per hectare per annum) from a global meta-analysis study[116] the economic value of biological control service from 147805 hectares of forests and 44371.60 hectares of cropland in PLTR is estimated to be Rs. 203.95 million per annum.

### 6.7.8.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to PLTR. Hence, it is not included in the valuation of the ecosystem service of PLTR in this study.

### 6.7.8.18 Pollination

Using estimates of economic value of pollination for tropical forests (Rs. 1980 per hectare per annum) and cropland (Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 147805 hectares of forests and 44371.60 hectares of cropland in PLTR is estimated to be Rs. 357.08 million per annum.

### 6.7.8.19 Nursery Function

The nursery function was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to PLTR. Hence, it is not included in the valuation of the ecosystem service of PLTR in this study.

### 6.7.8.20 Habitat for Species

Using estimates of economic value of habitat service for tropical forests (Rs. 2574 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 147805 hectares of forests in PLTR estimated to be Rs. 380.45 million.

### 6.7.8.21 Cultural Heritage

The reserve has a rich cultural backdrop as it is home to some of the most primitive Dravidian tribes of India such as Korwa, Birjia, Nagesa and Paharia. Their forest-based traditional-indigenous knowledge, customs, rituals, festivals and lifestyle along with their affinity for nature is a significant heritage. Apart from these mentioned tribes, Oraon, Chero, and Kherwar tribes also live in PLTR[167].

### 6.7.8.22 Recreation

In PLTR, tourism is not permitted in the core area. The tourism zone is confined to 37.7 sq km in Betla in the buffer zone. The buffer area has Kechki confluence, Auranga picnic spot, Palamau Fort, Garu-Koel riverside, Mirchaiya falls, Maromar, Suggabandh, Lodh Falls which are the highest falls in Jharkhand, Netarhat, lower and upper Ghagri Falls, Sarwat Hill (highest peak of PLTR), Tatha Pani which is a hot water stream, etc[167]. The zone also has numerous trekking routes, bird watching centres and interpretation centres. PLTR gets mainly domestic tourists and a few foreign tourists. In 2014, the total revenue earned was around Rs. 7.72 million[167].

### 6.7.8.23 Spiritual Tourism

Most of the population is tribal in the villages and hence there is traditional affinity for the forests. The customs are nature-based. There are sacred groves called *Sarna.* Worshipping of trees is common in the *Sarna* religion. Sal is worshipped during Sarhul and the Karam tree (*Adina cordifolia*) is worshipped during the Karma festival. Other than these no pilgrimage site exists within the reserve but an annual fair is held in Novemer/December every year near Betla at Palamau Fort[167].

### 6.7.8.24 Research, Education and Nature Interpretation

There is one nature interpretation centre at Betla. It is an admirable collection of various aspects related to the reserve like models, museum, dioramas, specimen displays, well-stocked library with many rare books and an auditorium[167].

The tiger reserves offer great opportunities for research and study of natural dynamics as they are inviolate areas and can be considered as live laboratories. Various aspects of Palamau Tiger Reserve has been studied and documented like studies on elephants, habitat preferences, habitat utilization, wildlife distribution, socio-economic profile of buffer villages, assessment of prey and predator densities, productivity analysis, and human-elephant conflict[167].

### 6.7.8.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (Rs. 792 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation from 147805 hectares of forests in PLTR is estimated to be Rs. 117.06 million.

### 6.7.8.26 Waste Assimilation

Waste assimilation was not relevant due to inadequate information and lack of supporting evident linkagesto attribute this service to PLTR. Hence, it is not included in the valuation of the ecosystem service of PLTR in this study.

### 6.7.8.27 Climate Regulation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 134904 per hectare per annum) and cropland (Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 147805 hectares of forests and 44371.60 hectares of cropland in PLTR is estimated to be Rs. 21.14 billion.

## 6.7.9 Spectrum of Values- Palamau Tiger Reserve

PLTR provides a variety of values that fall under economic, biological, ecological, conceptual, physical, scientific, educational, cultural, religious and historic values.

### 6.7.9.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| **Summary of Ecosystem Services Based on TEV Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **460.32** | **Rs. Million/Year** |
| Fuel wood, Fodder, Non-Timber Forest Products<br>* - Employment Generation, Fishing, Bamboo (Flow), Timber (Flow) | | |
| **Indirect Use Value** | **111233.90** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>*- Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Option Value** | **17850.06** | **Rs. Million/Year** |
| Genepool Protection | | |

| **Summary of Ecosystem Services Based on MA Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **343.25** | **Rs. Million/Year** |

| | | |
|---|---|---|
| Fodder, Fuel wood, NTFP<br>* - Employment Generation, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Regulating Services** | **128812.85** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool Protection<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Cultural Services** | **7.72** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Supporting Services** | **380.45** | **Rs. Million/Year** |
| Habitat for Species | | |

| **Summary of Ecosystem Services Based on Stock and Flow Benefits** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Flow Benefits** | **129.54** | **Rs. Billion/Year** |
| Fodder, NTFP, Fuel wood, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - Employment Generation, Timber (Flow), Fishing, Bamboo (Flow), Waste Assimilation, Moderation of Extreme Events, Nursery Function, | | |
| **Stock Benefits** | **967.45** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| **Summary of Ecosystem Services Based on Tangible/Intangible Framework** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Tangible Benefits** | **343.25** | **Rs. Million/Year** |
| Fodder, Fuel wood, NTFP<br>* - Employment Generation, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Intangible Benefits** | **1096648.15** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |

| Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **28881.71** | **Rs. Million/Year** |
| Fodder, Fuel wood, NTFP, Water Provisioning<br>* - Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Protection from Disease/Predators/Parasites** | **203.95** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **82600.84** | **Rs. Million/Year** |
| Carbon Sequestration, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Climate Regulation, Habitat for Species<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Socio-Cultural Fulfilment** | **7.72** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Employment Generation | | |
| **Ecosystem Assets** | **985297.19** | **Rs. Million** |
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| Summary of Ecosystem Services Based on EPA Effect Categories | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **1096983.69** | **Rs. Million** |
| Timber (Stock), Genepool Protection, Carbon Storage, Carbon Sequestration, Water provisioning, Soil Conservation/Sediment Retention, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Gas Regulation, Climate Regulation<br>* - Employment Generation, Timber (Flow) | | |
| **EPA Effect Category 2** | **7.72** | **Rs. Million** |
| Recreation | | |
| **EPA Effect Category 3** | **-** | |
| Research, Education and Nature Interpretation | | |
| **EPA Effect Category 4** | **Numerous (4-7 recorded)** | **Tribal Sub-Groups Associated to Dravidian Tribes** |
| Cultural Heritage | | |
| **EPA Effect Category 5** | **Sarna** | **Sacred Groves Present** |
| Spiritual Tourism | | |

### 6.7.9.2 Linkages to Human Health

Palamau Tiger Reserve emanates a range of ecosystem services vital for maintenance of human well-being. Amongst these, Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Biological Control, Pollination, Cultural Heritage, Recreation, Research, Education and Nature Interpretation, Gas Regulation, and Climate Regulation Services have huge direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 231.02 billion.

### 6.7.9.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Palamau Tiger Reserve for the year 2016-17, was around Rs. 32.37 million. Based on the flow benefits of Rs. 129.54 billion per year, for every rupee spent on management costs in PLTR, flow benefits of Rs. 3450.5 are realized within and outside the tiger reserve.

### 6.7.9.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Palamau Tiger Reserve was estimated at Rs. 0.65 million (Rs. 6.54 lakhs) per hectare.

### 6.7.9.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 1.45 percent of flow benefits accrue at the local level, 8.32 percent at the national level and 90.23 percent at the global level.

# Panna Tiger Reserve

Panna Tiger Reserve (PNTR) characterized with its extensive plateaus and gorges is situated in the Vindhyan mountain range of North Madhya Pradesh. It forms the northern most tip of the natural teak forests and the Ken river flows through the tiger reserve.

**The tiger reserve generates flow benefits worth Rs. 69.55 billion per year (Rs. 0.41 million per hectare) and stock benefits of Rs. 137.46 billion per year. Critical ecosystem services that emanate from this reserve include provisioning of water (Rs. 25.82 billion per year), climate regulation (Rs. 20.21 billion per year) and waste assimilation (Rs. 1.66 billion per year).**

**Under the Total Economic Value (TEV) framework, the annual direct-, indirect- benefits and option values were Rs. 0.78 billion, Rs. 53.11 billion and Rs. 15.65 billion, respectively.**

As per the MA framework, the value of provisioning services was Rs. 0.67 billion per year, that of regulating services was Rs. 68.48 billion per year, cultural services were Rs. 18.40 million per year and supporting services were Rs. 0.38 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 0.67 billion and Rs. 206.33 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 26.39 billion), protection from disease (Rs. 0.13 billion), benign physical and chemical environment (Rs. 27.24 billion), socio-cultural fulfilment (Rs. 0.12 billion) and ecosystem assets (Rs. 153.10 billion

The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 144.55 billion per year. The investment multiplier for PNTR was calculated as 1939.36.

## 6.8 Panna Tiger Reserve

### 6.8.1 Location, Landscape and Significance

Named after the city of diamonds Panna, Panna Tiger Reserve (PNTR) is like the emerald of Bundelkhand region. It spreads across Panna, Chattarpur and Damoh districts of Madhya Pradesh. Located in the Vindhyan ranges across the Panna, it has characteristic dense mixed forests, table top topography, gorges and waterfalls. The tiger reserve consists of Panna National Park, Gangau WLS and Buffer. The total area of PNTR is 1598.11 sq km out of which 576.14 sq km comes under the core zone[168].

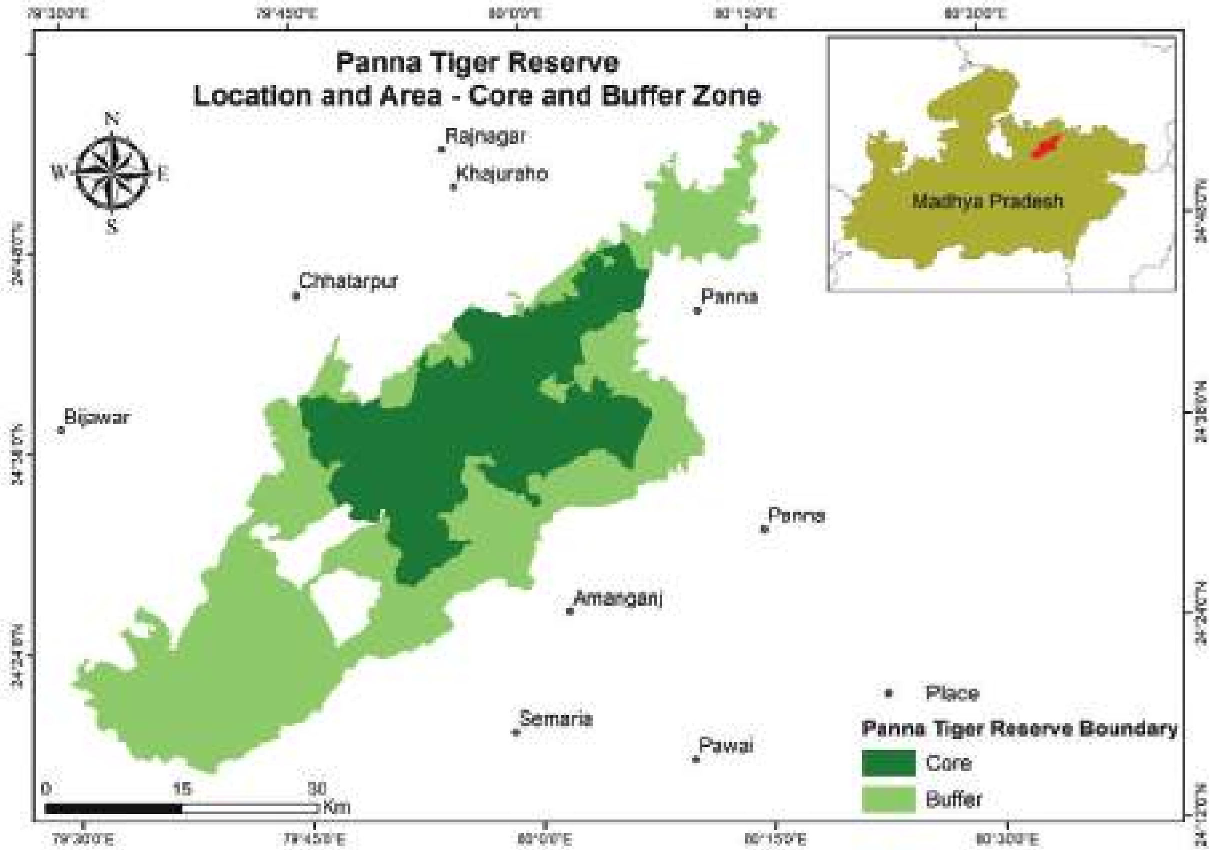



*Figure 6.8-1 Panna Tiger Reserve (Source: Forest Survey of India)*

PNTR floristically forms part of the Indo-Malayan Realm and zoo. Geographically, it is a member of the Oriental region and lies in Zone 6 E-'Deccan Peninsula – Central Highlands'. Plateau topography with underlying slopes, cliffs with *talus* and *sehas* offer the best combination of niche areas for the faunal components. Ken river, savannah forests, and mixed dense forests on the slopes offer variety of habitats, besides offering one of the best landscapes of dry deciduous tiger habitat of the country. *Dhundua Seha* offers a glimpse of the outstanding habitat and is popularly known as 'Tiger and Vulture Heaven' among wildlife enthusiasts[168].

There are long but narrow flat terraces - separated with higher or lower ones with hilly slopes, which vary in gradient from gentle to steep or precipitous slopes/vertical climb. 'Flats' generally have open forest with different varieties of grasses, whereas good forest cover, often with bamboo, is found on the slopes. Certain plant species are conspicuous in their distribution in particular areas/pockets, e.g. Kardhai, Salai, etc. River Ken, originating in Katni district south of Panna, traverses the tiger reserve for about 55 km and flows further down (northwards) for about 35 km and then passes through another important PA, the Ken Gharial Sanctuary, near Khajuraho[168].

### 6.8.2 History

Panna town used to be the seat of erstwhile Panna State, a small and but important Rajput kingdom of Central India. Panna used to be a *Sanad* state in the Bundelkhand Political Charge of the Central India Agency of the British. After India attained independence, the State of Panna was merged, along with other such kingdoms, within the present Madhya Pradesh at the time of reorganization of states in 1956. It is believed that the town derives its name from the deity of a small old temple of goddess Padmavati, which is situated on the banks of the Kilkila stream near the old town[168].

History of Panna and Chhatarpur forests can be traced back to the ancient Gonds who were the original 'rulers' of these central highlands. Many relics of their kingdom(s) can be found scattered in the tiger reserve. The area may, therefore, be taken as a repository of the ancient Gond civilization. The area has a long history of wildlife conservation; the major part of it has been the shooting reserve of former rulers. Old records of the Panna State mention that there was total ban on killing of females and young ones of all wild animals during the state rule[168].

Panna Tiger Reserve is the 22nd tiger reserve to be declared in 1994. The core area of the Panna Tiger Reserve encompasses the whole area of Panna National Park and part of Gangau WLS and was declared in the year 2007. This is part of the bigger Vindhyan landscape which covers more than 5000 sq km of the forest of districts Satna, Panna, Chattarpur, Damoh and Sagar. An adjoining area of 1022 sq km surrounding core from three districts (Panna, Chattarpur and Damoh) and four Forest Divisions (North and South Panna, Chattarpur and Damoh Forest Divisions) was declared as Buffer in the year 2012[168].

### 6.8.3 Rivers and Hydrology

The area drains the Yamuna systems of drainage and the major surface water flow is towards the north and north-east. However, due to the structural set-up of rocks, small ephemeral streams flow for a short distance towards south-east and then join the main northward drainage. Ken is the major river of this area. This river is part of the Ganga-Yamuna basin. Other main streams are Sambhua *nala*, Mohar *nadi* and Kilkila *nala*. The remaining streams are ephemeral in nature. Some springs are found in the area[168].

The National Park makes a small but highly significant catchment of river Ken, one of the twelve perennial rivers of MP. This river, finally making a tributary of Yamuna, contributes to the richness and fertility of the Gangetic plains. It enters the tiger reserve towards the south, flows through its western parts to emerge at Madla village in the north. It flows further north to meet Yamuna in Banda district of UP. Within the tiger reserve-limits Ken makes a boundary between the two districts of Panna and Chhatarpur and traverses a distance of about 55 km inside the tiger reserve[168].

### 6.8.4 Topography and Climate

PNTR is based on two plateaus. The plateau topography and juxtaposition of underlying slopes, cliffs and gorges gives the reserve distinctive features. It has a bench topography - three ranges of Panna district, viz., Panna, Hinouta and Madla, their respective plateaux stretch roughly in NE-SW direction, descend in that order from around 500 metres elevation near Talgaon in Panna Range to a little over 200 metres at Madla in Madla Range. The fourth range, Chandranagar, rises from Ken river and occupies hills and valleys of the Chhatarpur side all along the river course. The highest hillock of the tiger reserve is near Talgaon (538 mts), while the lowest point is Mahadeo Ghat at Ken river (210 mts)[168].

The climate of PNTR is characterized by very hot summers and severe winters with mean annual rainfall of 1100 mm, the region is also prone to droughts. The climate is hot and dry for about 7 months. Rains arrive with the south-west monsoon, from about the end of June till mid-September. Average annual rainfall for Panna district is 1,200 mm and about 1,100 mm in Chhatarpur. Slight winter rain from the northeast monsoon is received generally during December-January. Winter is from December to mid-February, with mean minimum temperature remaining around 7-8°C. However, average winter days are warm - the diurnal range of temperature varying widely by about 15-20°C. Frost is not frequent and does not persist[168].

### 6.8.5 Land Cover Classification

The land use and land cover map of Panna Tiger Reserve was obtained from the Forest Survey of India. The land cover of Panna is broadly categorized into deciduous forest, agriculture, plantation, built-up, wasteland and degraded forest (Figure 6.8-2).

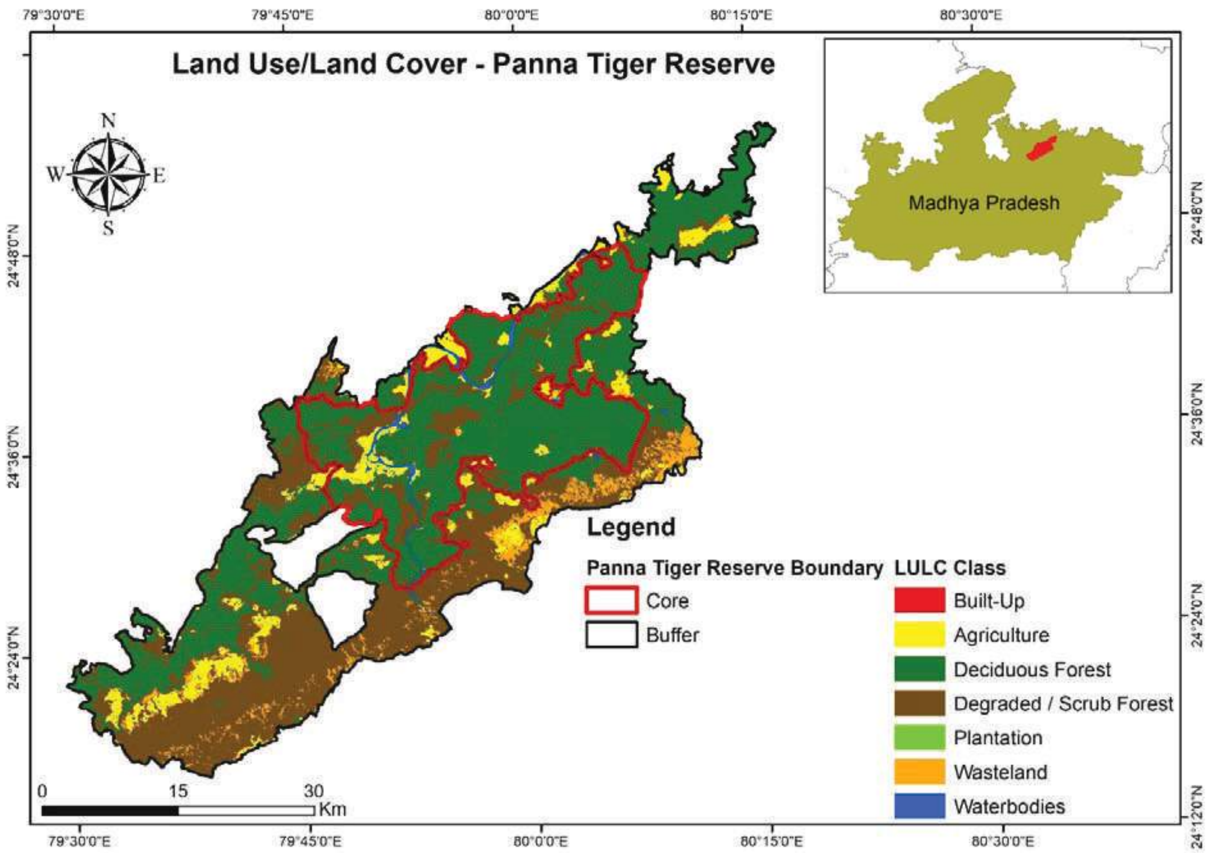



*Figure 6.8-2 Land Use/Land Cover: Panna Tiger Reserve (Source: Forest Survey of India, 2013-2014)*

The tiger reserve mainly consists mainly of deciduous forest (48.5 percent), degraded forest (37.7 percent), agriculture (7.8 percent) and wasteland (4.3 percent), while the small area is under habitation, plantation and waterbodies (Table 6.8-1).

*Table 6.8-1 LULC Classes PNTR*

| LULC Class | Area (ha) |
|---|---|
| Agriculture | 13306.68 |
| Built-up | 215.76 |
| Deciduous Forest | 82775.03 |
| Degraded / Scrub Forest | 64384.28 |
| Plantation | 10.04 |
| Wasteland | 7451.45 |
| Waterbodies | 2496.57 |

## 6.8.6 Biodiversity

Panna Tiger Reserve is among the important Protected Areas in the Central Indian Highlands complex. PNTR comes under Zone 6 E-'Deccan Peninsula – Central Highlands'. Its plateaus have savannah forests with very thin vegetation and continuous grass cover and the slopes are filled with dense forests of various types. There are long but narrow flat terraces - separated with higher or lower ones with hilly slopes, which vary in gradient from gentle to steep or precipitous slopes. 'Flats' generally have open forests with different varieties of grasses, whereas good forest cover, often with bamboo, is found on the slopes. Certain plant species are conspicuous in their distribution in particular pockets, e.g. Kardhai, Salai, etc. Ken riverine system, savannah forests, and mixed dense forests on the slopes offer a variety of habitats, which enhances the habitat value of the tiger reserve, besides offering one of the best landscapes of dry deciduous tiger habitat of the country[168].

Typical bench topography of the tiger reserve has provided a large number of unique habitats with combinations of rock shelters, cliffs, ledges, overhangs, caves, crevices, etc. – making these places ideal for big and small animals like sloth bear, hog, ratel, porcupine, civets, various reptiles, vultures and other birds, honey bees, etc. Perennial springs emanate from the base of these bench terraces providing water to the wild animals during summer[168].

The forest is mainly dry deciduous, with chief species being dry teak, Kardhai, Khair, Salai, common bamboo, a host of *euphorbia spp*., etc. *Anogeissus pendula* forest occurs in a long strip in the foothills from Pipartola to Gangau dam on both the banks of Ken river. *Sterculia urens* (Kullu) is in abundance in the reserve with good regeneration. Panna makes the northern boundary of natural distribution of teak and eastern boundary of teak-*Kardhai* forests in the country. Some of the rare plants, viz., *Strychnos potatorum, Nurvola* that are of high medicinal value, are found here. It also has rich repository of Amla *Emblica officinalis* genepool[168].

The area is rich in fauna– both by variety and by numbers. It contains as many as seven animals listed in Schedule I and in Part II, Schedule II of the WPA, 1972. PNTR supports a sizeable population of Sloth Bear (*Melursusursinus*), Leopard (*Pantherapardus*) and Striped Hyena (*Hyaenahyaena*). Other prominent carnivores are Jackal (*Canisaureus*), Wolf, Wild Dog (*Cuonalpinus*), Jungle Cat *(Felischaus*) and Rusty Spotted Cat. The major ungulates are Sambar (*Cervus unicolor*), Chital (*Axis axis*), Nilgai (*Boselaphustragocamelus*), Chinkara (*Gazellabennetti*), Four-Horned Antelope (*Tetracerosquadricornis*) and Wild Pig (*Susscrofa*). The Common Langur (*Presbytis entellus*) is widespread, while Rhesus Macaque (*Macaca mullata*) is found only along the forest peripheries. In 2012, the tiger was reintroduced in PNTR successfully[168].

There are over 150 bird species in PTR, and the important breeding birds include Marshall's Iora (*Aegithina nigrolutea*), White-Bellied Minivet (*Pericrocotus erythropygius*) and Striated Grassbird (*Megalurus palustris*), besides a variety of Galliformes including Peafowl (*Pavo cristatus*), Painted Spurfowl (*Galloperdix lunulata*) and Painted Francolin (*Francolinus pictus*). The area is known for its good vulture population. The rock cliffs with ledges provide a good habitat for the rock-nesting vultures. Egyptian Vulture, Long Billed Vulture, White Backed Vulture and Red Headed Vulture are the resident vultures of the tiger reserve and all four breed here. Eurasian and Himalayan Griffon Vultures and Cinereous Vultures are the migratory vultures of the tiger reserve. It also supports over 10 species of reptiles, and over 50 species of fishes including two globally threatened Masheer species (*Tortor, Tor putitora*), popularly known as 'King of Freshwater Fishes of India'. Both *Mugger Crocodilus palustris* and *Gharial Gavialus gangeticus* coexist in river Ken within the PA[168].

### 6.8.7 Socio Economic Situation

There are 3 villages in the core zone of Panna Tiger Reserve and around 49 villages in the buffer area in and around PNTR. Populations of these villages are mainly engaged in subsistence farming, livestock rearing and labour. Many villagers generate employment by engaging in tiger reserve management activities. PNTR being a popular tourist destination, tourism is also an importance source of livelihood. Apart from the eco-tourism destination developed by Tiger reserve authorities in Madla and Hinnouta, there are many hotels situated around the PNTR. NMDC diamond mines are also based in the Gangau Sanctuary and Panna national tiger reserve. Pardhis, Kondars and Gonds form the major tribal population of the reserve. They are nature-worshippers, they worship trees (Amla, Pipal, Saja, etc.), rocks and mountains and animals, including tigers, and hold various waterbodies, including River Ken, in high esteem[168].

### 6.8.8 Valuation Estimates for Panna Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES

#### 6.8.8.1 Employment Generation

Owing to scarcity of data for physical estimation of employment generation on the basis of man-days generated, the service has been estimated on the basis of wage-expenditure done by the Tiger Reserve management[169] on daily-wage labourers, watchers and other support staff. As per the estimates given by tiger reserve management[169], Panna Tiger Reserve incurred an expenditure of around Rs. 106.39 million in the year 2015-16. Therefore, as a proxy, this figure is taken as the monetary estimation for employment generation service in Panna Tiger Reserve.

### 6.8.8.2 Fishing

Owing to shortage of data and other relevant information to calculate the total annual fish catch, the economic value of this service has not been estimated in monetary terms here.

### 6.8.8.3 Fuelwood

On account of lack of sufficient information on exact fuelwood collection in PNTR, the same has been derived from Kanha Tiger Reserve (KTR). As per the Verma et al. (2015) study, fuelwood collection in KTR was approximately five tonnes per HH. The total number of households in Panna TR are 23577. Thus, the total fuelwood collection for PNTR is calculated as 117.88 kilo tonnes approximately per year. Using a local market price of Rs. 2 per kg, the total economic value of fuelwood collection from MTR is Rs. 235.77 million per year.

### 6.8.8.4 Fodder/Grazing

Using the total number of cattle *in the buffer* and core villages, given by the tiger reserve management[169], as equivalent cattle units, and assuming standard forage quantity at 22 kilograms per day per cattle unit[107]. The total annual quantity of fodder harvested is equal to 251772 tonnes in one year. Assuming an average price of Re. 1 per kilogram of fodder the economic value of annual grazing benefits provided by PNTR is approximately equal to Rs. 251.77 million.

### 6.8.8.5 Standing Timber (Stock)

The standing stock of PNTR has immense value. To estimate the economic value of the standing stock, growing estimates of timber species from the forest inventory database[108] of the Forest Survey of India (FSI) have been used to as per the forest type to estimate the total stock of PNTR. It is estimated that approximately 2.44 million cubic metres of standing stock of timber are contained in PNTR as shown in Table 6.8-2. In monetary terms, using an average price of 25000 per cubic metres after discounting for transportation and maintenance cost, the standing stock has value equal to Rs. 61.19 billion.

*Table 6.8-2 Timber Stock in the Forests of PNTR*

| **Forest Type** | **Forest Cover** | **Growing stock (cubic m per ha)** | **Area (ha)** | **Total Growing Stock(in thousand cubic m)** | **Economic Value (in million rupees)** |
|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 38.4 | 15625.58 | 600.02 | 15000.55 |
| Tropical Dry Deciduous Forests | MDF | 19.2 | 63815.76 | 1225.26 | 30631.57 |
| Tropical Dry Deciduous Forests | OF | 13.04 | 44139.98 | 575.42 | 14385.62 |
| Non-Forest | - | 1.07 | 44023.45 | 47.19 | 1179.71 |
| **Total** | | | | **2447.90** | **61197.45** |

For Panna Tiger Reserve, the growing stock estimated for Tropical Dry Deciduous Forests- VDF category has been derived by taking double the MDF value. Similarly, for Non-Forest- MDF and VDF category the values have been derived from OF by taking double and quadruple of its value respectively. There were no estimates of growing stock available for Plantation/TOF (121.83 ha) and hence it has been excluded from calculation of timber stock.

### 6.8.8.6 Timber Flow

No timber harvesting takes place in PNTR and hence the economic value of flow benefits from this service in PNTR is zero.

### 6.8.8.7 Bamboo

Due to paucity of data and other relevant information to calculate the total bamboo collection, the economic value of this service has not been estimated in monetary terms here.

### 6.8.8.8 Non-Timber Forest Produce

The area is known for high productivity of wild fruits and other NWFP like Amla, Chironji, Bael, Kaitha, Tendu, Siharu, edible and medicinal tubers, varieties of grasses, etc[168]. The forest produce is collected by the local people for consumption and other domestic uses. Owing to lack of exact estimation of NTFP collection, estimates for Kanha Tiger Reserve from Verma et al. (2015) have been used to derive the same. The study mentions that in the Kanha Tiger Reserve, the total number of households collecting NTFP are 21800. The total number of households in Panna TR are 23577. The quantity of NTFP given for Kanha in the study is extrapolated for Panna based on the number of households. The quantity of NTFP collected by these households is given in the Table 6.8-3 along with the prices for each type of NTFP adjusted for inflations[5] (2016-17 prices).

*Table 6.8-3: NTFP Collection Calculation*

| NTFP | Harvest qt. | Unit | Extrapolated for Panna | Unit | Adjusted Unit Price | Economic Value (Rs) |
|---|---|---|---|---|---|---|
| Tendu Leaf | 5500 | Standard bags | 5948.325688 | Standard bags | 3205.5 | 19067357.99 |
| Harra | 20 | Tonnes | 21.63027523 | Tonnes | 5342.5 | 115559.75 |
| Gum | 5 | Tonnes | 5.407568807 | Tonnes | 53425 | 288899.36 |
| Mohul Leaf | 500 | Tonnes | 540.7568807 | Tonnes | 10685 | 5777987.27 |
| Mahua | 1400 | Tonnes | 1514.119266 | Tonnes | 32055 | 48535093.07 |
| Cassia Tora Seeds | 50 | Tonnes | 54.07568807 | Tonnes | 10685 | 577798.73 |
| Van Tulsi Seeds | 50 | Tonnes | 54.07568807 | Tonnes | 53425 | 2888993.64 |
| Broomstick Leaf | 0.6 | Million number | 0.648908257 | Million number | 5.3425 | 3.47 |
| Palas Lac | 1.6 | Tonnes | 1.730422018 | Tonnes | 106850 | 184895.59 |
| Kosum Lac | 0.3 | Tonnes | 0.324454128 | Tonnes | 128220 | 41601.51 |
| **Total** | | | | | | **77478190.38** |

Thus, the total value of the NTFP collection from MTR is approximately Rs. 77.48 million per year.

#### 6.8.8.9 Genepool Protection

Due to lack of comprehensive primary data, the method of benefits-transfer has been used for valuation of this service. Using estimates of economic value of genepool protection for tropical forests (Rs. 100122 per hectare per annum) and cropland (Rs. 68772 per hectare per annum) from a global meta-analysis study[116], the annual economic value of this service from 147169.34 hectares of forests and 13306.68 hectares of cropland in PNTR is estimated to be Rs. 15.65 billion.

#### 6.8.8.10 Carbon Storage

The InVEST (Integrated Valuation of Ecosystem Services and Trade-Offs) model version 3.2.0, developed by the Natural Capital Project, Stanford University was used to estimate the amount of carbon stored in the carbon pools according to the land use maps. The biophysical model is used to estimate the carbon storage, i.e. the amount of organic carbon trapped by the ecosystem.

*Table 6.8-4 Carbon Stock in PNTR*

| Vegetation class | Forest Cover | Carbon Stock in Various Pools(tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total carbon Stock (million tC) |
|---|---|---|---|---|---|---|---|---|
| | | AGB | BGB | SOM | DW (incl. Litter) | | | |
| Plantation/TOF | VDF | 33.43 | 6.87 | 89.48 | 3.18 | 132.96 | 1.51 | 0.00 |
| Plantation/TOF | MDF | 14.22 | 2.92 | 56.77 | 2.09 | 76.01 | 37.78 | 0.00 |
| Plantation/TOF | OF | 4.14 | 0.85 | 22.28 | 5.27 | 32.54 | 82.55 | 0.00 |

[5] Using Inflation Index at calculatorstag.com (2016-17 prices)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 60.30 | 23.68 | 62.58 | 7.79 | 154.35 | 15625.58 | 2.41 |
| Tropical Dry Deciduous Forests | MDF | 57.08 | 22.41 | 57.45 | 0.55 | 137.50 | 63815.76 | 8.77 |
| Tropical Dry Deciduous Forests | OF | 11.64 | 4.57 | 22.12 | 0.47 | 38.80 | 44139.98 | 1.71 |
| Non Forest | | 1.31 | 0.11 | 15.32 | 0.00 | 16.74 | 44023.45 | 0.74 |
| Total | | | | | | | | 13.64 |

It should be noted that the non-forest area comprises mostly agriculture land. The average values of major crops like wheat, black gram, pigeon pea and green gram have been taken to calculate the AGB and BGB carbon pools[152]. While to calculate the carbon density in soil for the non-forest area the values of Soil Organic Carbon (SOC) has been referred based on the agro-ecological region [153]. The carbon pools of water have been assumed to be zero. According to the model, Panna Tiger Reserve stores approximately 13.64 million tonnes of carbon. The InVEST model gave outputs in the form of a carbon spread map (Figure 6.8-3) and a summary table(Table 6.8-4).

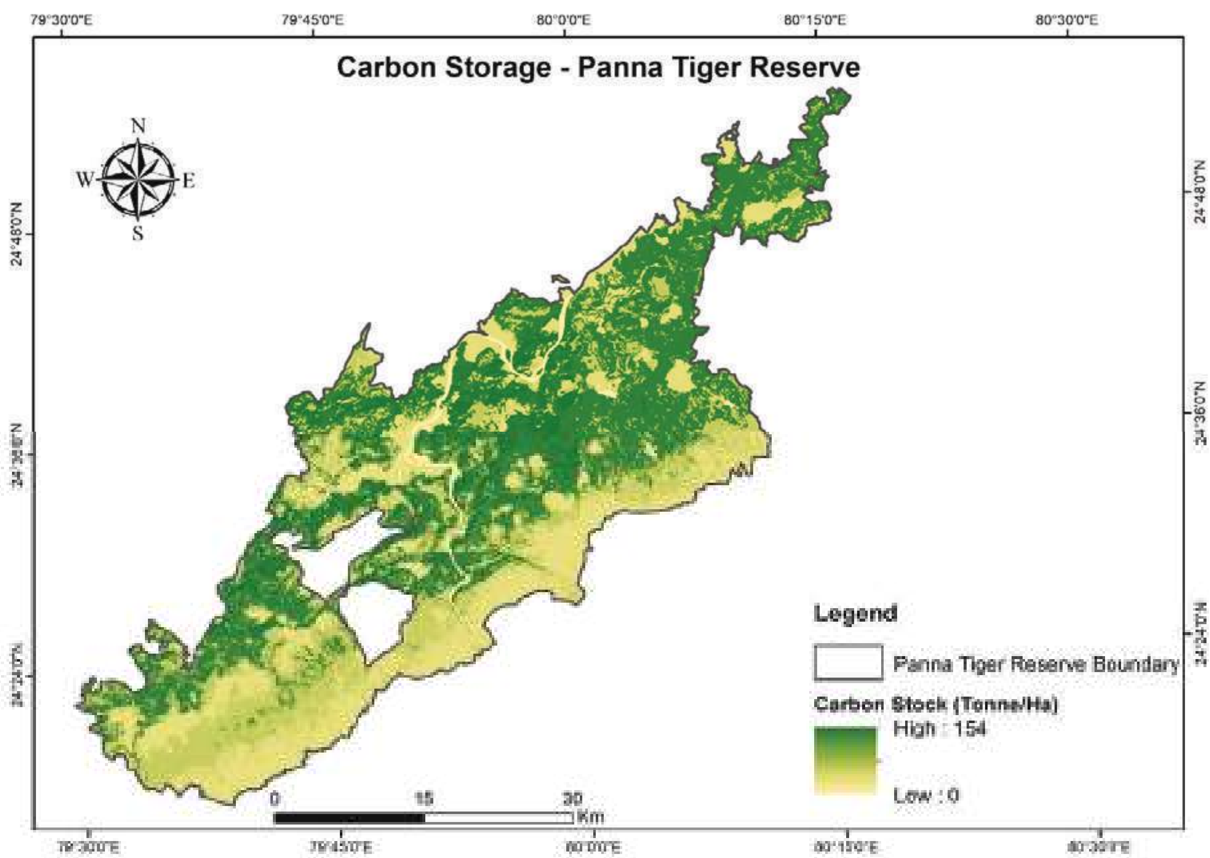



*Figure 6.8-3 Carbon Storage Map of Panna Tiger Reserve Created Using InVEST Model*

The estimates from the Carbon Stock model of InVEST as 13.64 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= Rs. 65 as the average for the year 2017-18, the economic value of carbon stock in PNTR is calculated as Rs. 76.26 billion.

### 6.8.8.11 Carbon Sequestration

Apart from 13.64 million tonnes of carbon stock in the forests of Panna Tiger Reserve, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the the Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database. Based on total biomass per unit area, mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type[120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, the total carbon sequestered in the forests of Panna Tiger Reserve by aggregating estimates for each forest type is equal to 104.3kilo tonnes annually. Detailed calculation is shown in Table 6.8-5.

*Table 6.8-5 Carbon Sequestration PNTR*

| Forest Type | Forest Cover | Total Biomass Per Unit Area (Tonnes/ha) | Mean Annual Increment Per Unit Area (Tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) | Total Value of Annual Carbon Sequestration (Million Rs. Per Year) |
|---|---|---|---|---|---|---|
| Tropical Dry Deciduous Forests | VDF | 92.54 | 3.34 | 15625.58 | 26070.30 | 1069.68 |
| Tropical Dry Deciduous Forests | MDF | 46.27 | 1.67 | 63815.76 | 53236.31 | 2184.32 |
| Tropical Dry Deciduous Forests | OF | 31.42 | 1.13 | 44139.98 | 25001.57 | 1025.83 |
| **Total** | | | | **123581.32** | **104308.18** | **4279.83** |

The social cost of carbon for India as per the latest paper[117] and the economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=Rs. 65, the total economic value of annual carbon sequestration in PNTR is calculated to be Rs. 4.27 billion.

### 6.8.8.12 Water Provisioning

PNTR has 4 main dams, viz. the Rampura reservoir, Gangau dam, Bariyarpur dam and Majhagawan dam. These dams supply water to the surrounding areas like Khandhawaha, Rampura, Jharkua, Bandhi, Shankargarh, Makargang, Simiriya, Hinouta, Majhagawan in Panna district, Madhya Pradesh and Banda in Uttar Pradesh for irrigation purposes. Apart from this Majhagawan dam supplies drinking water for Hinouta and Majhagawan village[169].

The output of the water yield model is very exhaustive. It provides raster and shapefile where various outputs can be spatially studied. It also provides the estimated values of mean actual evapo-transpiration, mean potential evapo-transpiration, water yield volume, etc. Figure 6.8-4 displays the total water yield volume from Panna Tiger Reserve as well as its fringe areas amounts to 1401.37 million cubic metres.

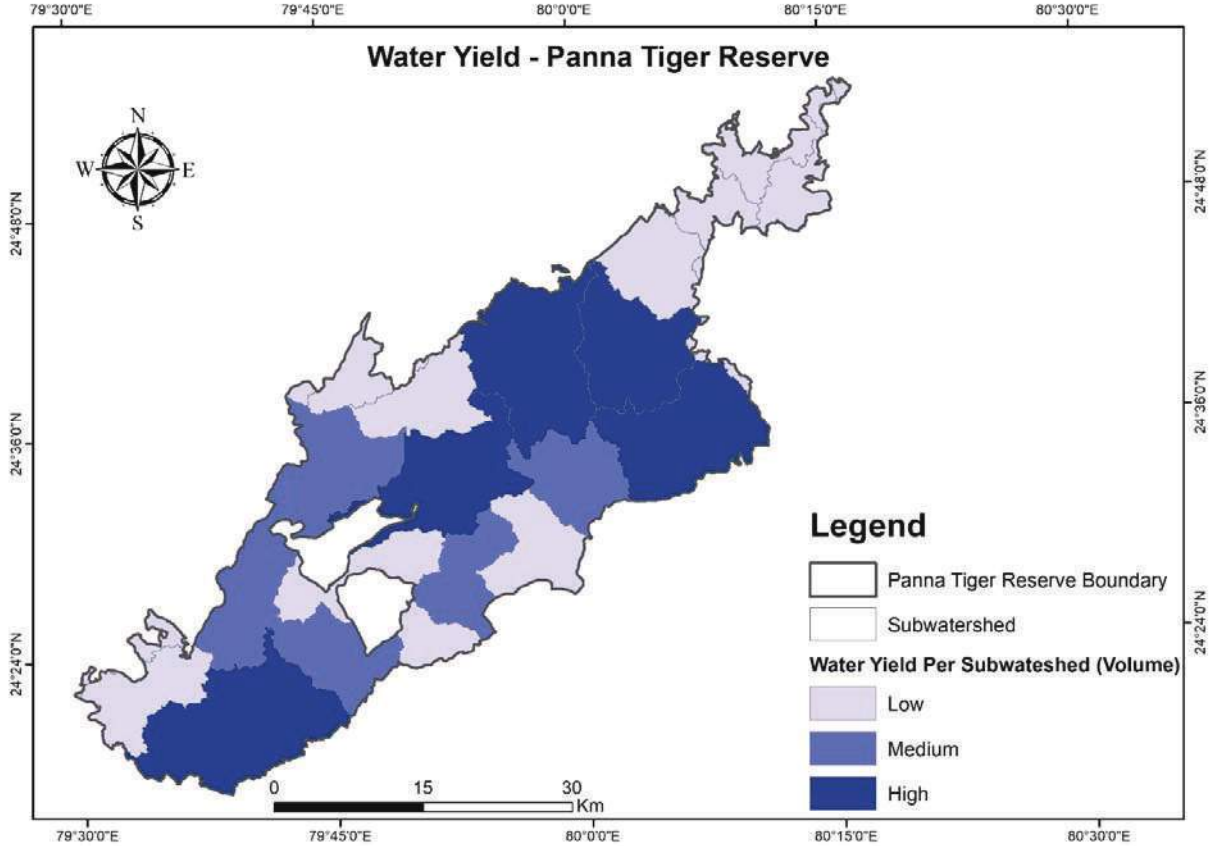



*Figure 6.8-4 Water Yield Output for Panna Tiger Reserve Created Using InVEST Model*

Using the monetary value of Rs. 18.43 per cubic metre[1], the economic value of water provisioning service from PNTR is estimated to be 25.83 billion per year.

### 6.8.8.13 Water Purification

Majhagawan dam supplies drinking water for Hinouta and Majhagawan villages[168,169]. The population in Hinouta and Majhagawanis 2271 and 1263 respectively (Census Data). The daily minimum water requirement as per the Bureau of Indian Standards is 40 litres per capita is taken as the lower bound estimate to calculate the total domestic water requirement[130]. Based on the total dependent population 3534 and per capita water requirement, the total domestic water requirement is 51596.4 kilo litres per annum. Only 10 percent of this estimate is used for valuation as sufficient data was not available to map the beneficiaries and their exact water supply for drinking purpose for the whole year, the annual drinking water requirement comes to around 5159.64 kilo litres. Using a lower bound estimate of average cost of treating water for domestic supply at Rs. 10/cubic m based on estimates for different municipalities of India[131], the avoided cost of water purification for drinking water is around Rs. 0.05 million per year.

### 6.8.8.14 Soil Conservation/Sediment Retention

The output of the model is very exhaustive. Figure 6.8-5 provides the values for the total amount of sediment exported in each subwatershed calculated modelled using InVEST SDR. The output suggests that high sediment loss is concentrated in the northern watersheds with areas of wasteland and agriculture in the Panna Tiger Reserve. The value of sediment export varies from 100 tons to 5500 tons per watershed.

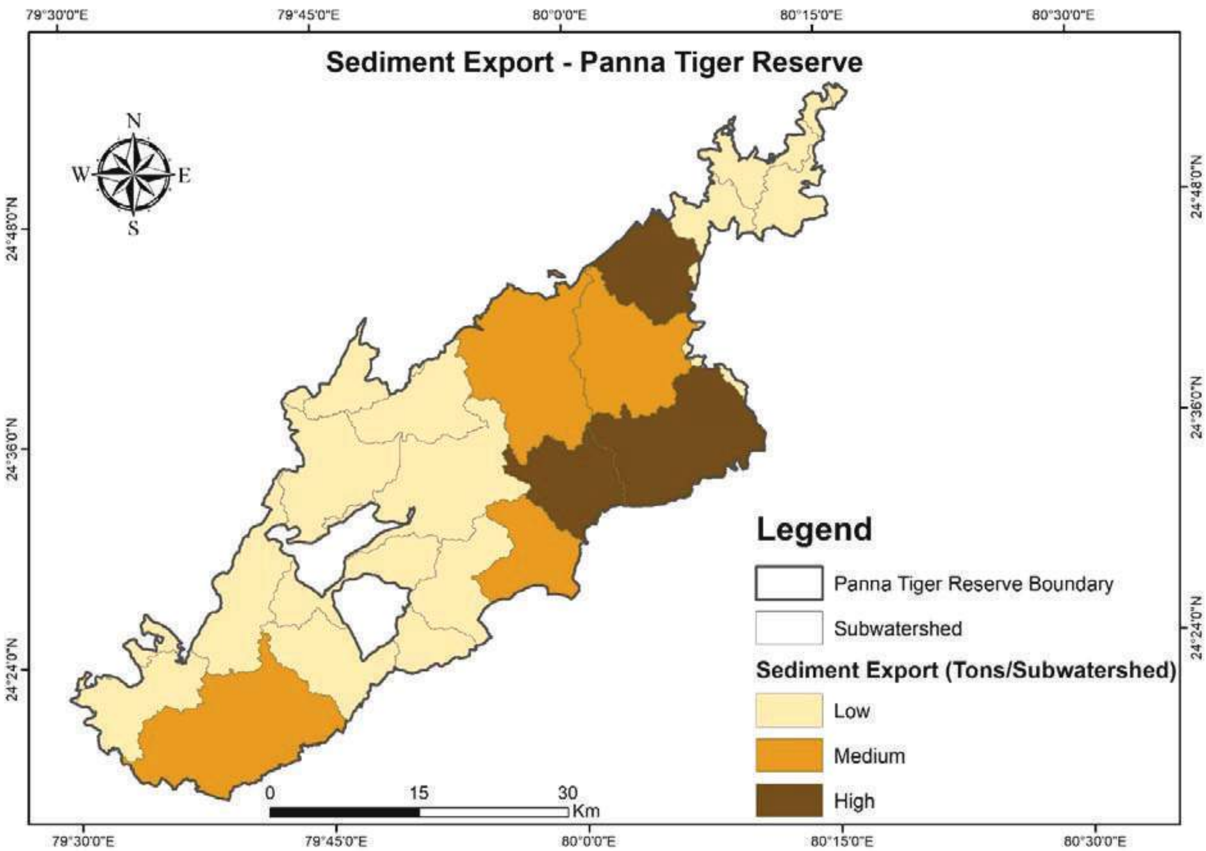



*Figure 6.8-5 Sediment Export from Panna Tiger Reserve Created Using InVEST Model*

As shown in Figure 6.8-6 the sediment retention in the Panna Tiger Reserve landscape is high across all the watersheds lying in the dense forest area of Panna Tiger Reserve. The degraded areas are spread across the southern part of PTR. The value of sediment retention ranges from 11150 tons to 3818400 tons per watershed.

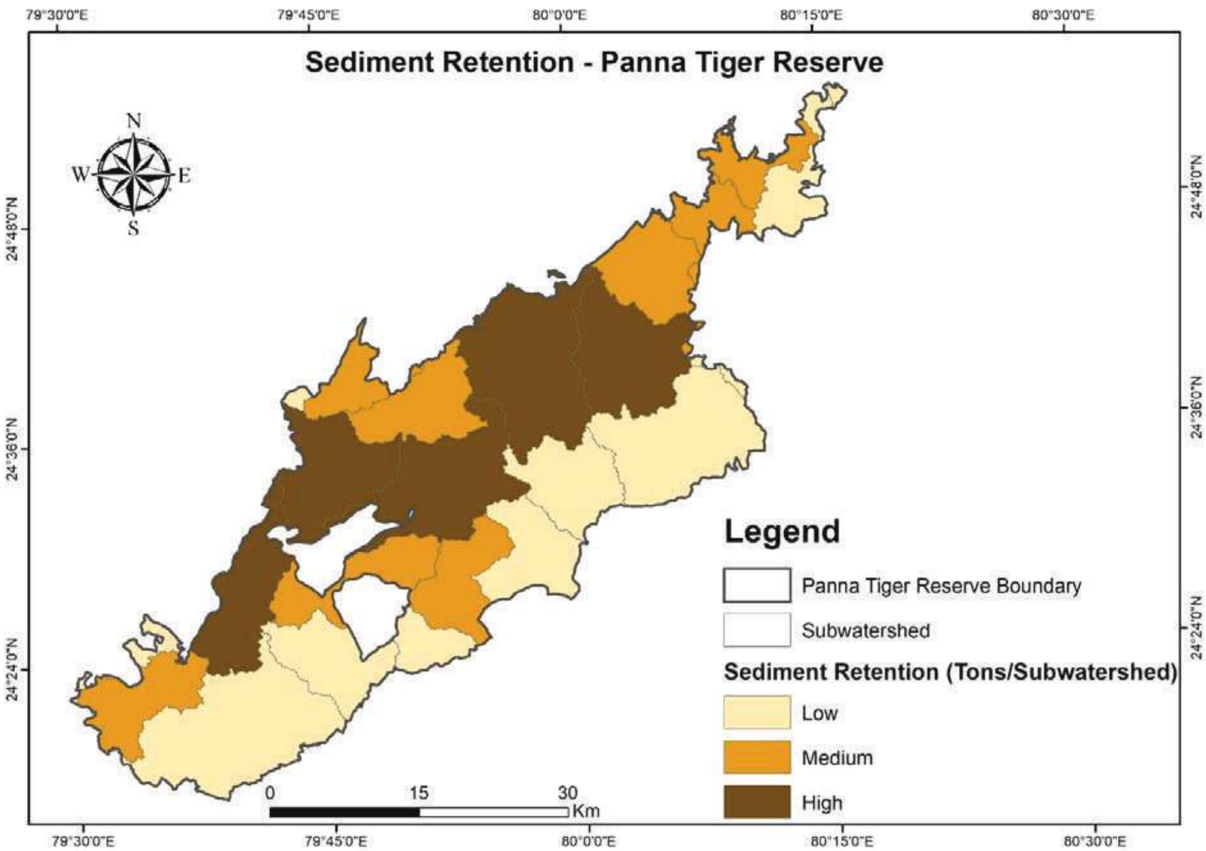



*Figure 6.8-6 Sediment Retention in Panna Tiger Reserve Created Using InVEST Model*

To estimate the economic value of soil loss avoided by the forests of PNTR, the cost of dredging/de-siltation has been considered. On account of lack of site-specific data, the cost estimate of Rs. 60 per cubic metre[132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 84.99 million annually.

### 6.8.8.15 Nutrient Retention

The total soil loss avoided from the InVEST Sediment Retention model of PNTR is around 1.87 million tons. To calculate the amount of nutrient retained, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust[147] has been used on account of lack of local estimates for the same. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations from Table 6.8-6, the total quantity of nutrients retained is approximately 3943.40 tonnes of N, 74.79 tonnes of P and 14022.87 tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary value has been derived. The total value of nutrient loss prevented by the forests of PNTR is equal to Rs. 191.48 million annually.

*Table 6.8-6 Nutrient Retention in PNTR*

| Nutrient | Soil Nutrient Concentration (g Per Kg) | Total Nutrient Loss Avoided (Tonnes Per Year) | Fertilizer (Substitute) Used for Valuation | Price of Fertilizer (Rs. Per Tonne) | Economic Value of Nutrient Retention (Million Rs. per Year) |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 3943.40 | Urea | 5360 | 21.14 |
| Phosphorous (P) | 0.044 | 74.79 | DAP | 20100 | 1.50 |

| | | | | | |
|---|---|---|---|---|---|
| Potassium (K) | 8.25 | 14022.87 | Muriate of Potash | 12040 | 168.84 |
| **Total** | | **18041.06** | | | **191.48** |

### 6.8.8.16 Biological Control

Using estimates of economic value of biological control for tropical forests (Rs. 726 per hectare per annum) and cropland (Rs. 2178 per hectare per annum) from a global meta-analysis study[116] the economic value of biological control service from 147169.34 hectares of forests and 13306.68 hectares of cropland in PNTR is estimated to be 135.83 million Rs. per annum.

### 6.8.8.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to PNTR. Hence, it is not included in the valuation of the ecosystem service of PNTR in this study.

### 6.8.8.18 Pollination

Using estimates of economic value of pollination for tropical forests (Rs. 1980 per hectare per annum) and cropland (Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 147169.34 hectares of forests and 13306.68 hectares of cropland in PNTR is estimated to be 310.72 million Rs. per annum.

### 6.8.8.19 Nursery Function

The nursery function was not found relevant due to lack of information and insufficient evident linkages to attribute this service to PNTR. Hence, it is not included in the valuation of the ecosystem service of PNTR in this study.

### 6.8.8.20 Habitat for Species

Plateau topography with underlying slopes, cliffs with *talus* and *sehas* offer the best combination of habitats for the fauna. Adding to that Ken river, savannah forests, and mixed dense forests on the slopes present a variety of habitat which provide niche areas to support various species (Panna TR, 2017). Using estimates of economic value of habitat service for tropical forests (Rs. 2574 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 147169.34 hectares of forests in PNTR is estimated to be Rs. 378.81 million.

*Key Habitat Areas of Panna Tiger Reserve*

Typical bench topography of the tiger reserve has provided a large number of unique habitats with combinations of rock shelters, cliffs, ledges, overhangs, caves, crevices, etc. making these places ideal for big and small animals like sloth bear, hog, ratel, porcupine, civets, various reptiles, vultures and other birds, honey bees, etc. Perennial springs emanate from the base of these bench terraces providing much needed water to the wild animals during summer. Certain mesoic sites are also associated. The area is dotted with ancient (about 2,000 years old) rock paintings. There are rock shelters, numerous cliffs and gorges that make the entire area one of the most beautiful and picturesque sites. Ken river and its gorges add to the beauty of the landscape[168,169].

*Corridor*

The location of Panna Tiger Reserve in the entire Vindhyan landscape is critical. It serves as the connecting link between the tiger population of the Aravallies (Ranthambore) and Vindhyan Ranges. Within Madhya Pradesh, it has corridor connections with Bhandhavgarh Tiger Reserve, Nauradehi WLS besides some meta-populations of tigers at Chitrakoot forests of Satna district on the north-eastern end and Sagar district[168].

**Vultures of Panna**

*Panna Tiger Reserve: Prime Vulture Habitat*

Panna National Park features unique topographical characters such as rocky cliffs, complex gorges, deep ravines, and waterfalls. A study by Taigor (2010) has shown that multiple vulture species were spotted to roost, nest, and breed on rock cliffs in Kuno National Park. In Panna Tiger Reserve, especially in Ken valley, the table-top topography gives form to such rocky cliffs making them suitable habitats for the vultures. The series of undulating hills and plateaus in this region provide suitable roosting, nesting, and breeding sites for these large birds of prey (Raju Lal Gurjar & Gawande, 2011).

Additionally, the vegetation of the landscape is mixed dry deciduous forests interspersed with grasslands. Studies have shown that in North Madhya Pradesh (Taigor, 2010) and parts of Rajasthan (Chhangani, 2007; Sharma, 1970), tree species such as Lannea coromandelica, Ficus spp., and Boswellia serrata are known to provide strong branches and excellent nesting spots for vultures. Such trees are found in abundance in Panna Tiger Reserve and are widespread throughout the landscape. Panna Tiger Reserve also has healthy prey base species such as Sambar, Chital, Chowsingha and other species for tigers. Leftover carcasses from such animals provide food for the vultures as they are primarily scavenger species, and thus, Panna supports a healthy population.

The ecosystem uniqueness of Panna Tiger Reserve is the phyto-diversity and physical features of the landscape. A study done by Porwal and Singh (2009) has shown that vegetation-type of dry deciduous and mixed dry deciduous forests with bamboo supports high species richness. They also showed that the slope of the landscape influenced the biological richness with moderate to steep, and steep to very steep slope categories having high biological richness than flat and gentle slopes. These natural structures that make up the unique landscape of Panna Tiger Reserve provide suitable habitat for both the resident and migratory vulture species.

### 6.8.8.21 Cultural Heritage

Panna has a rich historical heritage and cultural backdrop. Right from its significant role in the Rajput kingdom to being a *Sanad* state in the Bundelkhand Political Charge of the Central India Agency of the British. The world famous temples of Khajuraho tell the significance of geological formations of the area as most of them are built of Panna sandstone. The sandstone belonged to the Kaimur stage of Vindhyan Super Group and appears to have been obtained for the temples from quarries situated near Jhinna Pahar, north of Panna town. The area is dotted with ancient (about 2,000 years old) rock paintings[168]

The history of Panna and Chhatarpur forests can be traced back to the ancient Gonds who were the original 'rulers' of these central highlands. Many relics of their kingdom(s) can be found scattered in the tiger reserve. The area may, therefore, be taken as a repository of the ancient Gond civilization. The area has a long history of wildlife conservation; the major part of it has been the shooting reserve of erstwhile rulers[168].

Among the tribal population, Panna Tiger Reserve has the Pardhi tribe. They worship nature in the form of trees (Amla, Pipal, Saja, etc.), rocks and mountains and animals, including tigers, and hold various waterbodies, including river Ken, in high esteem[168,169].

### 6.8.8.22 Recreation

Panaa Tiger Reserve offers tremendous opportunities to people from all walks of life to know about the tropical dry forest ecosystem, learn its intricacy, learn animal behaviour and get closely associated with nature conservation.

Being only a half hour drive from Khajuraho, which is a World Heritage Site and a major tourist attraction, PNTR receives a mix of foreign and national tourist influx[168].

The scenic beauty of the PNTR landscape is unparalleled. Major tourist attractions of PNTR, apart from its equisite beauty, wilderness, and picturesque grasslands; are the *sehas.* They are *nallahs* originating from the reserve making falls. Popular *sehas* are Balaiya, Kaimasan, Dundhwa and Pandav falls. Ken river and its gorges add to the beauty of the landscape. The area also has historical significance in the form of relics of Gond civilization and ancient (about 2,000 years old) rock paintings. There are rock shelters, numerous cliffs and gorges that make the entire area one of the most beautiful and picturesque sites[168].

In the year 2015-16, PNTR had a total tourist inflow of around 114916, which includes 101027 Indian tourists and 13889 foreign tourists. The total revenue earned from tourism in the year 2015-16 was Rs. 18.4 million[169].

#### 6.8.8.23 Spiritual Tourism

Two temples of Lord Shiva are inside the core area and are open only during *Vasant Panchami*. *Bhairotek, Balakdev* and *Hindolamata* temples are in the buffer area are open throughout the year. During Makar Sankranti, the annual Pandvan Fair is organized in the buffer area every year which attracts a significant crowd [168]. Apart from this, there are many local deities and places of religious importance like Thakur Baba, Masan Baba, Bade Dev, etc. Talgaon Ki Chhatri was built by ancient rulers and is also one of the places where villagers go for worship[169]. A detailed account of all the sites and their significance is given in Table 6.8-7:

*Table 6.8-7 Places of Religious Importance PNTR [169]*

| No. | Name of Site | Category | Site Significance |
|---|---|---|---|
| <u>RANGE PANNA</u> | | | |
| 1. | **Thakur Babba** | Religious | Visited by people of Jhardhova and worshipped by villagers |
| 2 | **Masaan Babba** | Historical/ Religious | Worshipped by villagers |
| 3 | **Bade Dev (Kherva)** | Historical | Worshipped by villagers |
| 4 | **Amdar** | Historical | Ancient mango trees and ruins |
| 5 | **Talgaon ki Chhatri** | Historical | Built by ancient rulers |
| <u>RANGE HINAUTA</u> | | | |
| 1 | **Hanuman Bhatia** | Religious | Image of Lord Hanuman; worshipped |
| 2 | **Kalka Devi ki Madhia** | Religious | Worshipped by villagers |
| 3 | **Jhalariya** | Religious | Waterfalls on shivling |
| 4 | **Bhorgadh ke Hanumanji** | Religious | Lord Hanuman's image on Ken |
| 5 | **Devi ki Madhiya** | Religious | Images of deities;worshipped |
| 6 | **Tabela** | Religious | Waterfalls on shivlinga |
| 7 | **Debra Dev** | Religious | An attractive pillar |
| 8 | **Scuplture (Mahua Pani)** | Historical | Cave paintings of man and animal |
| 9 | **Sculpture (Chuheran ki Tor)** | Historical | Cave paintings of man and animal |
| 10 | **Sculpture(Sita Shaiyya)** | Historical | Cave paintings of man and animal |
| <u>RANGE MADLA</u> | | | |
| 1 | **Pandav Fall** | Religious | Pandava caves of the Mahabharata period |
| 2 | **Bhairav Tek Mandir** | Religious | Religious centre |
| 3 | **Laxmi Mandir** | Religious | Temple of Goddess Laxmi |
| 4 | **Nararan Mandir** | Religious | A temple; good source of water |
| 5 | **Hanuman mandir** | Religious | Religious centre |
| <u>RANGE CHANDRA NAGAR</u> | | | |
| 1 | **Swargeshwar** | Religious | Lord Shiva Temple; worshipped |
| 2 | **Badi Devi Temple** | Religious | Worshipped |
| 3 | **Hanuman Temple** | Religious | Worshipped |

| | | | |
|---|---|---|---|
| 4 | **Duggela Babba's Chabootra** | Religious | Worshipped |
| 5 | **Mahadeo Ghat** | Historical/ Religious | Ruins of Lord Shiva temple |
| 6 | **Jaria Jhor** | Historical/ Religious | Historical site; worshipped |
| 7 | **Dhava Tek** | Historical/ Religious | Historical site; worshipped |
| 8 | **Topkhana** | Historical/ Religious | Historical ruins; worshipped |
| 9 | **Beda Khakhri** | Religious | Ruins and broken images of deities |
| 10 | **Narsingh Ghori** | Religious | Sacred chabootra; worshipped |
| 11 | **Narsingh Ghori** | Religious | Sacred chabootra; worshipped |
| 12 | **Badi Khakhri** | Historical | Ruins of a ancient buildings |
| 13 | **Kalika Devi Temple** | Religious | Worshipped |
| 14 | **Kishor ju Mandir** | Hist/rel. | Ruins of temple |
| 15 | **Thakur Babba** | Religious | Sacred chabootra;worshipped |
| 16 | **Bundela Babba** | Religious | Sacred chabootra;worshipped |
| 17 | **Lagra** | Hist/rel. | Ruins; sacred chabootra |
| 18 | **Hanuman Temple** | Religious | Worshipped |
| 19 | **Ruins of Temple** | Hist/rel. | Ruins of a temple |
| 20 | **Hanumanji ki Madhia** | Religious | Worshipped |
| 21 | **Old Shiv Temple** | Hist/rel. | Historical site;worshipped |
| 22 | **Pandavan** | Scenic/rel. | Waterfall and site of Lord Shiva/Hanuman |
| 23 | **Kudiyan** | Religious | Lord Hanuman's place;worshipped |
| 24 | **Aam Dabar** | Religious | Puccka chabootra of Dev danav |
| 25 | **Purani Ghadi** | Historical | Ruins of ancient monuments |
| 26 | **Jhalariya** | Religious | Lord Hanuman temple worshipped by locals |
| 27 | **Bihari Ju ka Mandir** | Religious | Temple worshipped by locals |
| 28 | **Punniyayi Talaiyya** | Religious | Worshipped with bhajans |
| 29 | **Ghatoria** | Religious | Worshipped with bhajans |
| 31 | **Dhaudhan** | , | Shiva Temple; worshipped |
| 32 | **Ghodai Beehar** | Hisrorical | Historical beehar; source of water |
| 33 | **Badhrajan Roriya** | Hist/rel. | Ruins; worshipped |

### 6.8.8.24 Research, Education and Nature Interpretation

The tiger reserve provides an excellent opportunity to the researchers of various fields to undertake scientific research on various aspects of wild animals, plant communities, cultural and historical significane and mining. Aquatic life in Ken, both within and along the river course, terrestrial flora and fauna, socio-economic aspects in and around the reserve also provide ample scope for scientists to undertake research. A total of 35 studies have been conducted so far in PNTR on various topics like tiger ecology, population analysis, human-animal conflict, landscape dynamics, wildlife monitoring, corridors and biodiversity (Panna TR, 2017).

### 6.8.8.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (Rs. 792 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation from 147169.34 hectares of forests in PNTR estimated to be Rs. 116.56 million.

### 6.8.8.26 Waste Assimilation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 7920 per hectare per annum), waterbody (Rs. 60588 per hectare per annum) and cropland (Rs. 26202 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 147169.34 hectares of forests and 13306.68 hectares of cropland in PNTR is estimated to be RS. 1.66 billion per annum.

#### 6.8.8.27 Climate Regulation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 134904 per hectare per annum) and cropland (Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 147169.34 hectares of forests and 13306.68 hectares of cropland in PNTR is estimated to be Rs. 20.21 billion.

### 6.8.9 Spectrum of Values- Panna Tiger Reserve

PNTR provides a variety of values that fall under economic, biological, ecological, conceptual, physical, scientific, educational, cultural, religious and historic values. The TR is endowed with biological, ecological, geological, geomorphological, historical and cultural values so significant of central Indian highlands.

#### 6.8.9.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| **Summary of Ecosystem Services Based on TEV Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **787.97** | **Rs. Million/Year** |
| Fuel wood, Fodder, Non-Timber Forest Products, Employment Generation<br>* - Fishing, Bamboo (Flow), Timber (Flow) | | |
| **Indirect Use Value** | **53107.58** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Waste Assimilation, Climate Regulation<br>*- Moderation of Extreme Events, Nursery Function | | |
| **Option Value** | **15650.02** | **Rs. Million/Year** |
| Genepool Protection | | |

| **Summary of Ecosystem Services Based on MA Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **671.41** | **Rs. Million/Year** |
| Employment Generation, Fodder, Fuel wood, NTFP<br>* - Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Regulating Services** | **68476.94** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Waste Assimilation, Climate Regulation, Gene pool Protection<br>*- Moderation of Extreme Events, Nursery Function | | |
| **Cultural Services** | **18.40** | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Supporting Services** | **378.81** | **Rs. Million/Year** |
| Habitat for Species | | |

| **Summary of Ecosystem Services Based on Stock and Flow Benefits** |
|---|

| Type of Value | Value | Unit |
|---|---|---|
| **Flow Benefits** | **69.55** | **Rs. Billion/Year** |
| Employment Generation, Fodder, NTFP, Fuel wood, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Waste Assimilation, Climate Regulation<br>* - Timber (Flow), Moderation of Extreme Events, Nursery Function, Fishing, Bamboo (Flow) | | |
| **Stock Benefits** | **137.46** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| Summary of Ecosystem Services Based on Tangible/Intangible Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Tangible Benefits** | **671.41** | **Rs. Million/Year** |
| Employment Generation, Fodder, Fuel wood, NTFP<br>* - Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Intangible Benefits** | **206329.46** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Waste Assimilation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>*- Moderation of Extreme Events, Nursery Function | | |

| Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **26392.30** | **Rs. Million/Year** |
| Fodder, Fuel wood, NTFP, Water Provisioning<br>* - Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Protection from Disease/Predators/Parasites** | **135.83** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **27242.62** | **Rs. Million/Year** |
| Carbon Sequestration, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Waste Assimilation, Climate Regulation, Habitat for Species<br>*- Moderation of Extreme Events, Nursery Function | | |
| **Socio-Cultural Fulfilment** | **124.79** | **Rs. Million/Year** |
| Employment Generation, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Ecosystem Assets** | **153105.33** | **Rs. Million** |

| | | |
|---|---|---|
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| **Summary of Ecosystem Services Based on EPA Effect Categories** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **206982.47** | **Rs. Million** |
| Employment Generation, Timber (Stock), Genepool Protection, Carbon Storage, Carbon Sequestration, Water provisioning, Soil conservation/Sediment Retention, Nutrient Retention, Biological control, Pollination, Habitat for Species, Gas Regulation, Climate Regulation<br>* - Timber (Flow) | | |
| **EPA Effect Category 2** | **18.40** | **Rs. Million** |
| Recreation | | |
| **EPA Effect Category 3** | **35** | **Studies till 2015** |
| Research, Education and Nature Interpretation | | |
| **EPA Effect Category 4** | **Pardhi** | **Main Tribe Group** |
| Cultural Heritage | | |
| **EPA Effect Category 5** | **More than 30** | **Big/Small Sites/Temples Having Religious/Historical Importance** |
| Spiritual Tourism | | |

### 6.8.9.2 Linkages to Human Health

Panna Tiger Reserve offers a range of ecosystem services vital for maintenance of human well-being. Amongst these, Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Biological Control, Pollination, Cultural Heritage, Recreation, Research, Education and Nature Interpretation, Gas regulation, and Climate Regulation Services have a huge direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 144.55 billion.

### 6.8.9.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Panna Tiger Reserve for the year 2016-17, was around Rs. 35.86 million. Based on the flow benefits of Rs. 69.55 billion per year, for every rupee spent on management costs in PNTR, flow benefits of Rs. 1939.4 are realized within and outside the tiger reserve.

**Successful Tiger Re-Introduction- Highlighting Habitat Value**[169]

Panna Tiger Reserve is known for its conservation history. After losing tigers in 2009, a full-fledged reintroduction programme was initiated and successful 2012. It was achieved by two translocated tigers and re-wilding two orphaned tigers facilitate by Panna Tiger Reintroduction Programme. The breeding success in the shortest possible time of Panna reintroduced tigers is unparalleled. Panna Tiger Reintroduction project is a collaborative of MPFD and WII has completed its Phase I and is under the third year of phase II. It was credited as one of the best 'Adaptive Active Management Practice Model' and received the 'Award of Excellence' in the Active Management Category for the year 2010-11 and 2012 to 14 by NTCA. During the formative years of Panna TR, tiger density was less than 3 tigers per 100 sq km and has seen an increase to 7 tigers per 100 sq km during early 2000.

### 6.8.9.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Panna Tiger Reserve was estimated at Rs. 0.41 million (Rs. 4.08 lakhs) per hectare.

#### 6.8.9.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 7.45 percent of flow benefits accrue at the local level, 30.86 percent at the national level and 61.70 percent at the global level.

# Similipal Tiger Reserve

Similipal Tiger Reserve (STR) is part of the UNESCO World Network of Biosphere Reserves rich with more than 1000 species of plants including 94 species of orchids. The reserve comprises of different forest types including Sal *(Shorea robusta)* forest, moist deciduous forest and semi-evergreen patches.

**The tiger reserve provides flow benefits worth Rs. 160.30 billion per year (Rs. 0.59 million per hectare) and stock benefits of Rs. 498.33 billion per year. Main ecosystem services that arise from this tiger reserve include provisioning of water (Rs. 70.33 billion per year), water purification (Rs. 29.20 billion per year) and climate regulation (Rs. 34.82 billion per year).**

**Under the Total Economic Value (TEV) framework, the annual direct-, indirect- benefits and option values were Rs. 0.89 billion, Rs. 133.18 billion and Rs. 26.23 billion, respectively.**

As per the MA framework, the value of provisioning services was Rs. 0.69 billion per year, that of regulating services was Rs. 158.95 billion per year and supporting services were Rs. 0.66 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 0.69 billion and Rs. 657.94 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 70.42 billion), protection from disease (Rs. 0.20 billion), benign physical and chemical environment (Rs. 62.84 billion), socio-cultural fulfilment (Rs. 0.60 billion) and ecosystem assets (Rs. 524.55 billion).

The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 298.97 billion per year. The investment multiplier for STR was calculated as 3038.31.

## 6.9 Similipal Tiger Reserve

### 6.9.1 Location, Landscape and Significance

Located in the northern-most part of Odisha state, Similipal Tiger Reserve forms a part of the larger Central Indian landscape complex and falls in the biogeographic zone of the Deccan peninsula. Containing the single largest tiger population in Odisha, it covers an area of 2750 sq km which makes it the fourth largest in the tiger reserve network of India. The core area comprises 1194.75 sq km and the buffer zone comprises the Similipal Sanctuary, reserve forest blocks, proposed reserve forests and villages are spread over an area of 1555.25 sq km. Similipal forests account for more than one-fourth of the total geographic area and two-thirds of the total forested area of Mayurbhanj district[170].

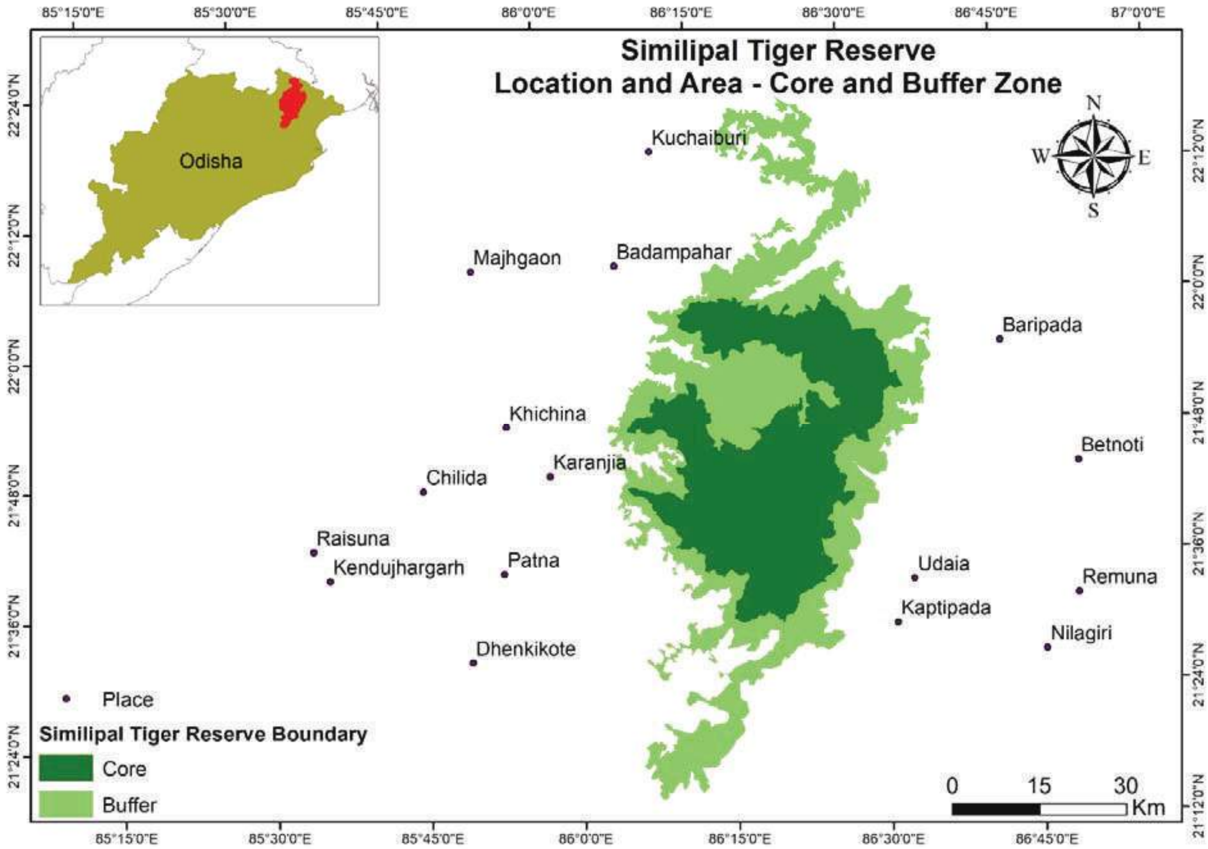



*Figure 6.9-1 Similipal Tiger Reserve (Source: Forest Survey of India)*

STR is one of the first nine tiger reserves of India and is the only home of the unique melanistic tiger. It has innumerable hills, dales and perennial streams which makes it an ideal abode for wildlife. Its tropical forests combined with its structural diversity make it a unique ecosystem. It has been declared as a biosphere reserve by the Government of India. One of the reasons for STR's prominence is its corridor connectivity with nearby tiger reserves like Satkosia Tiger Reserve. It also serves as a link between the flora and fauna of southern India and Sub-Himalayan north-east India[170].

### 6.9.2 History

The tiger reserve has a long history of management. It was once the hunting grounds for the Maharaja of Mayurbhanj. Forest management practices in Mayurbhanj date back to the later part of the nineteenth century. A forest policy was declared before 1885 by the then Maharaja of Mayurbhanj. At that time reserve forests of Mayurbhanj were under the management and control of the forest department whereas other protected forests were under the charge of the revenue department which were mainly maintained to meet the requirements of the rayats and residents and also subject to clearance for cultivation. The forest area was being given under 'Amal-Nama' lease by the revenue authorities and leases for reclamation of reserve forests were given under the special sanction of the Ruling Chief. In 1904, the Mayurbhanj narrow gauge railway line was built up to Baripada. This line was used for transportation of timber. The first working plan was prepared by Mr. C. C. Hart in 1896-97[170].

Mr. Saroj Raj Chaudhury, an eminent wildlifer of the country took charge as first Field Director of Similipal Tiger Reserve on dated December 5, 1973. In 1980, the Government of Odisha inititated the notification of declaring 303 sq km of the northern portion of Similipal as National Tiger reserve, which constituted the core of the tiger reserve. In 1986, an area of 542.70 sq km was added to core area bringing the total area of core to 845.70 sq km which came fully under the control of the Project Tiger. The remaining sanctuary area was under the control of Baripada, Karanjia and Rairangpur Divisions. A complete moratorium on tree felling was imposed in 1988. The present core or Critical Tiger Habitat of 1194.75 km˚ was declared in 2007[170].

### 6.9.3 Topography and Climate

The terrain is mostly undulating and hilly interspersed with open grasslands and wooded areas. There is an inclined plateau which rises abruptly from the low coastal plains of the district. The steep side faces the Bay of Bengal and runs northwards to finally merge with Chhotanagpur (average elevation of 500 mts). Numerous valleys supporting meadows lie in the basin of the hills. Elevation at the highest point is 1168.00 m above mean sea level locally known as Khairiburu. It stands along with Meghasani at 1165.00 m above MSL as twin towers of natural grandeur. The elevation of the central region of the plateau near Dhudurchampa is 1009.95 metres above mean sea level[170].

STR has a subtropical climate with three seasons, i.e summer, monsoon and winter. Summers are hot, rainfall is well-distributed and winters are normal. Winter extends from November to February and summer months are March to May. In winter frost occurs in the Upper Barakamuda valley and other adjoining valleys in south Similipal. Nawana Valley in central Similipal also receives sporadic frost resulting in a significant dip in temperature in these areas. The temperature ranges from 4˚ C to 34˚ C. The air is moslty humid with relative humidity always extending to 70 percent. During winter a cold wind blows inside the reserve locally called “Kaliani Paban”[170].

Monsoon is quite conspicuous from June to September. October constitutes the post-monsoon period. North Similipal is comparatively drier than Southern parts. The rainy season is sultry, humid and occurs between June-October. The south-west monsoon brings nearly 90 percent of the total annual precipitation. Most of the rainfall concentrates during June-September which also constitutes the maximum number of mean rainy days. Average annual rainfall is 2000 mm[170].

Diversity in the temperature regime between the northern and southern region, wetland diversity, including perennial water sources, altitude ranging from 40m to 1100m with Khairiburu, the highest peak at 1168m, frost valleys in central and south Similipal and high rainfall area with 1800-2900 mm precipitation in 135-158 days annually make Similipal unique[170].

### 6.9.4 Land Cover Classification

The land use and land cover map of Similipal Tiger Reserve was obtained from the Forest Survey of India. The land cover of Similipal is broadly categorized into deciduous forest, evergreen forest, agriculture, plantation, built-up, wasteland and degraded forest (Figure 6.9-2).

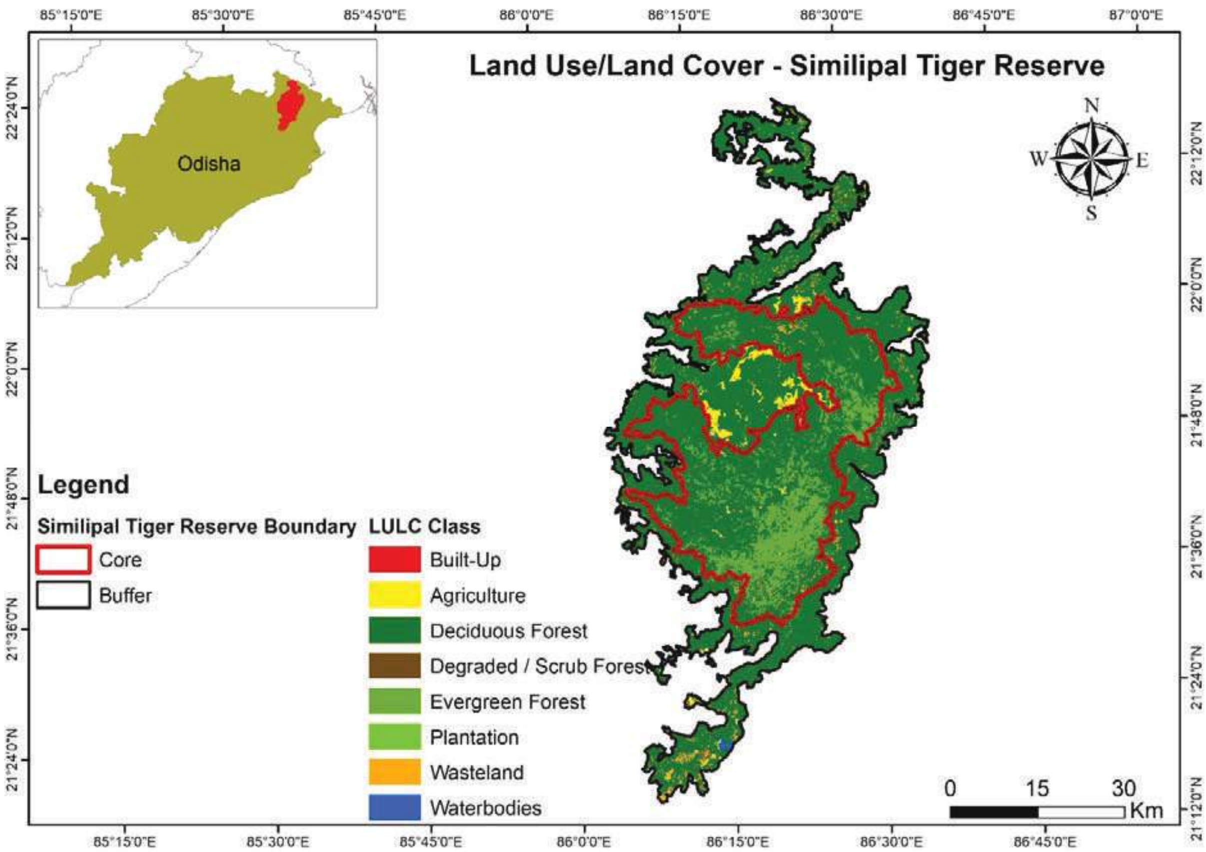



*Figure 6.9-2 Land Use/Land cover: Similipal Tiger Reserve (Source: Forest Survey of India, 2013-2014)*

The core and buffer area mainly consists of deciduous forest (83.40 percent), evergreen forest (10.38 percent), agriculture (2.89 percent) and wasteland (2.50 percent) of the total tiger reserve. The area under each of these land cover classes as shown in the Table 6.9-1.

*Table 6.9-1 LULC Classes STR*

| LULC Class | Area (ha) |
|---|---|
| Agriculture | 7874.81 |
| Built-Up | 344.02 |
| Deciduous Forests | 227000.30 |
| Degraded / Scrub Forest | 1309.59 |
| Evergreen Forests | 28267.28 |
| Plantation | 2.20 |
| Wasteland | 6807.00 |
| Waterbodies | 554.76 |

## 6.9.5 Rivers and Hydrology

Similipal Tiger Reserve is bestowed with numerous streams, waterfalls and other water sources. The core area has high water levels due to the presence of perennial streams converging to three rivers i.e. Budhabalanga, Salandi and Baitarani out of which the former two emerge from STR and the third one has its tributaries flowing from the PA. STR acts as a water tower for Odisha, West Bengal, Chhattisgarh and Jharkhand. The rivers flow through the districts of Mayurbhanj, Balasore and Bhadrak and finally converge to the Bay of Bengal. The other tributaries are Palpala, East Deo, West Deo, Khairi, Tel, Sanjo, Bherol, etc. along with many rivulets and *nullahs* most of which are perennial[170].

Perennial water flow is a characteristic of the ecosystem of Similipal hill forest. There are many waterfalls inside Similipal. Joranda (181m), Barehipani (217m), Shirsa (243m), Uski, Sitakund, Olkudar and Deokund are a few notable waterfalls among them[170].

The perennial water sources arean important source of water during the lean period when other streams go dry. Nine major perennial rivers such as the Budhabalanga, Deo, Sunei, Gangahaar, Jambhira, Khadkhai, Khairibhandan, Bankabal and Katra and their tributaries originate mostly from Similipal Hills. The riverine system of STR can be broadly divided into two categories[170].

### 6.9.6 East Flowing River System

The east flowing water drainage system which is also known as the Budhabalanga water drainage system is augmented with water resources in the northern and eastern part of the buffer area of the tiger reserve. The Budhabalanga river emerges from the core area of the tiger reserve and northern part of Similipal Reserved Forest with catchment areas of the river falls in Balanga East through districts of Mayurbhanj and Balasore. It serves as life-lines for the districts and finally winds its way into the Bay of Bengal. The perennial tributaries of the river Budhabalanga are Palpala, Kafra, Sanjo, East Deo, Kalo, Sono and along with many rivulets and *nallahs*. Most of them are perennial in nature and are a source of water supply during dry seasons. There is a small irrigation dam on river Kalo near Udala outside the tiger reserve[170].

### 6.9.7 West Flowing River System

The buffer zone is drained by the Baitarani drainage system with a number of perennial streams joining the main river Baitarini which emerge from Konasika of Keonjhar district. The major tributaries are Salandi, Bhandan, Khairi, West Deo, Tel, Sim and Kantamauli. These tributaries are perennial and most of them emerge from the core and buffer area of the tiger reserve in the western and southern parts[170].

### 6.9.8 Biodiversity

The forests of STR are a unique composition of different types of forests such as northern tropical mixed deciduous forests, northern tropical semi-evergreen forests, mixed deciduous hill forests, high level sal forests, dry deciduous sal forests, plain sal forests, grasslands and savannahs. Largest patch of sal forest is in the sal-teak transition zone and is similar to the flora-fauna composition of the Western Ghats and North-east India[170].

The landscape of Similipal harbours 7 percent flowering plants, 8 percent orchids, 7 percent reptiles, 20 percent birds and 11 percent mammals of India. It is the abode of more than 1253 species of flowering plants, 99 species of non-flowering plants, 21 species of amphibians, 62 species of reptiles, 361 species of birds, and 55 species of mammals. It bears 94 species of orchids, many of them endemic and endangered, and 72 of the species are Himalayan species. There are many species of rare, endangered, threatened and vulnerable plants and animals. Mahaseer, Hornbill, Chowsingha, Mouse Deer, Giant Squirrel, Flying Squirrel, Ruddy Mongoose, Mugger Crocodile and Rufus Tailed Hare are some of the examples of its unique biodiversity[170].

Similipal is also famous for its tigers and elephants. It is the only home of melanistic tigers in India. It consists of 50 percent tiger population and 25 percent elephant population of Odisha[170].

### 6.9.9 Tourism

It is dotted with numerous peaks, valleys, waterfalls and beautiful flora and fauna, and attracts many tourists from within and outside the country. Tourism activity is mostly confined to the buffer zone of the tiger reserve which extends over 130 km road length. Only a small area at Chahala (0.05 sq km) comes under the core area where day-tourists are allowed to visit. Besides, the tourist route passes through stretches of forests in the core area between Bhajam-Nigirdha over 18 km, Haldia Chhak to Chahala via Brundavan over 15 km and a small transit route near Kalikaprasad gate over 5 km[170].

### 6.9.10 Socio-Economic Situation

There are three human inhabited revenue villages in the core area, viz. Kabataghai, Jamunagarh and Bakua and 64 villages in the buffer area. The inhabitants are the Khadia, Kolhas and Santhal tribes. The people residing inside the core area mainly live on agriculture, supplemented by collection of tubers, roots, fruits and other NTFPs. They also keep cattle. Besides these three villages there are two settlements at Upper Barakamuda and Bahaghar. The tiger reserve is surrounded by about 1200 villages all around within 10 km from the periphery of the Tiger Reserve. According to the 2001 census around 5 lakh people reside in these villages[170].

The local people are engaged as guides to the tourists and on services rendered to the tourists at eco-tourism spots located at Gurguria, Jamuani, Chahala, Barehipani, Muktapur, Nawana and Joranda only. Some of them have been engaged on daily wages as protection assistants in anti-poaching camps. Many people living within and outside Similipal derive their livelihood from Similipal forests through collection of firewood, timber and several minor forest products like collecting honey, sal resin and arrowroot from the forests which they sell in the weekly markets. It is also a source of many medicinal plants. Weekly markets' or 'Hata' play a pivotal role in the economy. Sal leaves, honey, arrowroot, gums, wax and medicinal herbs are collected regularly and sold in the 'hata'. Khadia tribes, who are landless, mostly depend on the Similipal forests for their survival[170].

Other occupations in which local people are engaged include (i) mat making, (ii) sawing, (iii) basket making, (iv) working as blacksmiths, (v) tailoring, (vi) distillery (vii) livestock farming. The village SHGs have taken initiatives to market the handicraft products under the Tribal Handicraft Centre which promotes and helps in developing designs for different tribal handicrafts such as tribal jewellery and household articles in the Dhokra casting trade. It also helps in improvement of utility articles, statues, murals in stone carving trade, artistic as well as live models in terracotta and bronze casting, artistic bamboo crafts items, etc. The centre provides training to the tribal artisans and the models prepared during the course are marketed at the Pallishri Fairs[170].

### 6.9.11 Valuation Estimates for the Simlipal Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES.

#### 6.9.11.1 Employment Generation

The total number of man-days of employment generated from labour activities in STR is around 11000 man-days[171]. They include various labour activities under the forest department in STR. Assuming a wage-rate of Rs. 150 per day per labour, the total economic value of employment generation from STR is Rs. 602.25 million.

#### 6.9.11.2 Fishing

Due to scarcity of data and other relevant information to calculate the total fish catch, the economic value of this service has not been estimated in monetary terms here.

#### 6.9.11.3 Fuelwood

No harvesting of fuelwood is allowed in the Similipal Tiger Reserve.

#### 6.9.11.4 Fodder/Grazing

Using the total number of cattle in the core area (2 hamlets) and buffer (64 villages), given by the tiger reserve management[171], converting them to equivalent cattle units, and assuming standard forage quantity at 22 kilograms per day per cattle unit[107]. The total annual quantity of fodder harvested is equal to 89831 tonnes per year. Assuming an average price of Re. 1 per kilogram of fodder the economic value of annual grazing benefits provided by STR is approximately equal to Rs. 89.83 million.

#### 6.9.11.5 Standing Timber (Stock)

The standing stock of STR has immense value. To estimate the economic value of the standing stock, growing estimates of timber species from the forest inventory database[108] of the Forest Survey of India (FSI) have been used to as per the forest type to estimate the total stock of STR. It is estimated that approximately 14.18 million cubic metres of standing stock of timber are contained in STR as shown in Table 6.9-2. In monetary terms, using an average price of 25000 per cubic metres after discounting for transportation and maintenance cost, the standing stock has value equal to Rs. 354.52 billion.

*Table 6.9-2 Timber Stock in the Forests of STR*

| Forest Type | Forest Cover | Growing Stock (Cubic m Per ha) | Area (ha) | Total Growing Stock(in Thousand Cubic m) | Economic Value (in Million Rupees) |
|---|---|---|---|---|---|
| Tropical Moist Deciduous Forests | VDF | 35.58 | 95603.38 | 3401.09 | 85027.25 |
| Tropical Moist Deciduous Forests | MDF | 46.40 | 97234.50 | 4512.02 | 112800.41 |
| Tropical Moist Deciduous Forests | OF | 34.79 | 12013.05 | 417.92 | 10448.02 |
| Tropical Dry Deciduous Forests | VDF | 158.95 | 25495.33 | 4052.46 | 101311.44 |
| Tropical Dry Deciduous Forests | MDF | 79.47 | 15234.26 | 1210.73 | 30268.37 |
| Tropical Dry Deciduous Forests | OF | 28.45 | 8743.06 | 248.70 | 6217.62 |
| Plantation/TOF | - | 50.5 | 635.85 | 32.11 | 802.76 |
| Non-Forest | - | 19.79 | 15466.34 | 306.06 | 7651.46 |
| **Total** | | | | **14181.09** | **354527.33** |

For Similipal Tiger Reserve, the growing stock estimated for Tropical Dry Deciduous Forests- VDF and Non Forest-VDF category has been derived from taking double the MDF values of respective forest types. There was a mismatch in the forest type listing in the NFI data for STR and the forest types obtained from the modelling output using Remote Sensing-GIS based data. The NFI data had Tropical Semi-Evergreen Forests as a forest type while the modelling output did not contain this forest type. For the sake of simplifying calculations, the growing stock estimates from this forest type have been excluded from calculations. Also, some of the forest type had scrub values which were minimal, to ensure uniformity, it has not been included in calculation of timber stock.

#### 6.9.11.6 Timber Flow

No timber harvesting takes place in STR and hence the economic value of flow benefits from this service is zero.

#### 6.9.11.7 Bamboo

The presence of bamboo is limited in STR. No bamboo collection is recorded at STR and hence this ecosystem services is not included for valuation in this study.

#### 6.9.11.8 Non-Timber Forest Produce

Non-timber Forest Produce tubers, leaves, grasses, roots, and fruits are collected by the local people[170] for consumption and other domestic purposes. The major NTFPs collected are honey, sal resin and arrowroot from the forest which is then sold at weekly markets. Siali leaves are also collected which are used for rope and khalli making. Sabai grass is also used for rope making[170,171]. Owing to shortage of further information to calculate the total NTFP collection, the economic value of this service has not been estimated in monetary terms in this study.

#### 6.9.11.9 Genepool protection

STR has a rich biodiversity treasure which encompasses diverse wild genes with wide adaptability to diverse climatic and other ecological conditions prevailing here. Owing to lack of comprehensive primary data, the method of benefits-transfer has been used for valuation of this service.

Using estimates of economic value of genepool protection for tropical forests (Rs. 100122 per hectare per annum) and cropland (Rs. 68772 per hectare per annum) from a global meta-analysis study[116] , the annual economic value of this service from 256579.37 hectares of forests and 7874.81 hectares of cropland in STR is estimated to be Rs. 26.23 billion.

#### 6.9.11.10 Carbon Storage

The carbon storage for the Simlipal Tiger Reserve has been quantified and spatially mapped using InVEST modelling. Since no research exists on the quantity of carbon stored in various pools, estimates from the report of carbon stock in India's forests of the Forest Survey of India has been used. The estimated carbon stored in four major pools

– above ground biomass (above ground biomass (AGB), below ground biomass (BGB), dead wood (DW), litter and soil organic matter (SOM) for major forest types of Odisha is shown in Table 6.9-3.

*Table 6.9-3 Carbon Stock in STR*

| Vegetation class | Forest Cover | Carbon Stock in Various Pools(tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total carbon Stock (million tC) |
|---|---|---|---|---|---|---|---|---|
| | | AGB | BGB | SOM | DW (incl. litter) | | | |
| Plantation/TOF | VDF | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.61 | 0.00 |
| Plantation/TOF | MDF | 12.17 | 2.50 | 65.04 | 2.10 | 81.82 | 174.04 | 0.01 |
| Plantation/TOF | OF | 8.96 | 1.84 | 27.22 | 0.81 | 38.84 | 448.20 | 0.02 |
| Tropical Dry Deciduous Forests | VDF | 62.19 | 24.42 | 54.47 | 7.02 | 148.11 | 25495.33 | 3.78 |
| Tropical Dry Deciduous Forests | MDF | 58.87 | 23.12 | 43.23 | 0.78 | 126.00 | 15234.26 | 1.92 |
| Tropical Dry Deciduous Forests | OF | 14.83 | 5.82 | 40.93 | 0.60 | 62.18 | 8743.06 | 0.54 |
| Tropical Moist Deciduous Forests | VDF | 28.30 | 5.82 | 68.69 | 3.72 | 106.54 | 95603.38 | 10.19 |
| Tropical Moist Deciduous Forests | MDF | 23.91 | 4.92 | 49.48 | 3.85 | 82.16 | 97234.50 | 7.99 |
| Tropical Moist Deciduous Forests | OF | 17.38 | 3.57 | 45.71 | 2.01 | 68.67 | 12013.05 | 0.82 |
| Non Forest | | 2.96 | 0.32 | 26.03 | 0.00 | 29.31 | 15466.34 | 0.45 |
| Total | | | | | | | | 25.72 |

It should be noted that the non-forest area comprises mostly agriculture land. The average values of major crops like maize have been taken to calculate the AGB and BGB carbon pools[152]. While to calculate the carbon density in soil for the non-forest area the values of Soil Organic Carbon (SOC) have been referred based on the agro-ecological region[153], the carbon pools of water are assumed to be zero.

The InVEST model provides output in the form of a carbon spread map and a summary table. According to the model, Similipal Tiger Reserve stores approximately 25.72 million tonnes of carbon. The other output received is in the form of a map where the stored carbon values are mapped spatially across the landscape.

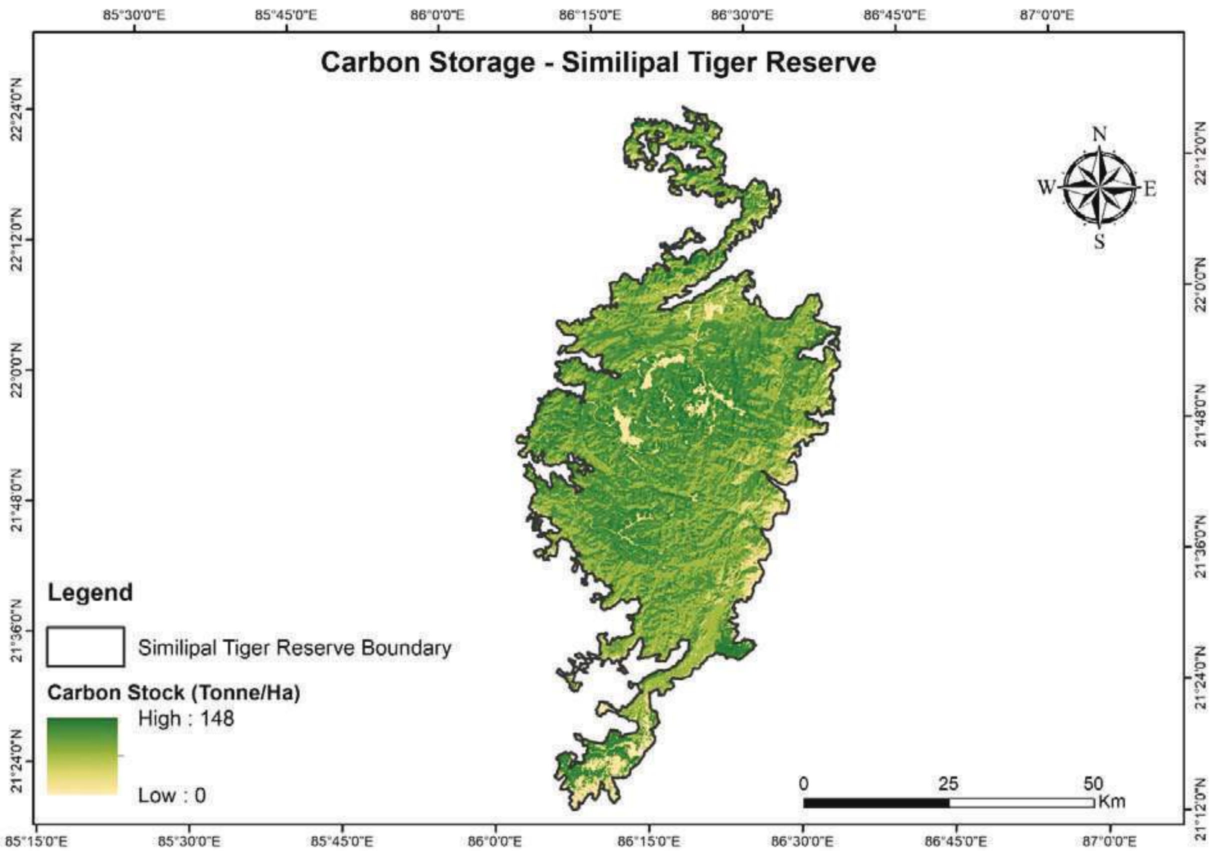



*Figure 6.9-3 Carbon Storage Map of Similipal Tiger Reserve Created Using InVEST Model*

Using the estimates from the Carbon Stock model of InVEST in conjunction of 25.72 million tonnes along with social cost of carbon for India the economic value of carbon stock has been derived. Taking the conversion rate of 1 USD= 66 Rs., the value of carbon stock in STR is equal to Rs. 72.02 billion.

The estimates from the Carbon Stock model of InVEST as 25.72 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= Rs. 65 as the average for the year 2017-18, the economic value of carbon stock in STR is calculated as Rs. 143.80 billion.

### 6.9.11.11 Carbon Sequestration

Apart from 25.72 million tonnes of carbon stock in the forests of Similipal Tiger Reserve, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the the Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database. Based on total biomass per unit area, the mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type[120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in the above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, the total carbon sequestered in the forests of Similipal Tiger Reserve by aggregating estimates for each forest type is equal to 556.42 kilo tonnes annually. Detailed calculations are indicated in Table 6.9-4.

*Table 6.9-4 Carbon Sequestration in STR*

| Forest Type | Forest Cover | Total Biomass per unit area (tonnes/ha) | Mean Annual Increment per unit area (tonnes/ha) | Area (ha) | Total annual carbon sequestration (tC) | Total Value of annual Carbon Sequestration (million Rs. per year) |
|---|---|---|---|---|---|---|
| Tropical Moist Deciduous Forests | VDF | 85.74 | 2.71 | 95603.38 | 129388.03 | 5308.87 |
| Tropical Moist Deciduous Forests | MDF | 111.83 | 3.53 | 97234.50 | 171651.11 | 7042.95 |
| Tropical Moist Deciduous Forests | OF | 83.84 | 2.65 | 12013.05 | 15899.01 | 652.35 |
| Tropical Dry Deciduous Forests | VDF | 383.07 | 13.81 | 25495.33 | 176074.81 | 7224.46 |
| Tropical Dry Deciduous Forests | MDF | 191.53 | 6.91 | 15234.26 | 52605.10 | 2158.42 |
| Tropical Dry Deciduous Forests | OF | 68.55 | 2.47 | 8743.06 | 10805.95 | 443.37 |
| **Total** | | | | **254323.58** | **556424.01** | **22830.41** |

The social cost of carbon for India as per the latest paper[117] and the economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=Rs. 65, the total economic value of annual carbon sequestration in STR is calculated to be Rs. 22.83 billion.

### 6.9.11.12 Water Provisioning

It serves as a watershed to many perennial rivers like Budhabalanga, Khadkei, Khairi, Bhandan, West Deo, Sanjo and Palpala. The principal 7 rivers from Similipal provide perennial water to the northern districts of Mayurbhanj, Keonjhar, Bhadrak and Balasore in the state of Odisha. Around 20 lakh people directly or indirectly depend on these 7 rivers and only *nalas* flowing from Similipa [170].

The model provides various data for spatial analysis of the area. It provides with raster and shapefile where various outputs can be spatially studied. It provides the estimated values of mean actual evapo-transpiration, mean potential evapo-transpiration, water yield volume, etc. Figure 6.9-4 displays the water yield output of the model. The total water yield volume from Similipal tiger reserve as well as its fringe areas amounts to 3816.08 million cubic metres. (Figure 32).

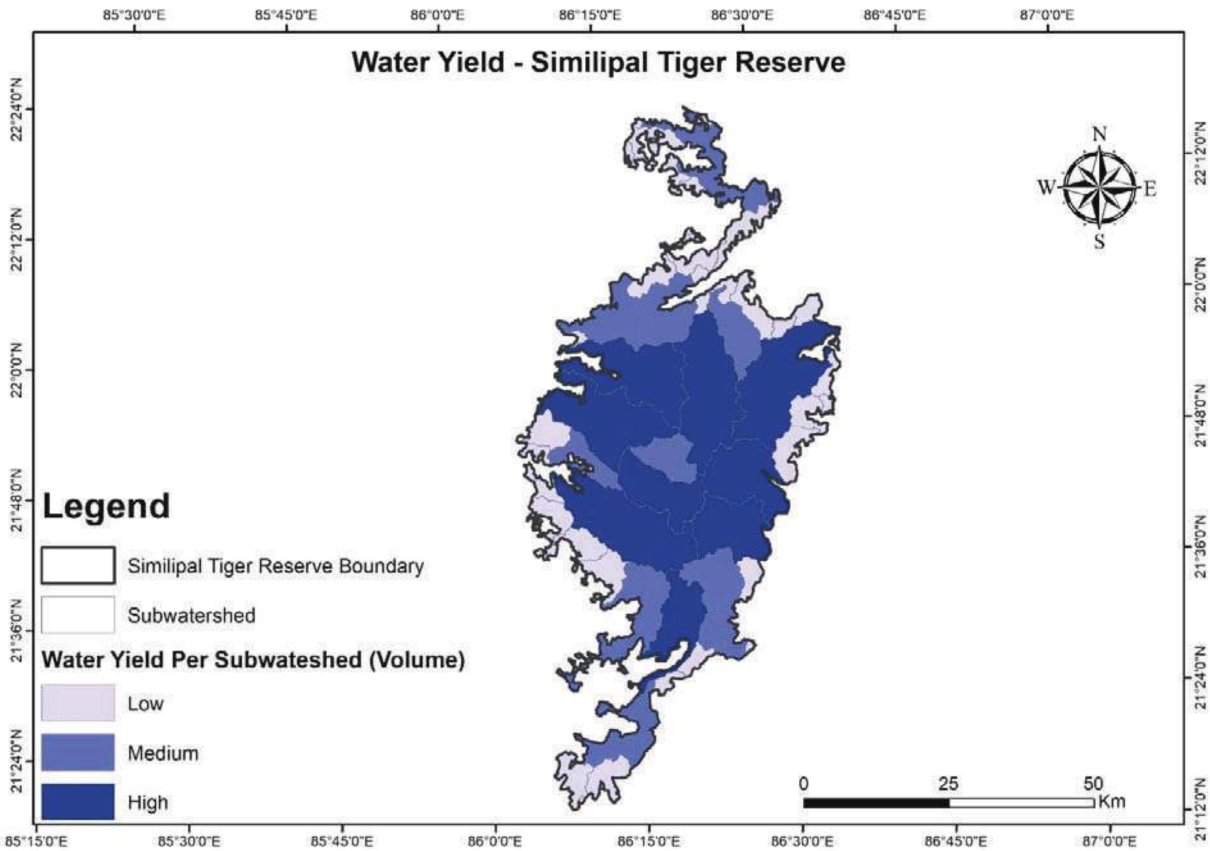



*Figure 6.9-4 Water Yield output for Similipal Tiger reserve Created Using InVEST Model*

Using the monetary value of Rs. 18.43 per cubic metre[1], the economic value of water provisioning service from STR is estimated to be 70.33 billion per year.

### 6.9.11.13 Water Purification

Around 20 lakh people are directly or indirectly dependent on these seven rivers and only *nalas* flowing from Similipal[171]. The daily minimum water requirement as per the Bureau of Indian Standards is 40 litres per capita is taken as the lower bound estimate to calculate the total domestic water requirement[130]. Based on the total dependent populationand per capita water requirement, the total domestic water requirement is 2920.05 kilo litres per annum. Only 10 percent of this estimate is used for valuation, as sufficient data was not available to map the beneficiaries and their exact water supply for drinking purposes for the whole year, the annual drinking water requirement comes to around 5159.64 kilo litres. Using a lower bound estimate of average cost of treating water for domestic supply at Rs. 10 per cubic m based on estimates for different municipalities of India[131], the avoided cost of water purification for drinking water is around Rs. 29.2 million per year.

### 6.9.11.14 Soil Conservation/Sediment Retention

The InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) tool developed by the Natural Capital Project, Stanford University was used to model SDR to compute the amount of eroded sediment, then the sediment delivery ratio (SDR), which is the proportion of soil loss actually reaching the catchment outlet. The value of sediment export varies from 500 tons to 185700 tons per subwatershed. Figure 6.9-5 provides spatial details of the total sediment exported to the stream per watershed in the study area.

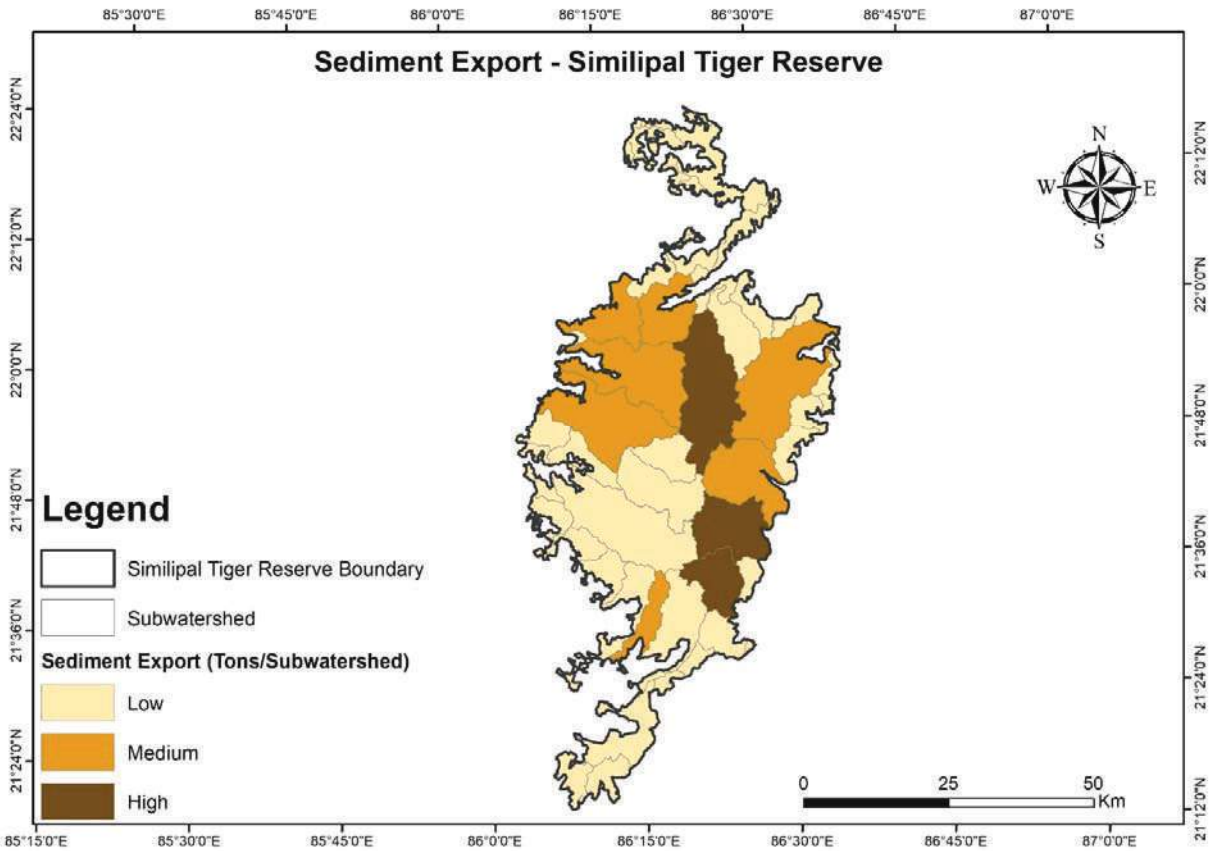



*Figure 6.9-5 Sediment Export from Similipal Tiger Reserve Created Using InVEST Model*

As shown in Figure 6.9-6 the high sediment retention values in the STR landscape overlap with the core area of the tiger reserve. The value of sediment retention ranges from 50000 tons to 40413700 tons per watershed.

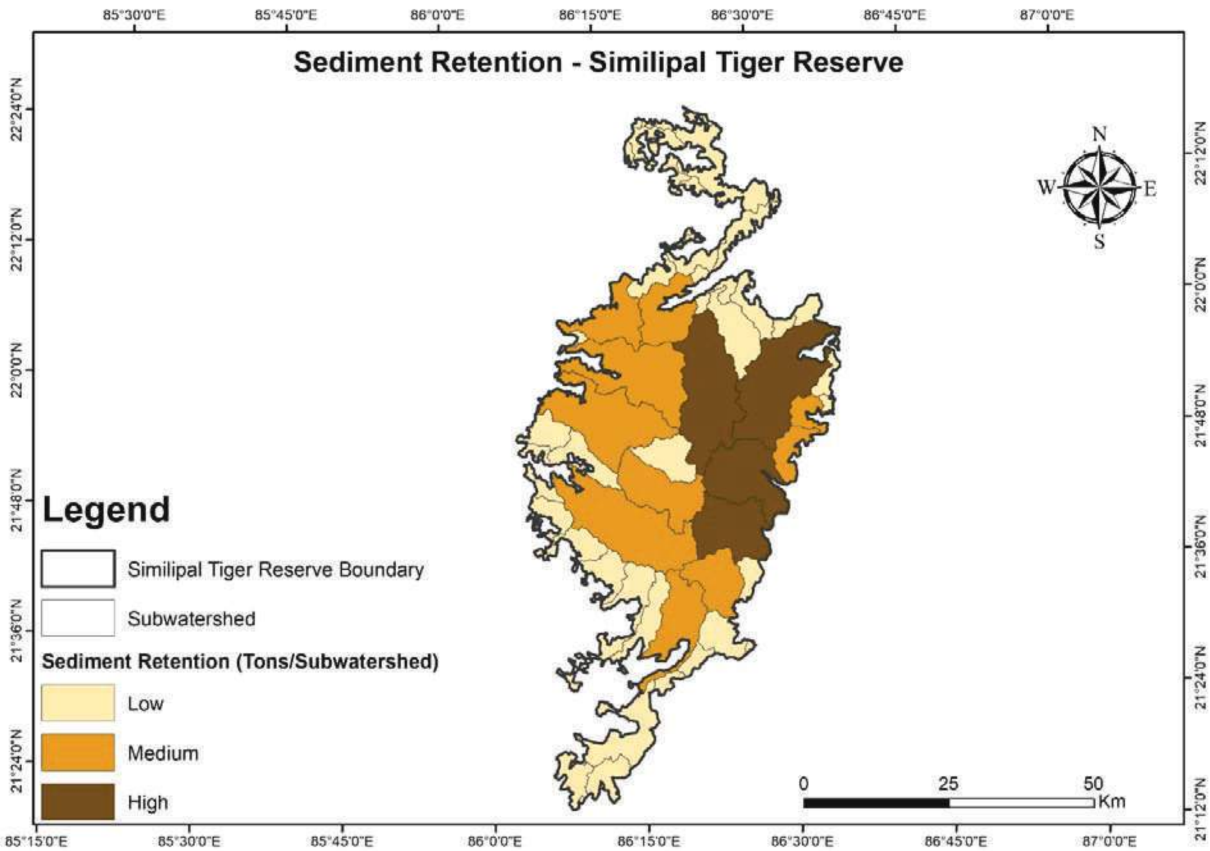



*Figure 6.9-6 Sediment Retention in Similipal Tiger Reserve (Source: Created Using InVEST Model)*

To estimate the economic value of soil loss avoided by the forests of STR, the cost of dredging/de-siltation has been considered. On account of lack of site-specific data, the cost estimate of Rs. 60 per cubic metre[132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 1160.28 million per year.

### 6.9.11.15 Nutrient Retention

The total soil loss avoided from the InVEST Sediment Retention model of STR is around 25.58 million tons. To calculate the amount of nutrients retained, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust[147] has been used on account of lack of local estimates for the same. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations from Table 6.9-5, the total quantity of nutrients retained is approximately 53837.36 tonnes of N, 1021.05 tonnes of P and 191447.50 tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary value has been derived. The total value of nutrient loss prevented by the forests of STR is equal to Rs. 2614.12 million annually.

*Table 6.9-5 Nutrient Retention in STR*

| Nutrient | Soil Nutrient Concentration (g Per Kg) | Total Nutrient Loss Avoided (Tonnes Per Year) | Fertilizer (Substitute) Used for Valuation | Price of Fertilizer (Rs. Per Tonne) | Economic Value of Nutrient Retention (Million Rs. Per Year) |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 53837.36 | Urea | 5360 | 288.57 |
| Phosphorous (P) | 0.044 | 1021.05 | DAP | 20100 | 20.52 |

| | | | | | |
|---|---|---|---|---|---|
| Potassium (K) | 8.25 | 191447.50 | Muriate of Potash | 12040 | 2305.03 |
| **Total** | | **246305.91** | | | **2614.12** |

### 6.9.11.16 Biological Control

Using estimates of economic value of biological control for tropical forests (Rs. 726 per hectare per annum) and cropland (Rs. 2178 per hectare per annum) from a global meta-analysis study[116] the economic value of biological control service from 256579.37 hectares of forests and 7874.81 hectares of cropland in STR is estimated to be Rs. 203.48 million per annum.

### 6.9.11.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to STR. Hence, it is not included in the valuation of the ecosystem service of STR in this study.

### 6.9.11.18 Pollination

Using estimates of economic value of pollination for tropical forests (Rs. 1980 per hectare per annum) and cropland (Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 256579.37 hectares of forests and 7874.81 hectares of cropland in STR is estimated to be 519.46million Rs. per annum.

### 6.9.11.19 Nursery Function

The nursery function was not found relevant due to scarcity of information and supporting evident linkages to attribute this service to STR. Hence, it is not included in the valuation of the ecosystem service of STR in this study.

### 6.9.11.20 Habitat for Species

Using estimates of economic value of habitat service for tropical forests (Rs. 2574 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 256579.37 hectares of forests in STR is estimated to be Rs. 660.44 million.

### 6.9.11.21 Cultural Heritage

Similipal is home to Birhors, Hill Khadias and Ujias which are some of the primitive tribes of Odisha. Apart from this, Bhumijas, Kolha, Gonds, Santhals, Kolhas, Bathudis, Mahalis, Mankdias and Mundas tribes are also common. The Bathudis were the earliest settlers of Similipal. The Khadias were originally from Panchpir/karanjia area and were making out their livelihood by collecting forest produce from Similipal. Later on they migrated to the deep dense forests of Similipal. The Gonds were also among the old settlers in certain parts of Similipal. In the course of migration of other tribes for various reasons, the Santhals, Kolhas, Mundas, Mahalis and Khadias came and settled there[170].

STR is also a repository of indigenous knowledge pertinent to conservation of biodiversity, ethno-botanical study and traditional ecological knowledge. The Santals and Mahalis are ‘Sarna’ by religion who also worships Hindu gods. They speak Santhali and use the Alchiki dialect. The Kolhas are Hindus. They speak in their own language and their dialect is Orangichiki. The Bathudis are also Hindus and use Oriya. The Khadia and Mankidias are nomads. The Santals and Mahalis tribes worship their deities under a Sal tree at the place of worship called Jahira and in the month of April they perform a ritual known as Phulbhanguni Puja. The priest is called Naeke and for other tribes the priest is locally known as Dehuri. The Bathudis, Khadias and Mankdias worship their Gods in the forest. The village priest serves as the people’s guide influencing their day-to-day activities[170,171].

The inhabitants live in huts made of brushwood and soil. They cook their food with the help of firewood collected from the forest and depend on the forest for repair of their houses and preparation of agricultural implements. They enjoy the folk dances on festive occasion.  Their relationship with the forest has been established for ages. They derive different products from forests such as NTFP, firewood, timber for their own consumption as well as for sale in the local/weekly market nearby[170].

The residents of the buffer area of the tiger reserve practise traditional agriculture. Their crops are usually rain-fed, Agriculture is the leading occupation of Santals, Kolhas, Bathudis and Mundas. The Mahalis are mainly bamboo artisans. The Khadias and Mankdias mostly depend on forest for food, shelter and day-to-day maintenance of their lives. They collect honey, sal resin and arrowroot from the forest and sell the products in the weekly markets[170,171].

### 6.9.11.22 Recreation

The landscape is studded with places of tourist interest carved by nature. STR is a major tourist attraction not only due to its magnificent waterfalls but also for its unique habitat of the melanistic tiger[170]. The reserve observes a huge tourist influx in the season. Owing to paucity of further information on tourist footfall and revenue generation, the same has not been included in this study for economic valuation.

### 6.9.11.23 Spiritual Tourism

Deokund and Atharadeuli are places of pilgrimages for the local people. Deokund situated inside the TR is a place of pilgrimage for Hindus and is famous for the deity of Goddess Ambica. Sacred Deokund was established by the royal dynasty of Mayurbhanj. Athardeuli, situated on the transitional zone of core and buffer area, is a place of worship by tribes belonging to the Bathudi community. They visit the place once a year during April and thousands of devotees offer obeisance to the tribal deity[170]. The number and frequency of visits to spiritual sites within the Similipal Tiger Reserve[171] are given in Table 6.9-6.

*Table 6.9-6 Annual Footfall for Religious Sites in STR* [171]

| Sl.No. | Place | Tourist Number | Season |
|---|---|---|---|
| 1. | Devkund | 1,20,000 | Nov-June |
| 2. | Atharadeula | 3,000 | March |
| 3. | Ranibhol | 300 | January |

### 6.9.11.24 Research, Education and Nature Interpretation

The tiger reserve has a great potential for research since it has diverse types of flora and supports a very high density and biomass of prey community. There is a plethora of diverse researches that have emerged from STR. It is the home of some indigenous tribes like Birhors, Hill Khadias and Ujias, which are some of the primitive tribes of Odisha. Similipal is a grand repository of indigenous knowledge pertinent to conservation of biodiversity, ethnobotanical study and traditional ecological knowledge[170].

An Interpretation Centre has been established at Ramatirtha through CEE, Ahmedabad to create awareness about the Similipal Tiger Reserve, forests, wildlife and the ecosystem among the locals and visitors. An innovative programme has been launched in Similipal Tiger Reserve namely ‘Friends of Similipal Tigers’ since July 2012. In this programme, the school and college students having an interest in tigers in villages and townships around the Similipal were invited to join as volunteers through an application forwarded by their respective principals. Selected students are taken for a field trip inside the tiger reserve for an on-the-spot realization of problems of encroachment, habitat and prey base of tigers. Debates, quizzes, poetry, essay writing and painting activities based on wildlife and forests of Similipal are being organized on the occasion of wildlife week and the winners rewarded[170].

### 6.9.11.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (Rs. 792 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation from 256579.37 hectares of forests in STR estimated to be Rs. 203.21 million.

### 6.9.11.26 Waste Assimilation

Waste assimilation was not relevant due to inadequate information and lack of supporting evident linkagesto attribute this service to STR. Hence, it is not included in the valuation of the ecosystem service of STR in this study.

#### 6.9.11.27 Climate Regulation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 134904 per hectare per annum) and cropland (Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 256579.37 hectares of forests and 7874.81 hectares of cropland in STR is estimated to be Rs. 34.82billion.

**Unique Attribute: Melanistic Tigers of Similipal**

Found only in the forests of Odisha, some tigers show darker and bolder black stripes resulting in melanistic tigers. This is due to a rare genetic phenomenon known as pseudo-melanism, which is characterised by excessive pigmentation of the dark colour in the skin of an animal. Research suggests that a variety of factors such as climatic conditions, genetic mutation, and inbreeding are responsible for this phenomenon that has been documented only in the forests of Odisha[184].

One of the reasons could be that the dense forests dominate the landscape of Similipal and the broad black stripes enable for the perfect camouflage in these dense forests. However, a genetic understanding of melanism suggests that this has occurred due to inbreeding between the tigers as a result of genetic mutation[185]. A general landscape-level analysis hints that the natural gene pool dispersal capacity of the tigers in this region is reduced owing to the restricted movement between the adjoining forests and fragmentation in the wildlife corridors, thus resulting in genetic aberrations due to inbreeding where the genes responsible for black pigmentation are prominently expressed.

### 6.9.12 Spectrum of Values- Similipal Tiger Reserve

STR provides a variety of values that fall under economic, biological, ecological, conceptual, physical, scientific, educational, cultural, religious and historic values.

#### 6.9.12.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| Summary of Ecosystem Services Based on TEV Framework (Flow Benefits) | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **895.29** | **Rs. Million/Year** |
| Fodder, Employment Generation<br>* - Fuel wood, Non-Timber Forest Products, Fishing, Bamboo (Flow), Timber (Flow) | | |
| **Indirect Use Value** | **133175.04** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>*- Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Option Value** | **26230.81** | **Rs. Million/Year** |
| Genepool Protection | | |

| Summary of Ecosystem Services Based on MA Framework (Flow Benefits) | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **692.08** | **Rs. Million/Year** |
| Employment Generation, Fodder<br>* - Fuel wood, NTFP, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Regulating Services** | **158948.63** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool Protection<br>* - Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Cultural Services** | | **Rs. Million/Year** |
| Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Supporting Services** | **660.44** | **Rs. Million/Year** |
| Habitat for Species | | |

| Summary of Ecosystem Services Based on Stock and Flow Benefits | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Flow Benefits** | **160.30** | **Rs. Billion/Year** |
| Employment Generation, Fodder, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - Fuel wood, NTFP, Moderation of Extreme Events, Nursery Function, Timber (Flow), Fishing, Bamboo (Flow), Waste Assimilation | | |
| **Stock Benefits** | **498.33** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| Summary of Ecosystem Services Based on Tangible/Intangible Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Tangible Benefits** | **692.08** | **Rs. Million/Year** |
| Employment Generation, Fodder<br>* - Fuel wood, NTFP, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Intangible Benefits** | **657937.10** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |

| Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **70420.34** | **Rs. Million/Year** |
| Fodder, Water Provisioning<br>* - Fuel wood, NTFP, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Protection from Disease/Predators/Parasites** | **203.43** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **62844.32** | **Rs. Million/Year** |
| Carbon Sequestration, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Climate Regulation, Habitat for Species<br>* - Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Socio-Cultural Fulfilment** | **602.25** | **Rs. Million/Year** |
| Employment Generation, Cultural Heritage, Recreation, Spiritual Tourism, Research, Education and Nature Interpretation | | |
| **Ecosystem Assets** | **524558.84** | **Rs. Million** |
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| Summary of Ecosystem Services Based on EPA Effect categories | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **658629.18** | **Rs. Million** |
| Employment Generation, Timber (Stock), Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Soil Conservation/Sediment Retention, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Gas Regulation, Climate Regulation<br>* - Timber (Flow) | | |
| **EPA Effect Category 2** | **No Data** | **Rs. Million** |
| Recreation | | |
| **EPA Effect Category 3** | **-** | |
| Research, Education and Nature Interpretation | | |
| **EPA Effect Category 4** | **3** | **Main Primitive Tribe Group** |
| Cultural Heritage | **Numerous** | Sub-Tribe Groups |
| **EPA Effect Category 5** | **More than 1 Lakh** | **Devotees Per Year** |
| Spiritual Tourism | | |

### 6.9.12.2 Linkages to Human Health

Similipal Tiger Reserve emanates a range of ecosystem services vital for maintenance of human well-being. Amongst these, Genepool Protection, Carbon Storage, Carbon Sequestration, Water Provisioning, Biological Control, Pollination, Cultural Heritage, Recreation, Research, Education and Nature Interpretation, Gas Regulation, and Climate Regulation Services have huge direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 298.97 billion.

#### 6.9.12.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Similipal Tiger Reserve for the year 2016-17, was around Rs. 52.76 million. Based on the flow benefits of Rs. 160.30 billion per year, for every rupee spent on management costs in STR, flow benefits of Rs. 3038.3 are realized within and outside the tiger reserve.

#### 6.9.12.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Similipal Tiger Reserve was estimated at Rs. 0.59 million (Rs. 5.89 lakhs) per hectare.

#### 6.9.12.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 5.15 percent of flow benefits accrue at the local level, 20.71 percent at the national level and 74.13 percent at the global level.

# Valmiki Tiger Reserve

The only tiger reserve in Bihar, Valmiki Tiger Reserve (VTR), sets an excellent example of Shivalik Hills and Gangetic Plains landscape with a mosaic of dense forests, open woodlands, swamps and grasslands.

**The tiger reserve provides flow benefits worth Rs. 69.00 billion per year (Rs. 0.74 million per hectare) and stock benefits of Rs. 436.83 billion per year. Critical ecosystem services that arise from this tiger reserve include provisioning of water (Rs. 22.16 billion per year), carbon sequestration (Rs. 25.90 billion per year) and climate regulation (Rs. 11.22 billion per year).**

**Under the Total Economic Value (TEV) framework, the annual direct-, indirect-benefits and option values were Rs. 0.39 billion, Rs. 59.87 billion and Rs. 8.73 billion, respectively.**

As per the MA framework, the value of provisioning services was Rs. 0.33 billion per year, that of regulating services was Rs. 68.46 billion per year and supporting services were Rs. 0.21 billion per year.

The annual tangible and intangible benefits were found to be worth Rs. 0.33 billion and Rs. 505.49 billion, respectively.

In terms of the human values and ecosystem assets framework, the annual worth of service categories were adequate resources (Rs. 22.49 billion), protection from disease (Rs. 77.06 million), benign physical and chemical environment (Rs. 37.70 billion) and ecosystem assets (Rs. 445.56 billion).

The collective worth of ecosystem services having direct indirect impact on human health was found to be Rs. 116.37 billion per year. The investment multiplier for VTR was calculated as 1235.57.

# 6.10 Valmiki Tiger Reserve

## 6.10.1 Location, Landscape and Significance

Valmiki Tiger Reserve is situated in Bihar state in the northern part of West Champaran district. It runs along the Indo-Nepal Border and has connectivity to Chitwan National Park (Nepal) at the foothills of Himalaya Terai. Valmiki Tiger Reserve (VTR) is spread across an area of 899.38 sq kilomters which includes Valmiki Wildlife Sanctuary. VTR is located at the eastern end in the Shiwalik foothills and is connected to Sohaghi Barwa Wildlife Sanctuary on the west in Uttar Pradesh and the southern side is contiguous with the revenue area of West Champaran district [172].

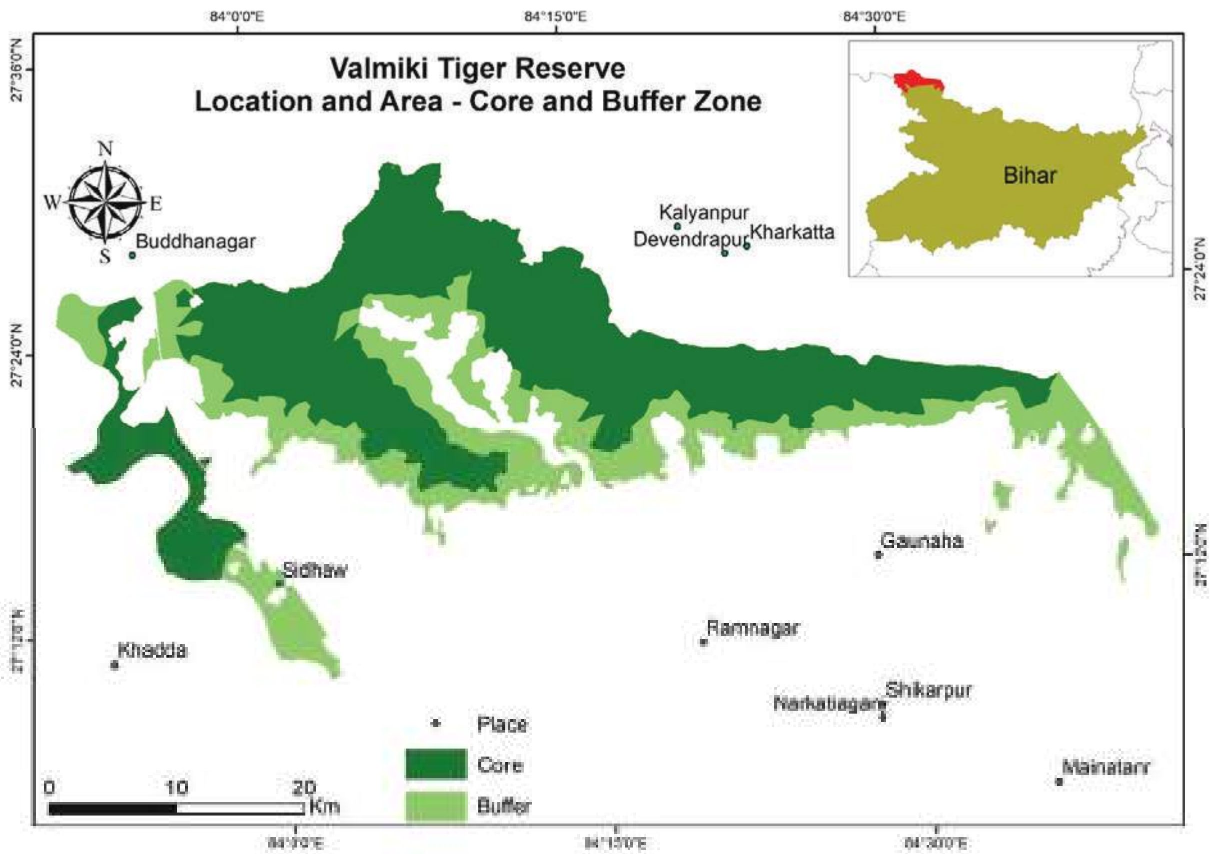



*Figure 6.10-1 Valmiki Tiger Reserve (Source: Forest Survey of India)*

It is representative of the ecology of a Shivalik Hills, Gangetic Plain and Terai Arc Landscape and has large tracts of Northern Indian Dry Siwalik Sal Forest habitat. The reserve has also been designated as an Important Bird Area (IBA) by the Indian Bird Conservation Network. VTR is a collection of picturesque locations and different habitats like dense forests, a number of grasslands, a barrage on Gandak at Valmikinagar, picturesque beauty of sunrise at Bhainsalottan and sunset view from Ganauli provide a real feeling of the wilderness. It consists of the zone of the origin of rivers - Gandak and Burhi Gandak[172].

## 6.10.2 History

It was declared as a tiger reserve in 1994 under the Project Tiger. The forests of Valmiki Tiger Reserve earlier formed a part of two erstwhile estates, namely Bettiah Raj and the Ramnagar Raj which used to own ninety percent of the forests. Madanpur and Triveni blocks belonged to the Bettiah Raj, whereas Kosil, Naurangia, Raghia and Someshwar blocks were in Ramnagar Raj. These forests were later on brought under the control of the state government and were notified[172].

## 6.10.3 Topography and Climate

The terrain of VTR is undulating with chains of steep ravinesvarying in depth from 30-60 metres in Someshwar Hills and 10 to 15 metres in Dun Hills. The ravines have sharp edges and precipitous walls formed due to land slips and soil erosion. Elevation varies from 140 m above MSL, the highest point being about 874 m above MSL (Someshwar point) in the Gobardhana Range and the average height of the hill ridges is about 500 m. Most of the area of VTR falls into flat to gentle slope category (0-22 degree) class. The north-western part of the reserved forests has a highly rugged terrain with steeper slopes (23-34 degree)[172].

Summers are hot and commence from mid-March. The season reaches its high in early May due to the hot westerly winds. The maximum temperature goes beyond 43°C. Winter starts from November and continues till the end of February with January being the coolest month. The temperature dips upto 5°C. Pre-monsoon thundershowers in April mark the onset of the monsoon season which usually sets in from mid-June and lasts till September. Average annual rainfall is about 1106 mm which varies from year to year[172].

### 6.10.4 Land Cover Classification

The land use and land cover map of Valmiki Tiger Reserve has been sourced from the Forest Survey of India. The land cover of Valmiki is broadly categorized into deciduous forest, evergreen forest, agriculture, plantation, built-up, wasteland and degraded forest (Figure 6.10-2).

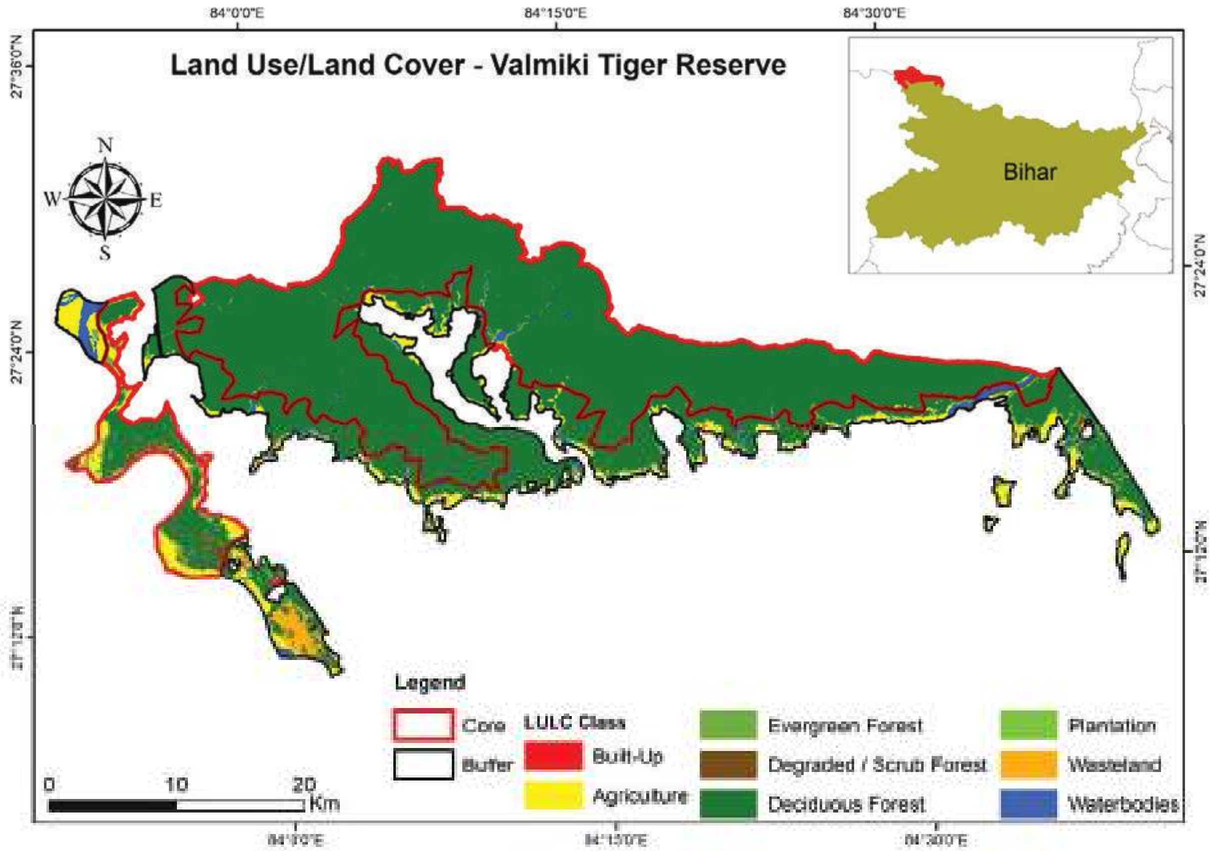



*Figure 6.10-2 Land Use/Land Cover: Valmiki Tiger Reserve (Source: Forest Survey of India, 2013-2014)*

The core and buffer area mainly consists of deciduous forest (81.87 percent), evergreen forest (4.02 percent), and agriculture (9.44 percent) of the total tiger reserve. The area under each of these land cover classes as shown in the Table 6.1-1.

*Table 6.10-1 LULC Classes VTR*

| LULC Class | Area (ha) |
|---|---|
| Evergreen Forest | 3740.62 |
| Waterbodies | 2258.86 |
| Degraded / Scrub Forests | 947.07 |

| | |
|---|---|
| Deciduous Forest | 76026.05 |
| Built-up | 145.51 |
| Wasteland | 950.84 |
| Plantation | 13.48 |
| Agriculture | 8770.45 |

### 6.10.5 Rivers and Hydrology

The tiger reserve is drained by a number of perennial and seasonal streams and *nalas* originating in the highlands in the northern zone and flowing mainly in a southerly direction. During summers, the major source of water and moisture are “Dobhs” which are pools of water left behind the dried-up streams. There are a few perennial springs locally called *Jhirs* in the Bhabar tract on the eastern slopes. Valmiki Tiger Reserve constitutes the catchments of two main rivers Gandak. Burhi Gandak has the tributaries Masan, Pandai, Manor, Bhapsa, Ganguly, Daini and Dorraham within the tiger reserve. The Gandak and Burhi Gandak rivers form a major component of the drainage basin of north-west Bihar[172].

### 6.10.6 Biodiversity

The forests of VTR fall in the Oriental (Indo-Malayan) realm bio-geographic classification. The major part of the forest vegetation is on the two hill ranges, namely the Someshwar and Dun hill ranges, the former being bigger. Someshwar and Dun hill ranges practically form the border with Nepal on the northern most side. The only breaks are the river passing through these from north to south. The main forest types as per Champion and Seth’s classification are Bhabar Dun Sal Forest, Dry Siwalik Sal Forest, West Gangetic Moist Mixed Deciduous Forest, Khair Sissoo Forest, Cane Breaks and Barringtonia Swamp Forest interspersed with Eastern Wet Alluvial Grasslands[172].

VTR has a unique mosaic of various habitat types and ecological systems which makes these forests abode of a rich biota. Besides the highly endangered tiger, the reserve also harbours a wide range of faunal species some of which figure prominently in the IUCN Red List. These species include *Panthera pardus, Cuon alpinus, Vulpes benghalensis, Melursus ursinus, Lutra perspicillata, Bos gaurus and Python molurus*. It harbours 58 species of mammals, approximately 250 species of birds, 37 species of reptiles and 50 species of fishes among the vertebrate fauna. In the invertebrate category, VTR contains 100 species of butterflies, 100 species of moths, 50 species of dragonflies and damselflies, 30 species of spiders and almost 250 species of other insects have been identified. The floral diversity comprises about 1000 species of angiosperms, about 10 species of pteridophytes, 10 species of bryophytes and about 35 species of fungi. The coomon species found here include Chital (*Axis axis*), Sambar (*Cervus unicolor*), Hog Deer (*Axis porcinus*), Barking Deer (*Muntiacus muntjak*), Gaur (*Bos gaurus*), Langur (*Presbytis entellus*), Wild Pig (*Sus scrofa*), Jackal (*Canis aureus*), Sloth Bear (*Melursus ursinus*), Wild Dog (*Cuon alpinus*), Leopard (*Panthera pardus*) and Tiger (*Panthera tigris*). Gandak River which forms the western boundary of the reserve is home to Ghariyals, Crocodiles and Dolphins. Valmiki Tiger Reserve is inhabited by a variety of avifauna (261 spp), reptiles (26 spp) and amphibians (13 spp)[172].

### 6.10.7 Tourism

Valmiki Tiger Reserve offers exquisite landscape beauty and a conservation set-up of its natural history. Visitors coming to Valmiki Tiger Reserve not only enjoy the scenic views but also get sensitized towards wildlife conservation. Major attractions are Jungle safari, nature trail to Ganauli wooden tower and the informative interpretation centre[172].

All tourism activities are restricted to a small tourist zone (also known as the eco-tourism zone), which is around 29.4 percent (270.58 sq km) of the protected area and protected forest. The average, annual tourist influx amounts to about 5,00,00 of which almost 90 percent are for religious tourism. The religious tourism occurs in January-April and October-November[172].

### 6.10.8 Socio-Economic Situation

There are152 villages located *in the buffer* area of VTR. The total population in these villages is approximately 2.09 lakhs, of which 48355 are from the Scheduled Caste and Scheduled Tribe community, i.e. 43.26 percent of the total population. (Source- Population Census of 2001). The tribal population is made up of Tharu, Oraon, Gonds and Bhuyia tribes. Tharus represents about 90 percent of the total Scheduled Tribe population in all four blocks. Musahar, Dussadh and Chamar form the bulk of the Scheduled Caste population[172].

Agriculture is one of the major sources of livelihood and income. It is mostly rain-fed, practised with primitive tools and conventional methods. Major crops are wheat, corn, pulses like chana, tuer, masoor, udad; oilseeds like mustard, sesame, and cash crops like sugar cane. Sugar cane is the major cash crop; others are predominantly crops of consumption. Labour work is the next major source of occupation in the area. People go out to other states to find labour work. Most of the farmers are landless or have small land holdings. Local communities are dependent on forests for various resources. Many community engagement programmes are going on run by the government as well as non-profit organizations[172].

### 6.10.9 Valuation Estimates for Valmiki Tiger Reserve

Given below are the valuation estimates for the tiger reserve for the selected ES.

#### 6.10.9.1 Employment Generation

Due to the paucity of data on man days of employment generation for the locals, the economic value of this service has not been estimated in monetary terms here.

#### 6.10.9.2 Fishing

Due to shortage of any recorded information this ecosystem service was not found applicable for VTR in this study.

#### 6.10.9.3 Fuelwood

As per the discussion in 4 villages, namely Madanpur, Naurangia, Gobardhana and Manugraha, during the field visit, per household average annual fuelwood requirement is around 300 kg per month which is used for cooking food as well as for keeping warm in winter[172,173]. Using these estimates, the total fuelwood requirement of all households in 152 villages is derived based on the assumption that only 50 percent of these villages are dependent on VTR for fuelwood. Thus, the fuelwood requirement is around 66 kilo tonnes per year. Taking the local market price of Rs 5 per kg, the economic value of fuelwood collection is approximately Rs. 330.12 million.

#### 6.10.9.4 Fodder/Grazing

Using the average number of livestock per family and converting them to the equivalent cattle unit, the total cattle unit in the 152 villages near VTR is 146724 cattle units[172]. Assuming the standard forage quantity at 22 kilograms per day per cattle unit [107] and 69.91 percent of livestock dependence on the forest for forage requirements, the total annual quantity of fodder harvested is equal to 2.25 kilo tonnes per year. Assuming an average price of Re. 1 per kilogram of fodder the economic value of annual grazing benefits provided by VTR is approximately equal to Rs. 2.25 million.

#### 6.10.9.5 Standing Timber (Stock)

The standing stock of VTR has immense value. To estimate the economic value of the standing stock, growing estimates of timber species from the forest inventory database[108] of the Forest Survey of India (FSI) have been used as per the forest type to estimate the total stock of VTR. It is estimated that approximately 15.55 million cubic metres of standing stock of timber are contained in VTR as shown in Table 6.10-2. In monetary terms, using an average price of Rs. 25000 per cubic metre after discounting for transportation and maintenance cost, the standing stock has the value equal to Rs. 388.79 billion.

*Table 6.10-2 Timber Stock in the Forests of VTR*

| Forest Type | Forest Cover | Growing Stock (Cubic m Per ha) | Area (ha) | Total Growing Stock(in Thousand Cubic m) | Economic Value (in Million Rupees) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Tropical Moist Deciduous Forests | VDF | 294.00 | 14066.22 | 4135.51 | 103387.69 |
| Tropical Moist Deciduous Forests | MDF | 17.85 | 20422.77 | 364.60 | 9115.08 |
| Tropical Moist Deciduous Forests | OF | 107.67 | 2957.02 | 318.37 | 7959.32 |
| Tropical Dry Deciduous Forests | VDF | 560.50 | 9134.58 | 5119.93 | 127998.33 |
| Tropical Dry Deciduous Forests | MDF | 197.07 | 24244.44 | 4777.77 | 119444.30 |
| Tropical Dry Deciduous Forests | OF | 109.20 | 3494.59 | 381.61 | 9540.23 |
| Littoral and Swamp Forests | VDF | 154.63 | 24.22 | 3.74 | 93.61 |
| Littoral and Swamp Forests | MDF | 243.06 | 74.31 | 18.06 | 451.58 |
| Littoral and Swamp Forests | OF | 62.57 | 341.87 | 21.39 | 534.73 |
| Plantation/TOF | - | 108.03 | 658.69 | 71.16 | 1779.01 |
| Non-Forest | - | 25.57 | 13283.02 | 339.67 | 8491.65 |
| **Total** | | | | **15551.82** | **388795.51** |

For Valmiki Tiger Reserve, the growing stock estimated for scrub and non-forest canopy class under the Tropical Moist Deciduous Forests, Littoral and Swamp Forests and Tropical Dry Deciduous Forests has not been included for ensuring uniformity. There were no growing stock estimates available for Tropical Wet Evergreen Forests (5466.31 ha) and thus it has not been included in the calculation of timber stock.

#### 6.10.9.6 Timber Flow

No timber harvesting takes place in VTR and hence the economic value of flow benefits from this service is zero.

#### 6.10.9.7 Bamboo

No bamboo collection is recorded at VTR and hence this ecosystem services is not included for valuation in this study.

#### 6.10.9.8 Non-Timber Forest Produce

Major NTFPs found in VTR are Maulan leaf, Cane, Mahua, Satawar, Sabai Grass, Chironji (Achar) and Munj. Their collection is one of the sources of seasonal income for villagers of the buffer zone [172]. Due to paucity of data and other relevant information to calculate the total NTFP collection, economic value of this service has not been estimated in monetary terms here.

#### 6.10.9.9 Genepool Protection

Using estimates of economic value of genepool protection for tropical forests (Rs. 100122per hectare per annum) and cropland (Rs. 68772 per hectare per annum) from a global meta-analysis study[116], the annual economic value of this service from 81591.12 hectares of forests and 8185.8 hectares of cropland in VTR is estimated to be Rs. 8.732 billion.

**Corridors and Connectivity**[172]

Valmiki Tiger Reserve is well connected to nearby Protected Areas within and outside the country. It has one inter-state corridor within country, i.e. with the Sohagibarwa Wildlife Sanctuary (482 sq km) in Maharajganj district of Uttar Pradesh which is connected to Madanpur Block of VTR in the western part. Its international corridor ensures contiguity with Chitwan National Park and Parsa Wildlife Sanctuary in Nepal.

#### 6.10.9.10 Carbon Storage

The InVEST model output provided a summary table and spatial assessment of carbon stored in the forests of Valmiki Tiger Reserve across different pools. As per the model, forests of VTR store 8.59 million tonnes of carbon across its four pools (Table 6.10-3).

*Table 6.10-3 Carbon Stock in VTR*

| Vegetation class | Forest Cover | Carbon Stock in Various Pools(tonnes C/ hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total carbon Stock (million tC) |
|---|---|---|---|---|---|---|---|---|
| | | AGB | BGB | SOM | DW (incl. litter) | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tropical Moist Deciduous Forests | VDF | 21.12 | 4.34 | 62.80 | 5.73 | 93.99 | 14066.22 | 1.32 |
| Tropical Moist Deciduous Forests | MDF | 19.43 | 4.00 | 55.54 | 4.34 | 83.31 | 20460.03 | 1.70 |
| Tropical Moist Deciduous Forests | OF | 11.69 | 2.40 | 33.40 | 2.40 | 49.90 | 2480.04 | 0.12 |
| Tropical Dry Deciduous Forests | VDF | 52.92 | 20.77 | 68.31 | 7.49 | 149.49 | 9067.89 | 1.36 |
| Tropical Dry Deciduous Forests | MDF | 50.11 | 19.68 | 64.68 | 0.62 | 135.08 | 24227.48 | 3.27 |
| Tropical Dry Deciduous Forests | OF | 9.72 | 3.82 | 17.95 | 0.39 | 31.87 | 3361.66 | 0.11 |
| Plantation/TOF | VDF | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 88.24 | 0.00 |
| Plantation/TOF | MDF | 22.50 | 4.63 | 37.78 | 1.64 | 66.53 | 364.00 | 0.02 |
| Plantation/TOF | OF | 12.71 | 2.61 | 23.87 | 0.46 | 39.65 | 180.90 | 0.01 |
| Littoral and Swamp Forests | VDF | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 24.22 | 0.00 |
| Littoral and Swamp Forests | MDF | 44.62 | 15.38 | 57.08 | 0.62 | 117.69 | 74.31 | 0.01 |
| Littoral and Swamp Forests | OF | 14.35 | 4.93 | 33.19 | 0.43 | 52.90 | 341.87 | 0.02 |
| Tropical Wet Evergreen Forests | VDF | 70.00 | 20.00 | 70.00 | 0.00 | 160.00 | 209.61 | 0.03 |
| Tropical Wet Evergreen Forests | MDF | 27.74 | 9.59 | 45.02 | 2.64 | 85.00 | 3617.51 | 0.31 |
| Tropical Wet Evergreen Forests | OF | 21.82 | 7.55 | 22.92 | 2.12 | 54.42 | 1568.76 | 0.09 |
| Non Forest | | 1.31 | 0.11 | 15.32 | 0.00 | 16.74 | 13258.89 | 0.22 |
| Total | | | | | | | | 8.59 |

It should be noted that the non-forest area comprises mostly agriculture land. The average values of major crops like wheat, black gram, pigeon pea and green gram have been taken to calculate the AGB and BGB carbon pools[152]. While to calculate the carbon density in soil for the non-forest area the values of Soil Organic Carbon (SOC) have been referred based on the agro-ecological region [153]. The carbon pools of water have been assumed to be zero. The figure shows the spatial distribution of higher carbon stock in the core area of VTR.

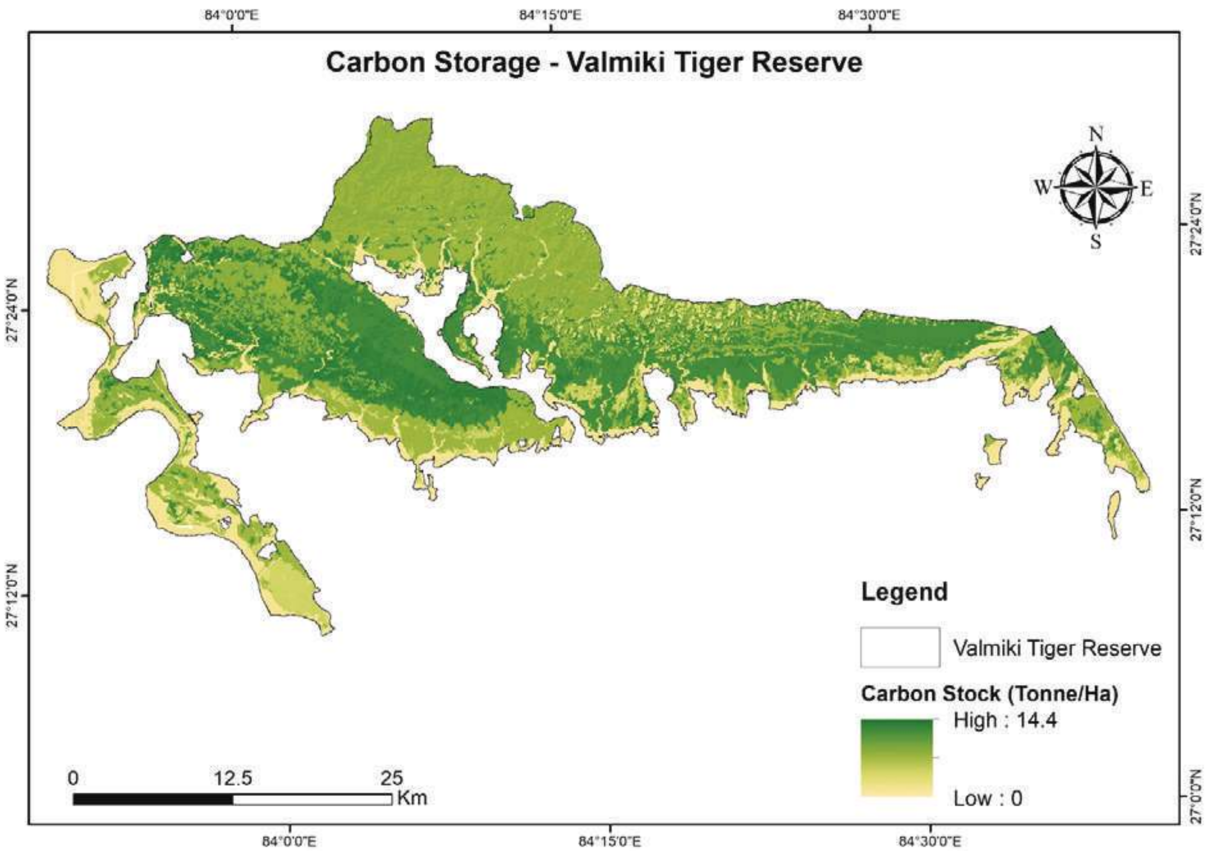



*Figure 6.10-3 Carbon Storage Map of Valmiki Tiger Reserve Created Using InVEST Model*

The estimates from the Carbon Stock model of InVEST as 8.59 million tonnes are used in conjunction with the Social Cost of Carbon to arrive at the economic value of carbon stock. As per the latest paper[117] which estimates that SCC for India is around USD 86 per $tCO_2$ and along with the conversion rate of 1 USD= Rs. 65 as the average for the year 2017-18, the economic value of carbon stock in VTR is calculated as Rs. 48.03 billion.

### 6.10.9.11 Carbon Sequestration

Apart from 8.59 million tonnes of carbon stock in the forests of Valmiki Tiger Reserve, these forests sequester carbon on an annual basis. The same has been estimated here based on the forest inventory database[108] of the the Forest Survey of India. The growing stock for tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous forests has been taken from the forest inventory database. Based on total biomass per unit area, the mean annual increment (MAI) has been calculated using the Von Mantel's Formula[119] and rotation period as per the forest type[120]. Assuming a biomass-to carbon conversion ratio of 50 percent[121], the mean annual increment in the above ground biomass has been converted to carbon sequestration in dry matter. Using this methodology, the total carbon sequestered in the forests of Valmiki Tiger Reserve by aggregating estimates for each forest type is equal to 631.45 kilo tonnes annually. Detailed calculations are shown in Table 6.10-4.

*Table 6.10-4 Carbon Sequestration in VTR*

| Forest Type | Forest Cover | Total Biomass Per Unit Area (Tonnes/ha) | Mean Annual Increment Per Unit Area (Tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) | Total Value of Annual Carbon Sequestration (Million Rs. Per Year) |
|---|---|---|---|---|---|---|
| Tropical Moist Deciduous Forests | VDF | 708.55 | 22.37 | 14066.22 | 157327.55 | 6455.24 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tropical Moist Deciduous Forests | MDF | 43.03 | 1.36 | 20422.77 | 13870.64 | 569.12 |
| Tropical Moist Deciduous Forests | OF | 259.48 | 8.19 | 2957.02 | 12111.89 | 496.96 |
| Tropical Dry Deciduous Forests | VDF | 1350.81 | 48.71 | 9134.58 | 222455.45 | 9127.48 |
| Tropical Dry Deciduous Forests | MDF | 474.93 | 17.12 | 24244.44 | 207588.92 | 8517.50 |
| Tropical Dry Deciduous Forests | OF | 263.17 | 9.49 | 3494.59 | 16580.49 | 680.31 |
| Littoral and Swamp Forests | VDF | 372.65 | 10.87 | 24.22 | 131.62 | 5.40 |
| Littoral and Swamp Forests | MDF | 585.78 | 17.09 | 74.31 | 634.93 | 26.05 |
| Littoral and Swamp Forests | OF | 150.79 | 4.40 | 341.87 | 751.85 | 30.85 |
| **Total** | | | | **74760.03** | **631453.34** | **25908.91** |

The social cost of carbon for India as per the latest paper[117] and the economic value of carbon stock has been estimated at USD 86 per $tCO_2$. Using the average conversion rate for the year 2017-18 as 1 USD=Rs. 65, the total economic value of annual carbon sequestration in VTR is calculated to be Rs. 25.9 billion.

### 6.10.9.12 Water Provisioning

The landscape of VTR is well drained by numerous rivers and streams. One of the major perennial sources of water is the Masan river, which almost bisects the VTR landscape. The other perennial rivers are Pandai which flows in the eastern segment of towards the west traversing the Manguraha range. Other streams are Ganguly, Deni, Dhoram, Dwardah near Sonbarsa, Singha, Manor, Bhapsa, Sonha, Rahua, Harha, and Akshor. Pools of water leftover from dried rivers locally knows as "dohs" help in maintaining the year round moisture and water supply[172].

The model estimated the total water yield volume for Valmiki Tiger Reserve at 1202.41 million cubic metres. This estimate does not account for consumptions as per land uses. Figure 6.10-4 shows the spatial distribution in water yield throughout VTR.

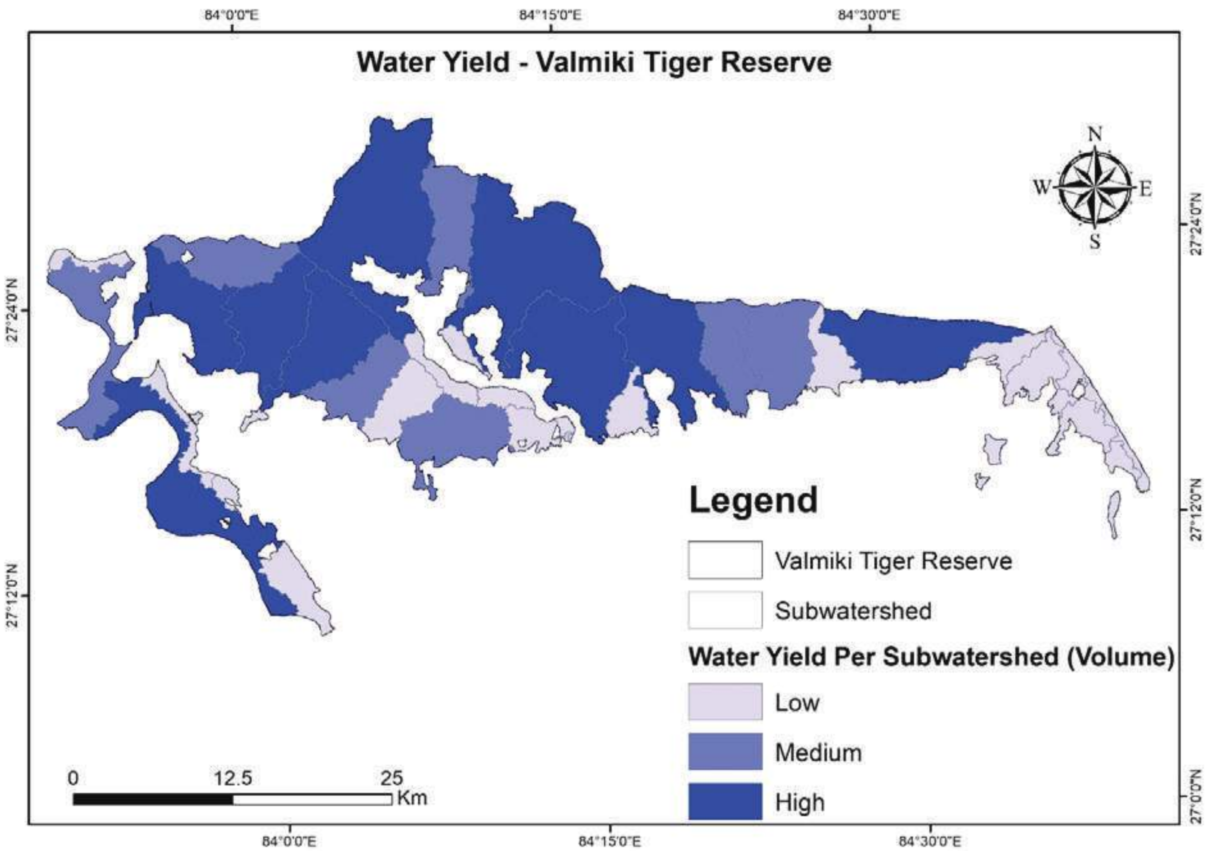



*Figure 6.10-4 Carbon Stock in Valmiki Tiger Reserve Created Using InVEST Model*

Using the monetary value of Rs. 18.43 per cubic metre[1], the economic value of water provisioning service from VTR is estimated to be 22.16 billion per year.

### 6.10.9.13 Water Purification

Owing to insufficient data on beneficiaries to establish attribution of this ecosystem service to VTR and lack of information on local water treatment facilities, this ecosystem service was not found relevant for VTR and therefore is not included for economic valuation in this study.

### 6.10.9.14 Soil Conservation/Sediment Retention

The model provides various outputs like modelled values of sediment export, sediment retention, potential soil loss, etc. Figure 6.10-5 displays sediment export output of the model. Although the sediment export is higher in the core area of VTR but the absolute values of sediment retention are much higher compared to sediment export in the core area of the tiger reserve. The values of sediment export ranges from 100 tons to 2100 tons per subwatershed.

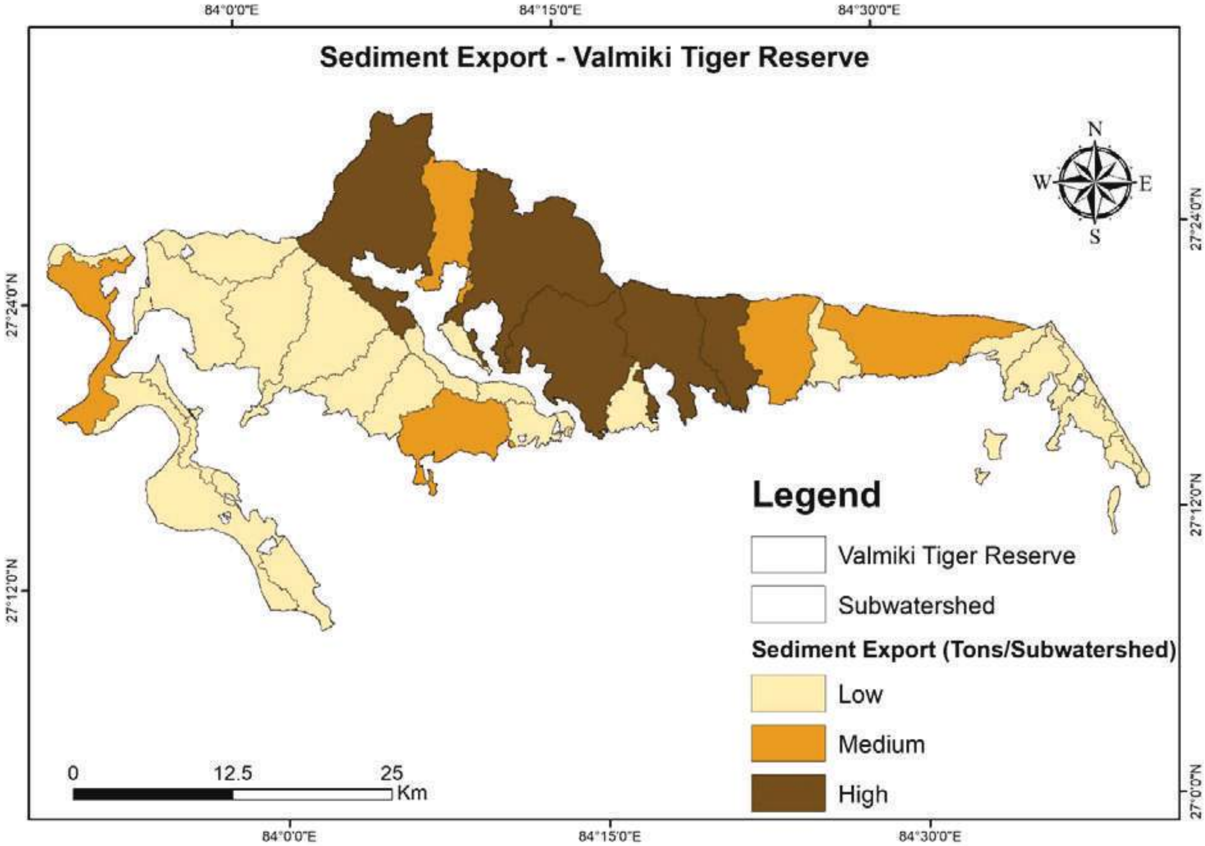



*Figure 6.10-5 Sediment Export from Valmiki Tiger ReserveCreated Using InVEST Model*

As shown in Figure 6.10-6 the sediment retention in the VTR landscape is medium to high across all the subwatersheds. The sediment retention values are higher in the core area of VTR. The values varies from 10000 tons to 5445000 tons per subwatershed.

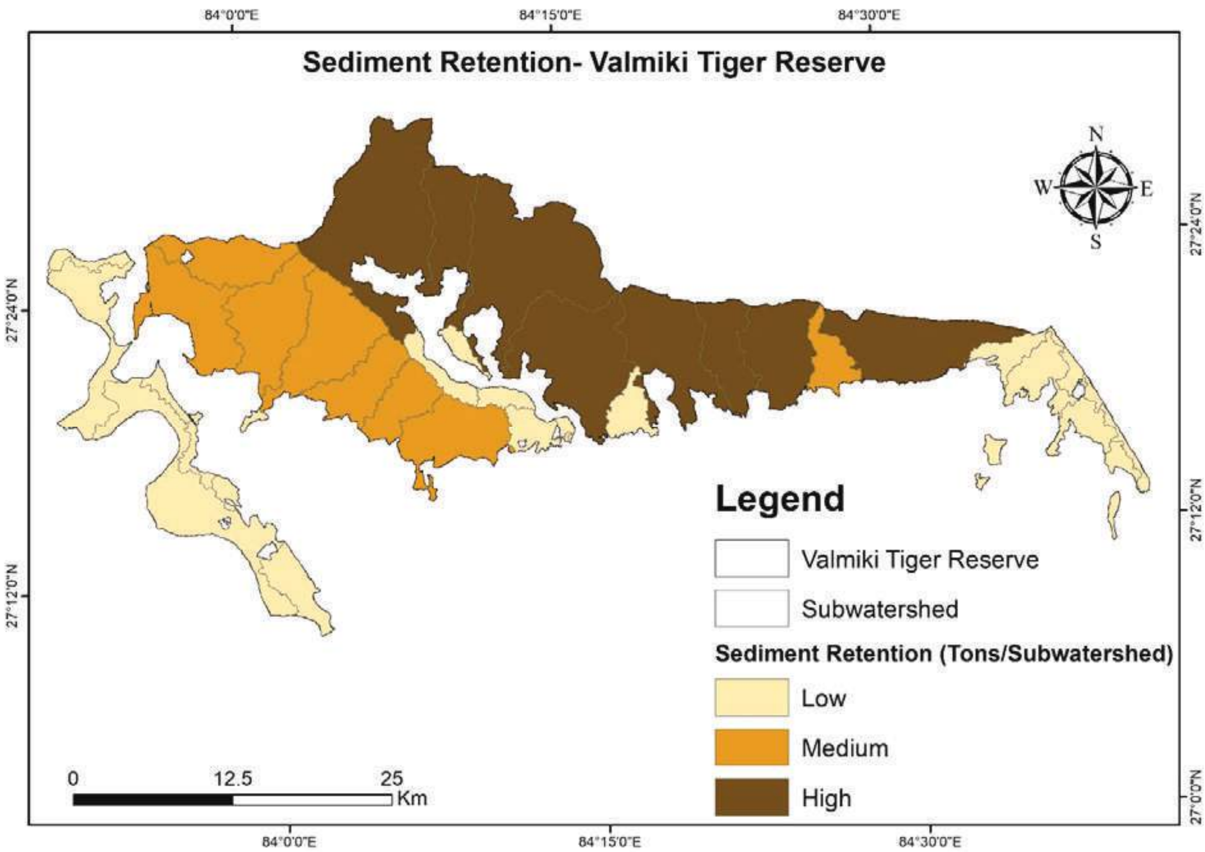



*Figure 6.10-6 Sediment Retention in Valmiki Tiger Reserve Created Using InVEST Model*

To estimate the economic value of soil loss avoided by the forests of VTR, the cost of dredging/de-siltation has been considered. On account of lack of site-specific data, a cost estimate of Rs. 60 per cubic metre [132] has been along with an assumed weight of soil as 1.2 tonnes/cum[133]. The economic value thus derived is equal to Rs. 35.37 million per year.

### 6.10.9.15 Nutrient Retention

The total soil loss avoided from the InVEST Sediment Retention model of VTR is around 779800.53 tons. To calculate the amount of nutrient retained, soil nutrient composition estimates for the state of Karnataka from a study conducted by the Green Indian States Trust[147] has been used on account of lack of local estimates for the same. Using the total soil loss avoided and soil nutrient Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations from the Table 6.10-5, the total quantity of nutrients retained is approximately 1641.22tonnes of N, 31.13 tonnes of P and 5836.24tonnes of K annually.

Taking the substitutes of these nutrients as their respective fertilizers, i.e. Urea for Nitrogen, DAP for Phosphorous and Muriate of Potash for Potassium[148], the monetary value has been derived. The total value of nutrient loss prevented by the forests of VTR is equal to Rs. 79.69 million annually.

*Table 6.10-5 Nutrient Retention in VTR*

| Nutrient | Soil Nutrient Concentration (g Per Kg) | Total Nutrient Loss Avoided (Tonnes per Year) | Fertilizer (Substitute) Used for Valuation | Price of Fertilizer (Rs. Per Tonne) | Economic Value of Nutrient Retention (Million Rs. Per Year) |
|---|---|---|---|---|---|
| Nitrogen (N) | 2.32 | 1641.22 | Urea | 5360 | 8.80 |
| Phosphorous (P) | 0.044 | 31.13 | DAP | 20100 | 0.63 |

| | | | | | |
|---|---|---|---|---|---|
| Potassium (K) | 8.25 | 5836.24 | Muriate of Potash | 12040 | 70.27 |
| **Total** | | **7508.59** | | | **79.69** |

### 6.10.9.16 Biological Control

Using estimates of economic value of biological control for tropical forests (Rs. 726 per hectare per annum) and cropland (Rs. 2178 per hectare per annum) from a global meta-analysis study[116] the economic value of biological control service from 81591.12 hectares of forests and 8185.8 hectares of cropland in VTR is estimated to be Rs. 77.06 million per annum.

### 6.10.9.17 Moderation of Extreme Events

Moderation of extreme events was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to VTR. Hence, it is not included in the valuation of the ecosystem service of VTR in this study.

### 6.10.9.18 Pollination

Using estimates of economic value of pollination for tropical forests (Rs. 1980 per hectare per annum) and cropland (Rs. 1452 per hectare per annum) from a global meta-analysis study[116], the economic value of pollination service from 81591.12 hectares of forests and 8185.8 hectares of cropland in VTR is estimated to be 173.44 million Rs. per annum.

### 6.10.9.19 Nursery Function

The nursery function was not relevant due to inadequate information and lack of supporting evident linkages to attribute this service to VTR. Hence, it is not included in the valuation of the ecosystem service of VTR in this study.

### 6.10.9.20 Habitat for Species

Valmiki Tiger Reserve offers a mosaic of habitat types for the rich flora and fauna of the area. It has numerous rivers, streams, canals and *nalas* traversing the entire landscape of the area with grassy blanks of Madanpur Block which offer suitable shelter and food to the herbivores. It has dense forest cover which supports abundant prey and provides cover to their predators[172].

Using estimates of economic value of habitat service for tropical forests (Rs. 2574 per hectare per annum) from a global meta-analysis study[116], the annual economic value of Habitat for Species service from 81591.12 hectares of forests VTR is estimated to be Rs. 210 million.

> Habitat is the most significant and viable factor in order to maintain the diversity and density of the wildlife found in the area. The main habitat regions of VTR [172] can be broadly identified as:
>
> **Sal Forests:** Dominated by the Sal species and its associates, these forests are found in the Triveni, Kosil, Naurangia, Raghia and part of the Someshwar Block.
>
> **Miscellaneous Forests:** Forests with mixed species occur in the Madanpur block and part of Someshwar Block.
>
> **Cane Brakes:** They usually occur in wet hollows and depressions along the course of various tributaries of the river Gandak in Madanpur and part of Triveni Block.
>
> **Grasslands:** Spread across in Madanpur Block in large area, and minor occurrence in parts of Someshwar and Triveni Block.
>
> **Swamp Forests:** They generally occur alongside river Gandak in Madanpur Block.

### 6.10.9.21 Cultural Heritage

Anthropologically, Valmiki Tiger Reserve comes under the region inhabited by Tharus who were Proto-Australoid, having a supposed racial affinity with the aborigines of Nepal, and belonging to the Aryan stock of Asian origin. The Tharus practised an animistic religion that centres on the cult of clan and village deities, together with ancestor and nature worship. Among the local people, most of them here speak Bhojpuri, a local dialect[172].

#### 6.10.9.22 Recreation

VTR is blessed with a picturesque landscape and natural heritage which offers great opportunities for recreation. But due to insufficient data on the number of tourist visits and their willingness to pay, the economic value of this service has not been estimated in monetary terms in this study.

#### 6.10.9.23 Spiritual Tourism

Due to paucity of information like annual footfall and information on spiritual sites, this service has not been included in valuation for this study.

#### 6.10.9.24 Research, Education and Nature Interpretation

Valmiki Tiger Reserve offers excellent research opportunities with its rich fauna, flora and diverse habitat. Studies on topics like population figures, water distribution and availability, distribution of vegetation, habitat management, wildlife ecology, etc have been carried out in VTR. Apart from these, WTI has conducted research studies on the following aspects: biodiversity characterization at landscape level using satellite remote sensing, ecological studies and conservation of tiger, prey monitoring and prey-predator relationships and dependency assessment study for villages[172].

#### 6.10.9.25 Gas Regulation

Using estimates of economic value of gas regulation service for tropical forests (Rs. 792 per hectare per annum) from a global meta-analysis study[116], the annual economic value of gas regulation from 81591.12 hectares of forests VTR estimated to be Rs. 64.62 million.

#### 6.10.9.26 Waste Assimilation

Moderation of extreme events was not found relevant due to insufficient information and evident linkages to attribute this service to VTR. Hence, it is not included in the valuation of the ecosystem service of VTR in this study.

#### 6.10.9.27 Climate Regulation

Using estimates of economic value of climate regulation service for tropical forests (Rs. 134904 per hectare per annum) and cropland (Rs. 27126 per hectare per annum) from a global meta-analysis study[116], the annual economic value of climate regulation from 81591.12 hectares of forests and 8185.8 hectares of cropland in VTR are estimated to be Rs. 11.229 billion.

### 6.10.10 Spectrum of Values- Valmiki Tiger Reserve

Representative biological diversity of the northern Indian Himalayan foothills including many rare and endangered flora of great medicinal, educational, scientific and conservation values are efficiently preserved in Valmiki Tiger Reserve.

#### 6.10.10.1 Presentation of Ecosystem Service Valuation Findings in Various Frameworks

* - Ecosystem Services – Not Applicable / Not Calculated

| **Summary of Ecosystem Services Based on TEV Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Direct Use Value** | **397.00** | **Rs. Million/Year** |
| Fuel wood, Fodder<br>* - Non-Timber Forest Products, Fishing, Bamboo (Flow), Timber (Flow), Employment Generation | | |
| **Indirect Use Value** | **59873.93** | **Rs. Million/Year** |

| | | |
|---|---|---|
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Cultural Heritage, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - Water Purification, Recreation, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Option Value** | **8732.02** | **Rs. Million/Year** |
| Genepool Protection | | |

| **Summary of Ecosystem Services Based on MA Framework (Flow Benefits)** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Provisioning Services** | **332.38** | **Rs. Million/Year** |
| Fodder, Fuel wood<br>* - Employment Generation, NTFP, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Regulating Services** | **68460.55** | **Rs. Million/Year** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool Protection<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Cultural Services** | | **Rs. Million/Year** |
| Cultural Heritage, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Recreation | | |
| **Supporting Services** | **210.02** | **Rs. Million/Year** |
| Habitat for Species | | |

| **Summary of Ecosystem Services Based on Stock and Flow Benefits** | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Flow Benefits** | **69.00** | **Rs. Billion/Year** |
| Fodder, Fuel wood, Carbon Sequestration, Water Provisioning, Genepool Protection, Water Purification, Sediment Retention/Soil Conservation, Nutrient Retention, Habitat for Species, Biological Control, Pollination, Cultural heritage, Spiritual Tourism, Research, Education and Nature Interpretation, Gas Regulation, Climate Regulation<br>* - Employment Generation, NTFP, Recreation, Timber (Flow), Fishing, Bamboo (Flow), Moderation of Extreme Events, Nursery Function, Waste Assimilation. | | |
| **Stock Benefits** | **436.83** | **Rs. Billion** |
| Standing Timber, Carbon Storage | | |

| Summary of Ecosystem Services Based on Tangible/Intangible Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Tangible Benefits** | **332.38** | **Rs. Million/Year** |
| Fodder, Fuel wood<br>* - Employment Generation, NTFP, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Intangible Benefits** | **505499.21** | **Rs. Million** |
| Carbon Sequestration, Water Provisioning, Sediment Retention/Soil Conservation, Nutrient Retention, Biological Control, Pollination, Gas Regulation, Climate Regulation, Gene pool protection, Habitat for Species, Standing Timber, Carbon Storage, Cultural Heritage, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Water Purification, Recreation, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |

| Summary of Ecosystem Services Based on Human Values and Ecosystem Assets Framework | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **Adequate Resources** | **22492.80** | **Rs. Million/Year** |
| Fodder, Fuel wood, Water Provisioning<br>* - NTFP, Timber (Flow), Fishing, Bamboo (Flow) | | |
| **Protection from Disease/Predators/Parasites** | **77.06** | **Rs. Million/Year** |
| Biological Control | | |
| **Benign Physical and Chemical Environment** | **37701.06** | **Rs. Million/Year** |
| Carbon Sequestration, Sediment Retention/Soil Conservation, Nutrient Retention, Pollination, Gas Regulation, Climate Regulation, Habitat for Species<br>* - Water Purification, Moderation of Extreme Events, Nursery Function, Waste Assimilation | | |
| **Socio-Cultural Fulfilment** | | **Rs. Million/Year** |
| Cultural Heritage, Spiritual Tourism, Research, Education and Nature Interpretation<br>* - Employment Generation, Recreation | | |
| **Ecosystem Assets** | **445560.66** | **Rs. Million** |
| Standing Timber, Carbon Storage, Gene pool Protection | | |

| Summary of Ecosystem Services Based on EPA Effect categories | | |
|---|---|---|
| **Type of Value** | **Value** | **Unit** |
| **EPA Effect Category 1** | **505831.58** | **Rs. Million** |
| Timber (Stock), Genepool Protection, Carbon storage, Carbon Sequestration, Water Provisioning, Soil Conservation/Sediment Retention, Nutrient Retention, Biological Control, Pollination, Habitat for Species, Gas Regulation, Climate Regulation<br>* - Employment Generation, Timber (Flow) | | |
| **EPA Effect Category 2** | **No Data** | **NA** |
| * - Recreation | | |

| | | |
|---|---|---|
| **EPA Effect Category 3** | **-** | |
| Research, Education and Nature Interpretation | | |
| **EPA Effect Category 4** | **Tharu** | **Tribe-Group Present** |
| Cultural Heritage | | |
| **EPA Effect Category 5** | **-** | |
| Spiritual Tourism | | |

#### 6.10.10.2 Linkages to Human Health

Valmiki Tiger Reserve offers a range of ecosystem services vital for maintenance of human well-being. Amongst these, genepool protection, carbon storage, carbon sequestration, water provisioning, biological control, pollination, cultural heritage, recreation, research, education and nature interpretation, gas regulation, and climate regulation services have a huge direct and indirect impact on human health. The aggregate estimated worth of these services is around Rs. 116.38 billion.

#### 6.10.10.3 Investment Multiplier

According to the last sanction from National Tiger Conservation Authority (NTCA), the annual amount released for management of Valmiki Tiger Reserve for the year 2016-17, was around Rs. 48.78 million. Based on the flow benefits of Rs. 69.00 billion per year, for every rupee spent on management costs in VTR, flow benefits of Rs. 1235.6 are realized within and outside the tiger reserve.

#### 6.10.10.4 Per Hectare Flow Benefits

The flow value of ecosystem services of Valmiki Tiger Reserve was estimated at Rs. 0.74 million (Rs. 7.41 lakhs) per hectare.

#### 6.10.10.5 Distribution Across Stakeholders (Flow Benefits)

Based on the framework for distribution of flow values presented in Phase-I study[1], approximately 2.09 percent of flow benefits accrue at the local level, 9.70 percent at the national level and 88.21 percent at the global level.

# 7 Chapter 7: Tiger Reserves: A Destination Brand

***Overview***

The chapter introduces the concept of Destination Brand and provides the rationale for exploring tiger reserves as Destination Brands. It further describes the parameters that measure Destination Brand and Brand Equity. The chapter contains findings of the online survey that was conducted as a part of this study.

***Key Insights***

A destination brand is a set of cultural and symbolic meanings related to a place. The tangible assets of the destination brand could include geographical features such as mountains, forests, historical sites, and attractions; intangible assets might include culture, customs, and history. Consumers going to a destination are seeking to experience tangible or intangible features that are different from those they can experience at home. To explore the potential of tiger reserves as destination brands, a pilot exercise was conducted for the six tiger reserves of Phase-I in the form of an online survey.  A structured questionnaire was used in Online Survey via snowball sampling. The attributes captured in the survey primarily included, awareness, perception, intention to revisit and recommendation of the respective tiger reserve. The brand perception was enquired regarding the destinations of which the respondents were aware of, whereas, intention to revisit and recommendation were administered only to the visitors of the destination brand. For six TRs of Phase-I (Corbett, Ranthambore, Kanha, Periyar, Sundarbans and Kaziranga).

Online Survey was conducted to study tourists' attitudes towards brand equity covering the parameters of destination brand. The parameters used for Destination Brand Measurement were Awareness/ Brand Identity, Image Attributes/Brand Perception and Recommendation and Willingness to Visit. Brand equity can be understood as a multidimensional construct composed of brand strength and brand value. While brand equity deals with a consumer-based perspective; brand value is more of a company-based perspective. In the case of tiger reserves, judging through the consumer perspective seemed more appropriate. As calculating brand value was not possible because the exercise is too data-intensive, as the surrogate of brand equity was considered to measure Destination Brand.

The initial survey helped assess the brand equity of tiger reserves in terms of awareness, brand perception, intention to revisit and recommendation. The survey findings indicate that visitors to Tiger Reserves seek natural beauty and not just tigers. Tiger Reserves like Corbett, Ranthambore and Kanha rank high in brand awareness. **In terms of Brand Image- Sundarbans and Kanha are perceived to be unique destinations by 54% and 48 percent respondents (higher than others).** In terms of the presence of religious, historical and cultural places, Ranthambore (49 percent) stands out among the lot. Tiger reserves like Corbett (60 percent) and Kanha (63 percent) are highly associated with scenic natural beauty. In the management aspect, Kanha outperforms on the service related parameters. Visitors have different perceptions across tiger reserves. The TR Corbett, Ranthambore and Kanha are perceived to be better on most of the parameters. **The Brand Equity score is highest for Kanha (296) followed by Ranthambore (258) and Corbett (228).**

## 7.1 Cultural Values-Recreation

Travel, tourism and recreation are important elements of human well-being. One of the important categories of consumer services emanating from tiger reserves is cultural services. Cultural services are defined by the Millennium Ecosystem Assessment (2003) as the 'non-material benefits that people obtain from ecosystems' such as spiritual, recreational, and cultural benefits. Besides recreation, many other cultural services can be considered as relevant for tourism, for example, aesthetic values, culture heritage, etc.

Nature-based tourism is a rapidly growing sector of the global economy, is an important ecosystem service, and generates support for conservation. In this sense, to understand how ecosystem services contribute to touristic experiences from the consumer point of view has been attempted in this phase of the study.

## 7.2 Destination Brand

A destination brand is a set of cultural and symbolic meanings related to a place. Destination brands are made up of both tangible and intangible assets[174]. Tangible assets could include geographical features such as mountains, forests, historical sites, and attractions; intangible assets might include culture, customs, and history. Consumers going to a destination are seeking to experience tangible or intangible features that are different from those they can experience at home[175].

A wildlife destination is much more multi-dimensional than a consumer good; it is actually a composite of many different products[176]. This can be explained by all that a traveller visiting a national park experiences, the natural beauty (fresh and pure environs, etc.), interactions with local people, observing the appearance, geography, and the area around oneself. All these components together make up the destination product, contributing to a tourist's overall experience with the destination.

A brand's underlying goal is to suggest feelings of trust, confidence, status and exclusivity that would make a consumer favour it over others[177]. As a result, tourists tend to develop loyalty to destination brands. This might be because of the reason that the destination visit experience fits well with their lifestyles[178].

The tiger reserves of India are unique and one of the most sought after places by travellers, not just from the country but also from across the world. During the field visits, these places were already perceived to be well-established destination brands by the local people.

An exercise was conducted in this regard through an online survey to study tourists' attitudes towards brand equity covering the parametres of destination brands.

## 7.3 Destination Brand Measurement-Parametres

The measurement of brand health comprises the following three components:

### 7.3.1 Awareness/ Brand Identity

The first component of brand equity is awareness of the brand, whether the place is well-known to the consumer. This can be either from an actual visit or word of mouth. Established destination brands are well known universally irrespective of whether they have been visited or not.

In this case, whether an individual remembers the name of the place measures this aspect.

Brand Awareness is considered a prerequisite to any other brand dimensions[179]. Without some level of awareness, the consumer cannot have perceptions on the destination's image, quality, etc.

### 7.3.2 Image Attributes/Brand Perception

The image of the brand in the consumer's mind is the brand's perception. [180] define the destination image as 'the sum of beliefs and impressions people hold about a place. Images represent a simplification of a larger number of associations and pieces of information connected to a place'. The image attributes are the perceptions about the place, irrespective of whether these places have been visited or not.

In this case brand perceptions have been categorized into three categories: aesthetic parameters, recreational parameters and service-related parameters.

### 7.3.3 Recommendation and Willingness to Visit

The recommendation to visit the place and the experience on visit are also inputs to the destination brand. Once a consumer visits the destination brand, based on the experience, whether he is willing to revisit the place adds to the component of branding. In other words, whether the destination brand has been able to fulfil the expectations from the visit is determined by this factor.

## 7.4 Destination Brand Measurement-Methodology

In order to assess this part of cultural services emanated by tiger reserves, a primary survey was conducted among recent and potential visitors of tiger reserves. The exercise was an attempt to study tourists' attitudes towards brand equity (brand awareness and brand image of tiger reserves) and value proposition, exploring the value as a destination brand. The survey was conducted through an online survey, the link of which was sent to target respondents.

For selecting the sample, the tourist database was requested from all six tiger reserves, which was used as the sampling frame for the study. The email ids and phone numbers were randomly selected from the database provided and survey links were sent to 1500 respondents through emailsand to 6000 through text messages. Most of the links were sent from the database provided by Kanha Tiger Reserve. As some of the tiger reserves were under-represented because of non-availability of tourist data, purposive snowballsampling was done to cover the required sample.

A structured questionnairewas prepared for the survey which attempted to capture the elements that make up a brand. The areas captured in the survey primarily included, awareness, perception, intention to revisit and recommendation of the respective tiger reserve. Brand perception was asked for the destinations the respondents were aware of, whereas intention to revisit and recommendation were administered only to the visitors of the destination brand. Apart from the branding components, questions like reasons for choosing a particular destination, satisfaction levels with the visit, demographic and profile attributes were captured.

About 204 responses were captured over a three-week time period from across the country.

In this study the six tiger reserves surveyed in the Phase-1 study, namely Corbett, Ranthambore, Kanha, Periyar, Sundarbans and Kazirangawere considered for this assessment of Brand Equity. However, the brand equity score could be derived for three out of the six tiger reserves namely, Corbett, Ranthambore and Kanha as the data was inadequate for the remaining. The respondents' profile is as shown in the figure (Figure 7.4-1). Most of the respondents are from age group 25-35 years, mostly working in private companies.

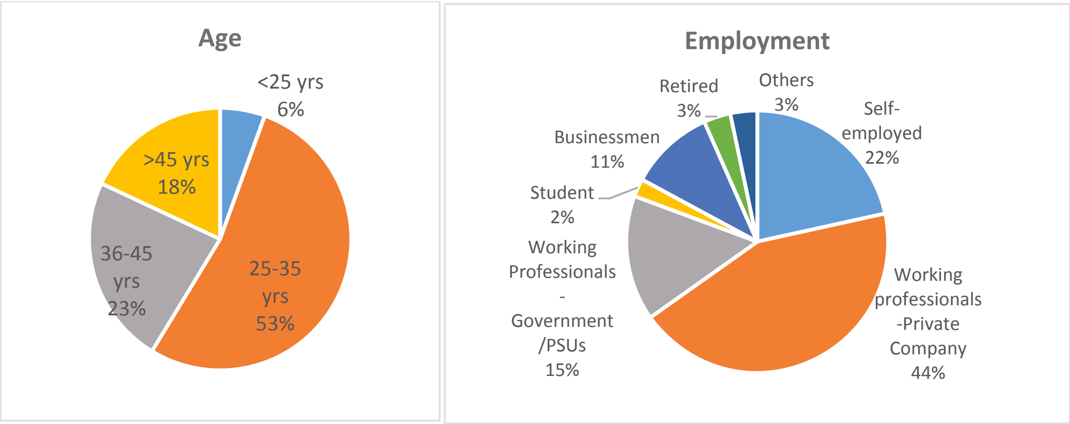



*Figure 7.4-1: Respondents' Profile (Shown as Percentage of Total Responses from the Survey)*

## 7.5 Brand Value Vs Brand Equity

Brand Equity is the value of a brand based on the extent to which it has a high brand loyalty, name awareness, perceived quality, strong brand associations[181]. Brand equity as a multidimensional construct composed of brand strength and brand value. While brand equity deals with a consumer-based perspective, brand value is more of a company-based perspective. In case of tiger reserves, judging through consumer perspective seemed more appropriate.

As calculating brand value was not possible because of scarcity of data, the surrogate of brand equity was considered. The primary survey helped assess the brand equity of tiger reserves in terms of awareness, brand perception, intention to revisit and recommendation.

## 7.6 Findings from the Primary Survey

### 7.6.1 Tiger Reserve Visitors Seek Natural Beauty (not just Tiger)

This parameter intended to find out the key triggers to visit the place. The primary motive to visit these reserves is to enjoy the services of 'nature'. As gathered from the respondents, among the main reasons to visit particular tiger reserves, enjoying nature/forest found the highest mentions followed by seeing tiger in wild (Table 7.6-1). Visiting to experience pure and fresh environs also seemed to have prominent mention. This indicates that the natural environment is sought after by tourists which indicates the need to spend time in nature. It emphasizes the fact that natural values are considered to be crucial for most leisure activities[182].

| ***Reasons to Visit*** | **Corbett** | **Ranthambore** | **Periyar** | **Sundarbans** | **Kanha** | **Kaziranga** |
|---|---|---|---|---|---|---|
| *To See Tiger In the Wild* | 20 | 19 | 6 | -- | 77 | 2 |
| *Enjoy Nature/Forests* | 23 | 13 | 8 | 3 | 82 | 3 |
| *Best Value Option* | 1 | 3 | 1 | 1 | 15 | 1 |
| *Close Proximity to my City/Town* | 9 | 5 | 4 | 1 | 31 | -- |
| *Other Wildlife/Bird Watching* | 13 | -- | 3 | | 35 | 4 |
| *Unwind from Busy Life* | 9 | 3 | 6 | 1 | 28 | 1 |
| *Heard from/Influenced by Friends/Family* | 3 | 2 | 2 | -- | 11 | -- |
| *Pure and Fresh Air/Environs* | 10 | 2 | 7 | -- | 51 | 2 |
| *Sample Size* | 32 | 26 | 13 | 3 | 102 | 5 |

*Caution-Low Base

*Table 7.6-1 Survey Findings: Reasons for Visiting TR (Shown as Number of Respondents form the Survey)*

### 7.6.2 Brand Awareness

If people recognize or identify the name of the place, it is counted as brandawareness, one of the components of the brand.

The awareness levels of almost all the six tiger reserves were found to be good. This means that most of the respondents were able to identify the name of the brand. More than two -thirds of the respondents were aware of almost all the six tiger reserves (Figure 7.6-1). This indicates healthy brand identity across the reserves. Comparatively, more people were aware of Corbett, Ranthambore and Kanha Tiger Reserves than the others.

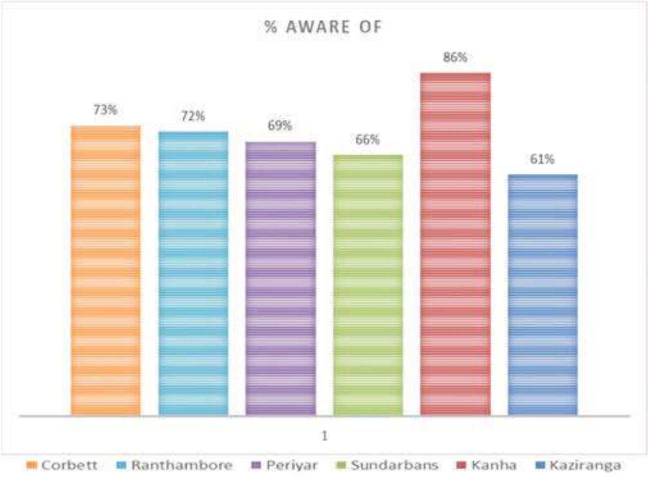



*Figure 7.6-1 Survey Findings: Brand Awareness (Percentage of Respondents who are Aware/Know/Heard Of)*

### 7.6.3 Brand Image Perception

Each destination has an image perception that is built by what it offers. For tiger reserves, it could be defined in terms of aesthetics, culture, recreation or service-related parameters. The combination of these parameters defines that particular brand. Some places may be considered unique by what they offer to the visitor, something that is found only there and not anywhere else while some may offer mountains, rivers, grasslands or similar landscapes that soothe the senses.

While the awareness of the tiger reserves was almost similar, stark differences were observed in terms of the brand image perceptions.

Sundarbans and Kanha are perceived to be unique destinations by 54 percent and 48 percent respondents respectively, which is slightly higher compared to other tiger reserves. In terms of presence of religious, historical and cultural places, Ranthambore (49 percent) stands out among the lot.

Corbett (60 percent) and Kanha (63 percent) are highly associated with scenic natural beauty compared to others. This indicates the kind of landscape consumers relate scenic natural beauty to.

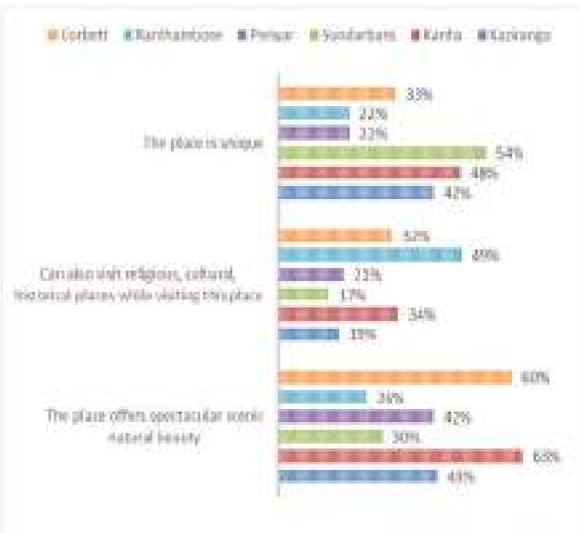
Kanha outperforms on the service-related parameters with nearly two thirds of the respondents associating it with having knowledgeable and experienced guides. To summarize the identity of each of the tiger reserves in the mind of the consumer:

- Jim Corbett Tiger Reserve is perceived as a place offering scenic natural beauty, offering wildlife sightings other than tiger and having experienced staff/guides.
- Ranthambore is perceived to have the highest on probability of tiger sighting, religious value and experienced staff and guides.
- Periyar is associated with scenic beauty and a place offering a range of recreational activities.
- Sundarbans finds highest uniqueness perception with regard to place as well as species found.
- Kanha's association was across aesthetic, service and recreational parametres, standing out particularly in other wildlife sighting, scenic beauty and experienced staff.

- Kaziranga was associated with unique species and mega fauna wildlife sightings.

Therefore, each tiger reserve is perceived to be associated with certain attributes more than the others (Figure 7.6-2). Corbett, Ranthambore and Kanha seemed more popular with higher endorsements across parametres. All these destination brands offer something unique in terms of experience. No other place can substitute the experiences and attractions of a particular place. Therefore, these perceptions add to the unique value of the destination (Table 7.6-2).

*Aesthetic/Cultural Value Perception*




*Service Value Perception*


*Recreational Value Perception*

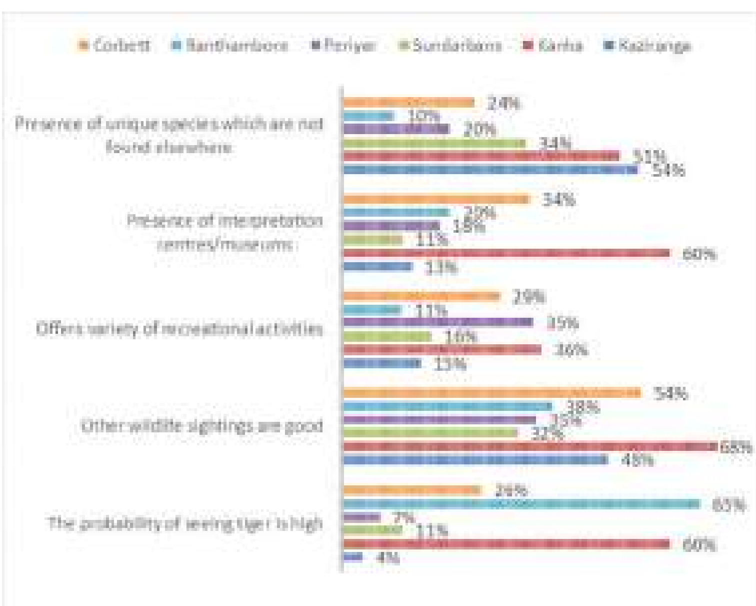



*Figure 7.6-2 Survey Findings: Brand Perception on Association Scale:*

| | Corbett | Ranthambore | Periyar | Sundarbans | Kanha | Kaziranga |
|---|---|---|---|---|---|---|
| *The place offers spectacular scenic natural beauty* | ● | | ● | | ● | ● |

| | | | | | | |
|---|---|---|---|---|---|---|
| *The probability of seeing tiger is high* | | ● | | | | |
| *Other wildlife sightings are good* | ● | | | | ● | |
| *Presence of interpretation centres/museums* | | | | | ● | |
| *Presence of unique species which are not found elsewhere* | | | | ● | | ● |
| *Can also visit religious, cultural, historical places while visiting this place* | | ● | | | | |
| *The place is unique* | | | | ● | ● | ● |
| *Booking safari/making payments is easy* | | | | | ● | |
| *Offers a variety of recreational activities* | | | ● | | ● | |
| *Has knowledgeable and experienced guides/staff* | ● | ● | | | ● | |

*Table 7.6-2: Unique Value Perception Grid (Survey Findings)*

### 7.6.4 Brand Recommendation/Intention to Revisit

The other important aspect of brand building is the endorsement for the brand. This is captured through intention to revisit and recommendation for the place. The intention to revisit and recommendation was mostly positive across places indicating positive experience visiting the place (Table 7.6-3). Owing to small sample sizes for some of the tiger reserves, numbers have been mentioned instead of percentages.

| ***Intention to Revisit*** | **Corbett** | **Ranthambore** | **Periyar** | **Sundarbans** | **Kanha** | **Kaziranga** |
|---|---|---|---|---|---|---|
| *Yes, Definitely* | 19 | 17 | 6 | 1 | 71 | 3 |
| *Yes, Maybe* | 7 | 8 | 5 | 2 | 22 | 2 |
| *Probably Not* | 4 | 1 | 2 | | 8 | |
| *Not at All* | 2 | | | | 1 | |
| | | | | | | |
| | | | | | | |
| ***Recommendation*** | | | | | | |
| *Yes, Definitely* | 19 | 23 | 11 | 2 | 87 | 5 |
| *Yes, Maybe* | 9 | 2 | 2 | 1 | 14 | |
| *Probably Not* | 3 | 1 | | | 1 | |
| *Not at All* | 1 | | | | | |
| | | | | | | |
| *Sample Size* | 32 | 26 | 13* | 3* | 102 | 5* |

*Table 7.6-3: Survey Findings: Brand Recommendation and Intention to Visit*

*Caution-Low Base

From the above scores it can be inferred that visitors have different perceptions across tiger reserves. While Corbett, Ranthambore and Kanha are perceived to be better on most of the parametres, Periyar, Kaziranga and Sundarbans in spite of good awareness are less familiar and not clearly defined by the consumers in terms of perception.

## 7.7 Brand Equity Score

Based on the components of brand equity- brand awareness, image perception, recommendation and willingness to revisit the place, a brand equity score has been derived as summation of these components. As the number of visitors captured has been too low for the other destination brands to calculate the score, the equity score has been calculated for three reserves only: Corbett Tiger Reserve, Ranthambore Tiger Reserve and Kanha Tiger Reserve.

Kanha Tiger Reserve gathers high endorsements and image perception from visitors with good awareness levels and therefore has a high equity score.

| | **Corbett Tiger Reserve** | **Ranthambore Tiger Reserve** | **Kanha Tiger Reserve** |
|---|---|---|---|

| Brand Equity Score | 228 | 258 | 296 |
|---|---|---|---|
| Intention to Revisit (Top Box) | 59 | 65 | 70 |
| Recommendation (Top Box) | 59 | 88 | 85 |
| Brand Image Perception (Average) | 37 | 33 | 55 |
| Awareness | 73 | 72 | 86 |

*Table 7.7-1: Findings: Brand Equity Score*

As per Keller's Brand Equity Model, how customers think and feel help build a brand. The type of experiences around the brand, certain specific, positive thoughts, feelings, beliefs, opinions, and perceptions about the product help to build up the pyramid of brand equity. Following the Keller Brand Equity model, Corbett, Ranthambore and Kanha seem to be established brands transforming from meaning to response, positive experiences leading to development of feelings for the brand. These places find high recommendation, revisit intentions and stronger brand associations. Periyar, Sundarbans and Kaziranga seem to have identity and moving towards meaning.

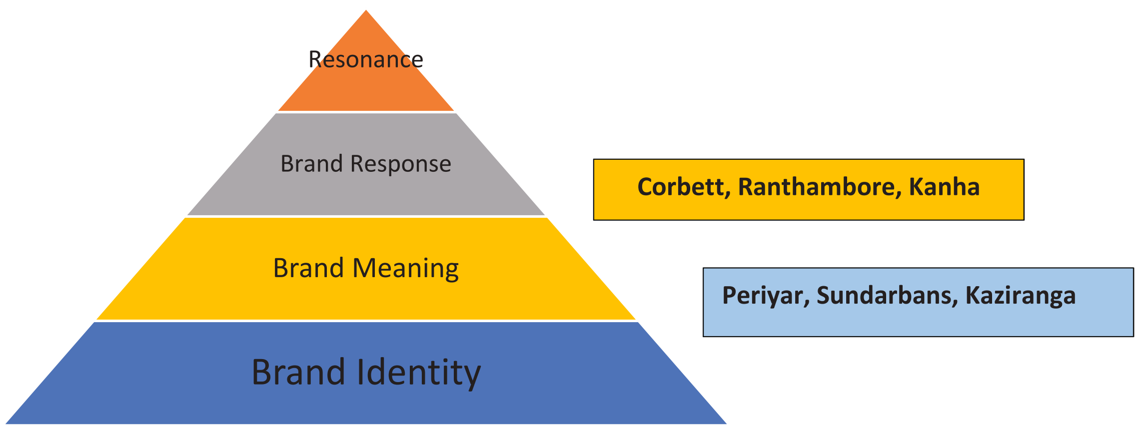



*Figure 7.7-1: Keller's Brand Equity Model-Tiger Reserves*

## 7.8 Limitations

As the sample size for tiger reserves other than Kanha are inadequate, simple summation has been taken for calculating brand equity scores. In case data is available with adequate sample size, weighted scores can be calculated based on the derived scores of factors affecting the experience.

Also, due to unavailability of database of tourists from many tiger reserves, the sampling methodology adopted was random sampling from the available database and snowball sampling for the tiger reserves where data was unavailable. As a large part of the sampling frame was from Kanha Tiger Reserve, the sample for Kanha might be biased as the responses were mostly from visitors.

## 7.9 Conclusion

Nature and wildlife tourism cannot thrive without nature and wildlife. These destination brands can use sustainability as a differentiator. With increasing awareness of environmental issues, sustainability has become an important element of destination brands. Particularly those seeking to enjoy natural beauty, forests and wildlife, any unsustainable means in upkeep of the place or poor management of the destination will cause the brand image to erode thereby diluting the concept of the brand as a place.

The tiger reserves can be green destination brands of the country. Proper management and planning, responsible and low impact tourism, respecting wildlife and culture, can help optimize the benefits while conserving and improving the status of these destination brands.

# 8 Chapter 8: Summary and Way Forward

***Overview***

The chapter provides summary of the findings from the study and also presents a conclusion and way forward.

***Key Insights***

**The study findings indicate that the monetary value of flow benefits from the selected ten tiger reserves range from Rs. 50.95 to 162.02 billion annually. These tiger reserves also conserve enormous stock of timber and carbon which is valued in the range of Rs. 137.46 billion to 967.45 billion.** The stock serves as a basis for the natural systems to flourish and emanate flow of ecosystem services. The per hectare values of these TRs fall in the range of Rs. 0.41 million to 0.74 million per year. The study findings also indicate that a sizeable proportion of flow benefits (as well as stock) are intangible and hence are often unaccounted for in the socio-economic scenario and policy formulation. Economic valuation helps in recognizing these benefits and internalise them into policy actions.

For better management, it is essential to put ecosystem services as a focal area in TR management. 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. Further, since tiger reserves generate such an immense quantum of values, adequate investment in natural capital contained in tiger reserves is essential to ensure the flow of ecosystem services in future. 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.

It is essential to integrate and utilize the values from the tiger reserves into designing an integrated management of a broader landscape and thus enhance ecological connectivity. 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. Also, it is necessary to conduct long term primary research focused on ecosystem services to get a better picture of the range of ecosystem services emanating and their bio-physical quantification from tiger reserves and other Protected Areas (PAs).

For streamlining data collection for future endeavours, data collection protocols for selected ecosystem services have been provided in the report to ensure standardization and periodic data collection at tiger reserve level. The protocols are to be incorporated in the Tiger Conservation Plans (TCPs) to ensure a formal system of data collection and reporting.

The tiger reserves are repositories of of natural ecosystems and biodiversity which emanate ecosystem services essential for human well-being. They continuously disseminate a range of economic, social, cultural and spiritual benefits. Tiger reserves as protected areas preserve the wilderness and natural systems which support ecological processes responsible for providing various goods and services. For instance, forests in tiger reserves aid in conserving the soil by preventing soil erosion and leaching of nutrients. They play a pivotal role in the water cycle and other bio-chemical cycles, help in regulating the climate and balance of gases in the atmosphere, and they help to mitigate disasters and protect the genetic diversity. These forests not only provide benefits for present direct and indirect use but also ensure the perpetuity of these benefits for future generations.

The ecosystem service is an interdisciplinary approach to the integrative study of both socio-economic and ecological systems. A proper understanding of the benefits in the form of ecosystem services from tiger reserves generates awareness and assists in assessing the tradeoffs and strengthens the case for conservation of our natural heritage.

**The study findings indicate that the monetary value of flow benefits from the selected ten tiger reserves range from Rs. 50.95 to 162.02 billion annually.** These tiger reserves also conserve enormous stock of timber and carbon which is valued in the range of Rs. 137.46 billion to 967.45 billion. The stock serves as a basis for the natural systems to flourish and emanate flow of ecosystem services. The per hectare values of these TRs fall in the range of Rs. 0.41 million to 0.74 million per year. The study findings also indicate that a large proportion of flow benefits (as well as stock) are intangible and hence are often unaccounted for in the socio-economic scenario and policy formulation. Economic valuation helps in recognizing these benefits and internalizing them into policy actions. The intangible values of around Rs. 206.32 to Rs. 1096.65 billion originate from the tiger reserve apart from tangible values ranging from Rs. 28 million to Rs. 767 million each year.

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 the 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 a continued flow of benefits in future.

The Total Economic Value of these tiger reserves depends on the direct, indirect and option values of the ecosystem services from these tiger reserves. According to the study findings, it is estimated that the quantum of collective direct benefits generated is in the range of Rs. 89.70 million to Rs. 1018.72 million. Interestingly, the indirect benefits from these tiger reserves are valued at Rs. 42.21 billion to Rs. 133.18 billion per annum. The tiger reserves offer resilience for climate change and other environmental challenges the world faces today by conserving what matters. They are crucial if future generations are to have an opportunity to enjoy natural landscapes that exist today. 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. This is illustrated in the enormous option value in the range of Rs. 8.65 billion to Rs. 32.16 billion. These include the potential for novel discoveries, e.g. in pharmaceuticals, crop resilience, bio-mimicry and other areas. Preservation of option values is a significant argument in its own right for managing and expanding the network of tiger reserves. In terms of Millennium Assessment classification, the provisioning values are Rs. 28 million to Rs. 767 millions, the regulating services are Rs. 50.26 billion to Rs. 160.48 billion while the cultural services are as high as Rs. 542.04 million annually.

It is important to realise the eminence of the ecosystem services in human lives and well-being. To articulate the same and highlight the linkages between them and human values, using framework suggested by K. J. Wallace in 2007, the study findings indicate that the natural ecosystems in the tiger reserves provide adequate resources to humans in the range of Rs. 16.43-70.42 billion. They offer protection from disease, predators and parasites which is an avoided cost in the range of 77 million to 241.5 million. They also help in maintaining a benign physical and chemical environment for amenable living conditions by providing necessary infrastructure and ecosystem services worth Rs. 25.67-92.01 billion. The tiger reserves play a major role in the lives of local communities and conserve a range of traditional values apart from providing recreation and leisure. Thus the socio-cultural fulfilment benefits from these tiger reserves ranges from 3 million to 621.44 million. They conserve ecosystems and natural assets worth Rs. 153.10-985.3 billion.

Tiger reserves are complex ecosystems and not all the benefits provided by nature can be quantified and assessed in monetary terms. Therefore, the study attempts to capture benefits beyond monetary values such as the number of indigenous tribes, footfall at the spiritual sites inside the TR, number of research studies undertaken for a particular tiger reserve, and medicinal plants of the TR. Further the study also highlights the benefits of forests on the health of human beings. The forests protected in these tiger reserves have a deep and holistic impact on the health and overall well-being of humans. The health benefits generated can be considered as a collective product of significant ecosystem services such as genepool protection, carbon storage, carbon sequestration, water provisioning, biological control, pollination, cultural heritage, recreation, nature interpretation, gas regulation, and climate regulation services that have a huge direct and indirect impact on human health.

Each tiger reserve is unique in itself. Some of them in terms of its location for acting as a corridor and/or buffer in a tiger landscape joining crucial tiger habitats and meta populations such as Bandipur Tiger Reserve, Pakke Tiger Reserve, Dudhwa Tiger Reserve and Valmiki Tiger Reserve. Some of them are unique in ecosystem value such as Dudhwa Tiger Reserve having Terai landscape features and a unique combination of wetland-grassland-woodland ecosystem. Similarly, Anamalai Tiger Reserve also encompasses a mosaic of ecosystems, Pakke Tiger Reserve depicts a unique Indo-Malaysian landscape and North-Eastern ecosystem and Panna Tiger Reserve has unique grassland-riverine-woodland ecology. Anamalai Tiger Reserve is also distinctive in terms of the Shola Forests within the TR which contains Grass Hill National Park and Kariyan Shola Forest both of which are critical biodiversity hotspots, rich in wildlife and contain many endangered and medicinal species. Dudhwa Tiger Reserve and Valmiki Tiger Reserve are also unique in terms of their placement along the international border and landscape sharing with Nepal. Tiger reserves like Melghat are one of the oldest and largest tiger reserves conserving tigers and biodiversity. Some tiger reserves have unique features such as Similipal Tiger Reserve which is the only Tiger Reserve which is the home of the Melanistic Tiger. The habitat value of all the tiger reserves is immense which is portrayed in various unique features. Panna Tiger Reserve is home to vultures and is an example of a successful tiger re-introduction case. All the tiger reserves are bestowed with rivers, springs, streams and other forms of waterbodies acting as vital sources of water in the lean season for the nearby areas. NSTR is unique with its management and water body showing that a proper management can help in the coexistence of human and natural infrastructure.

The popular perception of tiger reserves is that the tourists come there only for tiger sighting. To further explore the Tiger Reserves as tourism destinations, the study pilots the Destination Brand Survey which measures tourists Awareness/ Brand Identity, Image Attributes/Brand Perception, and Recommendation and Willingness to Visit for a particular Tiger Reserve. For the six tiger reserves of Phase-I, the survey was conducted to assess the brand equity of tiger reserves in terms of awareness, brand perception, intention to revisit and recommendation. The results of the exercise are envisaged to assist in identification of tourist perception to better equip protected area managers in managing these areas. It is proposed that such exercises be carried out for all tiger reserves in India for effective management of tiger reserves. The survey findings indicate that the visitors seek natural beauty and not just Tiger. Tiger Reserves like Corbett, Ranthambore and Kanha Tiger Reserves rank high in brand awareness. Sundarbans and Kanha are perceived to be unique destinations by 54 percent and 48 percent respondents (higher than others). In terms of the presence of religious, historical and cultural places, Ranthambore stands out among the lot. TRs like Corbett and Kanha are associated with scenic natural beauty while Kanha outperforms on the service-related parameters. It is also found that visitors have different perceptions across tiger reserves such as Corbett, Ranthambore and Kanha are perceived to be better on most of the parameters. Brand Equity score was highest for Kanha (296,) followed by Ranthambore (258) and Corbett (228).

While the common perception is that protected areas are a burden to local populations, the study findings indicate that tiger reserves are in fact beneficial if the local ecosystem services matrix is considered. Many benefits are provided by them at the local level including provisioning services from buffer areas, ecosystem services accruing at the local level such as pollination, and creation of employment for supporting tiger reserve 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.

Economic valuation not only helps in recognizing these benefits but also help in internalizing them into market and policy scenarios. Comprehensive analysis of ecosystem services may result in establishing partnerships with relevant stakeholders, effective policies and mechanisms for incentivizing conservation. 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. It is however important to mention here that valuation is not a panacea. Some important values that these tiger reserves 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.

For better management, it is important to put ecosystem services as a focal area in tiger reserve management. 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 the flow of ecosystem services in future, and is economically rational based on the study findings.

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. It is essential to integrate the values from these tiger reserves into the management of broader landscape and thus enhance ecological connectivity.

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 ten tiger reserves across the country. The study acknowledges the following major limitations which may be taken care of.

- High dependence on secondary literature to provide estimates on which the economic value for different ecosystem services is based upon.
- 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.
- 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, data on a number of parameters were obtained from tiger reserve authorities whose reliability could not be verified due to time constraints. In addition, data collection across tiger reserves is not standardized.
- Unavailability of site-specific data on specific input parameters (and constants) for the InVEST model. In such cases, global data has been used.

To streamline data collection for future endeavours, data collection formats have been provided with the report so that there is standardization and periodic data collection at tiger reserve level. Also, such protocols for data collection for ecosystem services need be incorporated in the Tiger Conservation Plans (TCPs) to ensure a formal system of data collection and reporting.

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# 10 Annexures

## Annexure-I

The following sections provide data collection protocols and formats for 15 ecosystem services at tiger reserve level.

### 1. Employment Generation

Step 1) Choose a zone of influence, i.e. the tiger reserve administrative boundary in this case.

Step 2) Identify various types of jobs provided to the locals as daily wagers i.e. the job categories. (*Example: Watchers, base camp labourers, maintenance labourers, construction labourers, strike force, etc.)

Step 3) Find the number of daily wage workers for each job category to calculate the number of man-days of employment generation and their respective wage rate. Collect data from ranges (if required) and aggregate to provide tiger reserve level estimates.

Data collection format (add rows if needed)

| **Name of the Tiger Reserve** | | | | **Year** |
|---|---|---|---|---|
| S. No. | Name of the component/work* (see example in Step 2) | Number of labourers employed | Number of days for which they are employed | Wage rate per day (Rs.) |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

### 2. Fishing

Step 1) Choose a zone of influence, i.e. the tiger reserve administrative boundary or just the buffer area.

Step 2) Identify the water-bodies where fishing is practised/allowed in the zone of influence and various types of fish species caught or other types of aquatic animals (if applicable) caught by the local people for market sale or self-consumption.

Step 3) Find the quantity (in kg) of total species-wise fish catchper year at range/division level. The per year fish catch can be calculated by estimating the weekly/daily fish catch for the fishing season and aggregating it accordingly.

Data collection format (add columns/ro0077s if needed)

| **Name of the Tiger Reserve** | | | | | **Year** |
|---|---|---|---|---|---|
| Fish Species/local name | Quantity of fish catch (kg) for TR Range/Division-1 (name of Range/Division) | Quantity of fish catch for (kg) TR Range/Division-2 (name of Range/Division) | Quantity of fish catch (kg) for TR Range/Division- 3 (name of Range/Division) | Quantity of fish catch (kg) for TR Range/Division- 4 (name of Range/Division) | Estimated average cost per Kg |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

### 3. Fuelwood

Step 1) Choose a zone of influence, i.e. the tiger reserve administrative boundary or just the buffer area.

Step 2) Gather data on the average quantity (in kg or tonnes) of fuelwood collected from the zone of influence per year from each range/division for market sale or self-consumption. Also find out the local market price.

Data collection format (add columns if needed)

| **Name of the Tiger Reserve** | | **Average Market Price Per Kg:** | | **Year** |
|---|---|---|---|---|
| Annual quantity Collected (Kg) from Division- 1 (Name of the Range/Division) | Annual quantity collected (Kg) from Division-2 (Name of the Range/Division) | Annual quantity collected (Kg) from Division-3 (Name of the Range/Division) | Annual quantity collected (Kg) from Division-4 (Name of the Range/Division) | Grand Total |
| | | | | |
| | | | | |

4. Fodder

Step 1) Choose a zone of influence, i.e. the tiger reserve administrative boundary or just the buffer area.
Step 2) Gather data on the number and type of livestock from each range/division in the zone of influence

Data collection format (add columns and rows if needed)

| **Name of the Tiger Reserve** | | **Average Market Price Per Kg:** | | **Year** |
|---|---|---|---|---|
| Type of livestock | Number of mentioned livestock in Range/Division-1 (Insert name of Range/Division) | Number of mentioned livestock in Range/Division-2 (Insert name of Range/Division) | Number of mentioned livestock in Range/Division-3 (Insert name of Range/Division) | Number of mentioned livestock in Range/Division-4 (Insert name of Range/Division) |
| Cattle Type | | | | |
| Cow | | | | |
| Ox | | | | |
| Sheep | | | | |
| Goat | | | | |
| Buffalo | | | | |

5. Timber (Stock)

Step 1) Choose a zone of influence, i.e. the tiger reserve administrative boundary or just the core/buffer area.
Step 2) Identify the forest types in the zone of influence. If possible, identify the canopy class or forest cover i.e. Very Dense Forest (VDF), Moderately Dense Forest (MDF) and Open Forest (OF) for each identified forest type.
Step 3) Gather data on growing stock for each canopy class or forest cover under the identified forest types.

Data collection format (add rows if needed)

| **Name of the Tiger Reserve** | | | **Year** |
|---|---|---|---|
| S.No. | Forest Type | Canopy Class or Forest Cover | Growing Stock (cubic m) |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

6. Bamboo

Step 1) Choose a zone of influence, i.e. the tiger reserve administrative boundary or just the core/buffer area.
Step 2) Gather data on bamboo collection (culms) from the zone of influence.
Data collection format (add columns if needed)

| **Name of the Tiger Reserve** | | **Average Price Per Kg** | | **Year** |
|---|---|---|---|---|
| Annual quantity collected (Kg) from Range/Division-1 (Insert name of Range/Division) | Annual quantity collected (Kg) from Range/Division-2 (Insert name of Range/Division) | Annual quantity Collected (Kg) from Range/Division-3 (Insert name of Range/Division) | Annual quantity Collected (Kg) from Range/Division-4 (Insert name of Range/Division) | Grand Total |
| | | | | |

7. NTFP

Step 1) Choose a zone of influence, i.e. the tiger reserve administrative boundary or just the buffer area.
Step 2) Identify the types of NTFP collected in the zone of influence by the local people for market sale or self-consumption.
Step 3) Find the quantity (in kg) of total species-wise/category-wise NTFP collection per year at range/division level.
Data collection format with some of the common NTFPs listed (add rows/columns if needed)

| **Name of the Tiger Reserve** | | | | **Year** | | |
|---|---|---|---|---|---|---|
| Sl. No. | NTFP Type | Quantity of NTFP collected in Range/Division-1 (Insert name of Range/Division) | Quantity of NTFP collected in Range/Division-2 (Insert name of Range/Division) | Quantity of NTFP collected in Range/Division-3 (Insert name of Range/Division) | Quantity of NTFP collected in Range/Division-4 (Insert name of Range/Division) | Avg Price per kg |
| 1 | Tamarind, Deseeded | | | | | |
| 2 | Tamarind, Tamarind Seed | | | | | |
| 3 | Mahua Flower | | | | | |
| 4 | Hill Brooms | | | | | |
| 5 | Thorn Broom (Jhadu or Ghoda Lanji) | | | | | |
| 6 | Phula Jhadu | | | | | |
| 7 | Broom Grass | | | | | |
| 8 | Nux Vomica (Kochila Seeds) | | | | | |
| 9 | Harida Myrobolons | | | | | |
| 10 | Bahada | | | | | |
| 11 | Amla | | | | | |
| 12 | Soap Nut (Ritha Phala) | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | Marking Nut (Bhalia) | | | | | |
| 14 | Cleaning Nut (Nirmala) | | | | | |
| 15 | Honey | | | | | |
| 16 | Siali Leaves | | | | | |
| 17 | Sabai Grass | | | | | |
| 18 | Mango Kernel | | | | | |
| 19 | Thatch Grass | | | | | |
| 20 | Simul Cotton | | | | | |
| 21 | Arrow Root (Palua) | | | | | |
| 22 | Dhatuki Flower | | | | | |
| 23 | Putrani | | | | | |
| 24 | Sikakai | | | | | |
| 25 | Jungal Jada or Gaba | | | | | |
| 26 | Palasa Seeds | | | | | |
| 27 | Siali Seeds | | | | | |
| 28 | Indro Jaba (Korai Seed) | | | | | |
| 29 | Gila (Seed and Coat) | | | | | |
| 30 | Benachera | | | | | |
| 31 | Bana Haladi | | | | | |
| 32 | Bana Kolatha | | | | | |
| 33 | Gaba | | | | | |
| 34 | Basil | | | | | |
| 35 | Makhana Seeds (Kanta Padma) | | | | | |
| 36 | Tala Makhana Seeds | | | | | |
| 37 | Baidanka Seeds | | | | | |
| 38 | Baghanakhi Seeds | | | | | |
| 39 | Kamala Gundi Fruit | | | | | |
| 40 | Landa Baguli | | | | | |
| 41 | Bela | | | | | |
| 42 | Chiratta (Bhui Neem) | | | | | |
| 43 | Khajuripata | | | | | |
| 44 | Rohini Fruit | | | | | |
| 45 | Bhursunga Leaves | | | | | |
| 46 | Rasna Root | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 47 | Phenphena Fruit | | | | | |
| 48 | Sidha Fruit | | | | | |
| 49 | Sathabari | | | | | |
| 50 | Katha Lai | | | | | |
| 51 | Atundi Lai | | | | | |
| 52 | Khelua Lai | | | | | |
| 53 | Suam Lai | | | | | |
| 54 | Eksira Fruit | | | | | |
| 55 | Katha Chhatu(mushroom) | | | | | |
| 56 | Mat Reed (Sapa Masina Grass) | | | | | |
| 57 | Ananta Mula | | | | | |
| 58 | Antia Pata | | | | | |
| 59 | Nageswar Flower | | | | | |
| 60 | Mankad Kendu | | | | | |
| 61 | Atundi Fruit | | | | | |
| 62 | Mahua Seeds | | | | | |
| 63 | Kusum Seeds | | | | | |
| 64 | Karanja Seeds | | | | | |
| 65 | Neem Seeds | | | | | |
| 66 | Char Seeds | | | | | |
| 67 | Chakunda Seeds | | | | | |
| 68 | Babul Seeds | | | | | |
| 69 | Any other item(s) as may be notified by the government | | | | | |
| 70 | Sal Leaves | | | | | |
| 71 | Sal Resin (Jhuna) | | | | | |
| 72 | Gums (Dharua Gum, Babul Gum, Genduli Gum, Bahada Gum, Palas Gum, Salai Gum, etc.) | | | | | |
| 73 | Khaira and Catechu | | | | | |
| 74 | Barks of Trees/Climbers (Sunari, Lodha, Medha, Phenaphena, Arjuna Barks, etc.) | | | | | |
| 75 | Roots of Patala Garuda (R.S. roots) | | | | | |
| 76 | Sandalwood | | | | | |
| 77 | Tassar Cocoon | | | | | |
| 78 | Canes | | | | | |

### 8. Water Provisioning and Water Purification

Step 1) Choose a Zone of influence by mapping the beneficiaries.

Step 2) Identify the major dams and other sources of water supply from the tiger reserve to the zone of influence. Map the cities/areas/number of beneficiaries of the water supply.
Data collection format along with list of main data requirements (add columns if needed)

| **Name of the Tiger Reserve** | | **Year** | |
|---|---|---|---|
| **Details** | **Dam 1** | **Dam 2** | **Dam 3** |
| Name of the dam | | | |
| Built on river (give name) | | | |
| Total capacity (in cubic metres) | | | |
| Established in (give year) | | | |
| Cost of establishment (in rupees) | | | |
| Estimated life-span of the dam (in years) | | | |
| Average annual water holding (in cubic metres) | | | |
| Water holding/supply in lean (dry) season (in cubic metres) | | | |
| Water supplied to (name of the dependent cities/villages/other human settlements) | | | |
| Total area under irrigation by water supply from the reserve (in hectares) | | | |
| Approximate number (human population)which are beneficiaries of water supplied from the tiger reserve (give estimated number for total water supply) | | | |
| Approximate number (human population)which are beneficiaries of drinking water supplied from the tiger reserve (give estimated number for total drinking water supply) | | | |
| Water supplied quantity for drinking (in cubic metres) | | | |
| Water supplied quantity for irrigation (in cubic metres) | | | |
| Water supplied quantity for industrial use, if any (in cubic metres) | | | |
| Cost of water purification from local purification plant or municipal corporation (in rupees) for per cubic metre of water | | | |
| Rate of water supplied for drinking (per cubic metre (in rupees)) | | | |
| Rate of water supplied for irrigation (per cubic metre (in rupees)) | | | |
| Rate of water supplied for industrial use (per cubic metre (in rupees)) | | | |
| Cost of de-siltation (in rupees) per year | | | |

9. Pollination

Step 1) Choose a zone of influence, i.e. the extent of flow of pollination service to neighbouring areas. For simplification take a two or five km buffer along the tiger reserve administrative boundary.
Step 2) Identify the types of pollinator species in the tiger reserve benefitting horticulture crops in the zone of influence and gather data on their average travel distance. Fill in the details below (add rows if needed).

| S. No. | Pollinator Species Identified | Maximum Distance Travelled by the Species From its Hive (in metres) |
|---|---|---|
| | | |
| | | |
| | | |

Step 3) Find the quantity (in kg) of crop production, cultivation areas and per hectare yield of the crops (mainly horticulture crops) in the zone of influence. Fill the detail in the following format (add rows if needed).

| **Name of the Tiger Reserve** | **Year:** |
|---|---|

| S. No. | Crop Name | Production Quantity (in Kg) | Area Under Agriculture (in Hectares) | Yield (Production in Kg Per Ha) | Rate Per kg (in Rs.) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

### 10. Cultural Heritage

Step 1) Identify the major tribes and traditional sites of important cultural and historical significance inside the tiger reserve.

Step 2) Gather data on the tribes and the sites on population, indigenous status, importance of the tiger reserve forests/biodiversity in their lives and culture, major festivals and traditions. Data may be collected through focused group discussion or household survey and fill in the following format (add rows if needed)

| S.No. | Tribe | Population | Indigenous (Yes/No) | Years of Residence in the Area | Remarks (From FGD)/Detailed Account on Festivals, Traditions and Biodiversity Impacting Their Culture. |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

### 11. Recreation

Step 1) Identify the major tourism sites inside the tiger reserve.

Step 2) Gather data on the annual footfall for the identified sites. Also collect data on the following points as listed in the following format.

| **Name of the Tiger Reserve** | |
|---|---|
| Tourist Season (specify months) | |
| Major tourists spots in the TR (please give a detailed account) | |
| Average number of foreign tourists (per year) | |
| Average number of indian tourists (per year) | |
| Average visitation in the last five years | |
| Annual Gate receipts (in rupees) | |
| Other fee/tax collected by tourists (in rupees) also specify category of tax (e.g. equipment/camera fee) | |
| Number of gypsy permits issued (per year) | |
| Cost of one permit (in rupees) | |
| Total annual revenue of the tiger reserve (in rupees) | |
| Revenue generating activities | |
| Are you aware of any consumer surplus or Willingness to Pay (WTP) studies being conducted in the TR? (Yes/No) | |
| If yes, please mention such studies (title, author(s) and year of publication) | |
| Please specify year of the data collected | |

### 12. Spiritual Tourism

Step 1) Identify the major sites of spiritual and religious significance inside the tiger reserve.

Step 2) Gather data on the annual footfall for the identified sites.

Data collection format (add rows if needed)

| **Name of the Tiger Reserve** | | **Year** |
|---|---|---|
| S.No. | Name of the Site/Sacred Grove | No. of Visitors / Year |
| | | |
| | | |
| | | |

### 13. Research, Education and Nature Interpretation

| | |
|---|---|
| Does the TR have any interpretation centre? (YES/NO) | |
| Footfalls in the interpretation centre/ number of people visiting the interpretation centre (annually) | |
| Price of entry ticket in the interpretation centre(s) (if any) | |
| Number of educational/school/college trips (per year) | |
| Total number of PhD theses on the tiger reserve till ____________(insert date) | |
| Number of research scholars working currently in the tiger reserve | |
| Number of papers/research work published on the TR | |
| Major topics of research on the TR | |

### 14. Carbon storage

Calculating carbon storage requires an element of technical input and may require modelling via available softwares like InVEST. However, the attached data collection format provides an overview of the data requirement for calculating the total bio-physical carbon stock.

Step 1) Choose a zone of influence, i.e. the tiger reserve administrative boundary or just the core/buffer area.
Step 2) Identify the vegetation class/forest types in the zone of influence. If possible, identify the canopy class or forest cover, i.e. Very Dense Forest (VDF), Moderately Dense Forest (MDF) and Open Forest (OF) for each identified forest type.
Step 3) Gather data on carbon stock (per hectare estimates) in various pools such as Above Ground Biomass (AFB), Below Ground Biomass (BGB), Soil Organic Matter (SOM) and Dead Wood (including litter) to calculate total carbon stock in all the pools which is to be used in conjunction with area estimates under each each forest cover/canopy class for the identified forest types. This data may also be obtained from secondary sources and forest-data collecting institutions.

Data collection format (add rows if needed):

| Vegetation Class/Forest Type | | Carbon Stock in Various Pools(tonnes C/ Hectares) | | | | Total Carbon Stock (tC/ha) | Total Area (ha) | Total Carbon Stock (tC) |
|---|---|---|---|---|---|---|---|---|
| | Forest Cover | AGB | BGB | SOM | DW (incl. litter) | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

### 15. Carbon Sequestration

Step 1) Choose a zone of influence, i.e. the tiger reserve administrative boundary or just the core/buffer area.
Step 2) Identify the vegetation class/forest types in the zone of influence. If possible, identify the canopy class or forest cover, i.e. Very Dense Forest (VDF), Moderately Dense Forest (MDF) and Open Forest (OF) for each identified forest type.

Step 3) For bio-physical estimation of carbon sequestration requires per hectare growing stock data as input to calculate per hectare total biomass which in turn is used to Mean Annual Increment (MAI). This data is then extrapolated on the basis of area under each forest cover/canopy class for the identified forest types.

Data collection format (add rows if needed)

| Forest Type | Forest Cover | Total Biomass Per Unit Area (tonnes/ha) | Mean Annual Increment Per Unit Area (tonnes/ha) | Area (ha) | Total Annual Carbon Sequestration (tC) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |

While tiger reserves are storehouses of ecological infrastructure providing various ecosystem services, it may be noted here that each and every ecosystem service may not be relevant to the context of a particular tiger reserve. This may occur due to multiple factors such as lack of proper understanding of its ecological processes, viability of data collection/assessment, technological restraints and existing trade-offs (especially in the case of provisioning services such as fuelwood, NTFPs, fodder/grazing etc.

Ecosystem services such as soil conservation/sediment retention and nutrient retention may require modelling or extensive primary research to assess the quantum of bio-physical benefits generated and further its utility in economic valuation. For some of the regulating services like moderation of extreme events, Habitat for Species, gas regulation, waste assimilation, nursery function, biological control, genepool-protection and climate regulationthe data collection process is a technical and long-term research and therefore cannot be interpreted from a simple data collection format. However to provide further guidance for data collection and valuation of such services, frameworks for a manual have been developed by the Indian Institute of Forest Management which may be accessed here: http://globaltigerforum.org/wp-content/uploads/2017/07/Economic-valuation-guidelines.pdf.

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## DISCLAIMER

The views expressed and any errors herein are entirely those of the authors. The views expressed do not necessarily reflect those of and cannot be attributed to the study advisors, contacted individuals, institutions and organizations involved. The information contained herein has been obtained from various sources including the respective Uttarakhand Forest Department, Forest Survey of India, discussions with stakeholders, a review of publications, deliberations of the workshops conducted and are to the best of our knowledge accurate. Despite all precautions taken to accurately reflect the information that was collected for this report, any errors pointed out subsequently by any party cannot lead to any liability on the part of the authors. The contents of this report may be used by anyone providing proper acknowledgements.

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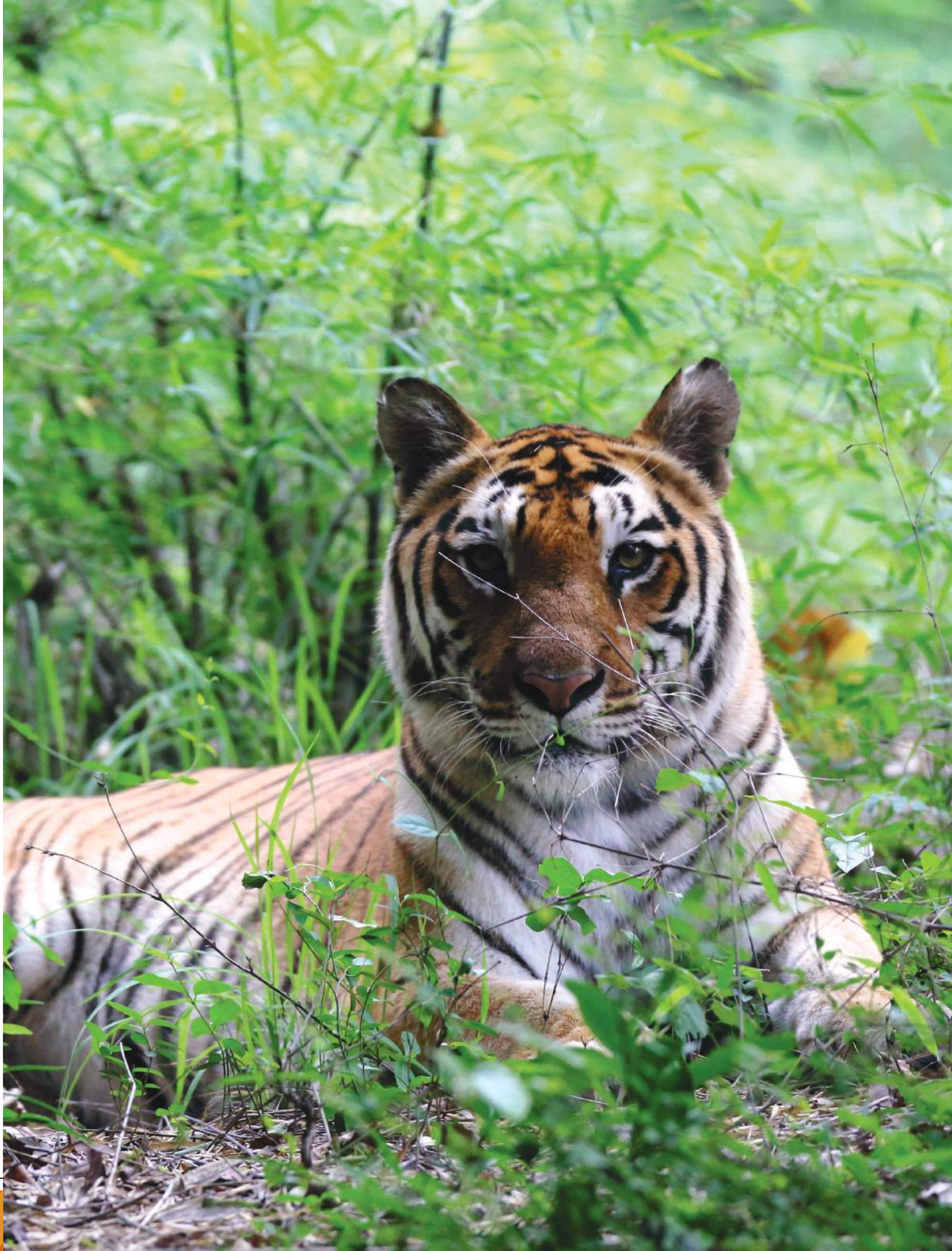
Established in 1982, the Indian Institute of Forest Management is a sectoral management institute, which constantly endeavours to evolve knowledge useful for the managers in the area of Forest, Environment and Natural Resources Management and allied sectors. It disseminates such knowledge in ways that 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."

CESM is a centre of excellence established in 2007 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.



## About the Report

Tiger reserves are repositories of natural ecosystems and biodiversity which continuously emanate a wide range of economic, social, cultural and spiritual benefits essential for human well-being. Tiger reserves preserve the wilderness and natural systems which support ecological processes responsible for providing various goods and services. The Centre for Ecological Services Management (CESM) at the Indian Institute of Forest Management (IIFM) executed the study entitled "Economic Valuation of Tiger Reserves in India: A Value+ Approach" commissioned by the National Tiger Conservation Authority (NTCA), during 2013- 15. Recognizing the management and policy relevance of the work, an extension of the study was suggested by NTCA and hence the second phase of the study was sanctioned to conduct the economic valuation of ten more tiger reserves and also improve upon the estimated values from the previous six tiger reserves and incorporate new methodologies and frameworks. To accomplish the same, Phase-II of "Economic Valuation of Tiger Reserves in India" was assigned to CESM, IIFM by NTCA, which has been executed during 2016-19. The report presents outcomes of quantitative and qualitative estimates of economic valuation for 26 ecosystem services from ten Tiger Reserves across various Tiger Landscapes in India. The study attempts to incorporate a wide range of the associated monetary and non-monetary values to provide a comprehensive assessment of the selected tiger reserves. Acknowledging that each tiger reserve is unique and has its own set of values, the same has been highlighted using latest IPBES protocols and other widely accepted frameworks. The report presents outputs of modelling of three ecosystem services using InVEST software. The report also includes the outcome of the pilot study on exploring tiger reserves as Destination Brands and data collection protocols for streamlining data collection process for institutionalising assessments on ecosystem services.

प्रगतेः मूलं प्रकृतिः

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