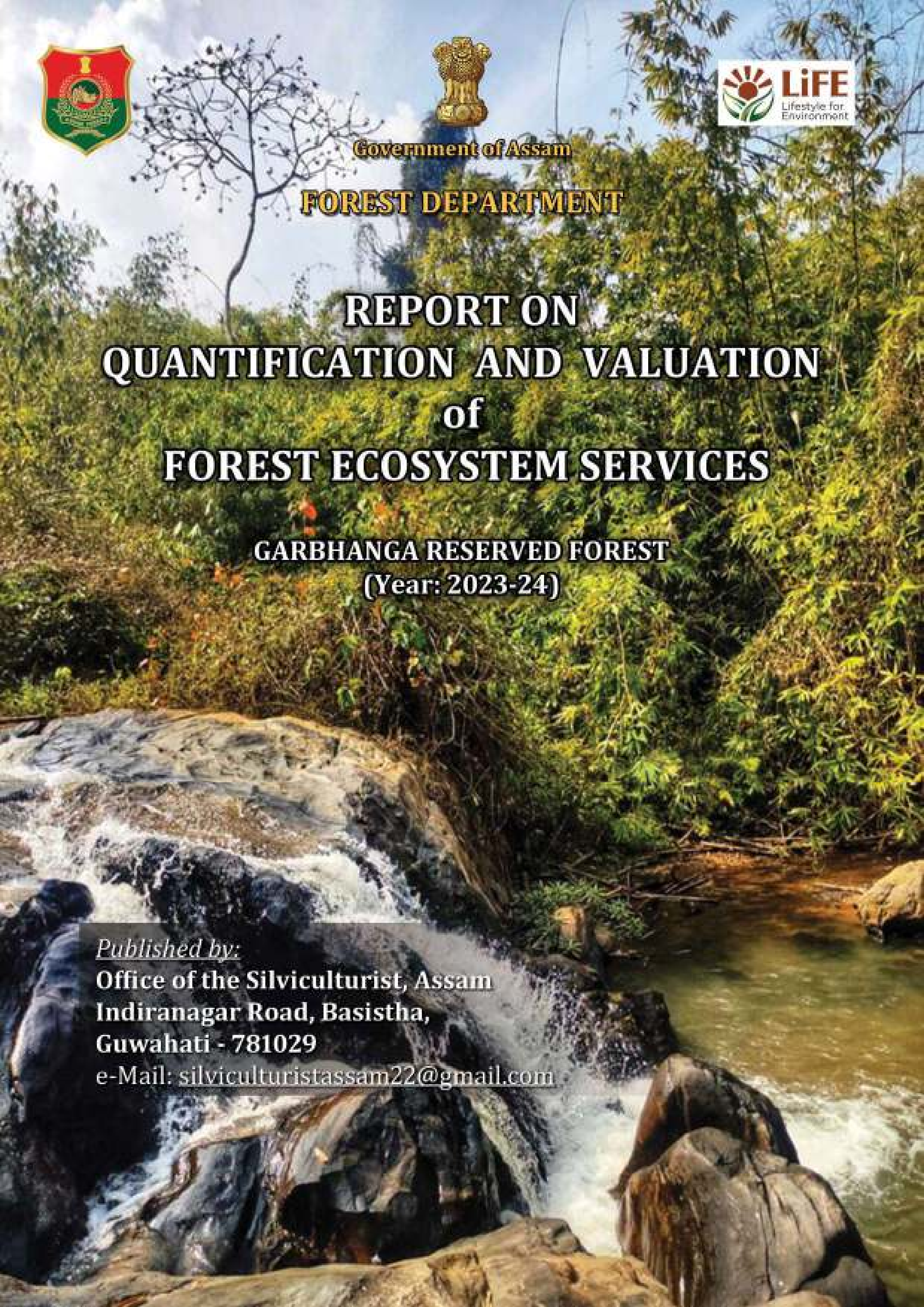
Government of Assam

FOREST DEPARTMENT

REPORT ON QUANTIFICATION AND VALUATION of FOREST ECOSYSTEM SERVICES

GARBHANGA RESERVED FOREST
(Year: 2023-24)



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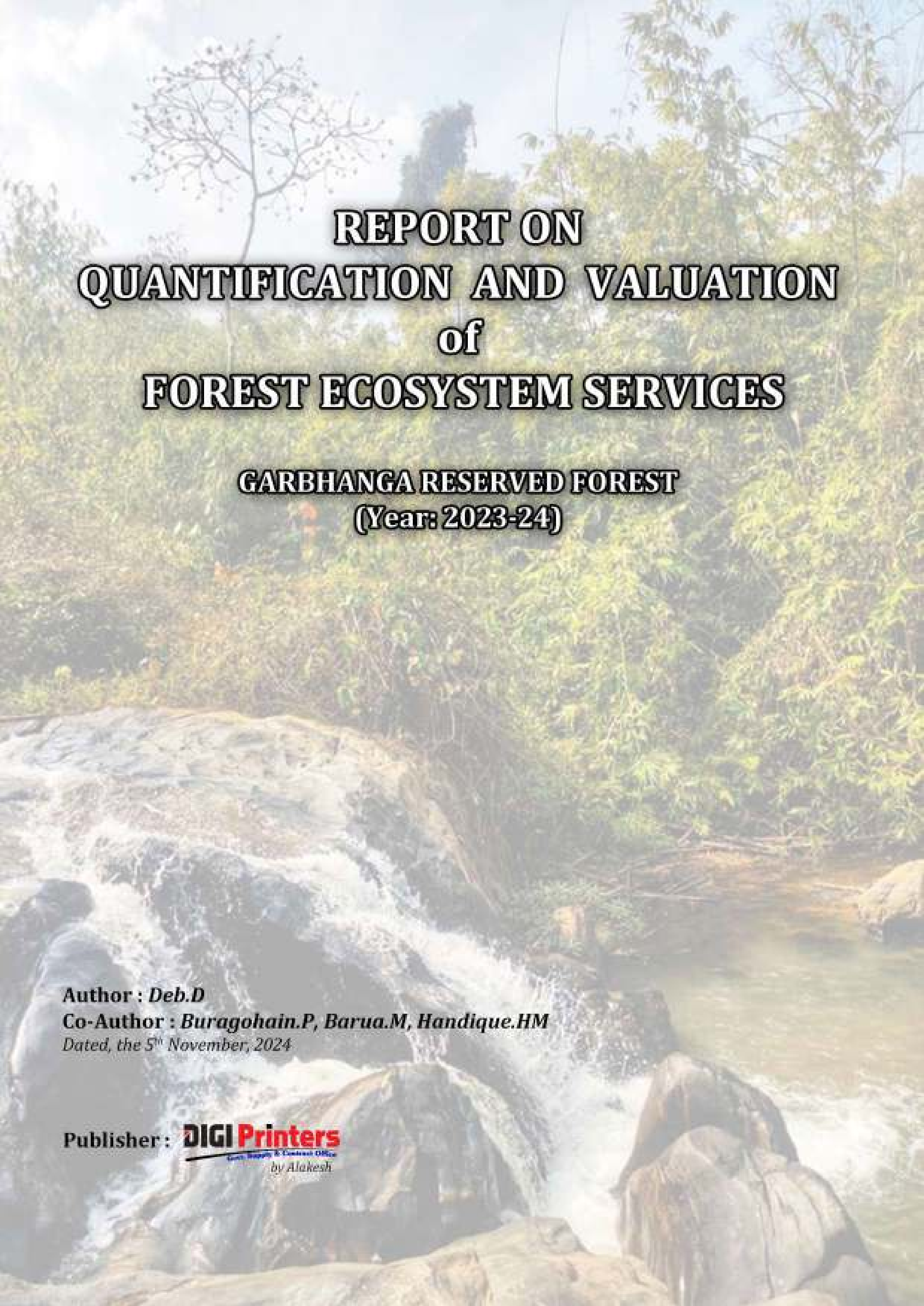

REPORT ON QUANTIFICATION AND VALUATION of FOREST ECOSYSTEM SERVICES

GARBHANGA RESERVED FOREST
(Year: 2023-24)

Author : ***Deb.D***
Co-Author : ***Buragohain.P, Barua.M, Handique.HM***

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চন্দ্ৰমোহন পাটোৱাৰী
মন্ত্ৰী
পৰিবেশ আৰু বন,
এক্ট ইষ্ট পলিছী এফেয়াৰ্ছ
সংখ্যালঘু কল্যাণ বিভাগ, অসম

Chandra Mohan Patowary
Minister
Environment & Forests Department
Act East Policy Affairs Department
Welfare of Minorities Department
Government of Assam

Date: 6/11/2024

MESSAGE

I am happy to know that Silviculturist, Assam, Environment and Forests Department is going to publish a report on "Quantification and Valuation of Forest Ecosystem Services for Garbhanga Reserved Forest (2023-24)". This meticulous work highlights the invaluable services our forests provide and offers a comprehensive economic valuation of these benefits.

The report showcases how Garbhanga Reserved Forest plays a crucial role in water retention, carbon sequestration, and climate regulation, among other ecosystem services, and it emphasizes the importance of factoring these contributions into Assam's Gross State Domestic Product (GSDP). Such insightful findings will greatly aid our efforts in sustainable forest management and help guide policy decisions that balance economic development with ecological preservation.

I commend the team's dedication in aligning this study with global frameworks, ensuring its scientific perspective and relevance. It is through such initiatives that we can build a future where our forests continue to thrive, benefiting both nature and the people of Assam. This report will serve as a valuable tool in our shared mission of forest conservation and sustainable development.

I extend my sincere appreciation to everyone involved in the preparation of the report. I hope that the report will be appreciated as a ready reckoner by all forest enthusiasts, including students, scholars and researchers.

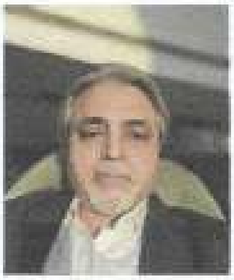
(Chandra Mohan Patowary)

Room No. 201, 'Janata Bhawan', Block 'F', 2nd Floor, Dispur, Guwahati-781 006, Kamrup (M) Assam, India
0361-2237014 cmpatowary02@gmail.com, cmpatowaryoffce@gmail.com

GOVERNMENT OF ASSAM
OFFICE OF THE PRINCIPAL CHIEF CONSERVATOR OF FORESTS &
HEAD OF FOREST FORCE, ASSAM
ARANYA BHAWAN, PANJABARI :: GUWAHATI-37

Phone No. (Off) 0361-2333252

Fax No. 0361-23337386
E-Mail: hoff-assam@gov.in



Sandeep Kumar, IFS
Principal Chief Conservator of Forests &
Head of Forest Force, Assam

Message

I am delighted to congratulate the entire team led by the Silviculturist, Assam on the successful completion of the pilot project on "Quantification and Valuation of Forest Ecosystem Services for Garbhanga Reserved Forest." This report is a landmark achievement, showcasing the immense value of our forests not only in terms of biodiversity but also as a key economic resource for Assam.

One of the most exciting aspects of this is the 'Carbon estimation', which has great potential in carbon trading. With accurate data and reliable models, this report sets a benchmark for future assessments of Carbon and other ecosystem services, guiding similar efforts in reserved forests, plantations & Protected Areas across the state.

The dedication and teamwork have produced a report that strengthens our ability to make appropriate decisions for sustainable forest management. I am confident that this work will inspire similar projects throughout the department, ensuring that Assam's forests are recognized for all the benefits they bring to our environment and economy.

I thank all the officers involved in the project for their hard work and commitment. The project report will provide suitable guidance on forest ecosystem service valuation and carbon trading.

Sandeep Kumar, IFS

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ARANYA BHAWAN, PANJABARI :: GUWAHATI-37.

E-Mail: statecampaassam@gmail.com

Dr. Satyendra Singh, IFS
Addl Principal Chief Conservator of Forests
& Chief Executive Officer
Assam State CAMPA

Message

I feel glad to endorse the publication of the report "Quantification & Valuation of Forest Ecosystem Services at Garbhanga Reserved Forest" for the year 2023-24 by the Silviculturist, Assam funded by CAMPA. This maiden effort by the Assam Forest Department marks a significant milestone in our commitment to understand and showcase the immense value of our forest ecosystem. The report stands as a document to the comprehensive approach undertaken despite limited financial resources.

I extend my heartfelt gratitude to Shri Dibakar Deb and his entire team for their exemplary efforts with dedication and hard work. This achievement not only enriches our knowledge base but also sets a benchmark for similar endeavours in the future.

Dr. Satyendra Singh, IFS

কাজিৰঙা ৰাষ্ট্ৰীয় উদ্যান আৰু ব্যাঘ্ৰ
সংৰক্ষিত বনাঞ্চল
काजीरंगा राष्ट्रीय उद्यान और टाइगर रिजर्व
Office of the Field Director
Kaziranga National Park & Tiger Reserve, Bokakhat Assam: 785612
Tel: +91- 941205121; Email: dir.kazirangan p@gmail.com
Website: https://kaziranga.nptr.in/

Dated: 29/10/2024

MESSAGE

It is indeed a matter of pride and honour for me to share a message for this pioneering work undertaken by Silviculture Division of Assam Forest Department on Valuation of Forest Ecosystem Services in the Garbhanga Reserved Forest.

Ecosystem services or Nature's contribution to People (NCPs) is broadly the monetary value of benefits freely accrued from nature. Various scientists and academics classify the valuation of these services using different economic methods, and they are broadly classified as Provisioning, Regulating, Cultural and Supporting services. However, in all the methods, the primary data collection is essential towards the economic evaluation.

In this regard, this study conducted entirely by the Research Education and Working Plan wing with systematic vegetation sampling, questionnaire survey, etc in and around Garbhanga RF has been the first of its kind in the State and Country.

The detailed data collection has been helpful to evaluate the ecosystem services that included a valuation of the drinking water, soil health, forest produce, carbon sequestration and benefits to the community.

I am delighted that the extensive sampling design and the methodology was fine-tuned over several deliberations during my tenure at REWP and duly executed by Shri Dibakar Deb Silviculturist and his team in the subsequent years. I congratulate one and all for this monumental work.

With Best Wishes,

(Dr. Sonali Ghosh, IFS, CCF)
Field Director,
Kaziranga National Park & Tiger Reserve
Bokakhat: Assam: 785612

Dr. Parimal Ch Bhattacharjee, Ph.D.

***Former Professor & Head**, Dept of Zoology, Gauhati University*
***President**, Northeast Science Movement. (NESM)*
***Emeritus Trustee**, Wildlife Trust of India (WTI)*
***Fellow**, International Ornithologist's Union (IOU)*
***Member**, IUCN Primate Special Group*
***Chairman**, Research Advisory Council, Assam State Biodiversity Board (ASBB)*

Foreword

In the contemporary world, landscapes are increasingly valued by the worth assigned to their natural resources. The cultural perspectives of people shape their appreciation and valuation of the living natural resources. Assam, a land rich in biodiversity, is home to endemic and ancient species of plants and animals, influenced by the Indo-Malayan, Afro-tropic, and Indo-Chinese bio-geographical realms, along with the Himalayan and Peninsular Indian elements. The state holds a remarkable variety of wild plants, serological insects, and more, many of which await thorough exploration.

Assam is fortunate to contain critical components of both economic and cultural progress. Its landscapes form part of two globally recognized biodiversity hotspots: the Eastern Himalayas and Indo-Burma. These areas host essential life forms across forests, wetlands, grasslands, and even urban spaces. Yet, in our current economic regime, natural assets are often overlooked unless they are economically quantified. Though the deeply nature-centric lifestyle of people of Assam celebrating numerous nature-based festivals, the actual economic value of these resources still sometimes has not appropriately surfaced.

The forests of Assam are an irreplaceable resource. They offer carbon sequestration, food and nutrition, safeguard water resources, contribute to soil formation and protection, store and recycle nutrients, break down pollutants, support climate stability, and harbor life from micro-organisms to elephants. Traditional and indigenous communities have played a vital role in preserving these forests, often regarding them as 'sacred.'

Until now, the total economic value of these ecosystem services has not been systematically measured in terms of local context. This pioneering project titled ***'Quantification & Valuation of Forest Ecosystem Services at Garbhanga Reserved Forest'*** carried out by the Silviculturist, Assam & his team of Environment & Forest Department marks a milestone as it delivers a comprehensive economic assessment of a forested landscape's multidimensional contributions. For the first time, the impact of forest ecosystem services on Assam's GSDP is quantified, an invaluable addition to the state's economic indicators. I am delighted to witness the success of this project and extend my heartfelt congratulations to the team & Assam Forest Department for their dedication and meticulous effort.

"Nature is not a place to visit, it is home." — ***Gary Snyder***

Dr. Parimal Ch Bhattacharjee

GOVERNMENT OF ASSAM
OFFICE OF THE SILVICULTURIST, ASSAM
BASISTHA :: GUWAHATI-29

Phone: +919508118957 **Email: silviculturistassam22@gmail.com**

Dibakar Deb, AFS
Silviculturist, Assam

PREFACE

The concept of assessing the economic value of forests has gained significant relevance in recent years as the vital role that natural ecosystems play in both environmental stability and economic development. In 2018, during my previous tenure as the Silviculturist, Assam, the idea was coined about how a structured economic valuation of forest ecosystem services could offer a transformative perspective on the invaluable contributions of forests of Assam. This approach not only acknowledges the ecological importance of our forested landscapes but also aims to reflect their economic value within the broader framework of Assam's economy. With this vision, we initiated a formal pilot project titled ***'Quantification & Valuation of Forest Ecosystem Services at Garbhanga RF'*** in 2023, supported through CAMPA funding, to make this pioneering effort a reality.

One of the core objectives of this project is to emphasize on the importance of forests including the economic value of forest ecosystem services in Assam's Gross State Domestic Product (GSDP). Forests provide a wealth of essential services, from carbon sequestration, water regulation, and nutrient cycling to climate stabilization, and support for biodiversity. Historically, these benefits have not been reflected in economic matrices, leading to an undervaluation of forests in economic policy. By integrating the economic contributions of forests into Assam's GSDP, there is a scope of more accurate and comprehensive measure of the state's wealth, capturing both its natural capital and environmental contributions.

This project demanded nearly eighteen months of dedicated effort, encompassing development of strategies for execution of the project, meticulous planning of data collection methodologies, effective human resource management to drive labour-intensive field data collection, integration of scientific insights, thorough data analysis, and the preparation of a comprehensive report.

Moreover, this comprehensive project report includes a carbon estimation protocol that serves as a model for future assessments of carbon stocks across Assam's forests and plantations. This protocol provides the foundation for potential carbon trading initiatives, aligning with national and global climate commitments and creating economic incentives for forest conservation.

This project has been a collaborative achievement, driven by partnerships with multiple prestigious institutions. We extend our deepest appreciation to NESAC, ASSAC, IIT Guwahati, TISS Guwahati, the Department of Environmental Science at Gauhati University, Department of Agriculture, Cotton University, USTM & all educational institutions for providing essential lab facilities and research support. Their collaboration has allowed us to conduct a rigorous analysis that integrates both scientific accuracy and practical insights, ensuring the project meets the highest standards.

I am honoured to express my thanks to Shri M.K. Yadava, Retd. IFS and Special Chief Secretary, Environment & Forest, Govt. of Assam, for his expert advice on the critical aspects of forest ecosystem service valuation. His experience and vision have greatly enhanced the depth and comprehensiveness of our

report. I extend my gratitude to Dr. Sonali Ghosh, IFS, for facilitating the smooth execution of the field exercise by deputing an adequate number of frontline staff from other divisions under the RE & WP wing during her tenure. This project has further benefited from the invaluable guidance of Dr. Parimal Ch Bhattacharjee, Former Professor and Head of Zoology at Gauhati University. His continuous support, scientific insights, and editorial guidance during report writing have enriched our work with a strong academic foundation. I convey my sincere gratitude for him.

I extend my sincere thanks to Dr. Paramita Dey, Associate Professor, Department of Chemistry, St. Mary's College, Shillong, and Dr. Priyanka Kumar, Assistant Professor, University of Texas at Permian Basin, Texas, for their invaluable expertise. Their guidance on the analysis of physiological data, digital data management, and advanced analytical methods has been instrumental in this work.

I am especially grateful to the core technical team & co-authors whose diligent work was central to the success of this project. Smt. Preeti Buragohain, Dy. Conservator of Forests, Sri Mrigen Barua, Asstt. Conservator of Forests, and Smt. Himamoni Handique, Research Officer, provided exceptional leadership in crafting a robust strategy for primary data collection. Their efforts in coordinating with various agencies, organizing interviews, and managing scientific data inputs have been indispensable in creating a comprehensive database and structured methodology for this project.

Additionally, I extend my sincere gratitude to all the frontline staff, guided by Sri Abhijeet Doley FR, Smt. Kasturi Goswami FR, Smt. Nigar Sultana FR, Smt. Munmi Gogoi FR, Smt. Pallavi Das FR, Smt. Panchali Hazarika FR, Sri Dharmeswar Nath FR, Pranjal Das Fr-I, Himangshu Bhattacharya Fr-I, Gayatri Gogoi Fr-I who led the on-ground efforts as team leaders. They carried out the complex and labour-intensive tasks of field data collection, ensuring accurate sampling, meticulous management of samples, and consistent digital data entry. Their work in challenging field conditions made this project possible. I also appreciate the contributions of Smt. Kankana Choudhury, Smt. Rekha Borgohain & Parasmita Bora, all of them Post-Graduate Interns, for their commitment to digital data management, precise measurement of field samples, and assistance in various calculations. Their dedication to detail has ensured the accuracy of our data, which forms the foundation of this report. I would further like to thank the DFO, Kamrup(E) Division & his staffs for extensive cooperation for carrying out field works & making required secondary data on Garbhanga RF available to us. I extend my sincere appreciation for DFO FRS Division, Director Forest School, DFO Genetic Cell Division for providing adequate human resource support.

We also extend our sincere thanks to the CAMPA authority for their crucial funding, which made this ambitious project possible. Without their financial support, we could not have achieved this level of research, which has truly set a milestone for forest ecosystem valuation in Assam.

The outcomes of this report open a new chapter for integrating the economic value of forest ecosystem services into Assam's Gross State Domestic Product (GSDP). This is a groundbreaking step, as it not only indicates the ecological value of Assam's forests but also positions them as key economic assets in the state's growth narrative. Additionally, the carbon estimation protocol developed during this project will serve as a valuable tool for future carbon assessments across Assam's forests and plantations. This protocol offers a scientifically grounded framework for advancing carbon trading initiatives, allowing the state to contribute meaningfully to national and global climate goals.

It is my hope that this report will help policymakers, researchers, and environmental advocates as they work to protect, utilize, and sustainably manage Assam's invaluable forest resources. Integrating forest ecosystem services into the state's macro-economic calculations marks a transformative step, ensuring that the contributions of forests of Assam are recognized and valued for generations to come.

Thanking you

Dibakar Deb

EXECUTIVE SUMMARY

This comprehensive research report aims to quantify and value the diverse ecosystem services provided by the Garbhanga Reserved Forest (RF), thereby help develop sustainable management practices and policy formulation. Despite forests covering approximately 36% of Assam's landmass and contributing significantly to societal well-being, their economic value is overlooked in traditional economic indicators, including the Gross State Domestic Product (GSDP) of Assam for 2023-24 which amounts to *₹ 5,70,243 Cr.*

OBJECTIVES AND METHODOLOGIES

The primary objectives of the research include establishing benchmarks, implementing monitoring programs, engaging stakeholders, reviewing best practices, designing standardized protocols, providing capacity building, pilot testing, and disseminating findings. By assessing the magnitude of ecosystem services, understanding drivers of change, refining quantification methods, estimating economic values, informing policy, enhancing stakeholder engagement, and contributing to knowledge sharing, the research aims to bridge the gap between science and policy for effective forest conservation and management.

The methodologies for assessing Forest Ecosystem Services (ES) align with the principles of the Millennium Ecosystem Assessment (MA), The Economics of Ecosystems and Biodiversity (TEEB). These frameworks ensure the credibility and comparability of the findings.

KEY FINDINGS

- Domestic Water Consumption: The total yearly domestic water consumption across 19 villages in the Garbhanga Forest ecosystem is *95,239,450* litres, with an average daily consumption per household of *538* litres.
- Forest Products Consumption: Products such as forest food, ethnic medicine, minor forest produce (MFP), small timber, firewood, bamboo, and fodder are consumed extensively, showcasing the significant reliance on forest resources for sustenance and livelihoods.
- Water Retention: During the year, the least quantity of water retained by Garbhanga RF is 2.993×10^{15} Ltr which includes waterbodies, biomass and soil providing valuable insights into the hydrological dynamics of the ecosystem.
- Temperature Regulation: The forest is generally cooler than Guwahati City by approximately *3.27°C* annually, illustrating its role in local climate regulation.
- Visitor Purposes: Various activities such as adventure outings, photography, bird watching, and field studies highlight the cultural services provided by the forest, with field studies being the most frequent purpose.
- Soil Characteristics: The forest soil exhibits very high organic carbon content and varies in nutrient levels, with a sandy loam texture predominating.
- Carbon Sink and Oxygen Release: Over a 20-year period, mature trees in the forest are estimated to sequester approximately *15,35,649.527* MG of carbon and release around *28,66,54,57,42,782.680* Ltr of oxygen.
- Comparison of value of Ecosystem Services: A comparison analysis was carried out to assess the economic value of ES among various studies carried out globally, nationally by Costanza, IIFM Bhopal and Mizoram University.
- Uncertainty Assessment: The report identifies and addresses uncertainties in estimating provisional, regulating, cultural, and supporting services, emphasizing the scope for more studies on ecosystem service quantification.
- Calculation of NAV (Net Asset Value): The NAV of the ES of Garbhanga RF for the year 2023 was calculated as *₹ 6,08,94,80,488.38* $Ha^{-1}Yr^{-1}$ by discounting liabilities and expenses for maintaining the ecosystem from Gross Asset value (GAV) of the ES for the year *2023-24*.

ECONOMIC VALUATION OF ECOSYSTEM SERVICES AGAINST THE YEAR *2023-24*

- Provisioning Services: Water consumption (valued at ₹ *979.49* per capita Yr^{-1} and ₹ *5219.18* $Ha^{-1}Yr^{-1}$), forest produce (₹*49,015.28* per capita Yr^{-1} and ₹ *7,225.71* $Ha^{-1}Yr^{-1}$).
- Regulating Services: Carbon sink (₹ *4,452.11* Ha^{-1} Yr^{-1} which includes all 8 strata of the forest), temperature regulation (₹ *4,27,64,520.34* $Ha^{-1}Yr^{-1}$), water retention (valued at ₹*3,28,96,15,502.12* Ha^{-1} Yr^{-1}).
- Cultural Services: Cultural services (₹ *3,311.46* Ha^{-1} Yr^{-1}).
- Supporting Services: Soil nutrient provision (₹ *8,99,997.00* Ha^{-1} Yr^{-1}), oxygen release *(₹ 2,75,62,93,983.00* Ha^{-1} Yr^{-1}).

CONCLUSION

The economic value of all the identified forest ecosystem services is indispensable for sustainable development. Recognizing and quantifying these values are essential for decision-making and policy formulation for encompassing the value in State GDP aimed at conserving and sustainably managing forest ecosystems for present and future generations. The research findings provide a foundation for strategic interventions, ensuring the continued availability and enhancement of the invaluable resources of the Garbhanga Forest ecosystem.

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The forest is a peculiar organism of unlimited kindness and benevolence that makes no demands for its sustenance and extends generously the products of its life activity; it affords protection to all beings, offering shade even to the axeman who destroys it.

~~~~Gautama Buddha

BACKGROUND

1. **Forests as Foundations: Ecological and Spiritual Perspectives from Ancient and Medieval India:**

In ancient Indian traditional people have always valued mountains, rivers, forests, and animals. Thus much of nature was valued and protected. Forests have been associated with the names of forest gods and goddesses both in the Hindu religion as well as in tribal culture. Ancient Indians had reconised the animals' right to coexist with man and therefore they were loved, nurtured and even worshipped. Nature worship that sprang from the unquestionable supremacy of nature; and it believed that the five element ***Agni*** (Fire)***, Jala*** (Water)***, Vayu*** (Air)***, Prithvi*** (Earth)***, Aakash*** (Space) have a great influence on life.

"आरोहन्ति स्वयं भोगान् वनेष्वपि तपस्विनः।
ऋषयः शमसंयुक्ता द्रुमाः फलवतीः पुनः॥"

~Kalidasa, Raghuvamsha, 5.56

"Even in the forests, the ascetics, filled with tranquility, ascend to the highest pleasures.
The trees, abundant with fruits, offer sustenance again and again."

"वनानि प्रस्थं विहरन्ति सिद्धाः
वनानि रम्याणि महान्ति वीराः।
धन्यास्तु ते ये निवसन्ति वृक्षैः
वनप्रस्थैः संयता ध्याननिष्ठाः॥"

~Valmiki, Ramayana, Aranya Kanda

"The great sages roam in the forests, The mighty heroes dwell in the delightful woods. Blessed are those who live amidst the trees, abiding in meditation, seeking the ultimate truth."

"वृक्षाणां तु वने वासः सदैव फलदायकः।
धर्मार्थकाममोक्षाणां साधनं प्राप्यते वने॥"

~Vishnu Purana

"The abode of trees in the forest always yields fruits, In the forest, the means to achieve Dharma (righteousness), Artha (wealth), Kama (pleasures), and Moksha (liberation) are found."

"वनानि नन्दन्ति पशवः नन्दन्ति मृगपक्षिणः।
वनं हि रक्ष्यमाणं तु प्रजानां परिपालकम्॥"

~Mahabharata, Vana Parva

"Forests bring joy to the animals, to the birds and beasts. When forests are protected, they in turn protect the people."

Ancient Indian philosophy has long recognized the deep interdependence between humans and nature, with forests playing a central role in this balance. Texts such as the **"Vedas", "Upanishads", and "Puranas"** emphasize the sanctity of forests, not only as sources of material resources like food, water, and shelter, but also as spaces of spiritual significance. The concept of "**Hrwita**" **'ঋত'** *(cosmic order)* reflects the idea that maintaining harmony with nature, particularly forests, is essential for sustaining life and the ecological balance. Forests provided critical ecosystem services such as air and water purification, climate regulation, and support for biodiversity, deeply embedding them in ancient Indian thought as sacred and necessary for human survival. Certain ideas of forest conservation and sustainable management ingrained in the pre-historic India. Apparently, both productive as well as protective aspects of forest vegetation were emphasized during the Vedic period *(~4500 and 1800 BC;c. 8000-1000 BC – eds.).*

"Chanakya" (Kautilya), the renowned political strategist and economist of ancient India, echoed this philosophy in his seminal work, the **"Arthashastra".** He stressed that for the successful settlement of a community, "the establishment of a forest was essential". This principle recognized that forests were foundational to both the economic and environmental needs of society. Chanakya outlined strategies for forest management, appointing forest officers **(Vanapalas)** and imposing strict penalties for illegal deforestation, as he understood that forests were vital for ensuring economic prosperity, providing resources for military strength, and maintaining ecological stability. His foresight in regulating forest use reflects a sophisticated understanding of what we today call ecosystem services. Chanakya's view that a thriving forest is the first step towards a sustainable settlement reveals a timeless principle of environmental stewardship, demonstrating that ecological preservation is crucial for the well-being of both people and the state.

During the Middle Ages in India, the philosophy of ecological balance and forest conservation continued to evolve, reflecting a deep-rooted respect for nature, with forests seen as sources of both material sustenance and spiritual guidance. The Bhakti and Sufi movements during this period further reinforced the idea of living in harmony with nature. Saints and poets like **"Kabir",** "**Tulsidas",** and **"Guru Nanak"** often invoked imagery from nature, including forests, rivers, and mountains, to express their spiritual messages of simplicity, self-sufficiency, and reverence for all life forms. Their teachings emphasized the interconnectedness of all beings, both human and non-human, and the need to live in balance with nature rather than exploiting it.

Kings and rulers of medieval India, particularly those of the "Rajput", "Maratha", and "Mughal" dynasties, also recognized the strategic and ecological importance of forests. Forests were often considered vital to the economy, and many rulers maintained "hunting reserves" **(Shikargahs)**, not just for recreation but also to preserve wildlife and forest resources. The Mughal emperor **"Akbar",** for instance, recognized the importance of maintaining forests for ecological and strategic purposes, integrating policies to protect forest lands and natural resources. The Maratha ruler **"Shivaji",** too, utilized forests as a means of defence while ensuring that forest communities were empowered and respected.

Philosophies during this era highlighted the "dharmic responsibility" of rulers and communities to protect natural resources, reflecting the belief that environmental degradation was not only an ecological loss but also a moral and spiritual one. Forests were considered essential for agriculture, rainfall, and maintaining the health of the land, and thus needed to be protected for the sustenance of future generations.

"Chanakya's principle", that "the establishment of a forest is essential for the settlement of a community," continued to resonate during the Middle Ages. Forests were viewed as foundational to a kingdom's prosperity, providing timber, medicinal plants, and wildlife, while supporting agriculture through rainfall and soil preservation. This period in Indian history further strengthened the belief that forests were indispensable to both spiritual well-being and the material success of society, intertwining religious, philosophical, and governance frameworks around the concept of sustainable environmental stewardship.

2. Srimanta Sankardeva and His Contributions to the Cultural Heritage of Assam through Scripts on Trees:

Referring to Srimanta Sankardeva's **Kirtan Ghosa**, a cherished scripture of Assamese Vaishnavism, gracefully weaves the essence of nature and trees into its verses, revealing their profound spiritual and ecological significance. Though Sankardeva did not specifically address modern notions like ecosystem services, his writings are imbued with a deep reverence for the natural world, harmonizing the realms of nature and spirituality.

"কৃপানিধি দয়া কৰি ব্ৰহ্মা বিষ্ণু মহেশ্বৰ।

সৃষ্টি স্থিতি লয় কৰে ইচ্ছামতে অনন্তৰ॥

বৃক্ষ লতা পশু পক্ষী সকলতে আছয় ঈশ্বৰ।

মুনি মানৱ নৰ নগৰ পূজিবে সদাশিৱ॥"

"The merciful Lord, in His infinite form, is present in Brahma, Vishnu, and Shiva. He governs creation, sustenance, and dissolution according to His will. The Lord resides in all — trees, plants, animals, and birds. Even the sages, humans, and cities worship Lord Shiva, recognizing divinity in all."

"জল মিলিবেক বৃক্ষৰ হৰষৰ

ফল দান কৰিবেক শীতল ছায়া।

মানৱৰ পৰম সখা বৃক্ষ হৰিষ

পৰম গুণৰ ধাৰা॥"

"Water is received by the joy of trees, They provide fruits and cool shade. Trees are the greatest friends of humans, Bestowing streams of great virtues."

Sankardeva's **Kirtan Ghosa** and related works, rich in spiritual and cultural depth, do not detail trees in the style of botanical texts. However, the references to specific trees are profound, underscoring their place in the sacred and cultural tapestry of the time.

"অৰ্জুন বৃক্ষৰ ছায়া লাগি শ্ৰান্ত ভৈলা কৃষ্ণ।

তখন কদমৰ তলে বিশ্ৰাম কৰিলা হৰিষ॥"

"Under the shade of the Arjun tree, Krishna, feeling weary, Then joyously rested beneath the Kadam tree."

"কুন্দ মল্লিকা বকুল কদম্বৰ।

গন্ধে পৰিপূৰ্ণ হৰিষ ত্ৰিভুবনৰ॥"

"With the fragrance of Kunda, Mallika, Bakul, and Kadam, The three worlds are filled with joy."
Here is the text in Assamese script:

"কুকুৰ, শৃগাল, গৰ্ধভৰো আত্মাৰাম জানিয়া।

সৱকো পৰি কৰিবা প্ৰণাম।"

"Knowing that even dogs, jackals, and donkeys possess the divine soul,
Bow down and offer your respect to all."

These verses exquisitely capture the sacred connection between trees and the divine within Sankardeva's spiritual and cultural narratives. Trees like Bakul, Kadam, and Arjun are not merely components of the natural landscape; they are woven into the very fabric of devotion and divine experience, serving as sanctuaries of peace and symbols of the eternal. Through their presence, they echo the harmonious balance between the earthly and the celestial, making them not just witnesses but participants in the divine play of existence. The verses reflects a deep philosophical understanding, acknowledging that even animals possess the same divine essence. The phrase urges everyone to show respect to all beings, recognizing the unity of all life.

3. Forest Ecosystem Services and Cultural Linkages with Assamese People and Tribes of Assam:

Forests play a critical role in maintaining ecological balance, providing a wide array of ecosystem services that are indispensable to human well-being and biodiversity. In Assam, a state blessed with rich and diverse forest cover, these services are not only ecological but also deeply interwoven with the cultural and socio-economic fabric of the Assamese people and the indigenous tribes. These communities have long contributed to the conservation of forest ecosystems through traditional practices that reflect a deep respect for nature.

Cultural Linkages and Contributions to Conservation

Forests in Assam are deeply embedded in the cultural heritage of the Assamese people and the various indigenous tribes, such as the Bodos, Mishings, Karbis, and Rabhas, among others. These communities have developed a symbiotic relationship with the forests, reflected in their traditions, beliefs, and daily lives, contributing significantly to forest conservation:

1. **Spiritual and Religious Significance**: Many indigenous tribes of Assam worship forests as sacred spaces inhabited by deities and spirits. Sacred groves and rivers , which are patches of forests protected for religious reasons, are common across the state. These groves act as conservation hotspots, preserving biodiversity and serving as repositories of rare plant species. The community-driven protection of these areas reflects a conservation ethic that predates modern environmental movements.
2. **Traditional Knowledge and Sustainable Practices**: Indigenous tribes possess a wealth of traditional knowledge about forest management, sustainable harvesting, and the medicinal properties of plants. Practices such as shifting cultivation are managed with fallow periods that allow the forest to regenerate, reflecting an understanding of the ecosystem's needs. Additionally, the use of NTFPs is often regulated by community norms that prevent over-exploitation, ensuring the sustainability of these resources.
3. **Community-led Conservation Initiatives**: Many tribes in Assam have established community reserves and have taken active roles in wildlife protection. For example, the Karbi and Mishing communities have initiatives for protecting river dolphins and wildlife habitats. By leveraging traditional governance systems, these communities enforce conservation rules more effectively than external regulations, showcasing a model of community-based conservation.
4. **Festivals, Rituals, and Environmental Stewardship**: Forests play a central role in numerous festivals and rituals. For instance, the Bihu festival includes offerings to nature, highlighting the reverence for natural resources. Similarly, the Bodos' Bathou Puja involves the worship of plants and nature as symbols of divine presence, reinforcing the cultural mandate to protect and respect forests. These cultural practices serve as reminders of the importance of forests, promoting environmental stewardship across generations.
5. **Art, Music, and Folklore**: Forests have inspired Assamese art, music, and folklore, which often convey messages about the importance of nature and conservation. These cultural expressions serve as tools for educating younger generations about the value of forests and the need for their protection.

4. Notable Scientists and Their Contributions to the Study of Assam's Forest Ecosystems

Assam's forest ecosystems, part of the Indo-Burma biodiversity hotspot, have been extensively studied by various scientists who have highlighted their ecological, socio-economic, and cultural importance. Here are some key scientists and their contributions:

a. Dr. M.P. Bezbaruah
An ecologist known for his work on biodiversity conservation and sustainable forest management in Assam. His research emphasizes integrating traditional knowledge with modern conservation practices to support local communities and maintain ecological balance.

b. Dr. Anwaruddin Choudhury
A prominent wildlife biologist and conservationist, Dr. Choudhury has authored numerous books and papers on Assam's wildlife and forests. His works focus on large mammals and lesser-known species, providing detailed insights into the region's biodiversity, as seen in his notable book "The Mammals of North East India."

c. Dr. Amalendu Chakravarty
A botanist specializing in Assam's plant diversity, Dr. Chakravarty has catalogued the state's endemic and rare plant species. His studies on vegetation types and ecological significance contribute valuable knowledge for plant conservation efforts.

d. Dr. P.C. Bhattacharjee
An ornithologist and ecologist, Dr. Bhattacharjee has focused on Assam's avifauna, exploring bird ecology and habitat conservation. His research has been pivotal in promoting bird conservation in Assam's forest habitats. He also introduced scientific studies of primates particularly on distribution, food – feeding habits, and social structures.

The work of these scientists has been instrumental in advancing the understanding of Assam's forest ecosystems, underscoring their critical role in biodiversity conservation, climate mitigation, and supporting local livelihoods. Their research provides a foundation for sustainable forest management and conservation strategies in Assam.

5. Economic Justification for Conservation and Restoration: Important Definitions with Reference to Scientists

Economic justification for conservation and restoration of forest ecosystems involves demonstrating that the benefits of conserving natural resources, including ecosystem services, outweigh the costs associated with their degradation or loss. This justification is often supported by the quantification and valuation of ecosystem services, which can reveal the true economic, social, and environmental value of forests. Notable scientists have contributed definitions and frameworks that highlight these concepts:

a. **Forest Ecosystem Service:** Forest ecosystem services refer to the benefits that humans derive from forest ecosystems, including provisioning, regulating, supporting, and cultural services. These services contribute to human well-being by providing resources such as food, water, timber, and medicine (provisioning services), regulating climate, water cycles, and carbon storage (regulating services), supporting biodiversity and soil formation (supporting services), and offering recreational, spiritual, and cultural values (cultural services). ~ Robert Costanza et al. (1997).

b. **Ecosystem Services Valuation:** Dr. Robert Costanza and colleagues pioneered the concept of valuing ecosystem services in monetary terms to make their benefits explicit in economic decisions. Their groundbreaking study in 1997 quantified the global value of ecosystem services, emphasizing that natural capital is a crucial component of the world's wealth. This approach provides a powerful economic justification for conservation and restoration, showing that the loss of ecosystems results in significant economic costs.

c. **Natural Capital and Sustainable Development:** Dr. Gretchen Daily (1997) in her work, ***"Nature's Services: Societal Dependence on Natural Ecosystems,"*** introduced the idea of ecosystem services and emphasized the importance of forests in supporting life on Earth.

She explored how forests provide vital services such as water regulation, soil conservation, and biodiversity, linking ecological health with human prosperity.

d. **Restoration of Forest:** Forest restoration refers to the process of regenerating and recovering degraded or destroyed forest ecosystems to restore their natural structure, biodiversity, and ecosystem services such as carbon sequestration, water regulation, and habitat provision. Notable contributions to this field include John Evelyn (1664), who emphasized sustainable reforestation in his work "Sylva", and Norman Myers (1988), who highlighted the importance of restoring biodiversity hotspots. Pedro Brancalion (2013) and Robin Chazdon (2014) have been influential in advancing tropical forest restoration, particularly through natural regeneration, with Chazdon's work emphasizing the potential of secondary forests. More recently, Thomas Crowther (2019) has underscored the role of large-scale forest restoration in mitigating climate change, advocating for global tree-planting initiatives to sequester carbon. These scientists have shaped the modern understanding of forest restoration as a critical approach to addressing environmental challenges.

e. **Cost-Benefit Analysis of Restoration:** Dr. Pavan Sukhdev led the "**The Economics of Ecosystems and Biodiversity (TEEB)"** initiative, launched by the United Nations Environment Programme (UNEP) in 2008. The initiative focused on quantifying the economic value of biodiversity and ecosystem services to highlight the cost of their degradation and loss. TEEB demonstrated how preserving nature yields significant economic benefits and provided policymakers with tools to integrate these values into decision-making processes.

f. **Biodiversity and Ecosystem Function:** Biodiversity refers to the variety of life forms, including species, genes, and ecosystems, within a given environment. Ecosystem function refers to the biological, geochemical, and physical processes that contribute to the sustainability and health of ecosystems, such as nutrient cycling, water filtration, and energy flow. The relationship between biodiversity and ecosystem function suggests that higher biodiversity generally enhances ecosystem resilience and productivity, enabling ecosystems to perform essential services more efficiently. Dr. Shahid Naeem (1994 onwards) has contributed significantly to understanding the relationship between biodiversity and ecosystem function, demonstrating that diverse ecosystems are more productive and resilient. This understanding supports the economic justification for conserving biodiversity as a means to maintain ecosystem functions that provide vital services. Naeem's research shows that investing in conservation can prevent costly ecosystem service loss due to reduced biodiversity.

g. **Payments for Ecosystem Services (PES):** Dr. Sven Wunder (2000- 2010) has defined Payments for Ecosystem Services as voluntary transactions where a service buyer pays a service provider for maintaining or enhancing ecosystem services. This concept provides a market-based economic justification for conservation, offering financial incentives to landowners and communities to preserve forests, thereby aligning economic interests with environmental sustainability.

h. **Sustainable Resource Management (SRM)** is a holistic approach that focuses on the responsible use and conservation of natural resources to ensure their availability for future generations while maintaining ecological balance. This concept has been significantly shaped by the work of various scientists.

   Dr. Elinor Ostrom (1990-2009), a Nobel laureate, contributed extensively to the understanding of collective resource management, emphasizing the importance of local governance and community involvement in managing common-pool resources such as forests. Her work demonstrated that communities could effectively manage resources sustainably without top-down regulation, provided they have the right institutional frameworks in place.

   Dr. Herman Daly (1977), a leading ecological economist, further advanced the principles of SRM by advocating for a steady-state economy where resource use is aligned with the Earth's ecological limits. His work 'Steady-State Economy' underlined the need to maintain natural capital and promote resource efficiency, thus ensuring that economic activities do not exceed environmental capacities.

Dr. Carl Folke (2004), a pioneer in resilience thinking, highlighted the need for adaptive management in SRM, advocating for systems that can respond and adapt to environmental changes while maintaining ecosystem services. His research underscores the importance of flexibility, learning, and incorporating ecological feedback into resource management practices.

Dr. Gretchen Daily (1997), contributed to integrating ecosystem service valuation into decision-making processes also support SRM by quantifying the benefits of natural resources, thus providing a clear economic rationale for their sustainable management. Her work has influenced policies that aim to balance human needs with environmental protection. Together, these scientists have laid the groundwork for SRM, emphasizing the interconnectedness of ecological, economic, and social systems and the need for sustainable approaches to managing the Earth's natural resources.

These definitions and contributions by scientists such as Costanza, Daily, Sukhdev, Naeem, and Wunder provide a strong economic foundation for conservation and restoration efforts. They collectively demonstrate that the benefits derived from healthy, functioning ecosystems justify investments in conservation, making the case that safeguarding natural resources is not only an environmental imperative but also an economically sound strategy.

Chapter I

INTRODUCTION, PURPOSE, OBJECTIVES and EXPECTED OUTCOMES

INTRODUCTION

The forest ecosystem service refers to the benefits that humans derive from forests and their ecosystems. These ecosystem services highlight the multifaceted value of forests beyond just their economic importance, emphasizing their critical role in maintaining ecological balance and supporting human well-being. The quantification and valuation of ecosystem services provided by forests has emerged as a critical component in understanding the intrinsic value of these ecosystems and the benefits they offer to human societies. Forests play a vital role in sustaining life on Earth by providing a wide array of ecosystem services, ranging from carbon sequestration and climate regulation to water purification, biodiversity conservation, and cultural enrichment. Recognizing and quantifying these services are essential for decision-making in natural resource management and conservation. Forests are complex ecosystems that offer a wide range of services, often classified into four main categories: provisioning, regulating, cultural, and supporting services.

Understanding and quantifying these ecosystem services are essential for sustainable forest management practices, conservation efforts, and policy decisions to explore sources of funds by way of selling carbon credits etc. aimed at maximizing the benefits derived from forests for economic upliftment of forest fringe community while indirectly ensuring long-term health and resilience of forests. Quantification and valuation of ecosystem services play crucial roles in understanding the contributions of natural ecosystems like forests to human well-being, informing decision-making processes, and fostering sustainable management practices.

As of the present, the Gross State Domestic Product (GSDP) of Assam for 2023-24 (at current prices) is projected to be ₹5,70,243.00 Cr. However, it's imperative to recognize that this figure does not encompass the substantial value derived from the state’s forest ecosystem services, which play a crucial role in supporting both the environment and the economy. The substantial value derived from the ecosystem services rendered by forests encompassing approximately 36% of the state's landmass. The exclusion of the value of forest ecosystem services underscores a missed opportunity to fully appreciate their vital contributions to the state's economy and societal well-being. Integrating the valuation of these services would likely reveal a more comprehensive and accurate representation of the State GDP, highlighting the indispensable role that forests play in promoting sustainable development and prosperity. The omission of ecosystem services from the GSDP calculation reflects a broader oversight in economic accounting, where the contributions of natural capital, such as carbon sequestration, water regulation, biodiversity conservation, and cultural services, are often undervalued or ignored. Dr. Pavan Sukhdev, through his work with The Economics of Ecosystems and Biodiversity (TEEB), has demonstrated the economic justification for including these services in national and state-level accounts, arguing that the failure to do so leads to a significant underestimation of natural wealth and misinformed policy decisions. Similarly, Dr. Herman Daly’s advocacy for sustainable development underscores the need for economic indicators that fully account for environmental assets to truly reflect a region’s prosperity and sustainability. By integrating the value of forest ecosystem services into Assam's GSDP, we can ensure a more comprehensive and accurate representation of the state's economic health and its commitment to sustainable growth.

Valuing ecosystem services in economic terms highlights the significant contributions of forests to local and global economies. This economic justification strengthens arguments for investing in conservation and restoration efforts, as well as sustainable forest management practices.
Quantifying the monetary value of ecosystem services provides a basis for assessing the cost-effectiveness of conservation measures and comparing them to alternative land uses. It helps identify opportunities for enhancing economic returns while maintaining ecosystem integrity.

PURPOSE

The quantification and valuation of forest ecosystem services at Garbhanga Reserved Forest (RF) is a critical initiative aimed at recognizing and integrating the ecological and economic contributions of forests into broader economic frameworks, such as the Gross State Domestic Product (GSDP) of Assam. As of 2023, Assam's projected GSDP is ₹5,70,243 crore. However, this figure does not fully account for the substantial benefits provided by forest ecosystems, including carbon sequestration, water regulation, biodiversity conservation, and cultural services, which remain undervalued or overlooked in traditional economic assessments.

The purpose of quantifying and valuing these services in Garbhanga RF is twofold:

1. **Economic Recognition:** Forest ecosystems play an indispensable role in Assam's economy, providing resources for industries, tourism, and local communities. Quantifying these services ensures their contributions are made visible in economic terms, enabling policymakers to incorporate them into the state's economic planning. This will lead to a more accurate representation of Assam's natural capital, ensuring that the GSDP reflects not just industrial output, but also the value of ecosystem services that sustain long-term economic growth.
2. **Sustainable Management and Policy Formulation:** Valuation provides a robust foundation for informed decision-making, highlighting the economic benefits of conservation and sustainable forest management. By understanding the financial worth of ecosystem services, such as climate regulation and biodiversity support, policymakers can justify investments in conservation initiatives and ensure that forests are protected for future generations. This approach aligns with Assam's development goals, ensuring that economic growth does not come at the cost of environmental degradation.

The enormity of valuing forest ecosystem services across various forest types is indeed a complex and resource-intensive task that cannot be accomplished simultaneously. To address this, a pilot project has been initiated at Garbhanga Reserved Forest (RF), being assigned with a legal protection status and represents a forest with high bio-diversity and wide range of forest ecosystem and their services. The valuation of Garbhanga RF's ecosystem services would bridge the gap between ecological preservation and economic development, ensuring a sustainable and holistic approach to Assam's economic growth in 2023 and beyond. Ultimately, the quantification and valuation of forest ecosystem services serve to balance development needs with environmental stewardship, ensuring the protection of these vital ecosystems for future generations.

OBJECTIVES

1. **Establishing benchmark of Quantification and Valuation:**
   Conduct a comprehensive baseline assessment of forest ecosystem services through this pilot project. Apply state-of-the-art quantification methods and models to estimate the quantity and spatial distribution of ecosystem services.

2. **Protocol Design:** Develop a standardized protocol that specifies procedures, methodologies, data requirements, quality assurance measures, and reporting guidelines for quantification and valuation activities.

3. **Assess the Magnitude and Distribution of Forest Ecosystem Services:**
   Quantify and valuing the various ecosystem services provided by forests, including provisioning, regulating, cultural, and supporting services.

4. **Monitoring and Evaluation for Future Changes:**
   Establish a monitoring program to track changes in forest ecosystem services over time.

5. **To Understand the Drivers of Change in Ecosystem Services:**
   Identify and analyse the biophysical, socio-economic, and institutional factors influencing the supply and demand for forest ecosystem services.

6. **To Assist Policy and Management Decision makers:**
   Provide decision-makers with actionable information on the economic and ecological importance of forest ecosystem services.

7. **To Contribute to Knowledge Sharing and Science-Policy Interface:**
   Disseminate research findings through publications, policy briefs, workshops, and conferences to enhance scientific understanding and inform policy debates.

EXPECTED OUTCOMES

1. Estimated Biomass and Carbon Sink of Garbhanga RF
2. Estimated water discharge during dry seasons and resultant assured least quantity of water retention in the streams, soil and biomass during within Garbhanga RF
3. Listing of Floral and Faunal biodiversity in Garbhanga RF
4. Estimation of economic value of natural resources included in the list of provisioning, supporting, regulating and cultural services of forest ES of Garbhanga RF being beneficial to the forest fringe community and citizens.
5. Regression models for calculating standing tree volume, biomass of all the tree species of Garbhanga RF.
6. Floral richness and diversity index
7. Identification of high Carbon sequestering tree species
8. Identifying the tree species under anthropogenic pressure

Chapter II

LITERATURE REFERENCES, CHALLENGES and GAPS IN EXISTING RESEARCH

LITERATURE REFERENCES

Definitions and classifications of ecosystem services:

There have been challenges in establishing universally accepted guidelines, policies, or frameworks for the assessment, quantification, and valuation of Forest Ecosystem Services (ES) on a global scale. It remains evident that no single framework has garnered unanimous acceptance as the most suitable option for quantifying ES. Millennium Ecosystem Assessment, TEEB and CICES are the established methodologies are in vogue across the globe. A comparison between the Millennium Ecosystem Assessment (MA), The Economics of Ecosystems and Biodiversity (TEEB), and the Common International Classification of Ecosystem Services (CICES) is as follows:

1. **Millennium Ecosystem Assessment[B] (MA):**
   Objective: The MA aimed to assess the state of the world's ecosystems and their contributions to human well-being, providing a comprehensive synthesis of scientific knowledge on ecosystem services.
   Framework: The MA adopted a framework that classified ecosystem services into four main categories viz., provisioning, regulating, cultural, and supporting services, offering a holistic perspective on the benefits provided by ecosystems.
   Assessment Process: The MA involved a global assessment, sub-global assessments, thematic assessments and synthesis reports, integrating ecological, social, and economic dimensions to evaluate ecosystem status and trends.
   Key Findings: The MA highlighted the significant contributions of ecosystems to human well-being while also identifying widespread degradation and loss of ecosystems worldwide, emphasizing the need for ecosystem-based approaches to environmental management.
   Policy Implications: The MA findings informed global policy discussions and initiatives aimed at addressing environmental challenges, influencing international agreements such as the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change.
   Proponent: UNFCC, Chaired by Dr. Robert Watson, 2001-2005

2. **The Economics of Ecosystems and Biodiversity[C] (TEEB):**
   Objective: TEEB focused on highlighting the economic value of ecosystem services and biodiversity, aiming to raise awareness among decision-makers about the economic costs of ecosystem degradation and the potential benefits of conservation.
   Framework: TEEB employed an economic framework to assess the monetary value of ecosystem services and biodiversity, emphasizing the economic rationale for investing in ecosystem conservation and sustainable management.
   Assessment Process: TEEB involved case studies, thematic reports, and policy recommendations, analysing the economic implications of ecosystem degradation and biodiversity loss in various sectors such as agriculture, forestry, and tourism.
   Key Findings: TEEB demonstrated the economic importance of ecosystem services for sectors such as agriculture, fisheries, and water supply, highlighting the potential economic benefits of investing in ecosystem conservation and restoration.
   Policy Implications: TEEB findings informed policy discussions and initiatives aimed at mainstreaming the economic value of ecosystems and biodiversity into decision-making processes, promoting the integration of ecosystem services into economic planning and development strategies.
   Proponent: Dr. Pavan Sukhdev, 2008

3. **Common International Classification of Ecosystem Services[D] (CICES):**
   Objective: CICES aimed to provide a standardized framework for classifying and categorizing ecosystem services, facilitating comparability and consistency in ecosystem service assessment and reporting.

Framework: CICES developed a hierarchical classification system that organizes ecosystem services into three main categories: provisioning, regulating, and cultural services, with further subdivisions and qualifiers for specific services.
Assessment Process: CICES provides guidelines and standards for ecosystem service assessment, offering a common language and classification system for researchers, policymakers, and practitioners to use in ecosystem service evaluations.
Key Findings: CICES does not produce assessment reports or findings directly but provides a standardized framework for ecosystem service assessment, facilitating the comparability of results across different studies and contexts [b]
Policy Implications: CICES supports the integration of ecosystem service considerations into policy and decision-making processes by providing a common classification system that enables stakeholders to communicate and compare ecosystem service values effectively.
Proponent: Dr. Roy Haines-Young, 2009

In summary, while the Millennium Ecosystem Assessment (MA) provided a comprehensive synthesis of ecosystem status and trends, The Economics of Ecosystems and Biodiversity (TEEB) focused on the economic valuation of ecosystem services, and the Common International Classification of Ecosystem Services (CICES) offers a standardized framework for classifying ecosystem services, facilitating comparability and consistency in ecosystem service assessment and reporting. Each initiative contributes to our understanding of ecosystem services and their importance for human well-being and informs policy and decision-making processes in different ways. In light of the Millennium Ecosystem Assessment (MA) of 2005 and The Economics of Ecosystems and Biodiversity (TEEB) report of 2010, which provide robust and coherent guidelines for the classification and economic valuation of Forest Ecosystem Services (ES), a deliberate effort was made to align methodologies with these esteemed frameworks. Recognizing the relevance and applicability of these guidelines, particularly in the context of the Garbhanga Reserved Forest Pilot Project, methodologies were carefully selected and adapted to adhere to the principles outlined by the MA and TEEB. This approach ensured a systematic and standardized approach to ES assessment, enhancing the credibility and comparability of results. By utilizing methodologies aligned with established frameworks, the project aimed to capture almost full spectrum of Forest ES.

In essence, the decision to adopt methodologies aligned with the MA and TEEB guidelines underscored a commitment to robust and scientifically rigorous ES assessment in the Garbhanga Reserved Forest. It reflected a strategic approach to leverage established frameworks and best practices to ensure the effectiveness, credibility, and relevance of the project outcomes.

PREVIOUS STUDIES ON QUANTIFICATION AND VALUATION

Similar case studies showcasing ecosystem services and their significance in India as well as in Assam:

Western Ghats Biodiversity Hotspot *- Dr. Harini Nagendra, 2011*

a) ***Location:*** *Western Ghats Mountain range along the western coast of India.*
b) ***Ecosystem Services:*** *The Western Ghats are rich in biodiversity and provide various ecosystem services such as water regulation, climate regulation, soil conservation, and carbon sequestration.*
c) ***Case Study:*** *The Western Ghats act as a crucial water catchment area, supplying water to major rivers in peninsular India. They also regulate regional climate patterns and support agriculture, tourism, and traditional livelihoods of local communities.*
d) ***Significance:*** *Conservation of the Western Ghats is essential for maintaining ecosystem services, supporting biodiversity, and sustaining the livelihoods of millions of people dependent on its resources.*

Sundarbans Mangrove Forests *- Dr. Kanchan Ratna Chakraborty, 2015*

a) ***Location:*** *The Sundarbans delta in the states of West Bengal and Bangladesh.*
b) ***Ecosystem Services:*** *Sundarbans mangrove forests provide coastal protection, carbon sequestration, fisheries support, and livelihoods for local communities.*
c) ***Case Study:*** *The mangrove forests of Sundarbans act as a natural barrier against cyclones, storm surges, and coastal erosion, protecting coastal communities and infrastructure. They also serve as nurseries for fish and other marine species, supporting local fisheries.*
d) ***Significance:*** *Conservation and sustainable management of Sundarbans mangrove forests are critical for coastal resilience, biodiversity conservation, and the well-being of communities vulnerable to climate change impacts.*

Western Himalayan Region *- Dr. Sharachchandra Lele, 2013*

a) ***Location:*** *Western Himalayan region covering states like Himachal Pradesh, Uttarakhand, and Jammu and Kashmir.*
b) ***Ecosystem Services:*** *The Western Himalayas provide ecosystem services such as water provisioning, carbon storage, soil conservation, and tourism.*
c) ***Case Study:*** *The region acts as the source of major rivers like the Ganges, Yamuna, and Indus, supplying water for irrigation, hydropower generation, and drinking purposes to millions of people in the plains. The Himalayas also support tourism activities such as trekking, mountaineering, and wildlife tourism.*
d) ***Significance:*** *Protection of the Western Himalayas is crucial for ensuring water security, maintaining ecological balance, and promoting sustainable tourism while addressing challenges such as deforestation, land degradation, and climate change.*

Agroforestry in Andhra Pradesh *- D. Madhavi, K. Sailaja, and M. Padma, 2019*

a) ***Location:*** *Andhra Pradesh, a state in southern India.*
b) ***Ecosystem Services:*** *Agroforestry systems in Andhra Pradesh provide multiple ecosystem services, including soil fertility enhancement, carbon sequestration, water regulation, and biodiversity conservation.*
c) ***Case Study:*** *The "Vanadhara Watershed Development Project" in Andhra Pradesh promotes agroforestry practices among local farmers to improve soil health, increase water retention, and diversify livelihood options. Agroforestry systems integrate trees with crops and livestock, enhancing productivity and resilience to climate change.*
d) ***Significance:*** *Agroforestry initiatives contribute to sustainable land management, poverty alleviation, and climate change adaptation while conserving natural resources and enhancing rural livelihoods in Andhra Pradesh.*

Urban Green Spaces in Bengaluru *- Dr. Harini Nagendra, 2016*

a) ***Location:*** *Bengaluru, the capital city of Karnataka.*
b) ***Ecosystem Services:*** *Urban green spaces in Bengaluru provide ecosystem services such as urban heat island mitigation, air purification, recreational opportunities, and mental well-being.*
c) ***Case Study:*** *Cubon Park and Lalbagh Botanical Garden in Bengaluru serve as vital green lungs, offering recreational spaces, biodiversity hotspots, and cultural landmarks within the urban landscape. These green spaces improve air quality, regulate microclimates, and provide recreational amenities for city residents.*
d) ***Significance:*** *Conservation and expansion of urban green spaces are essential for enhancing urban resilience, improving public health, and promoting sustainable urban development in Bengaluru amidst rapid urbanization and environmental degradation.*

Kaziranga National Park *- Dr. Nitya Nanda and Dr. Rina Mukherji, 2013*

a) ***Location:*** *Kaziranga National Park, located in the north-eastern state of Assam, India.*
b) ***Ecosystem Services:*** *Kaziranga provides various ecosystem services such as habitat preservation, biodiversity conservation, water regulation, and cultural values.*
c) ***Case Study:*** *Kaziranga is renowned for its population of the Indian one-horned rhinoceros, which is a globally threatened species. The park also supports significant populations of other iconic wildlife species, including tigers, elephants, and water buffaloes. Additionally, Kaziranga serves as a critical habitat for migratory birds and supports the livelihoods of indigenous communities residing in and around the park.*
d) ***Significance:*** *Conservation of Kaziranga National Park is crucial for preserving biodiversity, protecting endangered species, promoting tourism, and supporting the livelihoods of local communities dependent on the park's resources.*
e) ***Agencies:*** *Various organizations including:*
   - *Assam Forest Department*
   - *World Wildlife Fund for Nature (WWF)*
   - *Kaziranga Conservation Committee*

Brahmaputra River Basin *- Dr. Anjal Prakash, 2010*

a) ***Location:*** *The Brahmaputra River Basin spans several north-eastern states of India, including Assam.*
b) ***Ecosystem Services:*** *The Brahmaputra River Basin provides vital ecosystem services such as water provisioning, irrigation, flood regulation, sediment retention, and fishery support.*
c) ***Case Study:*** *The Brahmaputra River is a lifeline for millions of people in Assam, serving as a source of water for drinking, agriculture, and industrial use. The river's floodplains support fertile agricultural lands and diverse aquatic ecosystems, including fish, turtles, and dolphins. However, the region is also prone to frequent floods and erosion, posing challenges to human settlements and infrastructure.*
d) ***Significance:*** *Sustainable management of the Brahmaputra River Basin is essential for ensuring water security, mitigating flood risks, conserving biodiversity, and supporting the livelihoods of riparian communities in Assam.*
e) ***Agencies:***
   - *Brahmaputra Board*
   - *Central Water Commission (CWC)*
   - *Assam State Disaster Management Authority (ASDMA)*

Assam Tea Plantations *- Ranjit Barthakur and Tarun Gogoi, 2015*

a) ***Location:*** *Assam is renowned for its tea plantations, which cover large areas in the Brahmaputra Valley.*
b) ***Ecosystem Services:*** *Tea plantations in Assam provide ecosystem services such as soil conservation, carbon sequestration, biodiversity support, and economic livelihoods.*
c) ***Case Study:*** *Assam tea is globally recognized for its distinctive flavour and quality. Tea plantations in Assam support the livelihoods of millions of workers and their families, contributing significantly to the state's economy. Additionally, tea gardens play a role in conserving biodiversity by providing habitat for various plant and animal species.*
d) ***Significance:*** *Sustainable management of tea plantations is essential for maintaining soil health, preserving biodiversity, and promoting socio-economic development in Assam while addressing challenges such as land degradation and labour rights.*
e) ***Agencies:***
   - *Tea Board of India*
   - *Rainforest Alliance*
   - *Assam Branch Indian Tea Association (ABITA)*

Manas National Park *- Dr. Firoz Ahmed, 2015*

a) ***Location:*** *Manas National Park is situated in the foothills of the Eastern Himalayas in Assam.*
b) ***Ecosystem Services:*** *Manas National Park provides ecosystem services such as habitat preservation, biodiversity conservation, water regulation, and cultural values.*
c) ***Case Study:*** *Manas is a UNESCO World Heritage Site and Biosphere Reserve, known for its rich biodiversity and scenic landscapes. The park is home to several endangered species, including the Bengal tiger, Indian elephant, and pygmy hog. Manas also supports indigenous communities such as the Bodo, who have traditional cultural ties to the park.*
d) ***Significance:*** *Conservation of Manas National Park is vital for protecting biodiversity, preserving cultural heritage, promoting ecotourism, and supporting the livelihoods of local communities in Assam.*
e) ***Agencies:***
   - *Assam Forest Department*
   - *UNESCO*
   - *International Union for Conservation of Nature (IUCN)*

Community Forest Management in Assam *- Dr. Ashish Kumar Bohra and Dr. K. Upadhaya, 2010*

a) ***Location:*** *Various community-managed forests across Assam.*
b) ***Ecosystem Services:*** *Community-managed forests provide ecosystem services such as carbon sequestration, biodiversity conservation, watershed protection, and livelihood support.*
c) ***Case Study:*** *Community-based Forest management initiatives in Assam involve local communities in the conservation and sustainable use of forest resources. These initiatives empower communities to participate in decision-making, implement conservation measures, and benefit from ecosystem services such as non-timber forest products, eco-tourism, and carbon offset projects.*
d) ***Significance:*** *Community forest management promotes local stewardship of natural resources, strengthens social cohesion, enhances resilience to climate change, and contributes to poverty alleviation and sustainable development in rural areas of Assam.*
e) ***Agencies:***
   - *Joint Forest Management Committees (JFMCs)*
   - *Non-Governmental Organizations (NGOs): Organizations such as Oxfam India, Foundation for Ecological Security (FES), and WWF*
   - *Indian Institute of Forest Management (IIFM*

These case studies illustrate the diverse range of ecosystem services provided by different ecosystems in Assam and underscore the importance of conservation, sustainable management, and community participation for ensuring human well-being and environmental sustainability in the region.

CHALLENGES

1. Challenges in Soil Nutrient Loss Analysis: Premium institutes such as IIT, Guwahati and Gauhati University have advanced research facilities and expertise in soil science and environmental analysis. Their limited involvement and lack of interest, in spite of several round of discussions, in conducting studies on soil_nutrient loss analysis in Garbhanga RF resulted in a dearth of reliable data and scientific insights which subsequently impaired deriving quality in evaluation of these ES.

2. Challenges due to absence of established benchmarks on the estimated comprehensive carbon sink: Absence of any established benchmark against comprehensive carbon sink for Garbhanga Reserve Forest (RF) has posed significant challenges. This lack of benchmarks hindered the ability to establish a timeline for assessing the total carbon sink value for any given period. Without these benchmarks, it becomes difficult to accurately measure and evaluate the forest's carbon sequestration capacity over time.

GAPS

1. Gap in Soil Erosion Quantification: Despite the urgency of addressing soil erosion issues, there is a noticeable absence of in-depth research and monitoring efforts focused on soil erosion quantification, particularly at a finer spatial and temporal scale. Premium institutes with expertise in geospatial analysis, remote sensing, and hydrological modelling could have contributed substantially to fill the gap in quantifying the soil related services.

2. Gap resulting in discounting Pollination Services: Pollination services provided by insects, birds, and other pollinators are crucial for biodiversity conservation and ecosystem functioning. The value of pollination services is of utmost importance while going for quantifying and valuation of ES. Despite the significance of pollination services, there is limited research and valuation studies conducted by the department as well as premium institutes to quantify the economic and ecological benefits of pollination This lack of scientific evidence hampered efforts to integrate pollination considerations in list of Forest Ecosystem Services.

3. Gap in Nutrient Valuation of Soil in Garbhanga RF: One significant gap in the valuation of ecosystem services (ES) within the Garbhanga Reserved Forest (RF) pertains to the precise economic valuation of soil nutrients. The inability to accurately assign a monetary value to the nutrient content of soil stems from the lack of comprehensive market data on nutrient-enriched soils sold commercially. This limitation significantly impacts the ability to provide a precise economic valuation of the soil's nutrient content, which is crucial for a holistic assessment of the forest's ecosystem services. In the absence of detailed market data on nutrient-enriched soils, the valuation methodology had to rely on the general market value of soil harvested from forests. While this approach offers a relative perspective on the monetary value of soil within the Garbhanga RF, it falls short of capturing the nuanced economic benefits derived from the soil's nutrient composition. Forest soils are inherently rich in organic matter and nutrients, contributing significantly to ecosystem productivity, plant growth, and overall biodiversity. However, the market value of forest soil, as used in this assessment, does not adequately reflect these intrinsic benefits. The market price of soil typically factors in basic physical characteristics and general fertility but often overlooks specific nutrient concentrations and their ecological importance. Consequently, the economic valuation derived from such a market-based approach provides a limited view, potentially undervaluing the true worth of the forest soil's nutrient content.

The absence of comprehensive scientific knowledge and research initiatives within the department on critical ecosystem services such as soil nutrient dynamics, erosion processes, and pollination services created gaps in quantifying the entire ES at Garbhanga RF. In addition to this, the reluctance or lack of active engagement by premium institutes like IITs and GU despite several rounds of meetings in an effort of collaboration in conducting fundamental research and providing technical expertise on key ecosystem service issues exacerbates the knowledge gap. Without robust scientific insights and data-driven assessments, few of the important ES as outlined above were left out to be quantified.

Chapter III

SELECTION OF STUDY AREA, FUNDING, TIMELINE and COLLABORATION EFFORTS

SELECTION OF STUDY AREA

The selection of Garbhanga Reserved Forest (RF) as the study area holds immense significance due to its diverse and rich ecosystem, strategic proximity to Guwahati and acting as a watershed and extensive coverage of approximately 18,200 hectares. Situated along the border of Meghalaya, this forest area boasts a remarkable biodiversity and serves as a habitat for various plant and animal species unique to the region. Moreover, Garbhanga RF is intertwined with the livelihoods and cultural practices of 19 ethnic villages residing within its vicinity. The inhabitants of these villages heavily rely on the forest for sustenance, deriving benefits from its resources for food, fuel, medicine, and traditional practices. Beyond its ecological and socio-cultural importance, Garbhanga RF attracts significant attention from researchers, students, tourists, environmental enthusiasts, and photographers alike. Researchers are drawn to its ecological complexity and potential for studies on biodiversity, ecosystem services, and conservation strategies. Students find it a valuable outdoor classroom for fieldwork and experiential learning in ecology, forestry, and environmental science. Tourists are captivated by its natural beauty, offering opportunities for ecotourism, wildlife viewing, and adventure activities. Additionally, environment enthusiasts and photographers are inspired by the scenic landscapes, diverse flora and fauna, and cultural heritage of the region.

In summary, the selection of Garbhanga Reserved Forest as the study area presents a unique opportunity to explore the interconnections between biodiversity, ecosystem services, human well-being, and cultural heritage. Its proximity to Guwahati, rich biodiversity, and cultural significance make it an ideal location for interdisciplinary research, education, conservation initiatives, and sustainable tourism development, contributing to both local livelihoods and global conservation efforts.

Map of Area of Interest

=

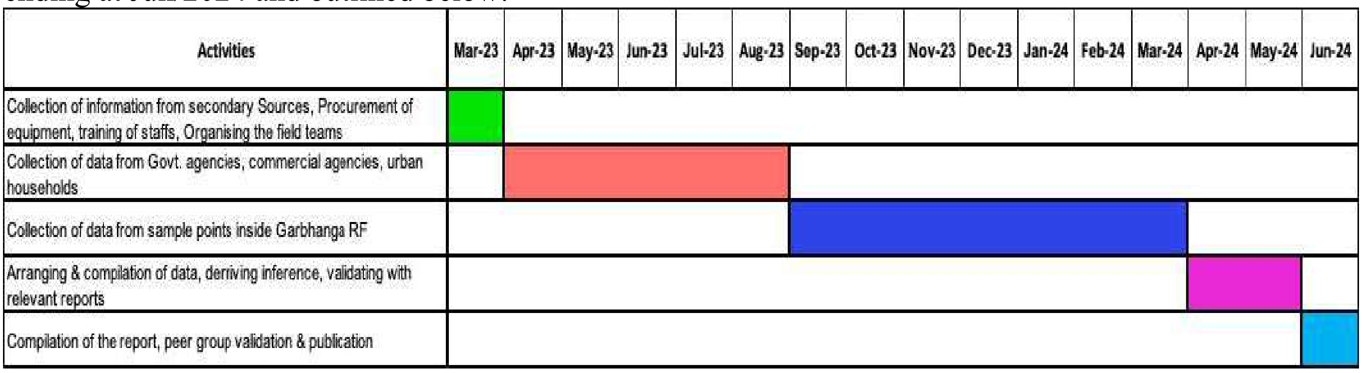

Aerial View of Garbhanga RF

SOURCE OF FUND

Entire funding was provided by the State CAMPA for an amount of 20.0 L, which includes expenses against survey, logistics, TA, DA and publication of the report.

TIME LINE

Encompassing various activities of the project a timeline was planned starting from Mar/2023 and ending at Jun/2024 and outlined below: -



COLLABORATION EFFORTS

Series of meetings and discussion were held with the institutions like Indian Institute of Technology (IIT), Guwahati, Gauhati University (GU), Assam State Space Application Centre (ASSAC), University of Science Technology and Management (USTM), TATA Energy Research Institute (TERI) and TATA Institute Social Science (TISS), Cotton University (CU) for developing strategies to carry out this huge exercise of quantification. The effort was successful to an extent in a way for adoption of selection of ES, data collection methodologies, use of GIS and other important technical inputs. Collaboration was initiated with the Department of Agriculture to utilize their laboratory facilities for analysing soil samples collected from the field. This partnership aims to generate comprehensive reports on soil nutrient levels and soil organic carbon content, providing valuable insights into the soil health and fertility of the study area.

Chapter IV

DATA COLLECTION STRATEGIES, MANPOWER MOBILISATION and EQUIPMENTS AND QUANTIFICATION METHODS FOR ECOSYSTEM SERVICES

DATA COLLECTION STRATEGIES and FORMS

Separate strategies were adopted to design the data collection formats of different entities of Forest ES in Garbhanga RF as furnished here –

1. **Carbon and Biomass Estimation and Socio-economic assessment**

   The Forest Survey of India (FSI) has meticulously developed data collection forms for the National Forest Inventory (NFI) program, aligning with international standards and best practices in forest monitoring and assessment. These data collection forms serve as essential tools for systematically gathering comprehensive information on forest resources across the country. The NFI data collection forms are meticulously designed to capture diverse aspects of forest ecosystems, including forest cover, tree species composition, forest health, regeneration status, and socio-economic parameter. They are structured to ensure consistency and comparability of data collected from different regions and enable the generation of reliable and comprehensive forest resource assessments at national and sub-national levels.

   Each data collection form is tailored to specific aspects of forest inventory, such as:

   - Forest Cover Mapping: Forms for mapping forest cover characteristics, including forest type, canopy density, and land use.
   - Vegetation Sampling: Forms for collecting data on tree species composition, density, diameter at breast height (DBH), height, and health status through systematic sample plots.
   - Socio-economic Surveys: Forms for assessing the socio-economic aspects of forests, including the dependence of local communities on forest resources, livelihood patterns, and traditional forest management practices.
   - Carbon Sequestration and Climate Change: Forms for quantifying carbon stocks, biomass density, and other parameters relevant to climate change mitigation and adaptation strategies.

   The NFI data collection forms developed by FSI adhere to standardized methodologies endorsed by international organizations such as the Food and Agriculture Organization (FAO) and the Intergovernmental Panel on Climate Change (IPCC). They have undergone rigorous testing, validation, and refinement processes to ensure accuracy, reliability, and efficiency in data collection and analysis.

2. **Water Retention and Flow**

   The format for data collection on water flow is designed in-house referring the reports and journal on hydrodynamics. Basically 'float method' was adopted to measure the volume of water flow through the stream.

3. **Climate factors**

   Temperature regulation by forest ecosystems is a multifaceted process integral to maintaining environmental balance and supporting biodiversity. Forests play a crucial role in modulating temperature at various spatial and temporal scales through a combination of biophysical, ecological, and physiological mechanisms.

   a. Shade and Canopy Cover:

      Forests provide shade and canopy cover, which help reduce solar radiation and heat absorption by the forest floor and surrounding landscape. The dense canopy intercepts sunlight, preventing it from directly reaching the ground and reducing surface temperatures. This shading effect can significantly lower temperatures in forested areas compared to open landscapes.

b. Evapotranspiration:
Trees and other vegetation within forests engage in evapotranspiration, a process where water is absorbed by plant roots, transported through the plant, and released into the atmosphere through transpiration. This evaporation of water from leaves and soil surfaces helps cool the surrounding air and reduces ambient temperatures through latent heat exchange. Evapotranspiration rates are typically higher in forests compared to non-forested areas, leading to localized cooling effects.

c. Albedo and Reflectivity:
Forests exhibit higher albedo, or reflectivity, compared to non-forested surfaces such as bare soil or urban areas. The lighter colour of leaves, branches, and forest litter reflects more sunlight back into the atmosphere, reducing heat absorption and lowering surface temperatures. This albedo effect contributes to the overall cooling of forested landscapes.

d. Microclimate Modification:
Forests create microclimates characterized by lower temperatures, higher humidity, and reduced wind speeds compared to adjacent open areas. These microclimatic conditions are conducive to the growth and survival of shade-tolerant species and provide refuge for wildlife during periods of extreme heat. Forested microclimates also influence local weather patterns and contribute to regional climate regulation.

e. Carbon Sequestration and Climate Regulation:
Forests play a vital role in climate regulation by sequestering carbon dioxide from the atmosphere through photosynthesis and storing it in biomass and soil organic matter. This carbon storage helps mitigate the greenhouse effect and reduce global temperatures by offsetting the accumulation of greenhouse gases in the atmosphere.

Formats were designed to record the temperature and humidity on daily basis inside randomly selected points which covers the ethnic villages as well. The temperature was recorded at four cardinal points (06:00, 12.00, 18:00 and 24;00 of each day during the field survey exercise.

4. **Ethnic Village information:** Relevant secondary information on list of ethnic villages, respective numbers of households, community, language and population was collected from the records available with the Divisional Forest Officer, Kamrup East Division to help field teams to locate those villages and subsequently collect socio-economic data.

DATA COLLECTION PLANNING

A comprehensive plan for data collection was developed for field surveys defining the parameters to be measured at each sampling plot, including –

- Vegetation characteristics (e.g., tree species, diameter at breast height, height, partial crown biomass)
- Soil properties (e.g., texture, organic carbon content)
- Environmental variables (e.g., topography, elevation)
- Climate (e.g., temperature, humidity)
- Water velocity, width and depth of stream
- Socio-economic survey of villagers
- Survey data from commercial and Governmental organisations, educational institutions, tour service providers, visitors, bikers, joggers, photographers and environment enthusiasts.

While designing the data collection forms National Forest Inventory carried out by Forest Survey of India was referred and adopted.

MANPOWER MOBILISATION and EQUIPMENTS

1. **Survey Team:**
   A total of 5 teams were formed comprising of 5 Forester-I each led by a Forest Ranger and assigned with survey and data collection works in equal number of sample plots, ethnic villages, streams, Govt. organisations and commercial establishments. Field staffs were deputed from Assam Forest School, Forest Resources and Survey Division, Genetic Cell Division specially for the exercise. Postgraduate interns were also engaged to assist field teams and data recording.

FES TEAMS FOR FEB-APR, 2023

TEAM I	TEAM II
TEAM LEADER	**TEAM LEADER**
ABHIJEET DOLEY, RFO	PALLAVI DAS, RFO
GROUP MEMBERS	**GROUP MEMBERS**
PRANJAL PRAKASH DAS, FR1	DILIP KALITA, FR1
NIRUPAMA BARUA, FR1	KAMAL DAS, FR1
GAYATRI GOGOI, FR1	MOIDUL ISLAM, FGD
NITYA NANDA DEKA, FGD	UMESH CH DAS, FGD

TEAM III	TEAM IV
TEAM LEADER	**TEAM LEADER**
PANCHALI HAZARIKA, RFO	KASTURI GOSWAMI, RFO
GROUP MEMBERS	**GROUP MEMBERS**
HIROK HINDOL SARMA, FR1	HIMANGSHU BHATTACHARYYA, FR1
NAYANMONI DEKA, FR1	PRANAB DEKA, FR1
PHUKAN CH DAS, MALI	MD TAZIMULLAH, FGD
PRADIP MAHANTA, FGD	JITEN CH. KALITA, MALI

TEAM V
TEAM LEADER
NIGAR SULTANA, RFO
GROUP MEMBERS
BISHAN BASUMATARY
JAN ALI BORA, FGD
HEMEN DAS
BEAUTY OWARY, FR1

FES TEAMS FOR OCT-DEC, 2023

TEAM I
TEAM LEADER
MUNMI GOGOI, RFO
GROUP MEMBERS
MUKUNDA MALAKAR, FR-I
HITESH KALITA, FGD
JAN ALI BORA, FGD
PRADIP MAHANTA, FGD

TEAM II
TEAM LEADER
NIGAR SULTANA, RFO
GROUP MEMBERS
GAYATRI GOGOI, FR1
MONALISHA KULI, FR-I
MOIDUL ISLAM, FGD
NARENDRA RAJBONGSHI, FGD

TEAM III
TEAM LEADER
PRANJAL PRAKASH DAS, FR1
GROUP MEMBERS
NAYANMONI DEKA, FR1
SUSHMITA PATIR. FGD
PHUKAN CH. DAS, MALI
ASIM TERON, FGD

TEAM IV
TEAM LEADER
HIMANGSHU BHATTACHARYYA, FR1
GROUP MEMBERS
BIPUL DAS. FR-I
NIRUPAMA BARUA, FR1
MD TAZIMULLAH, FGD
PRANJAL PANGING, FGD

TEAM V
TEAM LEADER
DHARMESHWAR NATH, RFO
GROUP MEMBERS
DILIP KALITA, FR-I
MD. ABDULLA, FR-I
DIBYOJYOTI BARUAH, FGD
JITEN KALITA, MALI

2. **Core Technical Group:**
   A core technical group is formed, led by Sri Dibakar Deb, *AFS, Silviculturist, Assam* comprising Smt. Preeti Buragohain, *AFS, Dy Conservator of Forests,* Sri Mrigen Barua, *AFS, Asstt. Conservator of Forests,* Smt. Himamoni Handique, *Research Officer* as members for designing the entire exercise, planning, monitoring, course corrections during field surveys, technical guidance to the field teams and coordination with different Governmental and Non-governmental organisations and data analysis for carrying out the activities in a seamless way.

3. **Equipment:**
   Ensured availability of necessary equipment, tools, and resources required for field data collection, such as GPS devices, measuring tapes, soil sampling kits, and field notebooks were assured. Capacity building of field personnel on survey protocols, data recording techniques, and safety measures was also carried out.

Garmin 78s GPS

Measuring Tape

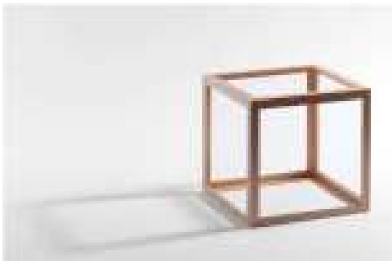
Thermo-Hygrometer

Soil Thermometer

Densiometer

DSLR Camera

Binocular



1 Cu mtr frame

Abney's Level

Ruler

Electronic Balance

Beaker

Hanging field weight balance

Nylon Rope

Ranging Rod

QUANTIFICATION METHODLOGY FOR ECOSYSTEM SERVICES

1. **Pre-survey activities**

The vector layers of Land Use, Land Use Change, and Forestry (LULUCF) 2014 maps obtained from NESAC, Meghalaya and feedbacks from the frontline staffs of Kamrup East Division posted inside Garbhanga RF provided crucial information about the land cover and forest characteristics within the Garbhanga Reserved Forest (RF) area. To modify the existing LULC forest classification vector of 2014 pertaining to Garbhanga Reserved Forest (RF) using data from pre-survey stratified random sample points, following steps were taken –

I. Existing LULC vector dataset obtained from NESAC prepared during in 2014 includes classified polygons representing different land cover classes e.g., VDF, MDF, OF, SF, Bamboo, Kharif, Plantation etc. of Garbhanga RF.
II. A stratified random sampling approach is designed, where the strata are defined by these different land cover classes. The goal was to ensure that your sample points are representative of each class proportionately to its extent in the LULC map.
III. Using GIS software\ e (QGIS/ArcGIS), pre-survey random sample points are generated within each stratum. The number of sample points generated for each stratum ensuring the field data collection would adequately represent the diversity of land cover types within Garbhanga RF.
IV. Each of the generated sample points in the field were visited and detailed observations and measurements related to land cover types, vegetation density, forest structure, and any changes or discrepancies compared to the 2014 LULC classification were recorded.
V. Attribute data for each sample point, including vegetation type, canopy cover percentage, tree species composition, disturbance levels, and any other relevant information was collected which can refine or update the existing LULC classification.
VI. Once field data collection is complete, the collected data was analysed to update or modify the existing LULC classification. This involved adjusting boundaries of existing polygons, reclassifying land cover types based on field observations, or adding new categories that better reflect the current state of Garbhanga RF.pppp
VII. Pre-survey field data was used to validate the accuracy of the existing LULC map. Areas were identified where the map needs revision based on discrepancies found during field surveys.
VIII. Pre-survey field survey data was incorporated into GIS environment to ethe attribute table of the LULC vector dataset to reflect the updated classification and attribute information gathered from the field and fresh map is generated by validating with Landsat 8 imageries. These maps are instrumental in re-delineation of various layers that represent different forest types and land use categories, enabling a comprehensive understanding of the landscape composition. Here's an elaboration on the delineated layers and the significance of each:

SCRUB FOREST

OPEN FOREST

MEDIUM DENSE FOREST

VERY DENSE FOREST

KHARIF

BAMBOO

PLANTATION

i. **Scrub Forests (SF <=10% canopy density):**
These areas comprise vegetation with a sparse canopy cover, typically less than or equal to 10% canopy density. Scrub forests often represent transitional or degraded forest areas, characterized by the presence of shrubs, grasses, and scattered trees.

ii. **Open Forests (OF 10% - 40% canopy density):**
Open forests have a moderate canopy cover ranging from 10% to 40%, allowing lesser sunlight than scrubs to penetrate the forest floor. These areas may include a mix of tree species with varying densities, providing habitat for diverse wildlife and supporting ecosystem functions such as carbon sequestration and soil stabilization.

iii. **Medium Density Forests (MDF 40% - 70% canopy density):**
Medium density forests exhibit a relatively denser canopy cover, ranging from 40% to 70%. These forests are characterized by a greater diversity of tree species and vertical structure, contributing to enhanced biodiversity and ecological resilience.

iv. **Very Dense Forests (VDF >70% canopy density):**
Very dense forests have a high canopy cover exceeding 70%, resulting in a dense and closed canopy structure. These forests are typically composed of mature and climax vegetation, supporting a rich array of flora and fauna and providing critical habitat for specialized species.

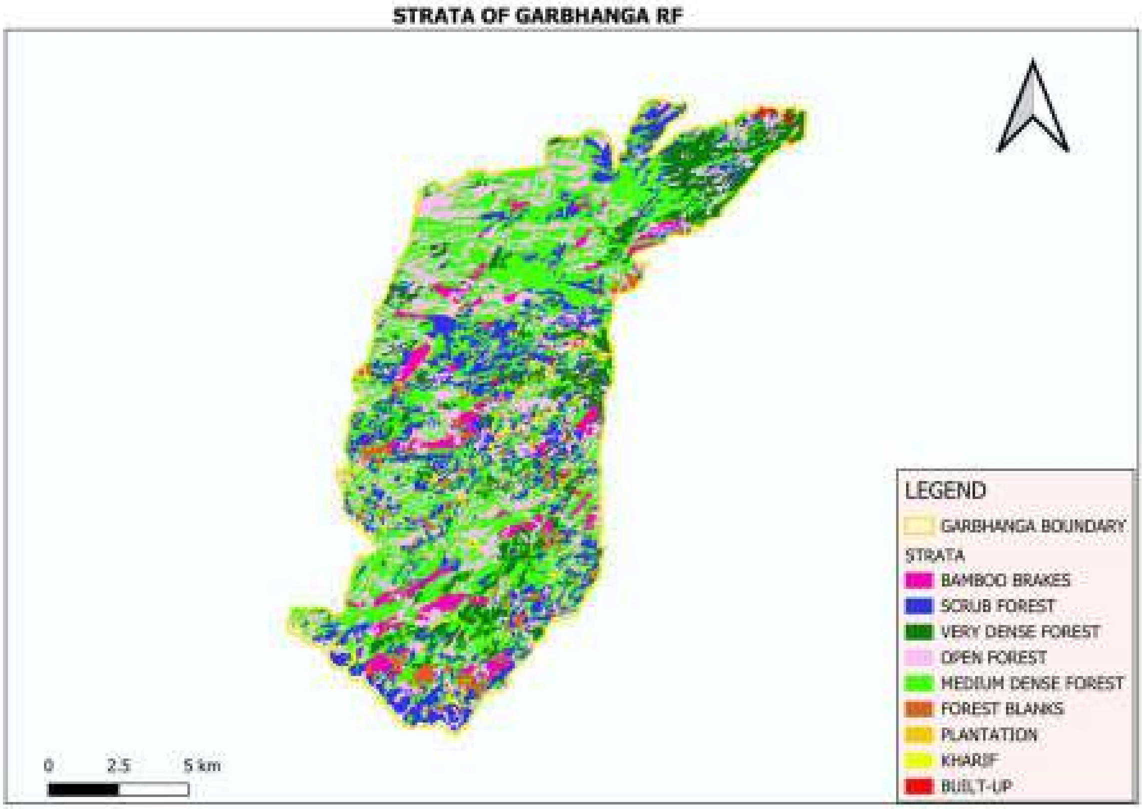
v. **Forest Blanks:**
Forest blanks represent non-forest areas within the Garbhanga RF, such as open grasslands, rocky outcrops, or barren terrain. These areas may serve as ecotones or transition zones between different forest stands, offering valuable insights into landscape heterogeneity and ecological processes.

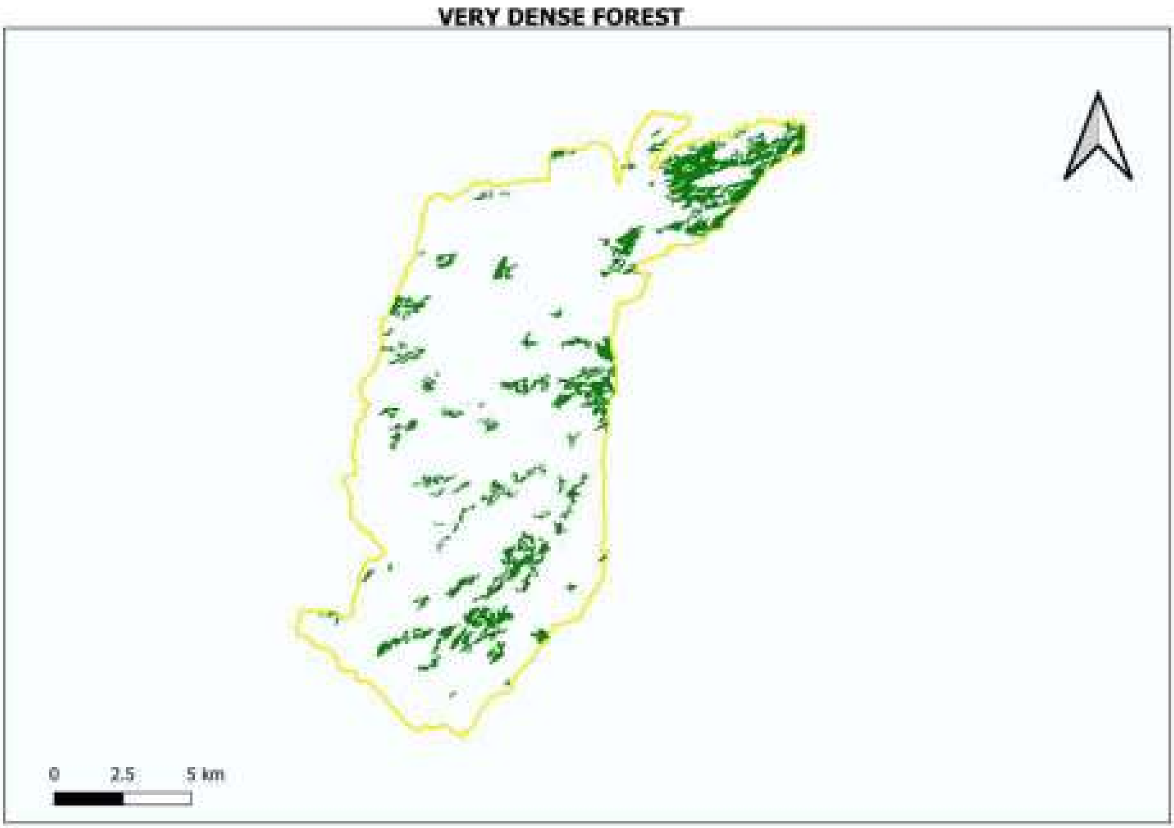
vi. **Kharif (Agricultural Lands):**
Kharif cultivation areas encompass agricultural lands within the Garbhanga RF, where seasonal crops are typically cultivated during the monsoon (Kharif) season. These lands may include rice paddies, maize fields, or other rain-fed crops, highlighting the interface between natural and anthropogenic land uses within the forest landscape.

vii. **Bamboo:**
Bamboo forests represent areas dominated by bamboo species, which are ecologically and economically significant components of forest ecosystems. Bamboo forests provide various ecosystem services, including soil stabilization, erosion control, and livelihood support for local communities through bamboo harvesting and crafts.

viii. **Plantations:**
Plantations refer to areas where trees are deliberately planted and managed for commercial or non-commercial purposes, typically in monoculture or mixed-species stands.

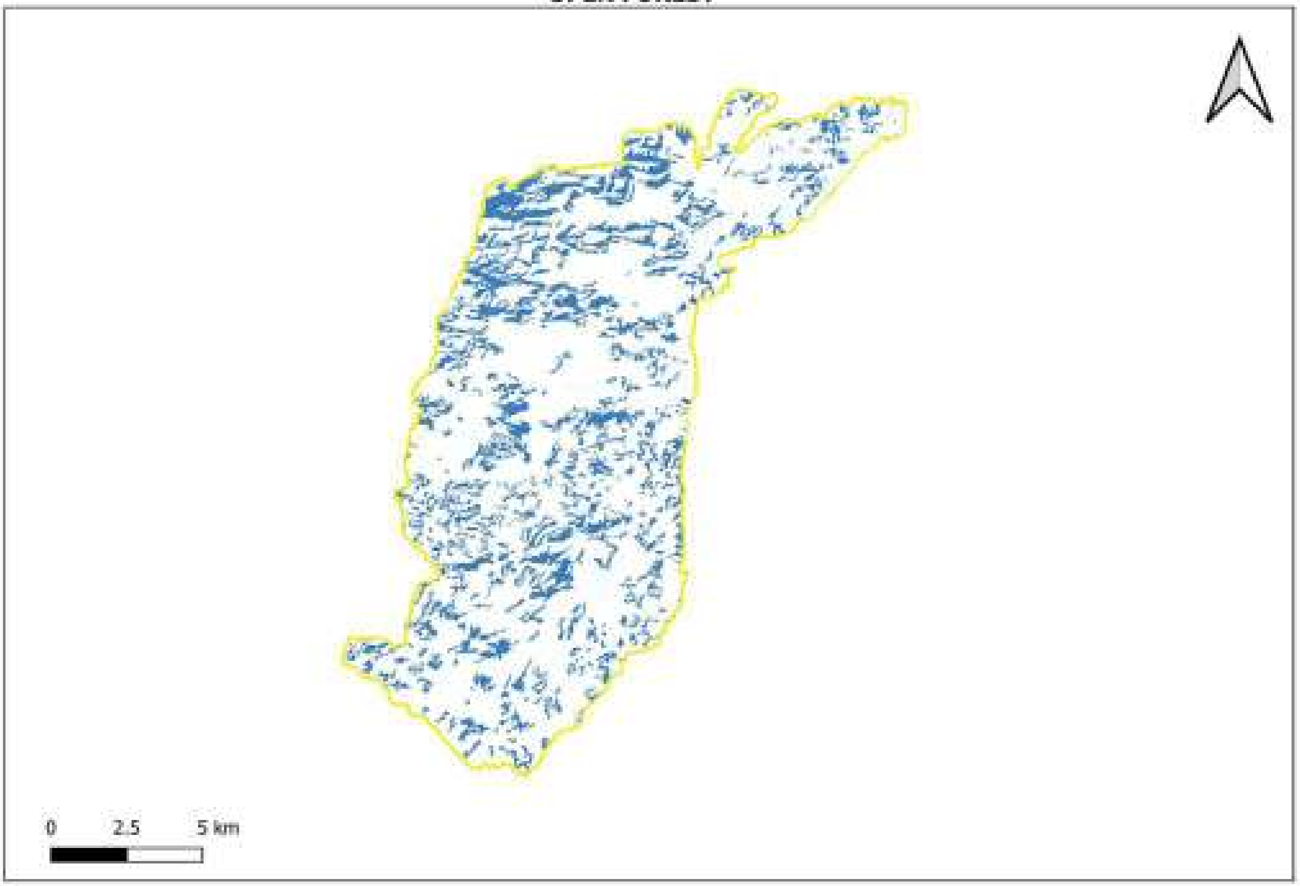
ix. **Water Bodies:**
Additionally, obtaining line shape files for rivers and streams flowing within the Garbhanga RF is critical for understanding hydrological dynamics, water flow patterns, and aquatic habitat connectivity within the forest landscape. These shape files facilitate the delineation of river networks, stream channels, and riparian zones, enabling assessments of water quality, aquatic biodiversity, and ecosystem health within the Garbhanga RF. The river/stream shape files obtained from NESAC serve as valuable geospatial datasets for characterizing the hydrological features within the Garbhanga RF.


STRATA OF GARBHANGA RF
LEGEND
GARBHANGA BOUNDARY
STRATA
BAMBOO BRAKES
SCRUB FOREST
VERY DENSE FOREST
OPEN FOREST
MEDIUM DENSE FOREST
FOREST BLANKS
PLANTATION
KHARIF
BUILT-UP
0
2.5
5 km

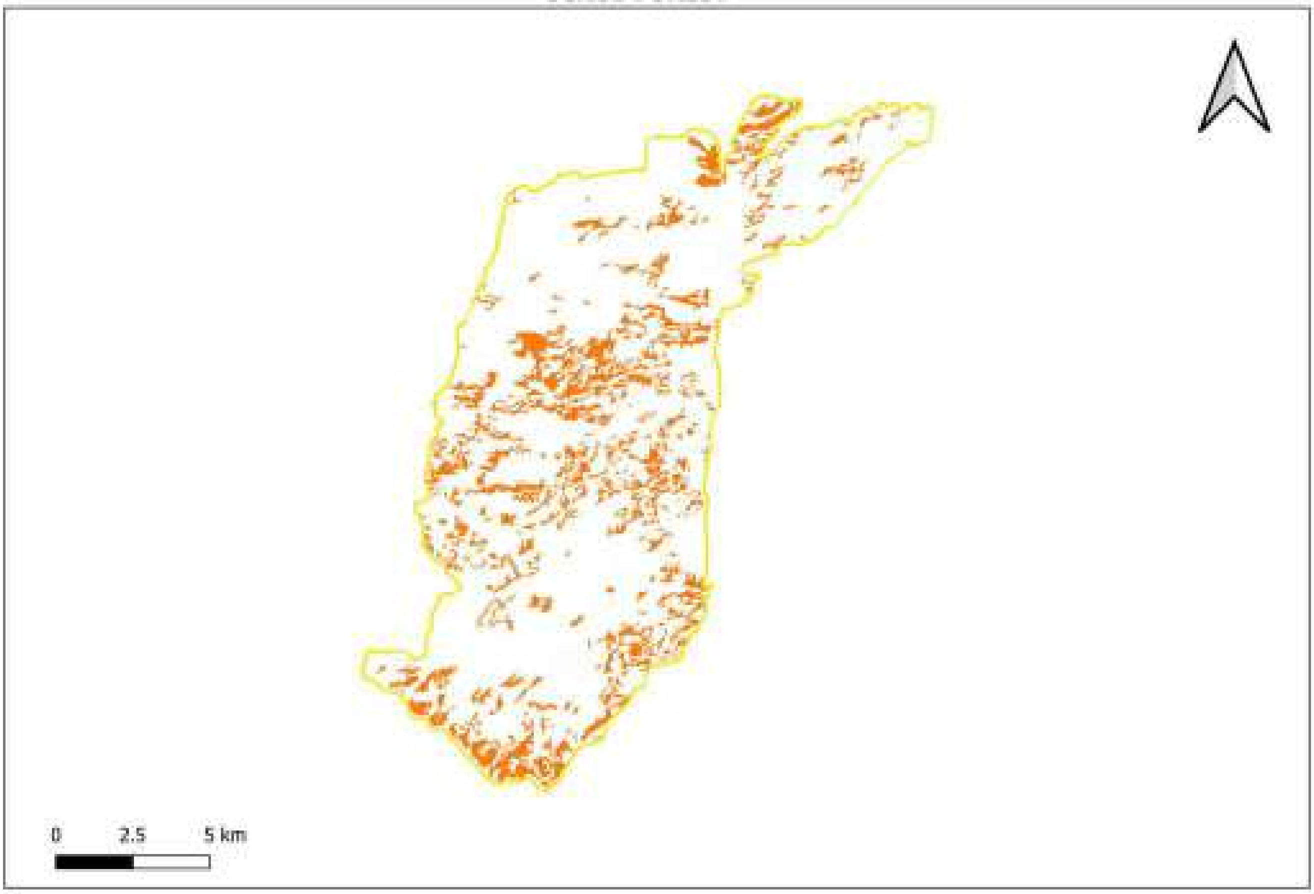

VERY DENSE FOREST
0
2.5
5 km

NEDIUM DENSITY FOREST

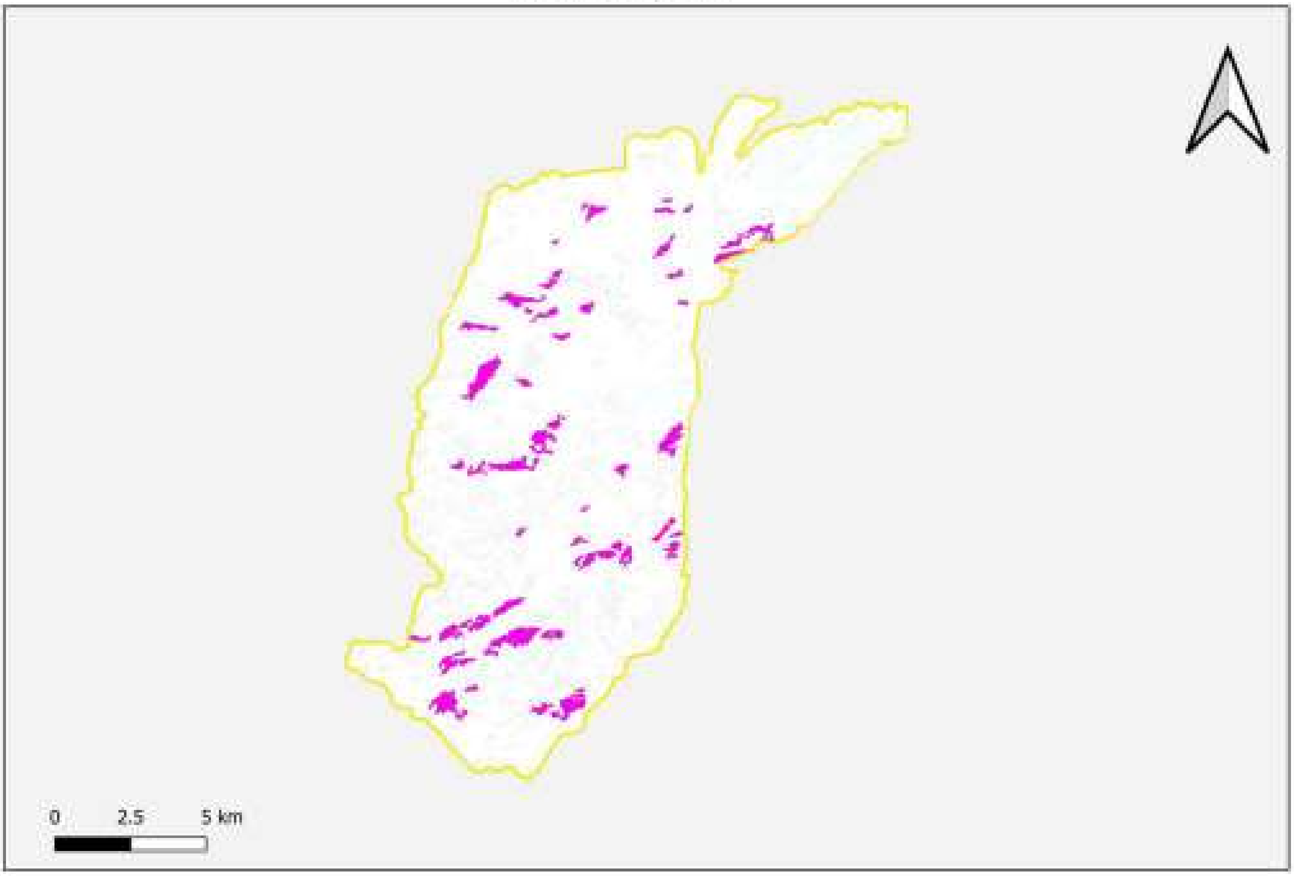
OPEN FOREST



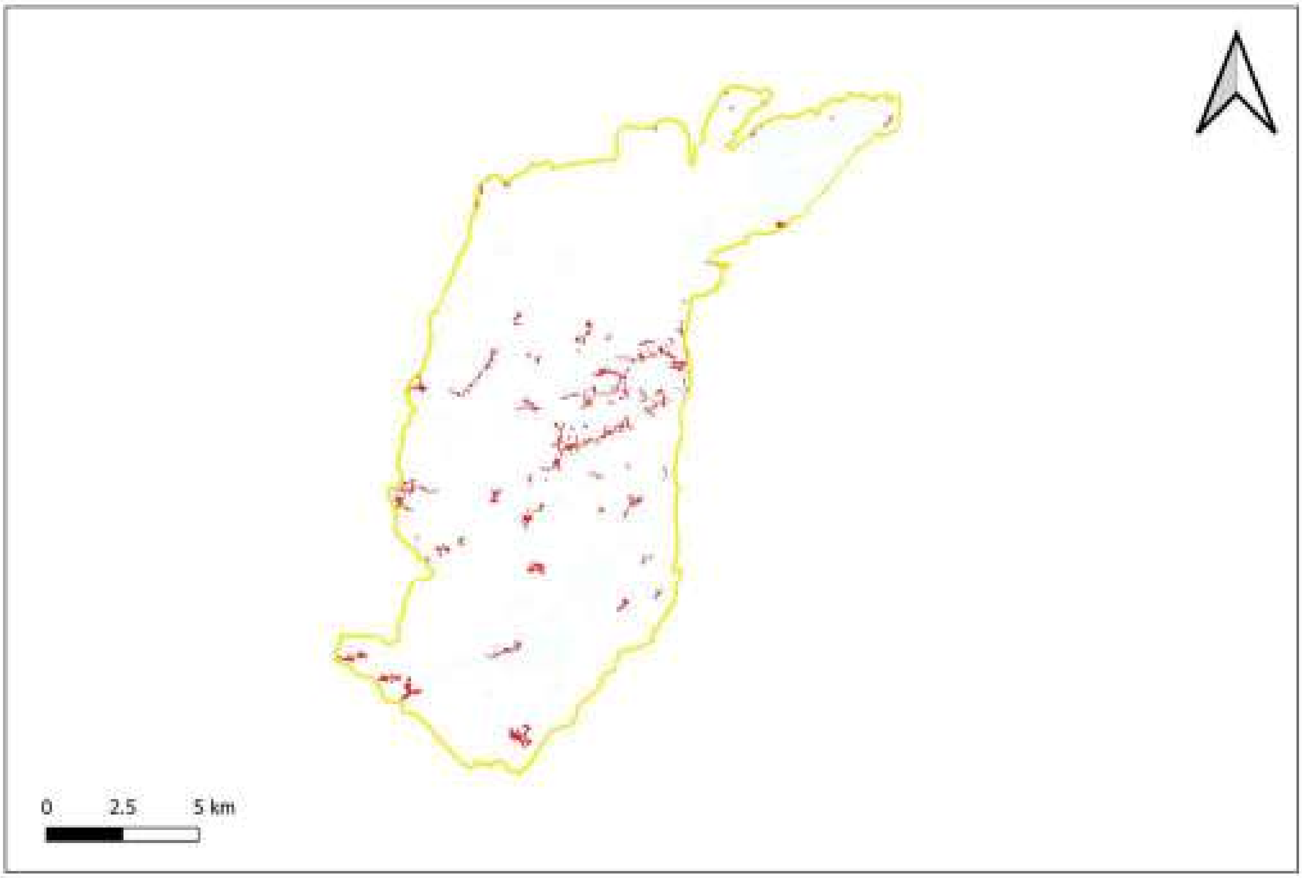
SCRUB FOREST



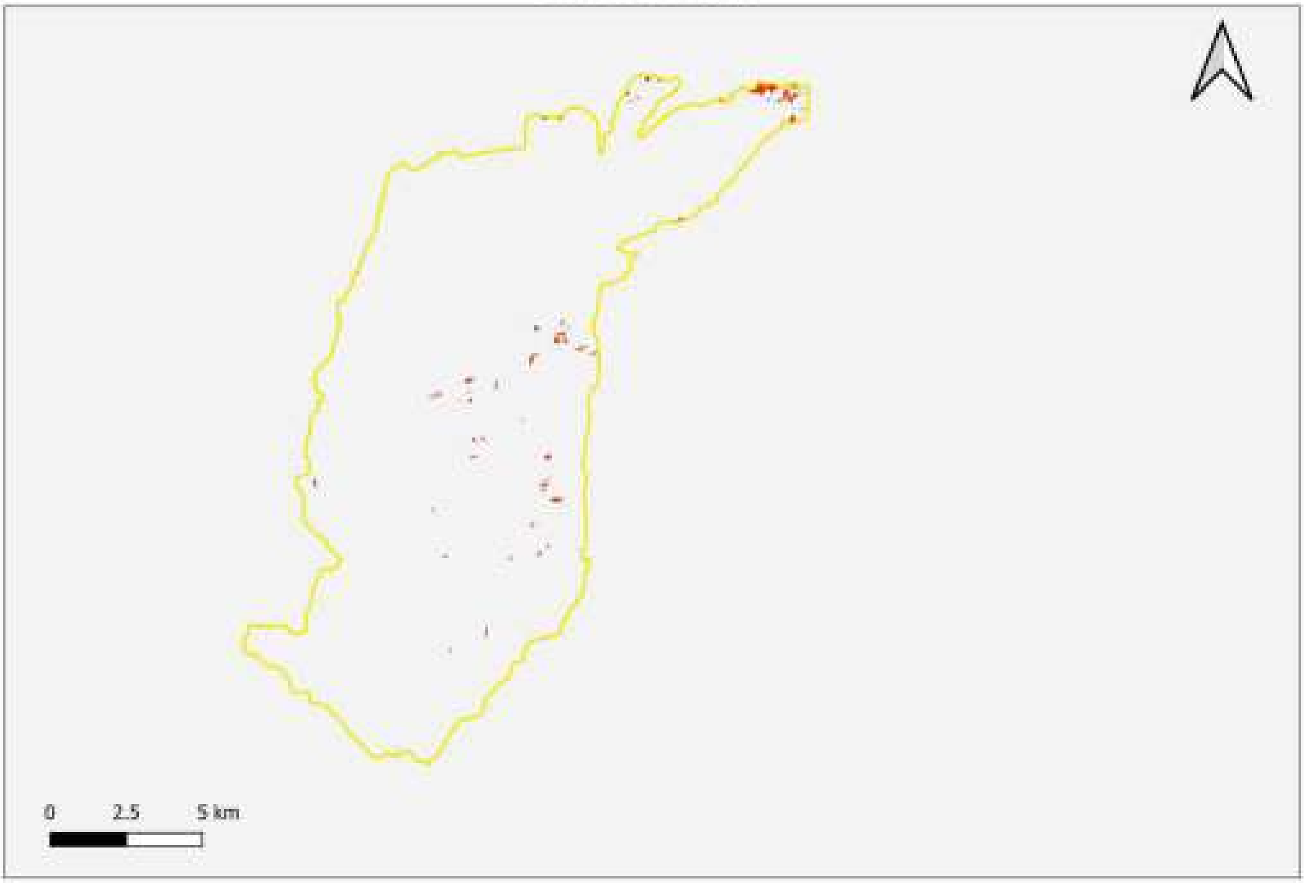
BAMBOO BRAKES



KHARIF



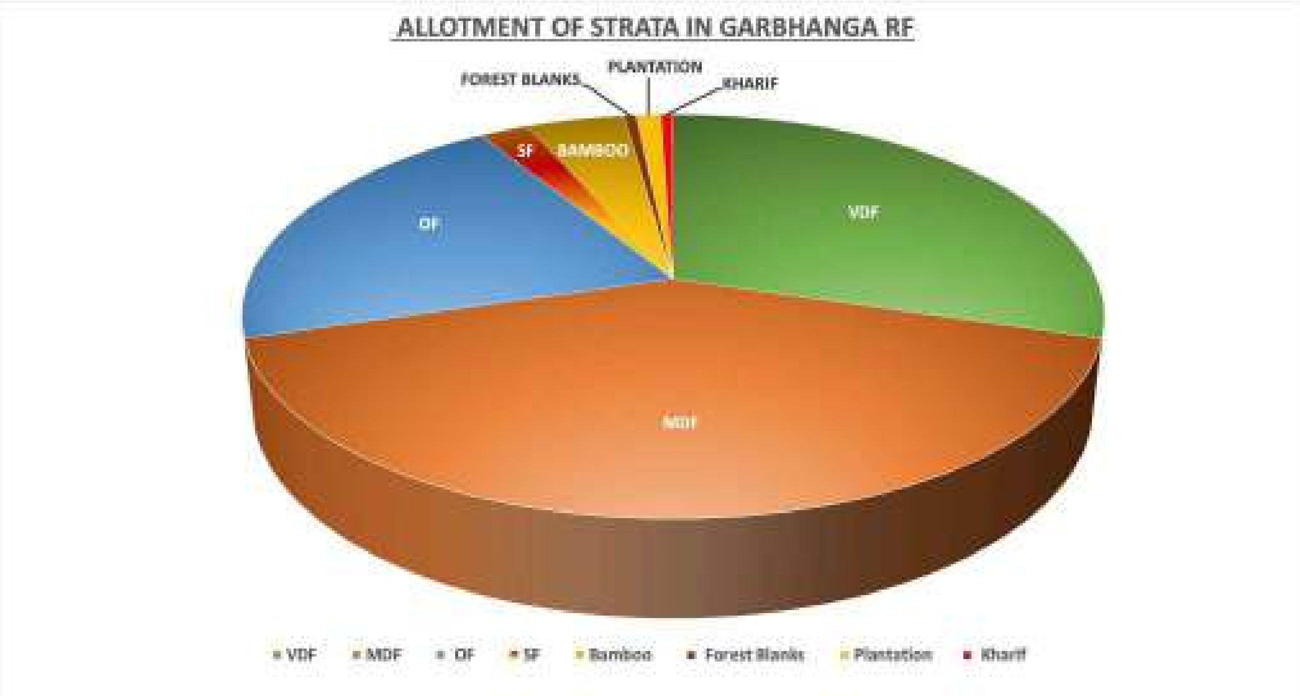
ETHNIC VILLAGES



x. Assigning sample points for biomass and carbon estimation:

By analysis of the fresh thematic LULUCF maps, the area assigned to following strata are –

No.	Strata	Area
1	VDF	5,400 ha
2	MDF	7,400 ha
3	OF	3,800 ha
4	SF	400 ha
5	Bamboo	800 ha
6	Forest Blanks	100 ha
7	Plantation	200 ha
8	Kharif	100 ha
	Total	**18,200 ha**



Applying stratified random sampling principle and 1% sampling intensity 182 Nos.. of sample plots of size 0.1 ha each have been distributed to all 8 land use strata in areas proportionately to each strata of forests taking strata, slope, accessibility, proximity to roads into consideration, as –

$\mathbf{N_i = (A_i / A_t) * N_t}$,

Where,

$\mathbf{N_i}$ = Number of sample points assigned to each strata;

$\mathbf{A_i}$ = Area assigned to each strata;

$\mathbf{A_t}$ = Total area of the Forest;

$\mathbf{N_t}$ = Total numbers of sample points;

No.	Strata	No. of sample points
1	VDF	54
2	MDF	74
3	OF	38

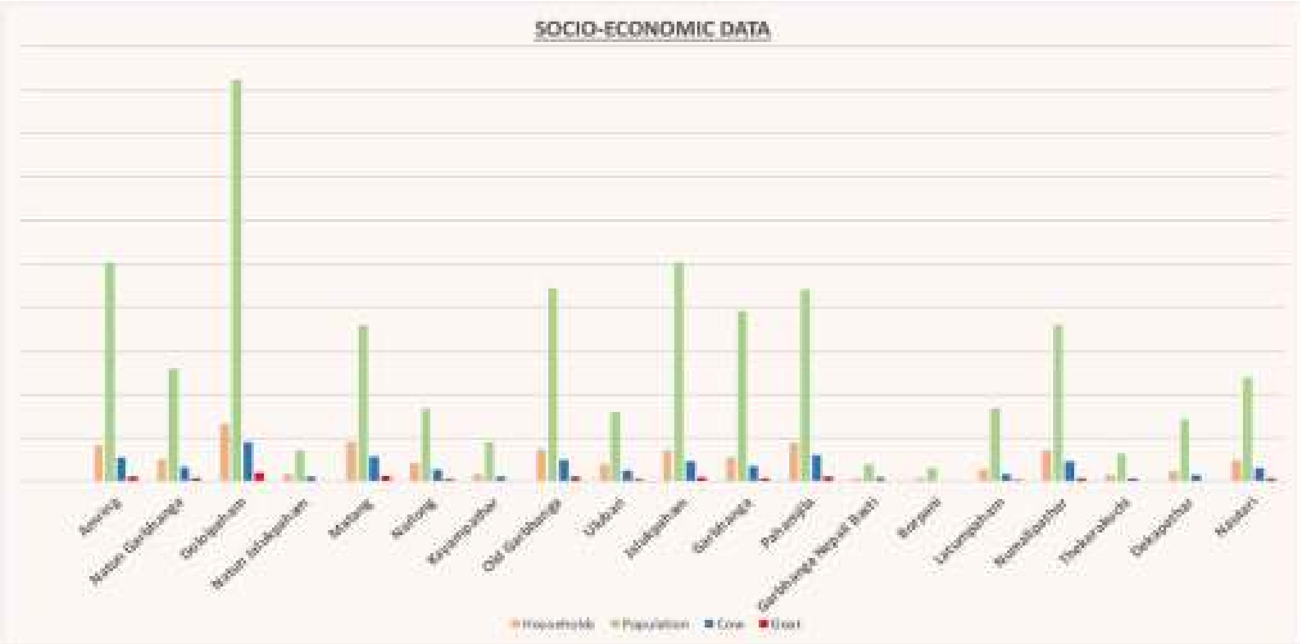
4	SF	4
5	Bamboo	8
6	Forest Blanks	1
7	Plantation	2
8	Kharif	1
	Total	**182**

2. **Assigning data collection points for water flow and retention**
Following the random sampling principle, data collection points are chosen along the rivers and streams within the Garbhanga Reserved Forest. These points are strategically selected to represent a diverse range of characteristics, including slope, spread, and bank features using GIS technology, ensuring a comprehensive sample of the water bodies' attributes. In total, a specified number of data collection points are distributed along the rivers and streams, which collectively span a total length of 150.11 kilometres. At these designated points, essential data such as water velocity, width, and depth are meticulously recorded during the dry season. This data collection process aims to accurately estimate the total water discharge of the rivers and streams, providing valuable insights into their water retention capacity within the Garbhanga RF.

3. **Identifying the location of Ethnic villages for socio-economic data collection**
Based on the records housed within the office of the Divisional Forest Officer, Kamrup East Division, comprehensive information regarding the number and geographical locations of villages, along with their corresponding tribal affiliations, was collated and documented for reference. These records offer valuable insights into the distribution and demographics of the local communities residing within the area of interest. In addition to gathering socio-economic data, the assessment also included documenting the dependency on forests through the utilization of water and other tangible benefits. This comprehensive approach sought to provide a holistic understanding of the multifaceted relationship between local communities and the forest ecosystem. By capturing information on water usage and other tangible benefits derived from forests viz., NTFPs like medicine, food, fodder, timber, bamboo, MFP and firewood, the assessment aimed to delineate the intricate interdependencies that underpin the livelihoods and well-being of forest-dependent communities. This data contributes valuable insights into the significance of forests beyond their economic contributions, highlighting their pivotal role in supporting essential ecosystem services and enhancing community resilience.

Sl No.	Village	Households	Community	Population	Live Stock Numbers	
					Cow	**Goat**
1.	Amring	42	Karbi	252	28	6
2.	Natun Garbhanga	26	Karbi	130	17	4
3.	Doloipaham	66	Khasi	462	45	10
4.	Natun Jalukpaham	09	Karbi	36	06	-
5.	Matang	45	Karbi	180	29	7
6.	Narlong	21	Karbi	84	14	3
7.	Kayampathar	09	Karbi, Nepali	45	06	-
8.	Old Garbhanga	37	Karbi	222	25	6
9.	Ulubari	20	Karbi	80	13	3
10.	Jalukpaham	36	Karbi	252	23	5
11.	Garbhanga	28	Karbi	196	18	4
12.	Pahamjila	44	Karbi	220	31	6

13.	Garbhanga Nepali Basti	04	Nepali	20	05	-
14.	Borpani	04	Karbi	16	-	-
15.	Latumpaham	14	Karbi	84	09	2
16.	Numalipathar	36	Karbi	180	23	4
17.	Thekerakuchi	08	Karbi	32	04	-
18	Dekapathar	12	Rabha	72	08	-
19	Nautari	24	Karbi	120	16	4
	Total:	**485**	-	**2683**	**320**	**64**



AERIAL VIEW OF ETHNIC VILLAGE

4. Identification of location of local markets

The identification, location, and assessment of local markets play a pivotal role in shedding light on the valuation of forest ecosystem services within the Garbhanga Reserved Forest (RF) context. Specifically, this assessment focuses on understanding the commercial value of tangible forest products, thereby helping in cognizance of the provisioning services rendered by the Garbhanga RF to local villagers and citizens of Guwahati alike. By meticulously examining the markets where forest products are traded, we gain a deeper understanding of the economic contributions made by the forest ecosystem, particularly in terms of tangible goods.

Selling activities in Local markets

This assessment serves as a crucial tool for determining the commercial value of provisioning services offered by the Garbhanga RF, which directly impact the livelihoods and well-being of local communities. Through the exchange of forest products in local markets, the Garbhanga RF provides essential resources such as forest food and traditional medicines, which not only meet the subsistence needs of forest-dependent communities but also cater to the diverse requirements of urban populations in Guwahati.

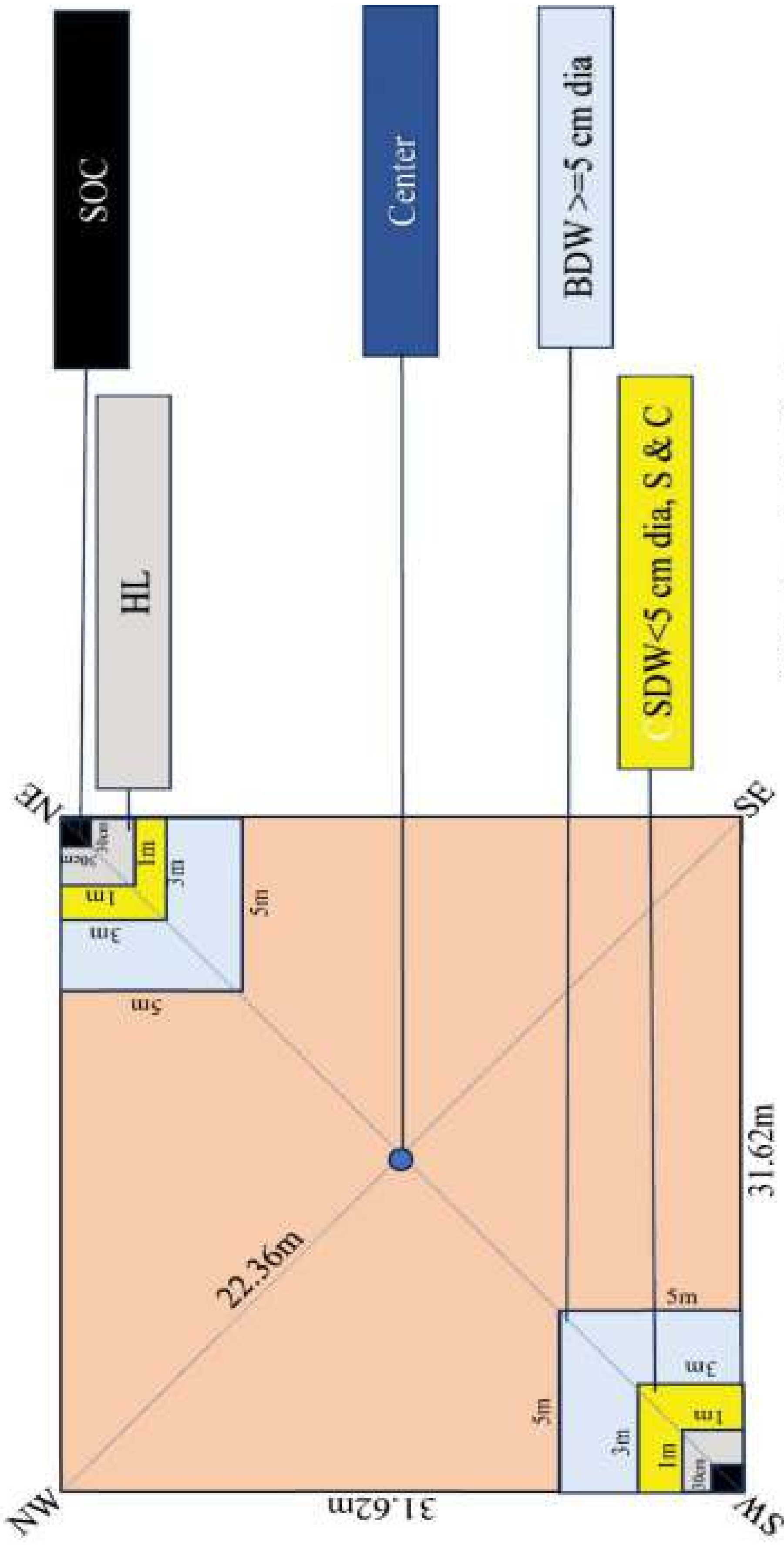
Acknowledging the diverse range of forest products traded in these markets, including edible plants, medicinal herbs, and raw materials for handicrafts, underscores the multifaceted nature of provisioning services offered by the Garbhanga RF. These products not only contribute to local economies but also uphold cultural traditions and promote biodiversity conservation. The list of local markets are listed as –

Sl No.	**Market**	**Location**
1.	Garbhanga	Lokhra, Guwahati
2.	Saokuchi	Saukuchi, Guwahati
3.	Lotakota	Basistha, Guwahati
4.	Beltola	Beltola, Basistha

5. **Laying out of sample plot of 0.1 ha for collection of tree biomass data:**
   Upon reaching the centre of the plot, points were established at the Northeast (NE) at 45^{o}, Southeast (SE) at 135 ^{o}, Southwest (SW) at 225 ^{o}, and Northwest (NW) at 315 ^{o} corners of the plot. This was achieved by measuring a horizontal distance of 22.36 meters (half of the diagonal) using a measuring tape in all four directions. Thin poles or bamboos with a diameter of 5 centimetres and a height of 1.5 meters were placed at these four corners to mark them. To ensure clear visibility from various points within the plot, the top end of these corner posts was marked with red colour. The dimensions of the plot were subsequently verified, with all sides measuring a horizontal distance of 31.62 meters.

   A comprehensive tree enumeration was conducted, encompassing the measurement and recording of various tree parameters. These parameters included tree height, tree bole height, diameter at breast height, and crown diameter along both major and minor axes. Additionally, biomass samples consisting of twigs, branches, and leaves were harvested from a selected portion of the crown, precisely measuring 1m x 1m x 1m in volume. This sampling was achieved using a wooden frame of identical volume. Subsequently, the green weight and dry weight of the biomass samples were meticulously recorded for each tree species surveyed.

6. **Laying out of sub-plots of 0.1 for collection of ground biomass and soil data[E]:**
   Concentric sub-plots of varying sizes were delineated within the study area using rope and sticks in the NE and SW corners of the sample plots. These sub-plots included:
   i. Sub-plots measuring 5m x 5m designated for the assessment of stumps and large deadwood (BDW). All dead stumps were measured and big dead wood >5 cm Dia were collected and weight measurement was carried out.
   ii. Sub-plots measuring 3m x 3m allocated for the examination of small dead wood (SDWS and C), shrubs and climbers. All shrubs with collar diameter <10 cm were also uprooted and carried to Hd/Qr to calculate its dry biomass. Similarly all small dead wood ≤ 5cm were collected and weighed.
   iii. Sub-plots measuring 1m x 1m designated for the inventory of herbs and litter (HL). At first herbs are uprooted subsequently litters including dry leaves, humus etc are collected and carried to Hd/Qr for measuring dry biomass. All herbs were uprooted and carried to Hd/Qr for measuring dry Biomass.
   iv. Sub-plots of size 30 cmX30 cm designated for soil assessment (SOC). Soil was dug out from the pits is mixed properly measuring 30cm x 30cmx 30cm and weighed. Out of which a sample of 500 grams were carried to Hd/Qr for drying and sending to laboratory for organic carbon and macro-nutrient analysis.



0.1Ha Sample Plot Design

Chapter V

VALUATION TECHNIQUES, LIST OF FOREST ECOSYSTEM SERVICES

VALUATION TECHNIQUES

1. **Market-based Approach**

The market-based approach to valuation of forest ecosystem services, particularly from the perspective of provisional services such as forest food, forest medicine, and firewood, entails assessing their economic worth through existing or potential market transactions. These services, deeply intertwined with human well-being and livelihoods, hold significant economic value that can be quantified through market-based mechanisms.

a. **Forest Food**:

Forests provide a diverse array of edible plants, fruits, nuts, and fungi that are harvested by local communities for consumption or sale. The market-based approach to valuing forest food involves assessing the demand and supply dynamics of wild edibles in local markets or estimating their potential market value. Factors such as seasonality, scarcity, and nutritional value influence the economic worth of forest food products. By quantifying the market value of forest food, policymakers can better understand the contribution of forests to food security, nutrition, and local economies.

b. **Forest Medicine**:

Forests are a rich source of medicinal plants and herbs used for traditional healing practices and pharmaceutical applications. The market-based valuation of forest medicine involves analysing the demand for and supply of medicinal plants in pharmaceutical, herbal remedy, and traditional medicine markets. Economic indicators such as market prices, trade volumes, and medicinal plant cultivation can provide insights into the economic value of forest medicine. Recognizing the market value of forest medicine highlights the importance of forest conservation for maintaining biodiversity and supporting healthcare systems.

c. **Firewood**:

Firewood remains a vital energy source for millions of people worldwide, especially in rural and forest-dependent communities. The market-based approach to valuing firewood involves assessing its market price and demand-supply dynamics in local fuelwood markets. Factors such as accessibility, energy content, and alternative fuel sources influence the economic value of firewood. By quantifying the market value of firewood, policymakers can address energy access challenges, promote sustainable fuelwood management practices, and explore alternative energy solutions.

d. **Bamboo:**

Bamboo refers to a diverse group of fast-growing perennial grasses found in forest ecosystems. This versatile plant includes various species, each with unique characteristics and uses. Bamboo can be utilized for multiple purposes, such as construction materials, furniture, paper production, handicrafts, and even as a food source. Additionally, bamboo serves as a raw material for producing products like bamboo charcoal, vinegar, and fibre.

Bamboo plays a crucial role in the livelihoods of forest-dependent communities, providing them with essential resources for shelter, income generation, and cultural practices. Furthermore, bamboo contributes to environmental sustainability and forest health by promoting soil stabilization, carbon sequestration, and water regulation. Its rapid growth and ability to regenerate quickly make bamboo a sustainable alternative to timber, reducing deforestation pressure.

One of the most significant environmental benefits of bamboo is its high carbon sequestration potential. According to research, bamboo can sequester carbon more effectively than many tree species due to its rapid growth rate and high biomass production. Studies have shown that bamboo can absorb up to 12 metric tons of carbon dioxide per hectare per year . Additionally, bamboo forests have been found to store between 17-34% more carbon compared to similar-sized tree forests .

Bamboo's ability to quickly regenerate after harvesting further enhances its carbon sequestration capacity. Unlike trees, which may take decades to mature, bamboo can be harvested in cycles of 3-5 years without replanting, allowing for continuous carbon uptake . Furthermore, bamboo's extensive root system helps in storing carbon in the soil, contributing to long-term carbon storage even after the above-ground biomass is harvested.

Bamboo[F] is often harvested and processed by local communities using traditional knowledge and techniques, and it is traded both locally and internationally. In many countries, including India, policies and programs have been developed to support the sustainable management and marketing of bamboo, aiming to improve the livelihoods of forest-dependent communities, conserve biodiversity, and promote sustainable forest management efforts. Given its high carbon sequestration potential, bamboo cultivation and management are increasingly recognized as vital components in global strategies to combat climate change.

d. <u>MFP:</u>

Minor forest produce (MFP) refers to a wide range of non-timber forest products derived from forest ecosystems. These products include various plant materials, such as seeds, nuts, fruits, leaves, roots, barks, resins, and flowers, as well as non-plant materials like honey, wax, lac, and bamboo. MFP also encompasses animal products such as honey, beeswax, silk, and lac, as well as other items like medicinal herbs, mushrooms, and handicraft materials.

These products play a crucial role in the livelihoods of forest-dependent communities, providing them with essential resources for food, medicine, shelter, income generation, and cultural practices. Additionally, MFP contribute to biodiversity conservation, sustainable forest management, and the overall ecosystem health by promoting the sustainable use of forest resources and reducing pressure on timber extraction.

MFP[G] are often harvested and processed by local communities using traditional knowledge and techniques, and they are traded both locally and internationally. In many countries, including India, policies and programs have been developed to support the sustainable management and marketing of MFP, aiming to improve the livelihoods of forest-dependent communities, conserve biodiversity, and promote forest conservation efforts.

2. **<u>Stated Preference Approach</u>**

The valuation of forest ecosystem services through the Stated Preference Approach[H] involves assessing the economic worth of these services by directly eliciting preferences and willingness to pay (WTP) from individuals or households. Unlike market-based approaches that rely on observed market transactions, the Stated Preference Approach uses survey-based techniques to collect data on people's stated preferences and values for specific ecosystem services.
Administering surveys to a representative sample of the population to gather data on preferences, values, and WTP for forest ecosystem services. Surveys were conducted through face-to-face interviews, mail surveys, online surveys, or phone interviews, depending on the target population and research objectives. This approach is suitable for recreational activities such as hiking, camping,

birdwatching, and wildlife viewing in forested areas and cultural values associated with forests, aesthetic significance.

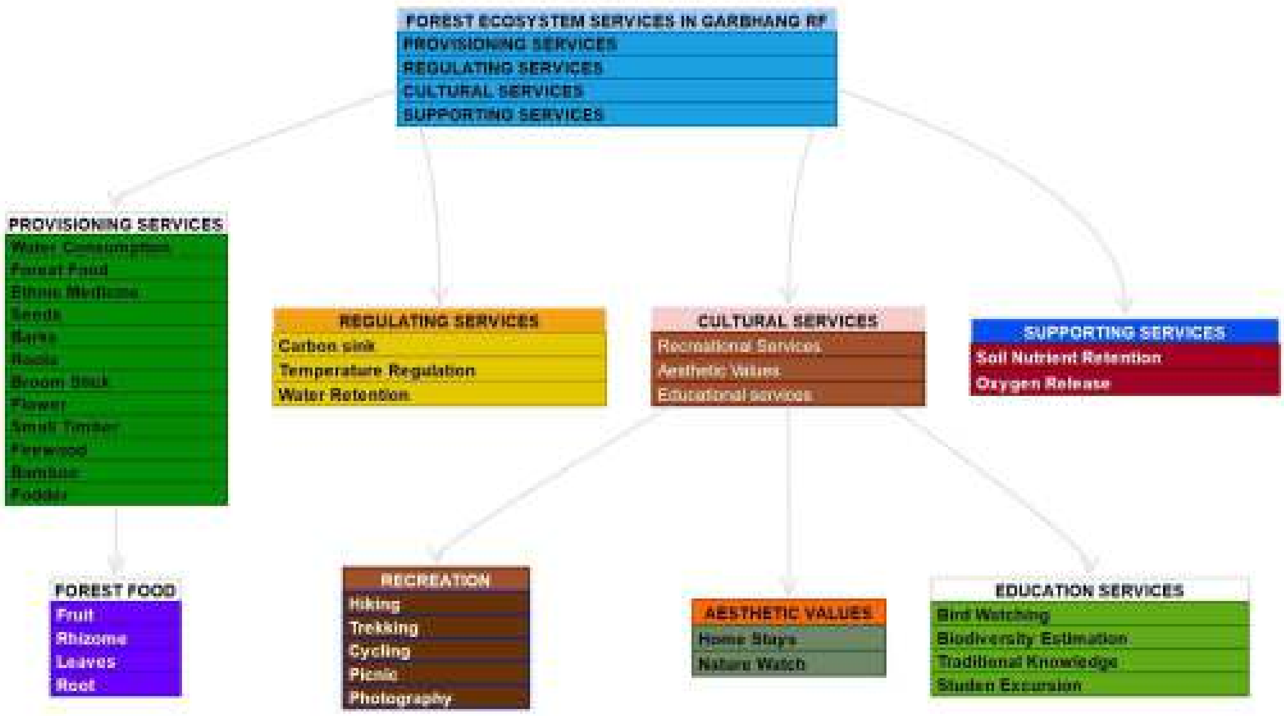
3. **Revealed Preference Approach[I]**
The valuation of forest ecosystem services using the revealed preference approach involves analysing actual market transactions and consumer behavior to infer the economic value of these services. Unlike stated preference methods, which rely on hypothetical scenarios and surveys, the revealed preference approach utilizes observed choices and behaviours to reveal the value that individuals place on ecosystem services. Key components those are taken into consideration for valuation of ES are of the revealed preference approach include:

   a. **Market Transactions Analysis:** This involves examining market transactions related to forest ecosystem services, such as timber sales, ecotourism revenues, and payments for ecosystem services (PES) schemes. By analysing these transactions, economists can infer the economic value that individuals or society as a whole assign to the services provided by forests.

   b. **Hedonic Pricing Analysis:** In the case of non-market goods or services, such as clean air, water quality, temperature regulation, water retention, Oxygen release or scenic beauty provided by forests, the revealed preference approach may involve hedonic pricing analysis. This method examines the relationship between urban pricing and the attributes of nearby ecosystems, allowing economists to estimate the implicit value that individuals place on these ecosystem services.

   c. **Travel Cost Method:** For recreational services provided by forests, such as hiking, birdwatching, or camping, the revealed preference approach may utilize the travel cost method. This method analyses the relationship between the cost of travel to recreational sites and the number of visits, allowing economists to estimate the value that individuals place on these recreational experiences.

In the calculation of the value of forest ecosystem services, a mixture of various valuation approaches was employed to capture the comprehensive economic worth of these invaluable natural resources. By integrating elements from market-based, stated preference, and revealed preference approaches, a nuanced understanding of the economic value of forest ecosystem services was achieved. By combining elements from these different valuation approaches, a holistic assessment of the economic value of forest ecosystem services was achieved.



CASE STUDIES ILLUSTRATING VALUATION OUTCOMES

Here are some case studies from India along with their implementing agencies carried out during the decade, illustrating valuation outcomes of forest ecosystem services:

Valuation of Carbon Sequestration in Western Ghats by Indian Institute of Science (IISc), Bangalore[J] (Dr. N.H. Ravindranath, 2011):

Description: *Researchers from IISc conducted a study to estimate the economic value of carbon sequestration in the Western Ghats, a biodiversity hotspot in India.*

Methods: *The study utilized a combination of remote sensing data, field measurements, and economic modelling to quantify the carbon storage capacity of forest ecosystems in the Western Ghats.*

Outcomes: *The study estimated the monetary value of carbon sequestration provided by the Western Ghats forests, highlighting their importance in climate change mitigation and the potential economic benefits of forest conservation efforts.*

Valuation of Ecotourism in Periyar Tiger Reserve, Kerala by Kerala Forest Department, Periyar Foundation and Wildlife Institute of India (WII), 2015:

Description: *Valuation of ecotourism in Periyar Tiger Reserve involves assessing the economic, environmental, and social benefits derived from ecotourism activities.*

Methods: *The study involved visitor surveys, expenditure analysis, and willingness-to-pay assessments to estimate the economic contributions of ecotourism to local communities and conservation efforts.*

Outcomes: *The study found that ecotourism generated significant revenue for local economies and provided incentives for forest conservation and community development initiatives in the Periyar Tiger Reserve.*

Estimation of Watershed Protection Value in Uttarakhand by Uttarakhand Forest Department IIFM[L] (Dr. Madhu Verma, 2007):

Description: *The Uttarakhand Forest Department conducted a study to estimate the economic value of watershed protection services provided by forests in the state.*

Methods: *The study utilized hydrological modelling, water quality assessments, and economic valuation techniques to quantify the benefits of forested watersheds in regulating water flow, reducing soil erosion, and maintaining water quality.*

Outcomes: *The study highlighted the critical role of forests in watershed management and the economic benefits of forest conservation for water security, agriculture, and ecosystem health in Uttarakhand..*

Valuation of Biodiversity in Western Ghats by Ashoka Trust for Research in Ecology and the Environment (ATREE)[M] (Dr. N. Madhusudan, 2005):

Description: *ATREE conducted a study to assess the economic value of biodiversity conservation in the Western Ghats, a global biodiversity hotspot.*

Methods: *The study employed participatory surveys, ecological assessments, and economic valuation methods to estimate the economic benefits of preserving biodiversity-rich ecosystems for local communities and ecosystem services.*

Outcomes: *The study provided insights into the economic importance of biodiversity conservation in the Western Ghats and conservation policies and management strategies to safeguard critical habitats and species.*

Economic Value of Timber Production in Himachal Pradesh by Himachal Pradesh Forest Department[N]:

Description: *The Himachal Pradesh Forest Department conducted a study to estimate the economic value of timber production in forested areas of the state.*

Methods: *The study involved timber inventory assessments, market surveys, and economic modelling to quantify the contributions of timber harvesting to regional economies, employment, and forest revenue.*

Outcomes: *The study focussed on forest management policies and sustainable harvesting practices in Himachal Pradesh, balancing economic benefits with ecological conservation objectives.*

These case studies highlight the diverse ecosystem services provided by forests in India and the importance of economic valuation in guiding forest management and conservation efforts. Through collaboration between research institutions, government agencies, and local communities, these studies contribute valuable insights into the economic contributions of forests and inform policies for sustainable forest management and conservation.

Chapter VI

ANALYSIS and FINDINGS

ANALYSIS and FINDINGS

Results and analysis of the data collected from Garbhanga Reserved Forest (RF) provide valuable insights into the quantification and valuation of forest ecosystem services in the region. The comprehensive study, conducted over a period of time, aimed to assess the various ecosystem services provided by the forest and assign economic values to these services. Here is a perspective on the results and analysis of the study:

1. **Water consumption:**
   a. The study rigorously evaluated the daily water consumption patterns within each household across all 19 ethnic villages situated within the Garbhanga Reserved Forest (RF). This assessment was conducted through structured interviews, wherein households were queried regarding their typical daily water usage habits. To standardize the measurement, a single standard unit of water consumption was established, defined as the volume equivalent to one standard bucket.
   By employing this standardized unit of measurement, the study aimed to facilitate a comprehensive comparison of water consumption practices across diverse households within the forested region. This approach enabled researchers to quantify the total daily water usage within each village, accounting for variations in household size, socio-economic factors, and cultural practices.

   b. Furthermore, the study extended its analysis to juxtapose the observed water consumption patterns in ethnic villages with those prevalent in urban areas located outside forested zones. This comparative examination provided valuable insights into the economic implications associated with accessing and utilizing water resources. Specifically, the study assessed the costs incurred by urban residents to obtain a similar quantity of water, considering factors such as water taxes, utility bills, and associated expenses. The quantification of water consumption is estimated over an area of 920.6 hectares where, ethnic villages are concentrated. Hence, the quantity of water consumption per hectare is subsequently calculated.

2. **Forest Food:**
   a. Identified the forest food in terms of Fruit, rhizome, leaves, root etc. against various species produced inside Garbhanga RF.

   b. Assessed how forest food resources are utilized by local communities or stakeholders This may involve conducting surveys, interviews, or participatory mapping exercises to understand consumption patterns, cultural significance, and traditional knowledge associated with forest foods.

   c. Conducted market surveys and price assessments to determine the economic value of forest food resources. This involves collecting data on the prices of similar food products in local markets, as well as assessing demand and market dynamics.

   d. Calculated the economic value of forest food resources based on their market prices, as well as any non-market values such as cultural, ecological, or health benefits. This involved using market prices as a proxy for economic value or applying methods such as contingent valuation or hedonic pricing to estimate non-market values.

3. **Ethnic Medicine:**
   a. Conducted ethno-botanical surveys and interviews with local communities to identify medicinal plants used in traditional medicine practices. Efforts have been made to document the indigenous knowledge associated with each plant, including its medicinal properties, preparation methods, and traditional uses.

   b. Efforts were also made to quantify the amount of ethnic medicine consumption by the households using structured questionnaire.

   c. A comprehensive survey was undertaken to systematically gather data from household members regarding the names of disease infestation in the villagers, identification and utilization of plant species obtained from forest ecosystems for the purpose of traditional medicinal practices within ethnic communities.

   d. Also carried out market surveys on expenses incurred by urban citizens in visits to doctor, treatment of the each disease and cost of medicines and derive the economic value by adopting revealed preference method of economic evaluation.

   e. Conducted market surveys to assess the demand for ethnic medicines and the prices paid for medicinal plants and herbal products in local markets. Collect data on market transactions, trade volumes, and prices to estimate the economic value of ethnic medicine trade.

4. **MFPs:**
   Quantifying and valuing minor forest products such as seeds, barks, roots, and broom sticks involves a comprehensive methodology that considers both ecological and economic factors. Here's a structured approach to quantify and economically value these minor forest produces:

   a. A detailed survey was conducted in the villages within Garbhanga RF to ascertain the quantity of above mentioned MFP for their personal use and commercial sale in the local markets. Units of quantity used were tukri, mootha, bosta etc. for standardising selling units to determine commercial value of produces in the local markets.

   b. Carried out surveys and interviews with local communities, traders, and markets to gather data on the demand, supply, and market prices of minor forest products. This information helped in understanding the economic value of these products and their contribution to livelihoods and local economies.

   c. Used market value approach to estimate the economic value of minor forest products. In addition to this, Common valuation techniques include market-based approaches (e.g., market price assessment), production-based approaches (e.g., cost of production), and non-market valuation methods (e.g., contingent valuation, travel cost method) were also adopted.

   d. The calculation of economic value of provisioning services is estimated over an area of 18,200 ha of Garbhanga RF as all the tangible items are produced across the whole forest area and economic value Ha^{-1} is calculated.

5. **Biomass and carbon sink estimation:**
   A. <u>Above Ground Biomass (AGB) of trees</u>:
      1. Stem volume is calculated by using –
         $V_{Stem} = (\Pi/3) \times H_{Stem} (D_1^2 + D_1D_2 + D_2^2)$

Where,
V_{Stem} = Stem Volume;
H_{Stem} = Stem Height;
D_1 = Diameter at breast height (DBH);
D_2 = Top diameter of the stem = DBH – Stem Height/Tree Height X 0.68 X DBH; *Considering average form factor 0.68 for each species.*

2. In the process of calculating aboveground biomass (AGB), a regression model was formulated to estimate the stem volume of individual tree species relative to their diameter at breast height (DBH). This model was developed as a statistical tool to establish the relationship between DBH, which serves as a proxy for tree size, and stem volume, which represents the spatial occupancy of tree biomass within the forest ecosystem.

3. Utilizing a regression approach involved fitting a mathematical equation to the empirical data collected from field measurements of DBH and corresponding stem volumes across various tree species. The regression model enabled the quantification of the volume occupied by each tree species based on their DBH measurements, facilitating the estimation of AGB by extrapolating the calculated stem volumes to the entire forested area.

4. This scientifically rigorous methodology allowed for the accurate assessment of aboveground biomass within the forest ecosystem, providing valuable insights into carbon sequestration dynamics and forest carbon stocks.

5. Stem biomass[OandP] is calculated using –
   $BM_{Stem} = V_{Stem}$ x Wood Density
   Where, BM_{Stem} = Stem Biomass

   Alternative method for calculating wood density was also used by following steps –

   A. Measuring the weight of the Block:
   Weight of the Block was measured using electronic weighing machine.

   B. Immersion of Block of Wood in Water:
   Block of wood completely submerged into the water in a calibrated large beaker half-filled with water. The volume of water displaced by the block of wood is equal to the volume of the block itself. Volume of displaced water is recorded.

   C. Calculating the Density of Wood:
   Using the formula for density: Density (D) = $\frac{\text{Mass (M) of the wood block}}{\text{Volume (V) of the displaced water.}}$

Table of wood density:

Sl. No.	Species	Volume (cc)	Weight (g)	Density (g/cc)
1	Makrisal	475	396.83	0.84
2	Sida	800	698	0.87
3	Sal	380	290.2	0.76
4	Koroi	475	428.12	0.90
5	Mirtenga	600	401.79	0.67

6	Gamari	400	265.06	0.66
7	Poma	650	466.97	0.72

D. **Crown volume** is calculated by using following formulae as per the shape of the crown –

i. $AD_{Crown} = \frac{DMajCrown + DMinCrown}{2}$

ii. $AR_{Crown} = \frac{ADCrown}{2}$

iii. $V_{CylindricalCrown} = \Pi \times AR_{Crown}^2 \times H_{Crown}$

iv. $V_{SphericalCrown} = \Pi \times AR_{Crown}^2$

v. $V_{ConicalCrown} = \frac{1}{3} \times \Pi \times AR_{Crown}^2 \times H_{Crown}$

vi. $V_{ParaboloidalCrown} = \frac{1}{2} \times \Pi \times AR_{Crown}^2 \times H_{Crown}$

vii. $V_{EllipsoidalVolume} = \frac{4}{3} \times \Pi \times \frac{DMajCrown}{2} \times \frac{DMinCrown}{2} \times \frac{HCrown}{2}$

E. **Crown biomass** is calculated by using following formula –

$BM_{Crown} = V_{Crown} \times$ Dry weight of 1 Cum of crown biomass

Where,

BM_{Crown} = Crown Biomass
AD_{Crown} = Crown Average Diameter
$DMaj_{Crown}$ = Crown Diameter at major Axis
$DMin_{Crown}$ = Crown Diameter at Minor Axis
AR_{Crown} = Crown Average Radius
$V_{**Crown}$ = Volume of Crown
H_{Crown} = Crown Height

Above Ground Biomass (AGB) of trees = BM_{Stem} + BM_{Crown}
Below Ground Biomass (BGB)of trees = AGB × 28%
(Considering average root to shoot ratio in 6 major global forest types[Q])

F. **Ground Biomass of Herbs, Shrubs <10 cm and Litter, climbers, SDW and BDW:**

$AGB_{SHLCDW} = DW_S + DW_H + DW_L + DW_{BDW} + DW_{SDW}$

Where,

AGB_{SHLCDW} = Above Ground Biomass of Shrubs, Herbs, Litter, Climber and Dead Wood.
DW_S = Dry Weight of Uprooted Shrubs, SDW and Climbers from 3m × 3m Sub-plot
DW_H = Dry Weight of Uprooted Herbs from 1m × 1m Sub-plot
DW_L = Dry Weight of Litters from 1m × 1m Sub-plot
DW_{BDW} = Dry Weight of BDW from 5m × 5m Sub-plot
DW_{SDW} = Dry Weight of SDW from 3m × 3m Sub-plot

G. **Bamboo:**

To assess the carbon sink potential of bamboo in the Garbhanga Reserved Forest (RF), a detailed enumeration was conducted based on diameter and length measurements, categorizing bamboos by age and diameter classes. The green weight of each bamboo clump was recorded, and a piece of 1-meter sample from each category was air-dried to get stable dry weight. The dry weight of these samples, representing the biomass excluding moisture, was then measured. Using a standard conversion factor (typically 48% of the dry biomass), the carbon content was estimated. This data was extrapolated to determine the total carbon sink potential of the bamboo population within the forest.

6. **Soil Organic Carbon:**
   Soil sample from all the strata were collected from the 30cm × 30cm pit is mixed well then 500 gm of sample is sent to laboratory to ascertain the Soil Organic Carbon (SOC) percentage and an average mass of Carbon is calculated in the soil samples thus collected.

The percentage of carbon in dry biomass can vary depending on the type of biomass and its moisture content. However, as a general approximation, carbon typically comprises around 45% to 50% of the dry weight of biomass. This estimate accounts for the fact that carbohydrates, which make up a significant portion of biomass, consist of carbon, hydrogen, and oxygen, with carbon being the predominant element. It's important to note that the exact percentage may vary slightly depending on the composition of the biomass and environmental facto₹ Hence total Carbon sink of the forest can be estimated considering 48% in average of dry biomass constituted by Carbon as –

$Carbon_{Total} = (AGB + BGB + AGB_{SHLCDW} + \text{Bamboo Biomass}) \times 48\% + SOC$

Considering the cost of carbon credit per metric tonne in global market[R] as \$4 i.e., ₹334.00 total economic value of the carbon sink can be calculated. The calculation of economic value of carbon sink is estimated over an area of 18,200 Ha of Garbhanga RF as the carbon is sequestered within the above attributes spreading over the forest area and thus, economic value of carbon Ha^{-1} is calculated.

7. **Temperature Regulation:**
   a. Temperature measurements were systematically conducted at four cardinal points of the day, namely 0600 hrs, 1200 hrs, 1800 hrs, and 2200 hrs, employing digital thermometers These measurements were strategically stationed within selected villages, forested areas, and urban regions located outside of forested zones. This comprehensive approach aimed to elucidate the nuanced dynamics of temperature stabilization within forest environments.

   b. By capturing temperature data across different times of the day and diverse environmental settings, the study sought to uncover the inherent capacity of forests to moderate temperature fluctuations. Comparisons were drawn between the average temperature differentials recorded within forested areas and those observed in adjacent urban landscapes. This juxtaposition provided valuable insights into the degree of temperature regulation facilitated by forest ecosystems.

   c. Furthermore, the study extended its analysis beyond mere temperature differentials to assess the tangible benefits accrued from the natural cooling effects of forests. Specifically, the average temperature reductions observed within forested environments were equated with the corresponding reductions achievable through artificial means, such as electric appliances utilized for indoor temperature control. This comparative analysis enabled a quantitative evaluation of the economic value associated with the temperature moderation services provided by forests.

   d. The scientific rigor of the study's methodology, coupled with its holistic approach to temperature assessment and economic valuation, positioned it as a pioneering endeavour in understanding the multifaceted role of forests in climate regulation. By elucidating the tangible benefits of temperature stabilization within forested landscapes, the study underscored the ecological and socio-economic significance of preserving and sustainably managing forest ecosystems in the face of climate change and urbanization pressures.

   e. The field staffs meticulously measured and recorded the indoor volume of air within households across all 16 villages situated within the Garbhanga Reserved Forest (RF). This comprehensive approach aimed to quantify the total volume of air within these households, which is inherently subjected to decreased temperatures owing to the surrounding forest cover.

f. By assessing the indoor air volume in each household, the study sought to estimate the cumulative effect of forest presence on temperature moderation within residential spaces. This analysis provided valuable insights into the extent to which forested environments contribute to indoor thermal comfort and reduced reliance on artificial cooling mechanisms.

g. Furthermore, the study juxtaposed the observed indoor air volumes within forested households with similar assessments conducted in urban areas located outside forested zones. This comparative analysis allowed for an examination of the economic implications associated with achieving lower indoor temperatures. Specifically, the study evaluated the costs incurred by citizens residing in urban areas to replicate the cooling effects attributed to forest cover, considering factors such as air conditioning usage and associated energy expenditures.

h. By quantifying the indoor air volume subjected to temperature moderation by forests and assessing the corresponding economic costs in urban settings, the study provided a nuanced understanding of the tangible benefits derived from forest ecosystem services. These findings underscored the ecological and socio-economic value of forest conservation and management initiatives, highlighting the importance of preserving forested landscapes for mitigating indoor heat stress and enhancing overall human well-being. Following steps were involved –

i. Measurement of plinth area and height of the house for calculating the indoor volume of a house. Similar exercise was carried out for all households in each of 16 ethnic villages inside Garbhanga RF.

ii. The study employed a standardized unit volume, precisely measured at 4.2672 m in length, 4.2672 m in width, and 3.048 m in height, as the foundational benchmark for its assessments. This meticulous selection ensured uniformity and consistency in evaluating the total indoor air volume across households within the study area. By employing this standardized unit, the study aimed to establish a robust framework for quantifying the collective indoor air volume influenced by the presence of forested environments.

iii. Through systematic extrapolation, the study derived the total number of such standardized units present across the residential spaces within the study region. This comprehensive approach allowed for a holistic assessment of the cumulative indoor air volume subject to temperature moderation attributed to the surrounding forest cover.

iv. Furthermore, the study leveraged this standardized unit volume to conduct a comparative analysis of the economic costs associated with temperature reduction strategies in urban settings. By quantifying the expenses incurred in urban areas to achieve lower temperatures within similar-sized indoor spaces, the study elucidated the tangible benefits and cost-effectiveness of forest ecosystem services in mitigating indoor heat stress.

v. This analytical framework enabled the study to estimate the potential economic costs that would have been incurred in the absence of forested environments. By extrapolating the findings to assess the hypothetical scenarios, the study provided valuable insights into the economic value and societal benefits derived from the presence of forests in enhancing indoor thermal comfort and reducing reliance on artificial cooling mechanisms.

$C_{ES} = TAV \times COST_{UNIT\ AIR\ VOLUME}$
Where,
C_{ES} is the economic value of Forest ES against temperature stabilisation.
TAV is total indoor air volume in the households of villages inside Garbhanga RF.
$COST_{UNIT\ AIR\ VOLUME}$ is the cost incurred by the urban people to reduce temperature per unit volume of air i.e., 4.2672m × 4.2672m × 3.048m by artificial means.

8. Water Retention:

A. Water Bodies:

The volume of water discharge by streams of **150.11 km total river length** indeed serves as an indicator of the water retention capacity within the basin of the stream at any given point in time. This relationship reflects the dynamic interplay between precipitation, surface runoff, infiltration, and storage within the watershed.

When streams experience high water discharge volumes, it suggests that the basin's water retention capacity may be nearing saturation or has exceeded its capacity to retain additional water. This scenario commonly occurs during intense rainfall events or periods of prolonged precipitation, where the rate of water input surpasses the landscape's ability to absorb and store it. Consequently, excess water flows overland and accumulates in streams, leading to increased stream discharge.

Conversely, during drier periods or when precipitation rates are moderate, stream discharge volumes tend to decrease. This reduction in discharge indicates that the basin's water retention capacity is effectively managing the incoming water, either by infiltrating it into the soil, storing it in groundwater reservoirs, or delaying its release through surface runoff. In such instances, the basin acts as a natural sponge, absorbing and storing water, thereby regulating stream flow and mitigating the risk of flooding downstream.

a) The total discharge of water through all the rivers inside a forest is equivalent to the total water retention capacity at a particular point in time due to the principles of hydrological continuity and dynamic equilibrium. This relationship underscores the interconnectedness of water flow and storage within the forest ecosystem

Hydrological Principles
Water Discharge:
Water discharge is the volume of water flowing through a river or stream per unit of time, typically measured in $m^3\ s^{-1}$.

Water Retention Capacity:
Water retention capacity refers to the ability of the river basins to hold or store water. This includes water held in the vegetation, surface soil up to 30 cm depth as well as water present in the river channels themselves.

Continuity Equation:
According to the continuity equation in hydrology, the inflow of water into a system must equal the outflow plus any changes in storage. For a forest river basin, this can be expressed as:

$$\mathbf{Q_{in} = Q_{out} + \Delta S}$$

Where
Q_{in} is the inflow,
Q_{out} is the outflow (discharge), and

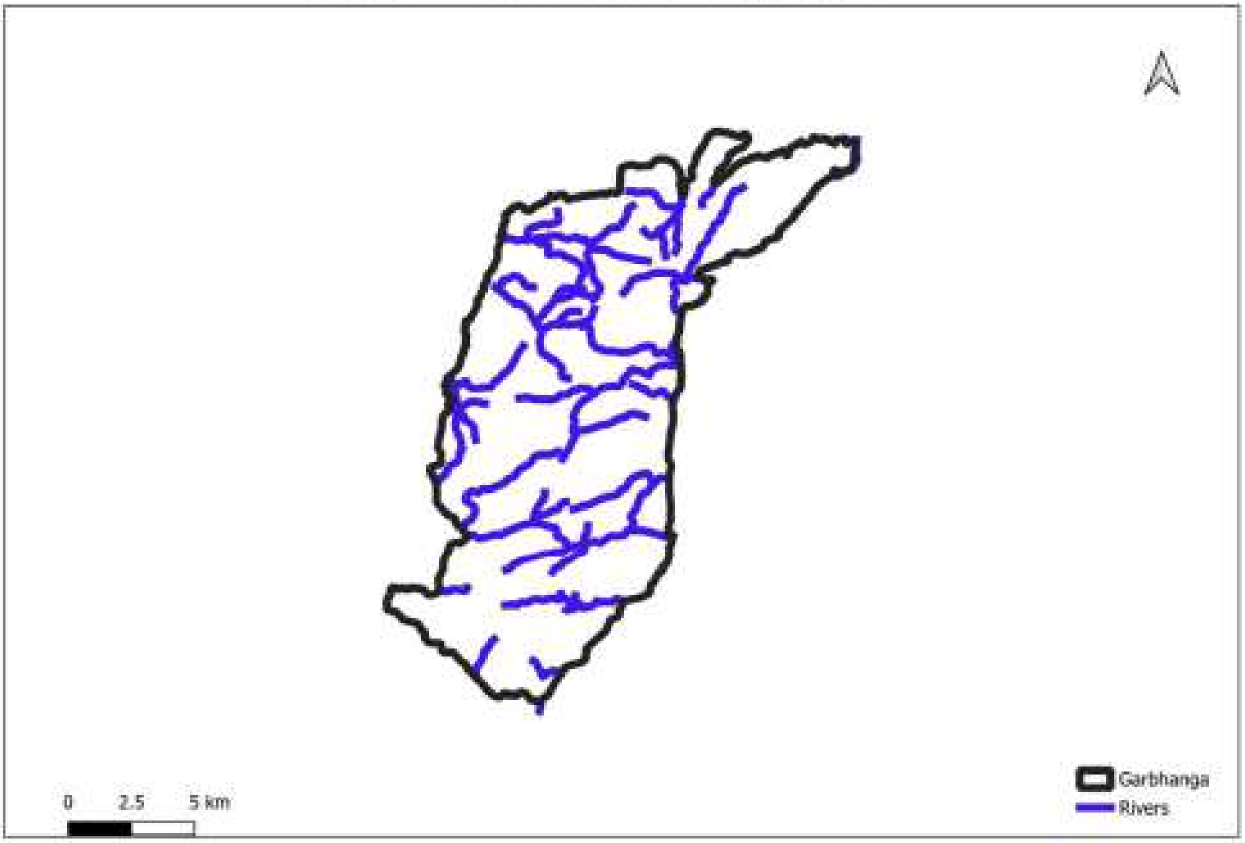
ΔS is the change in storage (retention)

b) Over a short period of 6 months, assuming negligible changes in storage, the discharge at any point in time closely reflects the water that was stored and is now moving through the system. In a dynamic equilibrium state, the amount of water entering the river basins from precipitation and other sources is balanced by the amount being discharged, indicating that the discharge represents the retention capacity at that moment.

Water retained in the soil contributes to base flow, which sustains river discharge during dry periods. Vegetation intercepts rainfall, slowing down runoff and enhancing infiltration, thereby increasing retention before it eventually contributes to river flow. Water stored in river channels and floodplains during high flow conditions is gradually released, maintaining discharge over time. Measuring discharge at multiple points along the rivers and integrating these measurements provides an estimate of the total discharge.

c) The utilization of Geographic Information System (GIS) technology facilitated the estimation of the length of each stream by leveraging the spatial database of water bodies assiduously compiled by the North Eastern Space Applications Centre (NESAC). From this expansive dataset, a systematic random sampling approach was employed to select a representative subset of streams for further analysis regarding water discharge during 6 months dry season i.e., October to March. Notably, all the measurements were taken using MKS system of units.

RIVER NETWORK INSIDE GARBHANGA RF



Id	Name	LENGTH (Km)
1	Um Ar	9.150
2	Unspecified	1.897
3	Unspecified	2.850
4	Unspecified	7.333
5	Unspecified	3.453
6	Unspecified	4.838
7	Unspecified	0.706
8	Unspecified	2.234
9	Unspecified	1.002
10	Satargaon Nadi	3.603
11	Satargaon Nadi	2.481
12	Unspecified	2.284
13	Unspecified	3.856
14	Unspecified	1.467
15	Unspecified	1.295
16	Unspecified	3.165
17	Unspecified	0.044
18	Unspecified	2.992
19	Unspecified	1.967
20	Sherupani Nadi	8.859
21	Unspecified	1.646
22	Unspecified	4.094
23	Unspecified	2.237
24	Unspecified	0.752
25	Unspecified	1.326
26	Unspecified	1.022
27	Unspecified	6.060

Id	Name	LENGTH (Km)
28	Jojoa Nadi	4.503
29	Unspecified	2.410
30	Unspecified	1.890
31	Unspecified	2.268
32	Unspecified	1.106
33	Unspecified	1.074
34	Basistha Nadi	9.160
35	Umkha Nadi	6.409
36	Unspecified	1.912
37	Unspecified	1.456
38	Unspecified	1.875
39	Unspecified	2.688
40	Patharchat N	3.319
41	Unspecified	1.060
42	Unspecified	2.168
43	Unspecified	2.517
44	Unspecified	2.380
45	Unspecified	0.650
46	Unspecified	0.184
47	Unspecified	0.028
48	Unspecified	0.154
49	Um Thana	1.753
50	Unspecified	1.622
51	Unspecified	1.212
52	Unspecified	5.476
53	Unspecified	7.305

d) Following the stream selection process, painstaking fieldwork ensued, whereby numerous sampling points along each chosen stream were identified and diligently marked. At these delineated points, a suite of essential hydrological parameters was thoroughly measured. This entailed determining the width of the stream as well as conscientiously gauging three distinct depths: one meter from the right bank, another meter from the left bank, and a third measurement taken at the midstream juncture.

I. The calculation of the cross-sectional area of each stream, pivotal for accurate water discharge assessment, followed a structured methodology. This involved employing a systematic yet robust formula:

$$A = W \times \frac{D1 + D2 + D3}{3}$$

Wherein,
A signifies the cross-sectional area of the stream, a fundamental metric for hydrological analyses.
W denotes the width of the stream, assiduously measured during fieldwork.
D_1 and D2 delineating depths measured at one meter from each respective bank, while D_3 represents the depth at the midstream location.

II. Velocity of the stream was measured using floating method, where a floater is deployed to flow for a distance of 100 meters along the stream and the time is recorded till the floater completes travelling 100 meters distance to reach a predestined point.

Using the formula $V = \frac{D}{T}$
Where,
V is the velocity of the stream

D is the distance travelled by the floater
T is the time taken by the floater to travel.

III Amount of water discharged per unit time is calculated by considering velocity of the stream water flow and length of the stream by using formula –
$X = A \times V \times L$

Where,
X is the volume of water discharged
A is the cross-sectional area of the stream
L is the total length of the stream

IV Total discharge in 6 dry months is calculated by using the statement –
$Discharge_{Total} = 60\ sec \times 60\ min \times 24\ hrs \times 180\ days \times X\ Ltr$

V Aggregating this values for each streams results in the total volume of water being discharged by the streams and water bodies of Garbhanga RF during dry seasons. From this data the water retention value during the dry seasons can be inferred and subsequently economic value may be assigned to store such quantity of water comparing with the money spent to store same quantity of water by the Govt. Organisation like GMWSS, GMC, GMDA and JICA etc.

VI Cost of storage of water in urban areas = Total water retention in streams x Cost incurred by Govt. organisation in storage of per unit volume of water.

B. Biomass Moisture:

Throughout the field exercise and laboratory trials, the desiccation process (Air Drying) was systematically documented for stem wood, crown biomass, ground biomass, litter, deadwood, and soil. These empirical observations were substantiated by a thorough review of contemporary literature and scholarly journals. This comprehensive approach aimed to ascertain the moisture content retained within the biomass of the vegetation and soil matrix by observing the percentage of moisture loss from the entities., which is furnished below –

1. Stem Biomass[T] – 12%±5%
2. Crown Biomass[U] – 25%±10%
3. Ground Biomass[V] – 15%±10%
4. Litter[W] – 11%±5%
5. Deadwood[W] – 7%±5%
6. Soil[X] – 15%±5%

Considering that the data collection occurred during the winter season, it is pertinent to acknowledge that the recorded moisture loss may exhibit a reduction from the established average. However, the determination of the forest's water retention capacity, attributed to both vegetation and soil components, is extrapolated from the aforementioned dataset. This calculation is facilitated through the utilization of a chart delineating the calculated biomass and the weight of soil up to a depth of 30 cm within the forest ecosystem. The moisture content in bamboo was discounted due to its negligible biomass in comparison to other attributes.

The calculation of economic value of regulating services comprising of above entities is estimated over an area of 18,200 Ha of Garbhanga RF as the temperature regulation and moisture retention is an important ecosystem function of Garbhanga RF, subsequently economic value of regulating services Ha^{-1} is calculated.

9. Recreational value:

a. Quantifying and valuing the recreational value of the Garbhanga Reserved Forest involves identifying the various recreational activities that visitors engage in within the Garbhanga Reserved Forest. This may include activities such as Hiking, trekking, cycling, picnic, photography. Conducted surveys and interviews with visitors to gather data on their recreational preferences, frequency of visits, duration of stay, and willingness to pay for recreational experiences. This information can provide insights into the demand for recreational opportunities within the forest.

b. Evaluation of the accessibility of the forest area, including transportation options, parking facilities, and trail infrastructure. Availability of amenities such as picnic areas, restrooms, signage, and interpretive displays, which can enhance the recreational experience for visitors were assessed.

c. Utilizing economic valuation techniques such as the travel cost method, contingent valuation method, or hedonic pricing method was adopted to estimate the recreational value of the Garbhanga RF. These methods involve analysing visitor behavior, preferences, and willingness to pay for recreational experiences.

d. In addition to direct recreational benefits, the non-use values associated with the forest, such as existence value (value derived from knowing that the forest exists) and bequest value (value passed on to future generations) were also considered. These values contribute to the overall societal importance of conserving the forest for recreational purposes.

e. **Aesthetic values:**
Quantifying and valuing aesthetic values such as home stays and nature watching experiences involves assessing the economic worth of these activities based on various factors including demand, visitor numbers, and willingness to pay. Here's how this process can be approached:

i. Quantification of the number of visitors engaging in home stays and nature watching activities within the area of interest. This was determined through visitor surveys, bookings data from home stay accommodations, and visitor counts at nature watching sites available with Kamrup East Division official documents.

ii. Conduct surveys or interviews with visitors to gauge their willingness to pay for these aesthetic experiences. This can help establish the perceived value of home stays and nature watching activities among visitors.

iii. Prices of similar aesthetic experiences in nearby regions or similar destinations was estimated to benchmark the value of home stays and nature watching. This provided the insights into market trends and pricing strategies.

iv. Economic impact of home stays and nature watching activities on the local economy was assessed, including expenditures on accommodation, meals, transportation, and souvenirs This can provide a comprehensive understanding of the economic value generated by these activities.

v. Adopted environmental valuation methods such as contingent valuation or travel cost analysis to quantify the non-market value of aesthetic experiences. These methods can help estimate the economic value that visitors place on preserving natural landscapes and biodiversity.

vi. Engaged with local communities, tourism operators, and conservation organizations to understand their perspectives on the value of home stays and nature watching. This can provide qualitative insights that complement quantitative data.

f. **Educational service:**
Quantifying and valuing educational services provided by ecosystems, such as bird watching, biodiversity estimation, traditional knowledge dissemination, and student excursions, involves several methodological approaches. For these structured survey questionnaire was designed for collection of data. Here's a scientific overview of how these services can be quantified and economically valued:

i. Bird watching and biodiversity estimation often involve direct observation and data collection. Researchers or enthusiasts record bird species sightings, abundance, and behavior using standardized survey methods such as point counts, transect surveys, or citizen science initiatives. Biodiversity estimation may include species inventories, vegetation sampling, and habitat assessments.

ii. Traditional knowledge and cultural experiences can be quantified through surveys and interviews with local communities, elders, or experts. Structured questionnaires or semi-structured interviews can be used to document traditional practices, indigenous knowledge, and cultural significance associated with the ecosystem.

iii. Student excursions and educational programs can be quantified by tracking the number of participants, duration of activities, and learning outcomes. Monitoring student engagement, knowledge acquisition, and behavior changes over time can provide insights into the educational value of ecosystem-based experiences.

iv. The economic value of bird watching and ecotourism activities can be assessed using the travel cost method. This approach estimates the value of ecosystem services based on the costs incurred by visitors, such as travel expenses, accommodation, and equipment rental. Surveys or visitor logs are used to collect data on visitation patterns and willingness to pay for recreational activities.

v. Traditional knowledge and cultural experiences may have economic value in markets for cultural products, crafts, or tourism souvenir. Market price analysis involves assessing the prices of traditional goods or services sold in local markets or tourist destinations to estimate their economic worth.

vi. For intangible cultural or educational services, such as traditional knowledge transmission or educational excursions, the contingent valuation method was used. This approach involves surveying individuals to elicit their willingness to pay for or willingness to accept compensation for the preservation or provision of ecosystem-based educational services.

The calculation of economic value of cultural services comprising the above mentioned components being enjoyed by the people throughout the forested areas of Garbhanga RF over an area of 18,200 ha. Hence, the total economic value of Garbhanga RF in terms of cultural services is estimated considering the whole Garbhanga RF, from which Ha-1 value of cultural services is calculated.

10. Soil Nutrient Retention:

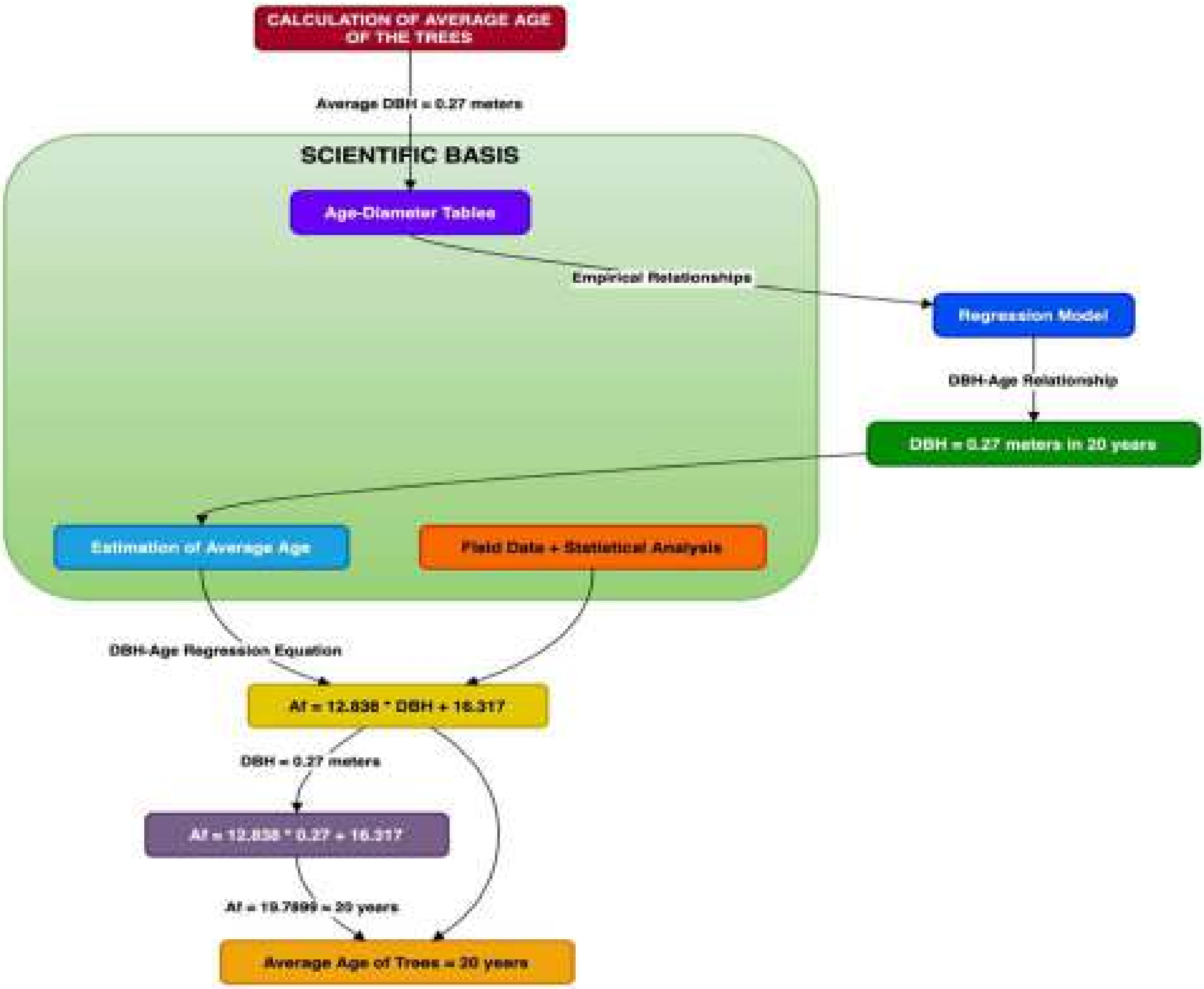
The quantification and economic valuation of soil nutrient retention ecosystem services (ES) in the Garbhanga Reserved Forest (RF) involve several systematic steps and methodologies. The soil nutrient analysis was focused on quantifying key macronutrients such as P_2O_5 (phosphorus pentoxide), K_2O (potassium oxide), pH, and soil texture. The economic value of these nutrients was determined using a market value approach.

i. Soil samples, weighing 20 kilograms in average, were collected from designated sub-plots measuring 30 cm x 30 cm. These sub-plots were strategically demarcated at the northeast (NE) and southwest (SW) corners of each 0.1 hectare sample plot within the forest. The collected soil samples were then sent to an agricultural laboratory for detailed macronutrient analysis.

ii. The market value of forest soil was obtained by collecting data on the price of similar soil types sold in the market. This market-based approach provided a basis for deriving the economic value of the soil from the Garbhanga RF. The economic valuation, therefore, reflects the current market prices of soil with comparable characteristics, offering a relative perspective on the monetary value of the soil's nutrient content within the Garbhanga Reserved Forest.

11. Oxygen Release:

Based on the tree enumeration database, it seems that the average diameter at breast height (DBH) of sampled trees in the Garbhanga Reserved Forest is 0.27 meter. From age-diameter tables specific to the forest types in this area, it was established that trees typically reach a DBH of 0.27 meters in approximately 20 years as per following steps –



DBH and Age Relationship: Age-diameter tables provide empirical relationships between the age of trees and their corresponding DBH. These tables are used for statistical analysis of tree growth in similar forest ecosystems.

Empirical Model: A regression model is used to establish these relationships. This model allowed us to estimate the age of a tree based on its measured DBH by deriving regression equation, $A_f = 12.838 \times DBH + 16.317$.

Average DBH of 0.27 meters: This measurement and analysis it is indicated that, on average, trees in the sampled area have reached a DBH of 0.27m

Estimation of Average Age: By referencing the age-diameter tables and using DBH – AGE regression model, it is specified that trees have achieved a DBH of 0.27m in approximately 20 years, an estimation of the average age of the forest crop can be made. This estimation assumes that the growth rate observed in the sampled trees is representative of the broader forest ecosystem in Garbhanga Reserved Forest.

Scientific Basis: The age-diameter tables are crucial as they provide a scientific basis for understanding forest growth dynamics. They integrate field data with statistical analysis to establish reliable growth patterns, which aid in forest management decisions and ecological research.

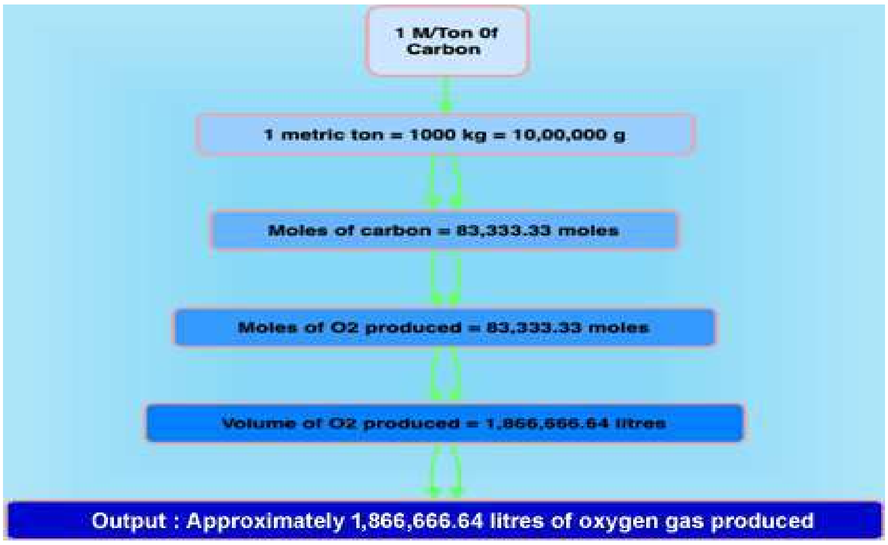
$A_f = 12.838 \times D_a + 16.317$ *where,*

A_f *= Average Age of the trees in Garbhanga RF*
D_a *= Average DBH of trees in Garbhanga RF = 0.27m*
Hence,
$A_f = 12.838 * 0.27 + 16.317 = 19.7899$, *i.e.,* ***20 years***

a. Carbon sequestration, a process by which trees absorb carbon dioxide from the atmosphere and store it in their biomass, leads to the release of oxygen as a by-product through photosynthesis. Utilizing this analysis, the quantity of oxygen released as a result of carbon sequestration over the specified timeline was calculated.

b. Furthermore, employing a market value approach, the economic worth of this oxygen volume was subsequently determined. This valuation method considers the market price of oxygen, typically measured in litres, and attributes a monetary value to the ecosystem service of oxygen production derived from forest carbon sequestration. The economic value of oxygen emitted by the Garbhanga Reserved Forest (RF) over the past 20 years can be estimated based on the total oxygen emissions and the prevailing market price of oxygen cylinders By multiplying the total amount of oxygen emitted by the forest by the market price per litre of oxygen, the economic value of the oxygen can be determined.

c. To calculate the amount of oxygen produced by the sequestration of 1 metric tonne (1000 kilograms) of carbon in trees, we need to use the stoichiometric ratio of carbon dioxide to oxygen during photosynthesis.



During photosynthesis, one molecule of carbon dioxide (CO_2) is converted into one molecule of glucose ($C_6H_{12}O_6$) and six molecules of oxygen (O_2), according to the following equation:

$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$
From this equation, we can see that for every 6 moles of CO_2 fixed, 6 moles of O_2 are released.

To determine how much oxygen is produced from 1 metric ton (1000 kilograms) of carbon during photosynthesis, we follow a similar approach as before but adjust for the larger quantity of carbon:
1 metric ton = 1000 kilograms = 10,00,000 grams.
Atomic mass of carbon (C) is approximately 12 grams per mole.
Moles of carbon $= \frac{10,00,000\ g}{12\ g/mol} = 83,333.33$ *moles*
From the stoichiometry of photosynthesis, 1 mole of CO_2 produces 1 mole of O_2

Therefore, moles of O_2 produced = moles of carbon = 83,333.33 moles.
At standard temperature and pressure (STP: 0°C and 1 atm), 1 mole of gas occupies 22.4 ltr.
Volume of O_2 produced = moles of O_2 × 22.4 Ltr/mol.

Moles of carbon, nC $= \frac{10,00,000\ g}{12\ g/mol} = 83,333.33$ *moles*
Moles of O_2 produced, nO_2 = 83,333.33 moles
Volume of O_2 produced, VO_2 = 83,333.33 moles × 22.4 Litre/mol = 18,66,666.64 ltr
=83,333.33 moles × 22.4 L/mol=18,66,666.64 ltr

d. The formula to calculate the economic value of oxygen is as follows:
Economic Value of Oxygen = Total Oxygen Emitted × Market Price of Oxygen

Where,
Total Oxygen emitted represents the cumulative amount of oxygen emitted by the trees of Garbhanga RF over the past 20 years.
Market Price of Oxygen represents the price per litre of oxygen in the market[S], which is assumed to be ₹350.00.

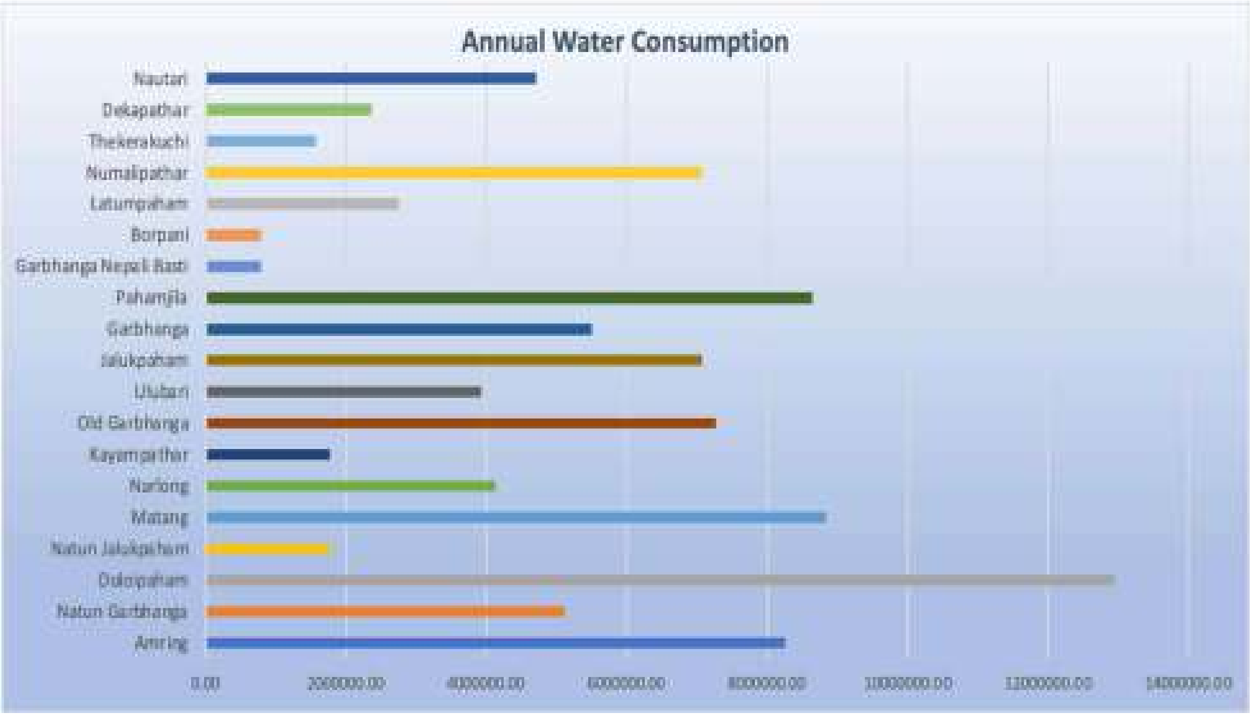
e. The calculation of economic value of supporting services is estimated in terms of soil nutrient retention and oxygen release through carbon sequestration of trees over an area of 18,200 Ha of Garbhanga RF from which Ha^{-1} value of supporting services is calculated.

QUANTIFICATION OF PROVISIONING SERVICES

i. **Water Consumption[Y]:**

During a socio-economic survey conducted in the ethnic villages of Garbhanga Reserved Forest (RF), data on domestic water consumption per household were collected using buckets, drums, and containers as volume units. The analysis revealed that the average water consumption per household is 538 ltr day^{-1}. This calculation is based on the baseline data of individual water consumption, which is 107.6 ltr p/c day^{-1}. Given that the average household size is five members, the total domestic water consumption aligns with these findings.

Sl No	Villages	Total No. of Households	Average No. of Family Member Per Households	Total Population	Average Daily Domestic Consumption of Water Per Household (Ltr) ±5%	Yearly Domestic Consumption of Water (Ltr)	Yearly p/c Consumption of Water (Ltr)
1	Amring	42	6	252	538	82,47,540	32,728.33
2	Natun Garbhanga	26	5	130	527	50,01,230	38,471.00
3	Doloipaham	66	7	462	552	1,32,97,680	28,782.86
4	Natun Jalukpaham	09	4	36	525	17,24,625	47,906.25
5	Matang	45	4	180	527	86,55,975	48,088.75
6	Narlong	21	4	84	533	40,85,445	48,636.25
7	Kayampathar	09	5	45	523	17,18,055	38,179.00
8	Old Garbhanga	37	6	222	524	70,76,620	31,876.67
9	Ulubari	20	4	80	555	40,51,500	50,643.75
10	Jalukpaham	36	7	252	540	70,95,600	28,157.14
11	Garbhanga	28	7	196	526	53,75,720	27,427.14
12	Pahamjila	44	5	220	528	84,79,680	38,544.00
13	Garbhanga Nepali Basti	04	5	20	560	8,17,600	40,880.00
14	Borpani	04	4	16	557	8,13,220	50,826.25
15	Latumpaham	14	6	84	545	27,84,950	33,154.17
16	Numalipathar	36	5	180	534	70,16,760	38,982.00
17	Thekerakuchi	08	4	32	522	15,24,240	47,632.50
18	Dekapathar	12	6	72	547	23,95,860	33,275.83
19	Nautari	24	5	120	551	48,26,760	40,223.00
		485		**2,683**	**Avg = 538**	**9,49,89,060**	**39,179.73**



ii. **<u>Forest food, Ethnic Medicine, MFPs, Small timber, Firewood, Fodder, Bamboo</u>:**
Through socio-economic surveys, data were collected on the identification and quantity of forest food, ethnic medicine, and minor forest products (MFPs) consumed by local communities for personal use and sold in local markets throughout the year. The collected data were analysed to provide insights into the types and volumes of these forest resources being utilized and their significance in the communities' livelihoods and local economy as furnished below

Sl. no	Product	Consumption / Sale per year (±10%)	Unit	Name of the villages where products are consumed
Forest Food				
1	Kolful	1,27,116	Nos.	Notun Garbhanga, Matang, Narling, Amring, Kayam Pathar, Old Garbhanga, Ulubari, Jalukpaham, Garbhanga, Pahamjila, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi, Nautari
2	Dhekia	81,108	Bundles	Notun Garbhanga, Matang, Narling, Amring, Kayam Pathar, Old Garbhanga, Ulubari, Jalukpaham, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi, Nautari
3	Kosu loti	15,392	Bundles	Notun Garbhanga, Amring, Old Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi
4	Pani kosu	15,120	Bundles	Notun Garbhanga, Narling, Kayam Pathar, Jalukpaham

5	Sojina	7,453	Bundles	Notun Garbhanga, Ulubari, Garbhanga, Pahamjila, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi, Nautari
6	Bet gaaj	15,072	Nos.	Notun Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi
7	Gondh kosu	42,384	Bundles	Notun Garbhanga, Matang, Narling, Ulubari, Jalukpaham, Garbhanga, Pahamjila, Latum Paham, Numoli Pathar, Thekera kuchi, Nautari
8	Baah gaaj	28,640	Nos.	Notun Garbhanga, Matang, Kayam Pathar, Ulubari, Jalukpaham, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi
9	Tokomar phool	14,560	Bundles	Notun Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Latum Paham, Numoli Pathar, Thekera kuchi
10	Meteka phool	12,012	Bundles	Notun Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi
11	Miri tenga	12,012	Bundles	Notun Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi
12	Mushroom	7,801	KG	Notun Garbhanga, Matang, Old Garbhanga, Ulubari, Jalukpaham, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi, Nautari
13	Tita bhekuri	806	KG	Notun Garbhanga, Matang, Narling, Amring, Kayam Pathar, Old Garbhanga, Ulubari, Jalukpaham, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi, Nautari
14	Owtenga	9,660	Nos.	Notun Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi
15	Mosondori	10,432	Bundles	Notun Garbhanga, Garbhanga Nepali Basti, Latum Paham, Nautari
16	Leteku	557	KG	Notun Garbhanga, Jalukpaham, Garbhanga
17	Kosu	10,800	Bundles	Matang
18	Honey	180	Litres	Jalukpaham
19	Mechka tenga	2,400	KG	Amring, Old Garbhanga, Nautari
20	Kothal	1,630	Nos.	Kayam Pathar, Nautari
21	Kothal guti	3,640	KG	Notun Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi
22	Gos aloo	864	KG	Kayam Pathar

23	Korobi kosu thuri	1,020	Bundles	Ulubari, Borpani
24	Kola kosu	4,320	Bundles	Jalukpaham
25	Amara	688	KG	Jalukpaham, Nautari
26	Jaam	22	KG	Jalukpaham
27	Gar jibha	34,080	Bundles	Jalukpaham, Nautari
28	Dudh kosu	4,992	Bundles	Pahamjila, Numoli Pathar
29	Nil kosu	2,808	Bundles	Pahamjila
30	Nilaji	800	KG	Nautari
31	Nol tenga	48	Bundles	Ulubari
32	Garo kosu	75,000	KG	Nautari
33	Bangi/Bami	4,000	KG	Nautari
34	Kordoi	988	KG	Notun Garbhanga, Old Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar
35	Panjari tenga	1,560	Nos.	Ulubari
		1,040	Bundles	Borpani
Ethnic Medicine				
1	Bhedai lota	9,516	Bundles	Notun Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi
2	Amlokhi	14,553	KG	Notun Garbhanga, Matang, Jalukpaham, Latum Paham, Nautari
3	Bhomora	156	KG	Notun Garbhanga, Garbhanga
4	Bahaka phool	468	KG	Notun Garbhanga, Pahamjila, Borpani, Thekera kuchi
5	Hilikha	14,405	KG	Notun Garbhanga, Matang, Ulubari, Jalukpaham, Garbhanga Nepali Basti, Numoli Pathar
6	Pepper	616	KG	Jalukpaham, Nautari
7	Bih dhekia	260	KG	Notun Garbhanga, Garbhanga Nepali Basti, Latum Paham,
8	Hansum	780	KG	Notun Garbhanga, Garbhanga, Numoli Pathar,
9	Kasi dira	1,040	Bundles	Ulubari
10	Manimuni	1,620	Bundles	Notun Garbhanga, Pahamjila, Thekera kuchi
11	Mehek	520	Bundles	Ulubari
12	Mehek paat	3,952	Bundles	Borpani, Numoli Pathar, Thekera kuchi,
13	Surat paat phool	52	KG	Notun Garbhanga
14	Surat paat	780	Bundles	Pahamjila
MFP				
1	Jharu	80,364	KG	Notun Garbhanga, Matang, Old Garbhanga, Ulubari, Jalukpaham, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Numoli Pathar, Nautari

2	Paan	37,622	Bundles	Notun Garbhanga, Old Garbhanga, Ulubari, Garbhanga, Pahamjila, Garbhanga Nepali Basti, Borpani, Latum Paham, Numoli Pathar, Thekera kuchi, Nautari
Small Timber				
1	Small Timber	485	Cft	As per survey each household requires 1 Cft of timber in average during a year for repairing of their dwelling houses.
Firewood				
1	Firewood	70,812	Mootha	It was estimated that at least 1 mootha of firewood is consumed by each household for cooking, fireplace and preparation of livestock fodder in two and half days.
Bamboo				
1	Bamboo	72,750	Nos.	During survey it was evident that each household requires at least 150 Nos. of Bamboo per annum in average to repair their dwelling houses and fencing
Fodder				
1	Cow Fodder	29,20,000	KG	Socio-economic survey revealed that there are 320 Nos. of domestic cow being possessed by the villagers in total which requires at least 25 KG of fodder per day in the form of leaves, twigs and grasses.
2	Goat Fodder	5,84,000	KG	Total no of Goats in 19 ethnic villages are 64 only which needs at least 5 KG of fodder each in the form of leaves, twigs and grasses.

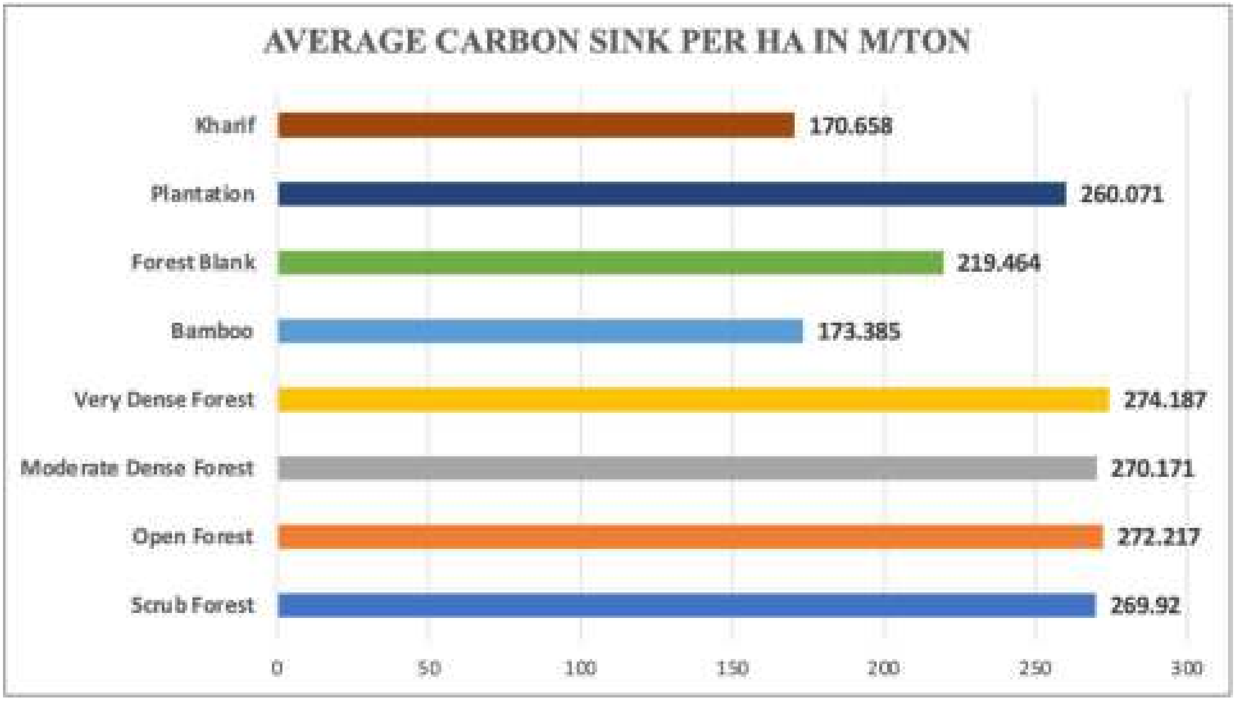
QUANTIFICATION OF REGULATING SERVICES

i. **Carbon Storage in Forest:**

All attributes, including aboveground biomass (AGB), belowground biomass (BGB), which encompasses shrubs, herbs, dead wood, litter, and soil organic carbon (SOC) of the carbon sink, were calculated based on field measurements of biomass and soil data. The results obtained for each forest stratum were extrapolated to the total allocated area for each stratum.

This process involved rigorous data collection and analysis methodologies to accurately quantify the carbon storage capacity of the forest ecosystem. By accounting for various components of biomass and soil carbon, we were able to comprehensively assess the carbon sequestration potential of different forest strata, providing valuable insights into the ecosystem's contribution to climate change mitigation and carbon cycle dynamics. It is noteworthy that the plantation selected is a young plantation.

Sl No	Strata	Average Carbon per sample plot of 0.1 ha in M/Ton (±5%)	Average Carbon ha in M/Ton (±5%)	Area assigned under each strata in Ha	Strata wise total Carbon in M/Ton (±5%)
1	Scrub Forest	26.9920	269.920	400	1,07,968.00
2	Open Forest	27.2217	272.217	3800	10,34,424.60
3	Moderate Dense Forest	27.0171	270.171	7400	19,99,265.40
4	Very Dense Forest	27.4187	274.187	5400	14,80,609.80
5	Bamboo	17.3385	173.385	800	1,38,708.00
6	Forest Blank	21.9464	219.464	100	21,946.40
7	Plantation	26.0071	260.071	200	52,014.20
8	Kharif	17.0658	170.658	100	17,065.80
Total				**18200**	**48,52,001.80**



iii. **Water Retention:**

a) Water Bodies:

The meticulous collection and analysis of hydrological data are paramount in understanding the water dynamics within the Garbhanga Reserved Forest. This study employed a rigorous and comprehensive methodology to assess water depths, widths, and velocities at strategically selected points. Using techniques and instruments, we calculated the total water discharge during the dry season, providing critical insights into the water retention capacity of the river basins.

Key findings indicate that accurate measurements of water flow patterns, obtained through manual gauging, offer a robust foundation for sustainable water resource management. The data collected were subjected to rigorous statistical analysis, including regression techniques, ensuring precise and reflective calculations of total water discharge.
Understanding the water retention capacity is vital for supporting forest-dependent communities and maintaining the overall health of the ecosystem. Reliable water resources are essential for local livelihoods, agriculture, and daily needs, making these scientific evaluations crucial for socio-economic stability and ecological preservation.

Basis of calculation is –
Total length of the river L = 150.11km = 150.11×1000 m = 1,50,110 m
L=150.11km=150.11×1000 m = 150,110 m
Time in seconds T=180 days × 24 hr day^{-1} × 60 min hr^{-1} × 60 sec min^{-1}
T = 180 × 24 × 60 × 60 = 15,552,000 sec
Volume per second V_o = 63.225 Cum 100 m^{-1} s^{-1}
V_o = 0.63225 Cum m^{-1} s^{-1}
Total volume V_t = 0.63225 m^{-1} s^{-1} × 1,50,110 m × 1,55,52,000 s
V_t = 0.63225 × 1,50,110 × 15,552,000 = 1.47 x 10^{12} cum
Total volume in litres V_{ltr} = 1.47 × 10^{12} Cum × 1,000 ltr Cum^{-1}
V_{ltr} = 1.47×10^{15} litres

So, the total volume of water retained in the basins is approximately 1.47 ×10^{15} litres in 180 days
Hence, Least quantity of water retained during a year is 2.993 x 10^{15} Ltr

Avg Volume Mtr/Sec in cum (±10%)	Total Volume of 180 days (Dry season) in cum (±10%)	Total Volume of 180 days (Dry Season) in Ltr (±10%)	Total volume of water retained per day during dry season in Ltr (±10%)	Least Quantity of water retained during the year 2023-24 in Ltr (±10%)	Least Quantity of water retained in Ltr Ha^{-1} Yr^{-1} (±10%)
0.632	1.47 x 10^{12}	**1.47 x 10^{15}**	8.20 x 10^{12}	**2.993 x 10^{15}**	**1.644 x 10^{11}**

Least Quantity of Water retained = 1.644 x 10^{11} Ltr Ha^{-1} Yr^{-1}

This comprehensive analysis underscores the importance of integrated water resource management. It highlights the necessity for ongoing research and monitoring to adapt to environmental changes and safeguard water resources. The insights gained from this study enable policymakers and conservationists to devise effective strategies that promote sustainable development while ensuring the forest's long-term health and resilience. This proactive approach is critical for addressing climate change challenges and fostering a harmonious coexistence between human activities and natural processes.

b) Soil moisture and biomass:

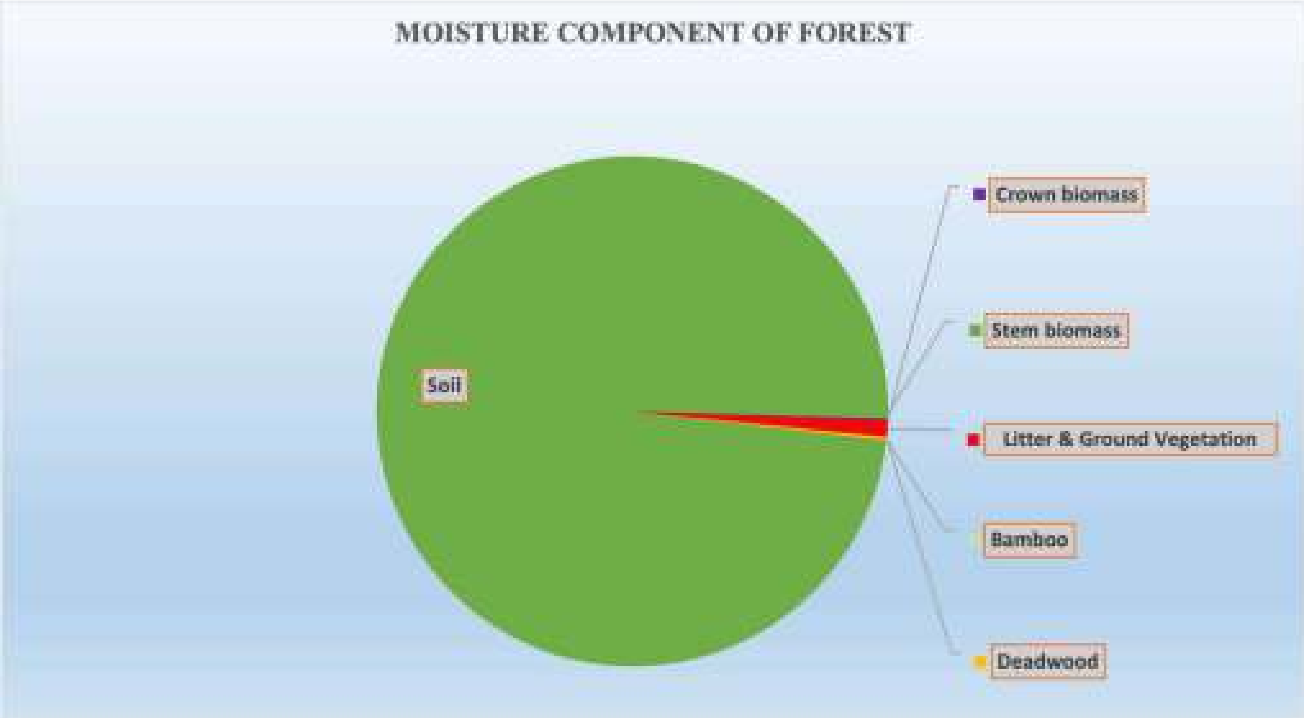
The assessment of moisture retention within the vegetation and soil of the Garbhanga Reserved Forest (RF) could be approximated through a meticulous integration of biomass and soil data, juxtaposed with the observed moisture loss from various samples including wood, crown, ground, litter, deadwood, and soil specimens analysed within laboratory settings. To approximate moisture retention, samples from different parts of the forest were collected first, including wood, crown, ground, litter, deadwood, and soil specimens. These samples are then subjected to laboratory analyses to determine the moisture content and the rate of moisture loss under controlled conditions. The moisture loss observed in laboratory conditions is considered equivalent to the water retention capacity of the biomass and soil in natural conditions. This laboratory data provides precise measurements of how much water each component of the forest ecosystem can hold and how quickly it loses moisture.

By synthesizing the comprehensive dataset that includes both biomass measurements and detailed soil characteristics, the moisture retention capacity of different components of the forest with the observed moisture loss from the laboratory analyses could be correlated. This correlation helps in creating a more nuanced and accurate model of moisture dynamics within the forest. This scientific approach enables the derivation of insights into the water-holding capacity of both the vegetation components and the soil matrix,

Sl. No.	Components	Mass(KG)	Moisture loss% in lab condition	Water Retained (Litres) per day	Water retained (Litres) in 180 days
1	**2**	**3**	**4**	**5**	**6**
1	Stem biomass	22,31,714.222	12%±5%	2,67,805.706±5%	4.821 x 10^7±5%
2	Crown biomass	2,68,782.076	25%±10%	67,195.519±10%	1.22x 10^7±10%
3	Litter and Ground Vegetation	58,23,794.35	11%±5%	6,40,617.378±5%	1.153x 10^8±5%
4	Deadwood	19,15,626.627	7%±5%	1,34,093.863±5%	2.414 x 10^7±5%
5	Bamboo	1577.723	17%±5%	268.21±5%	4.828 x 10^4±5%
6	Soil	40,44,44,44,444.000	15%±5%	6,06,66,666.666±5%	1.092 × 10^{10}±5%

Total Water Retention by biomass and soil each day = 6.177 x 10^7 Ltr
Therefore, Quantity of water retained by biomass and soil during the year 2023-24 = 5.56 x 10^8 Ltr
Hence, Total quantity of water retained in water bodies during the year 2023-24 = 2.99299410693164 x 10^{15} Ltr
Hence, Total quantity of water retained in water bodies, biomass and soil is = 2.99355010693164 x 10^{15} Ltr Yr^{-1}

Moisture retained is 1.644 x 10^{11} Ltr Ha^{-1} Yr^{-1}



Comparative analysis of the water retention capacities among the different components of the forest ecosystem:

i. **<u>Mass and Moisture Loss Percentage</u>:**
   - Stem Biomass has the higher mass among all components, indicating its significant contribution to the total biomass of the forest. However, it exhibits a relatively moderate moisture loss percentage of 12% ± 5%.
   - Crown Biomass, while lighter than stem biomass, crown biomass still retains a considerable mass. However, it has a higher moisture loss percentage of 25% ± 10%, indicating faster water loss compared to stem biomass.
   - Litter has a substantial mass, and its moisture loss percentage of 11% ± 5% falls between that of stem and crown biomass, making it an important intermediary in water retention.
   - Deadwood, despite having a lower mass than stem biomass, deadwood retains a significant amount of water. It has a relatively low moisture loss percentage of 7% ± 5%, indicating its effectiveness as a water reservoir.
   - Soil has the highest mass among all components by several orders of magnitude, reflecting its dominant role in the forest ecosystem. However, it also has a moderate moisture loss percentage of 15% ± 5%, indicating ongoing water retention and loss processes.

ii. **<u>Water Retention Capacity</u>:**
   - When considering the water retained, soil emerges as the primary reservoir, retaining approximately 10.92 billion ± 5% litres of water. Litter follows with around 115.3 million ± 5% litres, demonstrating its significant contribution to water retention despite its lower mass compared to soil.
   - Stem biomass and deadwood retain similar volumes of water, approximately 48.21 million ± 5% and 24.14 million ± 5% litres, respectively. Crown biomass retains a smaller volume, approximately 12.17 million ± 10% litres, reflecting its higher moisture loss percentage.

iii. **<u>Overall Contribution to Water Balance</u>:**
   - While these components have lower masses compared to soil, they play crucial roles in water retention, especially considering their lower moisture loss percentages. They contribute significantly to maintaining soil moisture levels and supporting plant growth.

- Despite its higher moisture loss percentage, crown biomass still retains a notable volume of water, contributing to microclimate regulation and supporting canopy functions.
- As the largest component, soil acts as the primary water reservoir, storing and releasing water for plant uptake, groundwater recharge, and streamflow regulation.

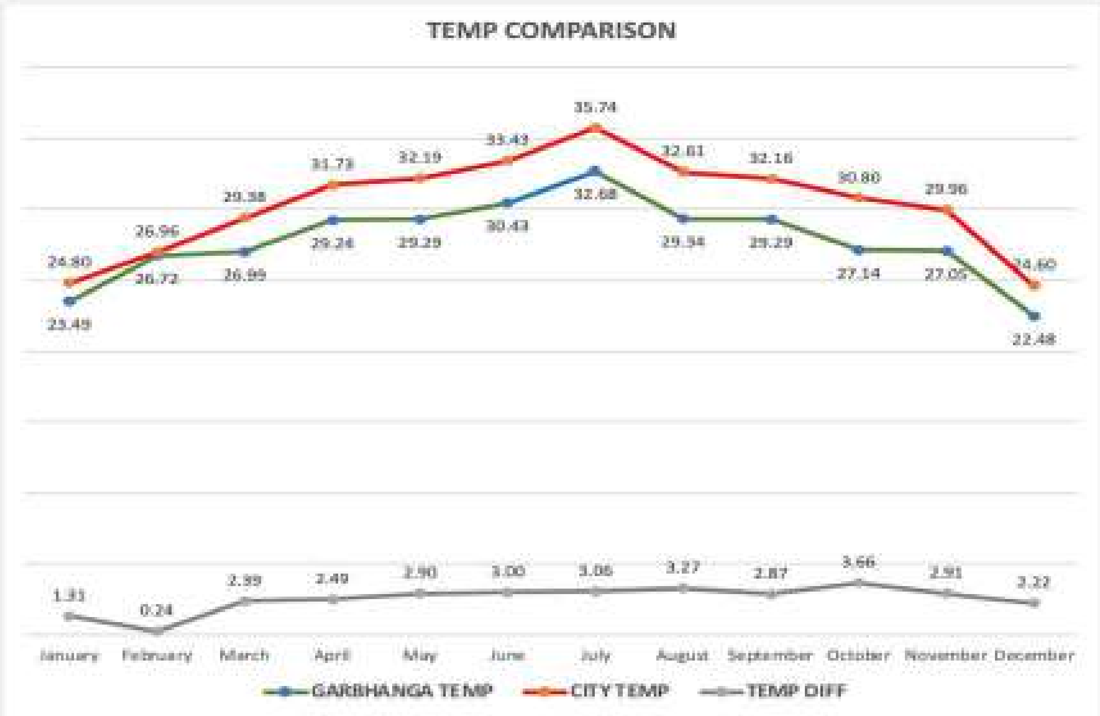
Each component of the forest ecosystem plays a distinct yet interconnected role in water retention, reflecting its mass, moisture loss characteristics, and ecological functions. While soil serves as the primary water reservoir, stem biomass, deadwood, litter, and crown biomass also make significant contributions to maintaining water balance and supporting ecosystem health. Understanding the comparative water retention capacities of different components is essential for effective forest management and conservation, especially in the context of climate change and water resource management.

iv. **<u>Temperature Regulation</u>:**

The study was conducted to compare the temperature differences between the Garbhanga Reserved Forest (RF) and the urban area of Guwahati City[Z]. Temperature readings were recorded throughout the year 2023 at four cardinal points of the day: 0600 hrs, 1200 hrs, 1800 hrs, and 2200 Ha The mean temperature difference was calculated to understand the cooling effect of the forest.

Month	Average month wise temperature (^{0}C) inside Garbhanga RF	Average month wise temperature (^{0}C) at Guwahati City	Average month wise Temperature (^{0}C) difference	Average yearly temperature (^{0}C) difference
January	23.49	24.80	1.31	3.27
February	26.72	26.96	0.24	
March	26.99	29.38	2.39	
April	29.24	31.73	2.49	
May	29 .29	32.19	2.90	
June	30.43	33.43	3.00	
July	32.68	35.74	3.06	
August	29.34	32.61	3.27	
September	29.29	32.16	2.87	
October	27.14	30.80	3.66	
November	27.05	29.96	2.91	
December	22.48	24.60	2.22	

The average temperature difference during April/23 to Sept/23 is 2.93^{o}C



a. *Seasonal Variation:*
   The temperature difference between Garbhanga RF and Guwahati City varies throughout the year, indicating distinct seasonal patterns.
   During the winter months (December to February), Garbhanga RF generally maintains a cooler temperature compared to Guwahati City, with differences ranging from 0.24°C to 2.22°C. This suggests that the forest environment might provide some insulation against colder temperatures.
   In the transition months of spring (March to May), the temperature gap between Garbhanga RF and Guwahati City widens, reaching its peak in May with a difference of 2.90°C. This could be due to factors such as increased vegetation activity and shade provided by trees, which help regulate temperatures within the forest.
   During the summer months (June to August), Garbhanga RF consistently exhibits significantly cooler temperatures compared to Guwahati City, with differences ranging from 3.00°C to 3.27°C. This suggests that the forest environment offers significant relief from the heat, possibly due to the presence of dense tree cover and evaporative cooling from nearby water bodies.
   In the transition months of autumn (September to November), the temperature difference remains substantial, albeit slightly reduced compared to the summer months. Garbhanga RF continues to maintain a cooler climate, with differences ranging from 2.87°C to 3.66°C.

b. *Yearly Average:*
   The average yearly temperature difference of 3.27°C indicates that Garbhanga RF consistently maintains a cooler climate compared to Guwahati City throughout the year.
   This significant temperature contrast suggests that Garbhanga RF serves as a natural temperature regulator for the region, providing a cooler microclimate that may have ecological, environmental, and social implications.

a. *Potential Influencing Factors:*
   Vegetation Cover: The presence of vegetation within Garbhanga RF likely plays a crucial role in regulating temperatures by providing shade, reducing solar radiation, and facilitating evaporative cooling.

Elevation: *Garbhanga RF may be situated at a higher elevation compared to Guwahati City, which can contribute minuscule to cooler temperatures due to the lapse rate phenomenon, where air temperature decreases with increasing altitude.*

Presence of Water Bodies: *Garbhanga RF has 150.11 km of water body network in the form of rivers and rivulets, which can moderate temperatures through evaporative cooling and the formation of local breezes.*

Urban Heat Island Effect: *Guwahati City may experience higher temperatures compared to Garbhanga RF due to the urban heat island effect, where urban areas retain more heat than rural or natural areas due to human activities, infrastructure, and lack of vegetation.*

b. *Implications:*

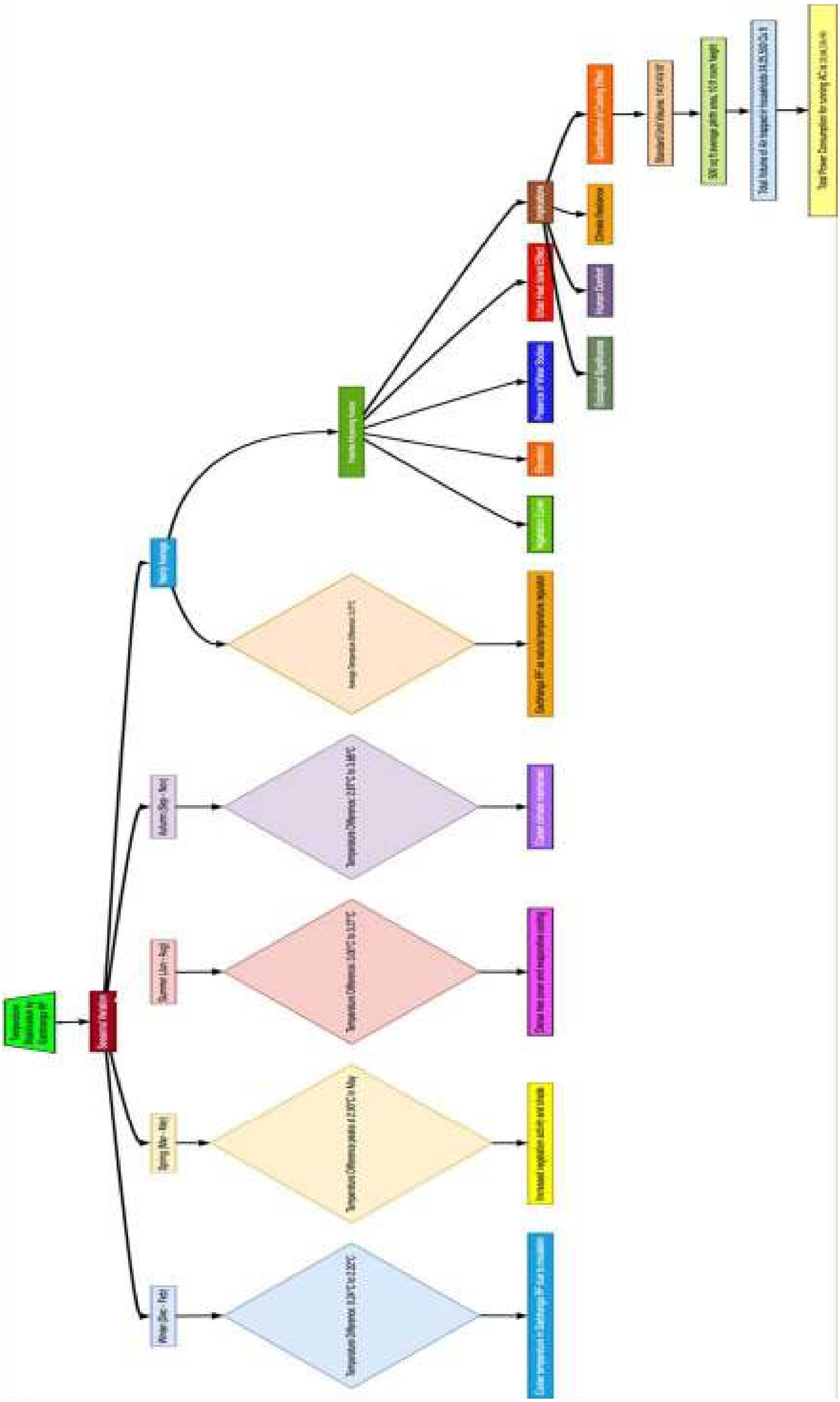
Ecological Significance: *The cooler microclimate of Garbhanga RF may support diverse flora and fauna adapted to lower temperatures, contributing to its ecological richness and biodiversity.*

Human Comfort: The cooler temperatures of Garbhanga RF offer residents and visitors a natural escape from the heat, providing recreational opportunities and enhancing overall quality of life.

Climate Resilience: *Garbhanga RF serves as a natural buffer against extreme heat events and climate change impacts, highlighting its importance for climate resilience and adaptation strategies in the region.*

Overall, the temperature differences observed between Garbhanga RF and Guwahati City underscore the importance of natural ecosystems in regulating local climates and mitigating the effects of climate change. Understanding these dynamics is essential for sustainable land management, conservation efforts, and urban planning initiatives in the region.

For quantification of this cooling effect, a standard unit volume of air trapped inside a house was defined as 4.2672m x 4.2672m x 3.048m. This volume is considered typical for a single room in a household in urban areas where Air Conditioners are used. The results showed a significant mean temperature difference between the forested area and the urban area, indicating the cooling effect of the Garbhanga RF. The total number of standard units were determined by dividing the total volume of air trapped inside households of Garbhanga RF by standard unit volume i.e., 4.2672m x 4.2672m x 3.048m = 55.50 Cum (±10%). The average plinth area of the houses within the Garbhanga Reserved Forest is measured to be 18.21 sq m, with an average room height of 3.048m, based on data collected from the surveyed households.



Average Volume of air within each house of Garbhanga RF (±10%) in Cu Ft	Total no. of Households inside Garbhanga RF	Total volume of air houses inside Garbhanga RF (±10%) in Cu Ft	Total no. of unit volume
5,000	485	24,25,000	1,237.245

Referring the data provided in the table, the total area of the Garbhanga Reserve Forest (RF) is taken into account. Subsequently, the total number of unit areas, each measuring 4.2672m by 4.2672m, is calculated. The average crop height within these unit areas is then considered to compute the total volume. This approach ensures a comprehensive and precise assessment of the volume based on the average crop height across the designated unit areas within the Garbhanga RF.

Unit Area (4.2672 x 4.2672) in Sq mtr	No. area units in Garbhanga RF (±10%) in Sq mtr	Average crop height of Garbhanga RF in Meters	Total volume of air inside Garbhanga RF within Average Canopy Height (±10%) in Cum	Total no. of unit volume
18.21	**99,95,059.673**	14.65	2,66,64,47,036.854	4,80,44,090.754

From sample surveys conducted in households within the highly populated areas of Guwahati city, data were collected regarding the average time required to reduce the room temperature by 3°C during summer using electrical appliances, specifically 1.5 Ton Air Conditioners, for a standard room size of 4.2672m x 4.2672m x 3.048m. Additionally, the average electrical power consumption necessary for achieving this temperature reduction was also estimated. The findings are as follows:

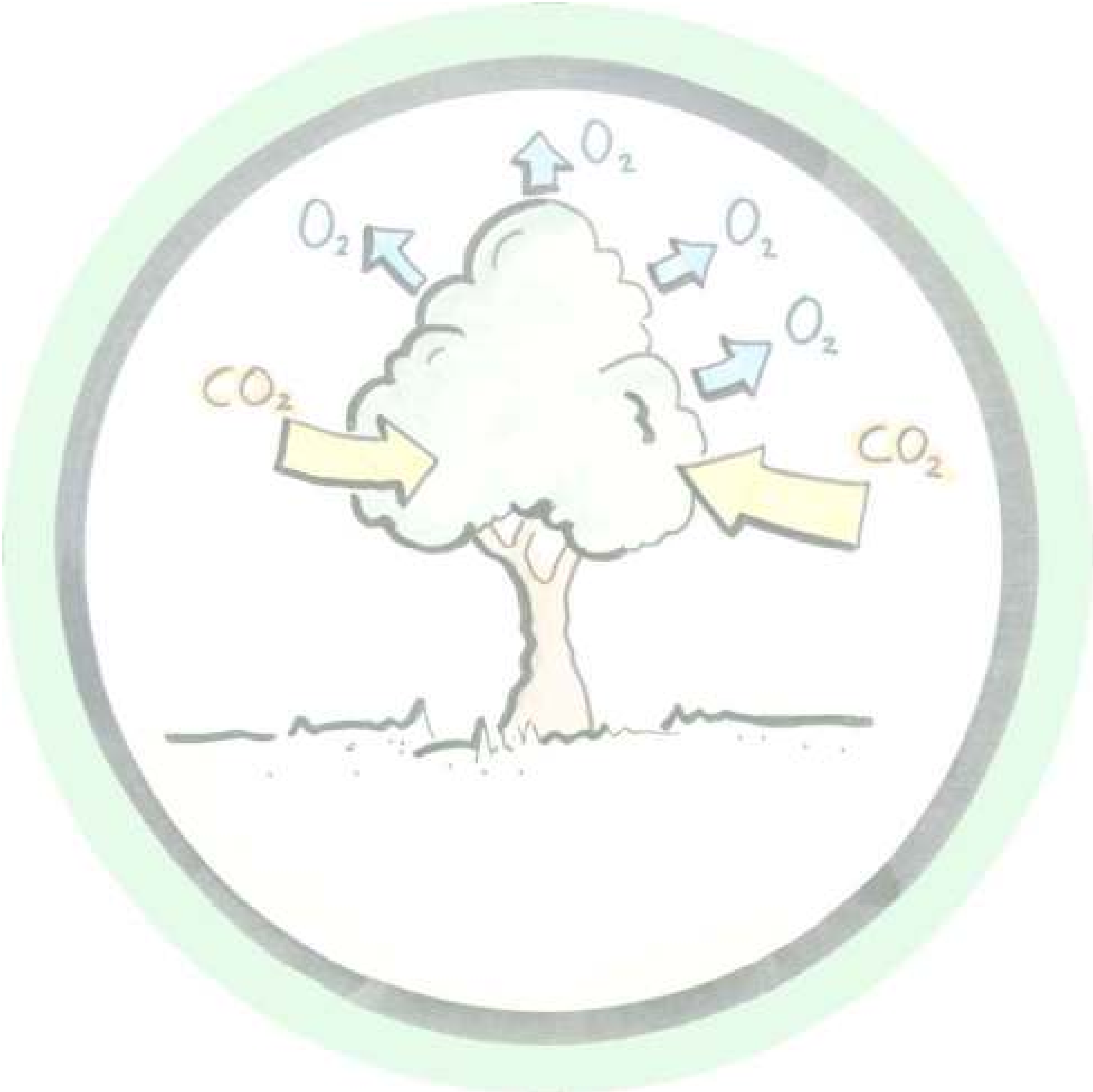
Power Rating 1.5 Ton AC in kWh	Average time required to reduce room (4.2672m x 4.2672m x 3.048m) temperature by 2.93°C ≈ 3°C using 1.5 ton AC in hours	Power Consumption during the cooling in kWh	Total Power consumption would have been required for cooling up to 2.93°C ≈ 3°C lower for estimated volume of air inside Garbhanga RF for the months from April to September in kWh
1.5	0.416	0.624	77,83,14,27,021.50

Calculating the power consumption of a 1.5 ton air conditioner running for 6 hours a day for 180 days of summer, needs following step –

1. A 1.5 ton air conditioner typically has a power rating of about **1.5 kW** (this can vary, but 1.5 kW is a common estimate).
2. 25 minutes needs to be converted to Hr
3. 25 minutes = 25/60 hours = 0.416 Hr
4. Energy consumption (kWh) = 1.5kW × 0.416 Hours = **0.624 kWh**
5. Energy consumption (kWh) for 1 Hour, X = 0.624 kWh/0.416 Hr =X kWh Hr^{-1} Therefore, X = 1.500 kWh
   So, the total power consumption for 1 hour would be approximately **1.500 kWh**.
6. Considering that AC is used 6 hourly a day in urban areas

Total energy consumption in summer months *(Implicitly for the whole year as AC is not used during rest of the months in urban areas)* in the 4,80,44,090.754 units of volume of air trapped inside Garbhanga RF = 1.500 kWh x 6 Hours x 180 Days x 4,80,44,090.754 = **77,83,14,27,021.50 kWh**

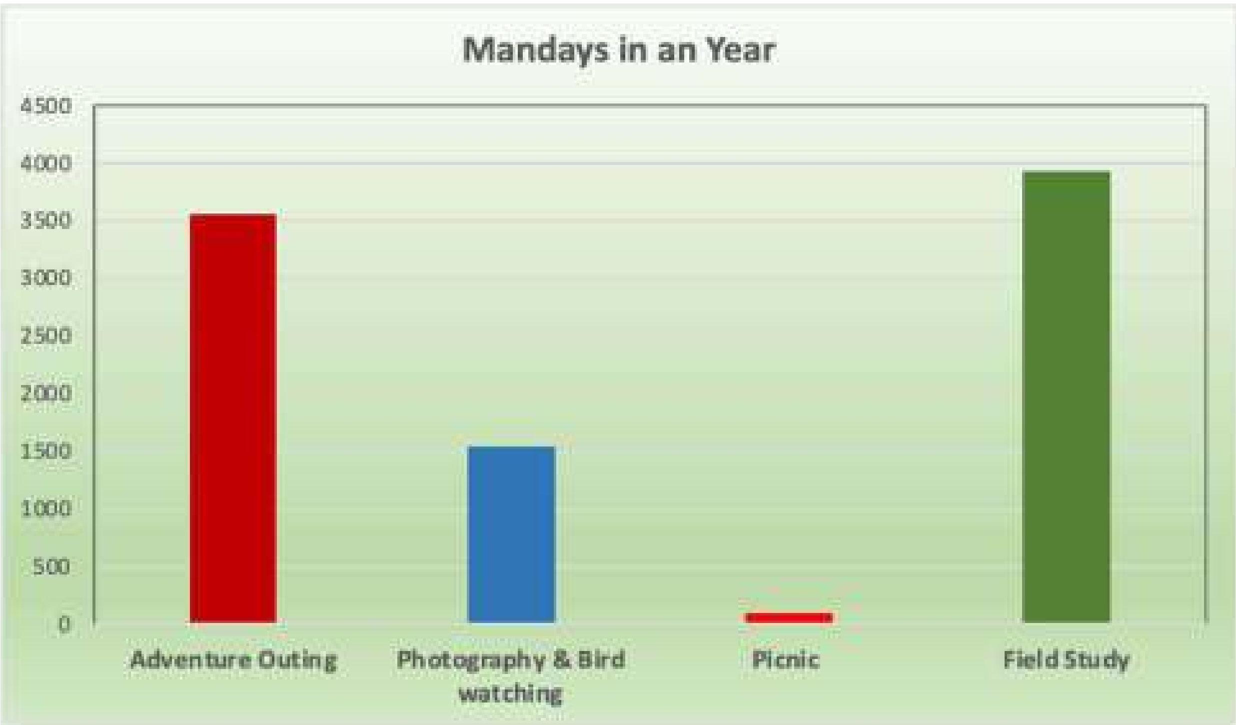
Hence, Energy Consumption **= 42,76,452.03 kWh Ha^{-1} Yr^{-1}**



QUANTIFICATION OF CULTURAL SERVICE

Based on extensive surveys and interviews with visitors, village households, and representatives from educational institutions and NGO offices, four distinct cultural services have been identified within Garbhanga RF. These services include Adventure Outing, Photography and Bird Watching, Picnics, and Field Studies. To quantify the engagement with these cultural services, the estimated number of visitors for each category over the course of a year has been compiled as follows –

Sl. No.	Purpose of visit	No. of persons	Average no. of days visited per year per person	Total Mandays
1	Adventure Outing	79	45	3555
2	Photography and Bird Watching	57	27	1539
3	Picnic	93	1	93
4	Field Study	262	15	3930



1. High engagement in Adventure Outing and Field Study activities with substantial total man-days.

2. Moderate engagement in Photography and Bird Watching, indicating a dedicated group of enthusiasts.

3. Low engagement frequency in Picnic activities despite a relatively high number of participants. Field Study is the most popular activity in terms of visitor numbers and total man-days.

4. Adventure Outing and Field Study activities demonstrate frequent visits and high levels of participant engagement. Picnicking, although popular in terms of the number of participants, is typically a one-time annual activity for most visitors

QUANTIFICATION OF SUPPORTING SERVICES

1. **Soil nutrient retention[AA]:**

The analysis of soil samples was carried out in the soil analysis laboratory under Agriculture Department., Govt . of Assam, Ulubari for estimating SOC, pH value, Nitrogen, P_2O_5 and K_2O as macronutrients to determine the nutrient quality of the of the soil against each strata of Garbhanga as furnished below –

Sl. No.	Assigned density class	pH	Remarks	Organic carbon in %age	Remarks	C/N	Soil Nitrogen in %age	P_2O_5 in Kg/Ha	Remarks	K_2O in Kg/Ha	Remarks	Texture
1	Scrub Forest	4.952	Very Strongly Acidic	3.858	Very High	14.838	0.260	3.2894	Very Low	370.946	Medium	Sandy Loam
2	Open forest	4.744	Extremely Acidic	3.984	Very High	17.322	0.230	3.1504	Very Low	483.570	High	Sandy Loam
3	MDF	5.156	Strongly Acidic	3.894	Very High	18.543	0.210	2.7299	Very Low	399.168	High	Sandy Loam
4	VDF	4.555	Very Strongly Acidic	3.585	Very High	13.788	0.260	8.1955	Very Low	334.655	High	Sandy Loam
5	Plantation	4.588	Very Strongly Acidic	4.453	Very High	18.553	0.240	1.7785	Very Low	254.680	Medium	Sandy Loam
6	Forest Blank	4.850	Very Strongly Acidic	4.278	Very High	18.600	0.230	0.7398	Very Low	414.760	High	Sandy Loam
7	Khar IT	4.740	Very Strongly Acidic	3.550	Very High	17.750	0.200	0.598	Very Low	52.420	Very Low	Sandy Loam
8	Bamboo Patch	4.830	Very Strongly Acidic	4.588	Very High	17.647	0.260	0.598	Very Low	443.744	High	Sandy Loam

Taking C:N ratio as 0.236 as average, Soil Nitrogen is calculated.

A) pH Levels:

All plots exhibit very strongly acidic conditions, a common characteristic of forest soils. This acidity can impact nutrient availability and microbial activity but is typical for many forest ecosystems. The acidic nature of forest soils, as observed across all plots, is a fundamental characteristic shaped by various natural processes inherent to Garbhanga forest ecosystems. These acidic conditions stem from several factors, including the decomposition of organic matter, the accumulation of organic acids from decaying vegetation, and the leaching of acidic substances from surrounding vegetation and rainfall.

a) Factors Contributing to Acidity in Forest Soils:

- **Organic Matter Decomposition:** Forests are rich in organic matter, comprising fallen leaves, twigs, and decaying plant material. Microbial activity involved in organic matter decomposition releases organic acids into the soil, contributing to soil acidity over time.
- **Leaching of Organic Acids:** Rainfall in forested areas interacts with organic matter on the forest floor, leaching organic acids into the soil profile. These acids include humic and fulvic acids, which further lower soil pH levels as they percolate through the soil layers.
- **Vegetation Influence:** Many trees and plants in forest ecosystems have specific adaptations to acidic soils. They actively contribute to soil acidity through the release of acidic compounds from their roots or litter, maintaining an environment conducive to their growth while shaping soil chemistry.
- **Soil Weathering Processes:** Soil minerals undergo weathering processes over time, releasing ions such as aluminium and hydrogen, which contribute to soil acidity. These ions can accumulate in the soil solution, lowering pH levels and affecting nutrient availability.

b) Impact on Soil Health and Ecosystem Functioning[AB]:

- **Nutrient Availability:** The acidic environment of forest soils influences the availability of essential nutrients such as phosphorus, calcium, and magnesium. While some nutrients may become more soluble and readily available, others may be less accessible to plants due to pH-induced chemical reactions.

- **Microbial Activity:** Soil microorganisms play crucial roles in nutrient cycling, organic matter decomposition, and overall soil health. However, the acidic conditions of forest soils can impact microbial communities, affecting their diversity, activity, and function.
- **Plant Adaptations:** Many plant species in forest ecosystems have evolved strategies to thrive in acidic soils. These adaptations include specialized root systems, symbiotic relationships with mycorrhizal fungi, or the ability to tolerate high levels of aluminium toxicity associated with acidic conditions.

B) Nutrient Levels:

a. **Nitrogen[AC]**

Kharif plantation areas shows the lowest nitrogen level (0.20%), indicating potential nitrogen deficiency. Nitrogen is crucial for plant growth, and its scarcity may affect vegetation development in this plot.

Probable reasons for Low Nitrogen:

- **Crop Rotation and Harvesting:** Frequent harvesting and crop rotation in Kharif plantation areas can deplete soil nitrogen levels, as crops continuously extract nitrogen from the soil.
- **Leaching and Volatilization:** Sandy loam soils are prone to leaching, where rainfall or irrigation washes nitrogen deeper into the soil, making it less available to plants.
- **Insufficient Nitrogen Fixation:** Lack of nitrogen-fixing plants or insufficient microbial activity to fix atmospheric nitrogen into a usable form for plants could contribute to low nitrogen levels.

b. Phosphorus[AD]

Forest Blanks has the highest phosphorus level (0.230), followed by Bamboo patches (0.260), and Kharif areas has the lowest (0.200). Low natural processes like organic matter decomposition, manifests low phosphorus availability varies among the plots.

Probable reason for High Phosphorus:

- **Natural Phosphorus Sources**: The presence of natural phosphorus sources, such as decaying organic matter, rocks, and soil minerals, can contribute to higher phosphorus levels in forest soils.
- **Low Erosion and Leaching**: Forest ecosystems typically experience less soil disturbance and erosion, which helps retain phosphorus in the soil.

Probable reason for Moderate Phosphorus:

- **Moderate Organic Matter Decomposition:** Bamboo patches might have a balanced rate of organic matter decomposition, providing a steady supply of phosphorus without significant accumulation or depletion.
- **Efficient Nutrient Cycling:** Bamboo plants might efficiently recycle nutrients, maintaining moderate phosphorus levels in the soil.

Probable reason for Low Phosphorus:

- **Intensive Agriculture:** Continuous cropping and removal of plant residues can deplete soil phosphorus levels.
- **Poor Organic Matter Decomposition:** Reduced organic matter decomposition rates might limit the release of phosphorus into the soil.
- **Soil Fixation:** Phosphorus can become fixed in forms that are not readily available to plants, especially in sandy soils with low organic matter content.

c. Potassium[AD]

All plots exhibit low potassium levels, which may affect nutrient cycling and plant stress tolerance in the forest ecosystem.

Reason for Low Potassium:

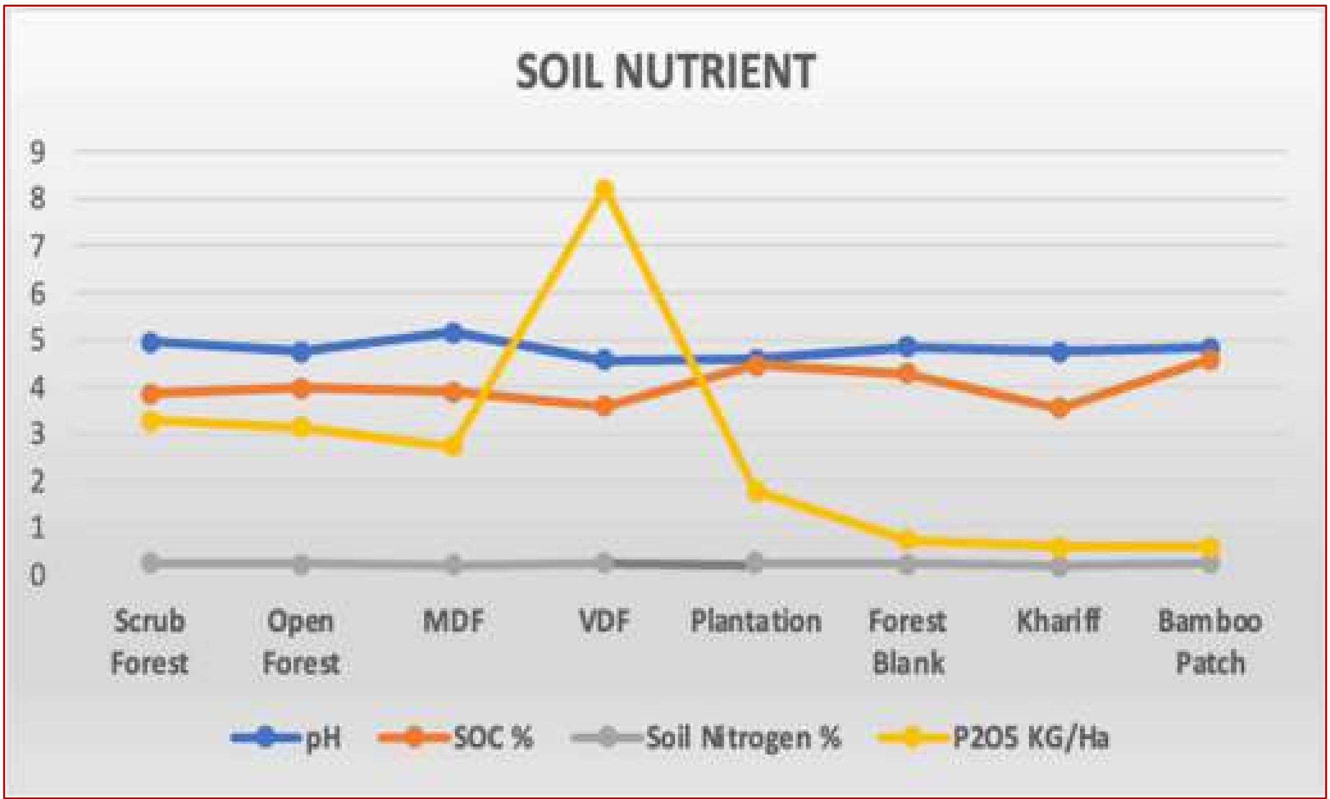
- **Leaching:** Sandy loam soils are susceptible to leaching, where potassium is washed away by rainfall or irrigation, reducing its availability to plants.
- **Crop Uptake:** High plant uptake of potassium without adequate replenishment can lead to depletion of soil potassium levels.
- **Mineral Weathering:** Slow weathering of soil minerals that release potassium might contribute to low levels in these soils.

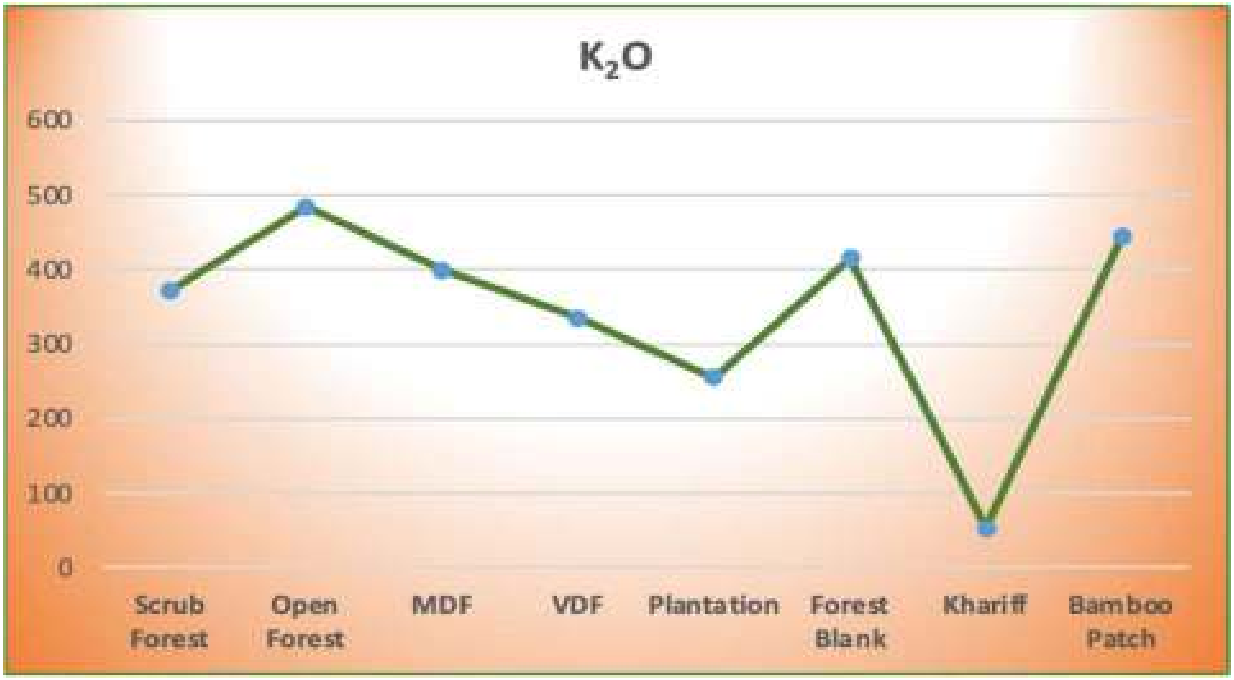
d. Organic Matter[AE]

Despite variations in nutrient levels, all plots maintain high organic matter content, a characteristic feature of forest soils. Organic matter contributes to soil structure, moisture retention, and nutrient cycling in natural ecosystems.

Reason for High Organic Matter:

- **Forest Ecosystem:** Forest soils generally have high organic matter due to continuous leaf litter, plant residues, and minimal soil disturbance, promoting accumulation and decomposition of organic matter.
- **Biodiversity:** High biodiversity in forest ecosystems supports diverse microbial communities that contribute to the breakdown of organic matter, enriching the soil.
-





e. Soil Texture[AF]

All plots share a sandy loam texture, providing good drainage and aeration, typical of forest soils. While natural, sandy soils may experience nutrient leaching, influencing nutrient availability to vegetation.

Reason for Sandy Loam Texture:

- **Parent Material:** The soil texture is often determined by the parent material from which the soil is formed. Sandy loam soils might be derived from weathered sandstones or other coarse-textured parent materials.
- **Natural Soil Formation Processes:** The natural processes of soil formation, including weathering of rocks and deposition of sediments, can result in the sandy loam texture observed in these forest plots.

The quantity of soil, measured in cubic meters (cum), was calculated by first determining the weight of a 0.3 mtr x 0.3 mtr x 0.3 mtr soil sample. This unit volume weight was then used to estimate the total volume of soil in cubic meters for each strata. This approach aligns with local market practices, where forest soil is typically sold in cubic meter units.

Total Area in ha	Area of sub-plot for soil sample in Sq mtr	Total no. of sub-plot units Ha^{-1}	Total Volume of Soil Cum Ha^{-1}	Total no. of sub-plot units	Volume of soil per unit in Cum	Total volume of Soil for estimation inside Garbhanga RF in Cum
18,200	0.09	1,11,111	**2,999.99**	2,02,22,20,200.00	0.027	5,46,60,000

Hence, Volume of Soil Ha^{-1} = 2,999.99 Cum

2. Release of Oxygen[AGandAH]:

a) In the assessment of the total oxygen released by the Garbhanga Forest ecosystem, only carbon storage in trees with a diameter greater than 0.30 meters was taken into account. This selective criterion was established to focus specifically on mature trees, as they typically contribute significantly to carbon sequestration and oxygen production within the ecosystem.

b) Given the average age of the tree crop considered as a whole is 20 years *(Refer Page - 64)*, the decision to exclude shrubs, herbs, litter, and soil organic carbon (SOC) from the analysis was made due to limitations in scientific data availability pertaining to these components across the area of interest. While the age of the tree crop could be reliably estimated based on established growth patterns and age-volume relationships, similar data for shrubs, herbs, litter, and SOC were not readily accessible and bamboo biomass is quite negligible.

c) This cautious approach ensures that the assessment of oxygen release is based on robust and verifiable data, thereby maintaining the scientific integrity of the analysis. Although the exclusion of certain components may introduce some limitations to the scope of the study, it allows for a focused and rigorous examination of the oxygen release attributed specifically to mature tree biomass within the Garbhanga Forest ecosystem.

Total Carbon Sink of Trees in M/Tons in 20 years (±5%)	Total Oxygen Released in Litres in 20 years (±5%)	Total Oxygen released in Litres during 2023-24 by trees (±5%)	Total Oxygen released in Ltr Ha^{-1} during 2023-24 by trees (±5%)
15,35,649.527	28,66,54,57,42,782.680	1,43,32,72,87,139.134	78,75,125.67

QUANTIFICATION AND VALUATION OF FOREST ECOSYSTEM SERVICES OF GARBHANGA RF IN TERMS OF PER UNIT HA AREA

Quantifying and valuing the forest ecosystem services of Garbhanga Reserved Forest (RF) on a per hectare basis provides crucial insights from both economic and scientific perspectives. Scientifically, this approach allows for the precise assessment of ecosystem services such as carbon sequestration, water purification, biodiversity conservation, and soil stabilization. By quantifying these services, we can compare the ecological health and productivity of Garbhanga RF with global standards, ensuring that conservation efforts are on par with international benchmarks. Economically, valuing these ecosystem services translates the ecological benefits into monetary terms, making it possible to recognize the forest's contributions to the economy. For instance, the carbon sequestration capacity of Garbhanga RF can be valued based on global carbon market prices, while biodiversity can be assessed through its potential to attract ecotourism and its role in sustaining local agriculture. This inclusion would not only highlight the significant economic contributions of ecosystem services but also reinforce the importance of sustainable forest management and conservation policies, ensuring that the ecological wealth of Garbhanga RF is preserved for future generations while supporting the state's economic growth.

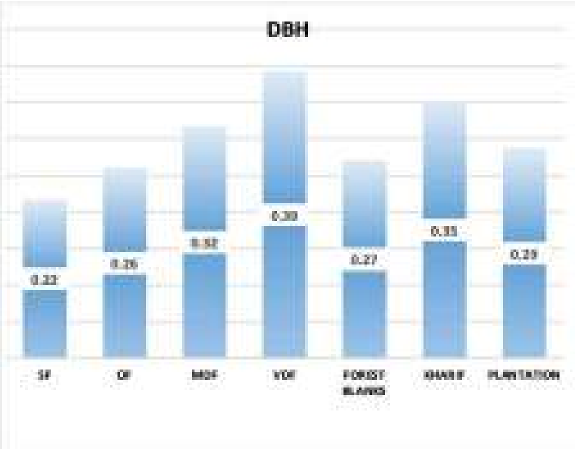
Quantifying and valuing forest ecosystem services of Garbhanga Reserved Forest (RF) on a per hectare basis, stratified by forest types, is essential for several reasons. Different forest strata, such as VDF, MDF, OF, SF, Forest Blanks, Kharif and Bamboo brakes, provide varying levels of ecosystem services. Scientifically, stratified quantification allows for a detailed assessment of the specific contributions each forest type makes to carbon sequestration, biodiversity support, soil conservation, and water regulation etc. For instance, VDF often have higher biomass and carbon storage capacity compared to other strata.

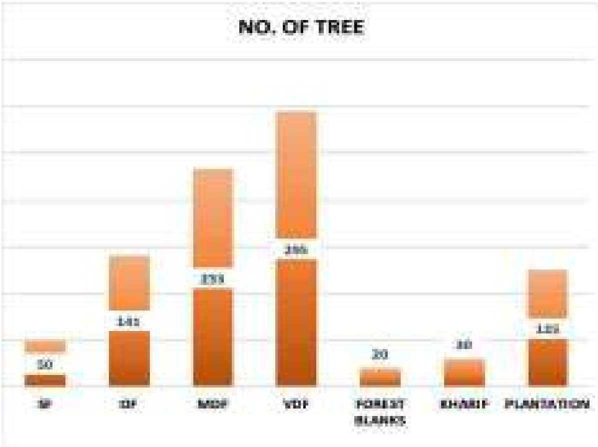
Economically, this stratified approach enables the precise valuation of ecosystem services, reflecting the true economic value of each forest type. For example, VDF might be more valuable for carbon credits, while MDF might be important for biodiversity conservation and ecotourism. Assigning monetary values to these services on a per hectare basis provides a clear picture of the economic contributions of each forest stratum, facilitating better resource allocation and investment decisions.

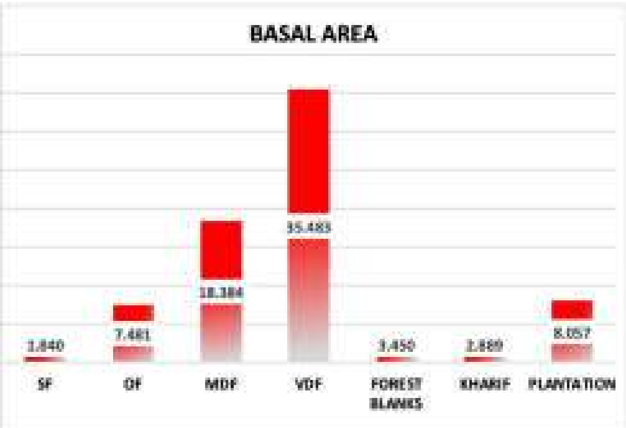
Incorporating this stratified valuation into the State GDP aligns with the scope of integrating natural capital into economic planning. By recognizing the diverse contributions of different forest types, policymakers can make decisions that promote sustainable forest management and economic development. This comprehensive scientific analysis and economic valuation not only underscore the importance of conserving Garbhanga RF but also enhance its role in supporting the state's economy and ecological health. Such an approach ensures that the forest's full range of ecosystem services is acknowledged and preserved, contributing to both environmental sustainability and economic prosperity.

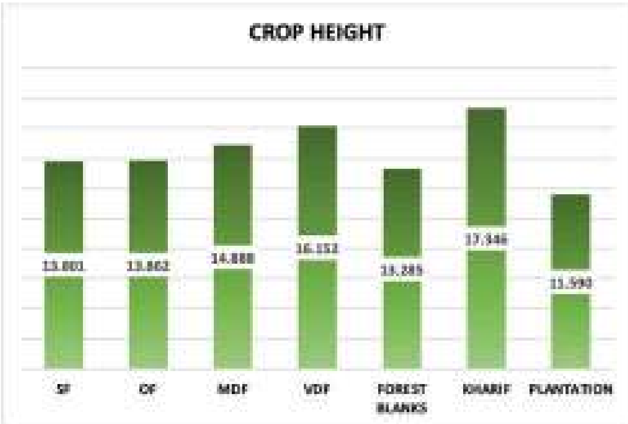
The details is furnished as –

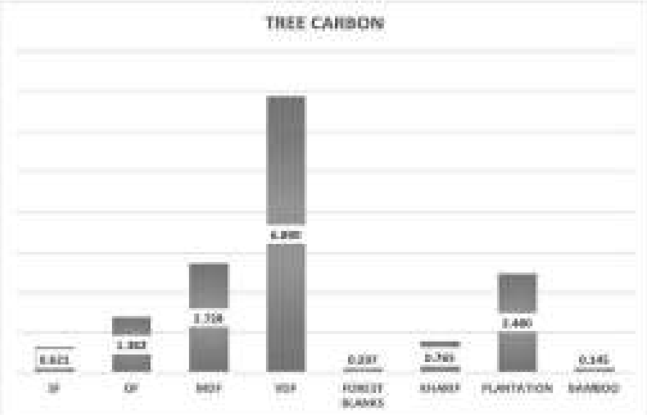
SF	OF	MDF	VDF	FOREST BLANKS	KHARIF	PLANTATION	BAMBOO	ATTRIBUTES
0.22	0.26	0.32	0.39	0.27	0.35	0.29		AVG DBH m
5	14	23	29	2	3	13		AVG TREE NO. PER PLOT
400	3,800	7,400	5,400	100	100	200	800	AREA ALLOTED Ha
4	38	74	54	1	1	2	8	NO. OF SAMPLE POINT
50	141	233	285	20	30	125		EXTRAPOLATED NO. OF TREES Ha^{-1}
1.840	7.481	18.304	35.483	3.450	2.889	8.057		BASAL AREA m^2 Ha^{-1}
13.801	13.862	14.888	16.152	13.285	17.346	11.590		AVG CROP HT m
0.621	1.382	2.728	6.890	0.207	0.785	2.488	0.145	TREE CARBON MG Ha^{-1} Yr^{-1}
27,50,333.80	4,85,128.68	3,55,036.73	1,24,248.54	24,24,117.81	52,82,512.24	0.00	3,23,609.81	WATER BODY MOISTURE RETENTION Ltr Ha^{-1} Yr^{-1}
62.785	299.282	562.933	1,468.433	27.860	339.369	544.495	542.700	STEM MOISTURE RETENTION Ltr Ha^{-1} Yr^{-1}
18.043	83.418	180.745	340.770	25.385	20.831	99.231		CROWN MOISTURE RETENTION Ltr Ha^{-1} Yr^{-1}
14.148	30.489	32.655	33.898	69.575	17.675	13.778	6.156	GROUND BIOMASS MOISTURE IN Ltr Ha^{-1} Yr^{-1}
2.573	3.268	3.773	3.742	2.582	4.881	2.747	0.334	DEADWOOD BIOMASS MOISTURE IN Ltr Ha^{-1} Yr^{-1}
13,333.333	15,000.000	16,666.667	18,888.889	12,222.222	13,333.333	17,222.222	15,555.556	SOIL MOISTURE IN Ltr Ha^{-1} Yr^{-1}
11,58,756.422	35,78,870.204	50,92,374.528	1,28,60,432.342	3,87,220.169	14,27,559.160	46,25,589.348	2,69,019.996	OXYGEN RELEASED IN Ltr Ha^{-1} Yr^{-1}

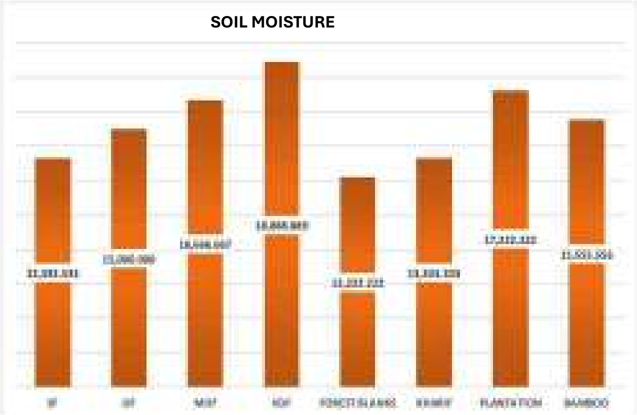


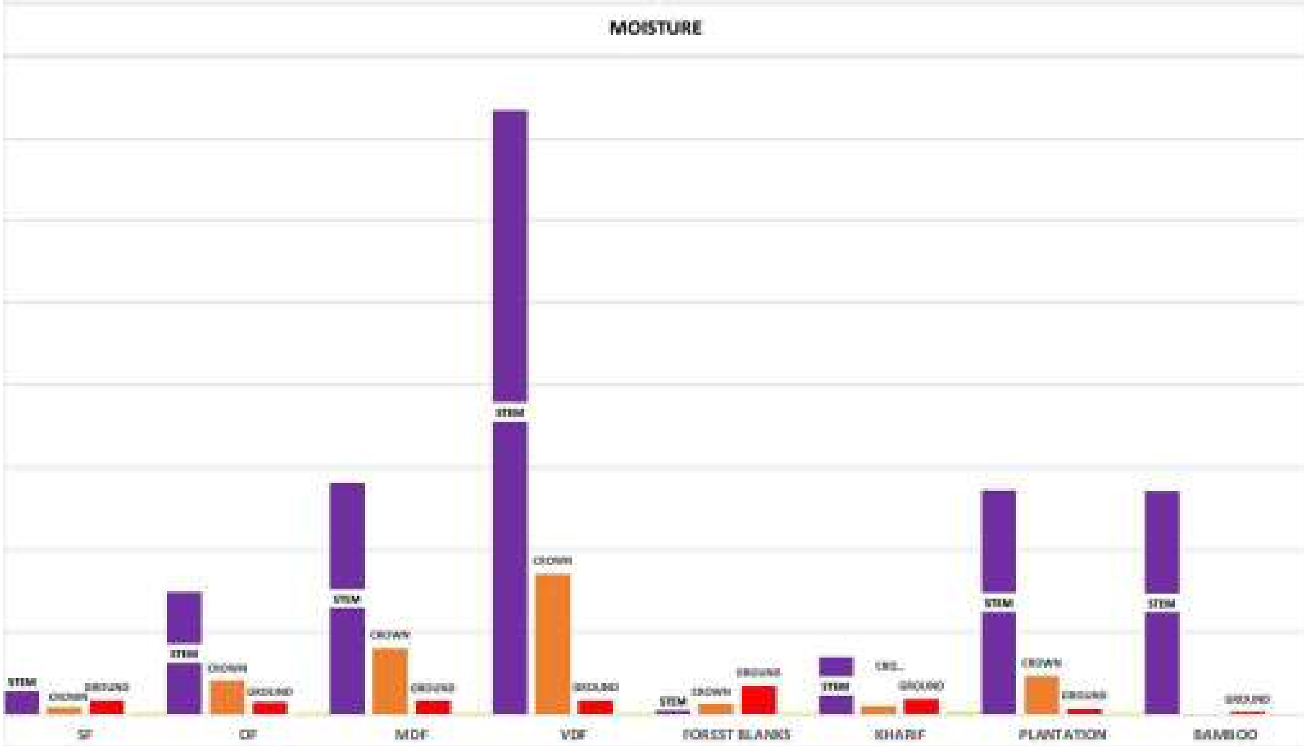


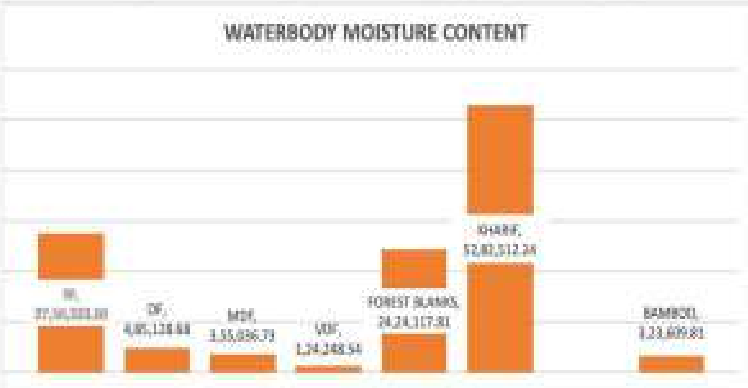












The table provides various attributes related to different LULC categories, which include Scrub Forest (SF), Open Forest (OF), Moderately Dense Forest (MDF), Very Dense Forest (VDF), Forest Blanks, Kharif, Plantation, and Bamboo. Each category has specific characteristics, influencing its ecological and environmental contributions. Here's a detailed analysis with explanations:

1. <u>Forest Density and Biomass</u>
    a. Very Dense Forest (VDF)

i. Basal Area (35.483 m^2 Ha^{-1}): The high basal area indicates a large cross-sectional area of tree trunks per hectare, reflecting high tree density and biomass.
ii. Carbon Storage (340.770 MG Ha^{-1} Yr^{-1}): Dense forests have more biomass, leading to greater carbon sequestration. Trees in VDF store more carbon due to their size and density.
v. Moisture Retention: High stem, crown, and ground biomass moisture retention values suggest a significant role in maintaining the hydrological cycle. Dense canopies reduce evaporation and increase water infiltration into the soil.

b. Moderately Dense Forest (MDF)
Comparison to VDF: MDF has lower but still significant values in basal area, carbon storage, and moisture retention, showing it also plays a crucial role in ecosystem services, though to a lesser extent than VDF.

2. Moisture Retention
- Plantations
  i. High Moisture Retention: Stem Moisture Retention (544.499 Ltr Ha^{-1} Yr^{-1}) and Crown Moisture Retention (27.760 Ltr Ha^{-1} Yr^{-1}): Plantations, often consisting of fast-growing species, retain a lot of moisture, which helps in local climate regulation and supports the water cycle.
  ii. Ground Biomass Moisture (6.156 Ltr Ha^{-1} Yr^{-1}): The litter layer in plantations helps retain soil moisture, supporting root systems and microbial activity.

- Comparison to Forest Blanks and Kharif:
  i. Forest Blanks have significantly lower moisture retention values due to the lack of vegetation, which plays a crucial role in retaining moisture.
  ii. Kharif land, primarily agricultural, also shows lower moisture retention compared to forested areas, reflecting the difference in land cover and its impact on water cycles.

3. <u>Carbon Sequestration</u>
a. Very Dense Forest (VDF)
  i. High Carbon Storage: VDF stores the most carbon (340.770 MG Ha^{-1} Yr^{-1}) due to its high tree density and biomass. Large, mature trees sequester more carbon than younger, smaller trees.
  ii. Importance for Climate Mitigation: High carbon storage in VDF helps mitigate climate change by absorbing CO_2 from the atmosphere.

b. Plantations
  i. Significant Contribution: Plantations also have substantial carbon storage (27.760 MG Ha^{-1} Yr^{-1}), emphasizing the role of managed forests in carbon sequestration efforts.

4. <u>Oxygen Release</u>
a. Plantations
  i. High Oxygen Production: Plantations release the most oxygen (17,222.222 Ltr Ha^{-1} Yr^{-1}), highlighting their role in improving air quality. Fast-growing species in plantations contribute to higher oxygen output.
b. Very Dense Forest (VDF) and Moderately Dense Forest (MDF)
  i. Substantial Contribution: Both VDF and MDF also contribute significantly to oxygen release due to their dense tree cover and high photosynthetic activity.

5. <u>Agricultural Land (Kharif)</u>
a. Lower Ecological Values:

i. Carbon Storage (27.860 MG Ha^{-1} Yr^{-1}) and Moisture Retention values are lower in Kharif compared to forested areas. Agricultural lands typically have less biomass and fewer trees, resulting in reduced carbon sequestration and moisture retention.
ii. Implications for Land Management: The data suggest a need for integrating agroforestry practices to enhance carbon storage and moisture retention in agricultural lands.

6. Bamboo
   a. Unique Ecological Role:
      i. Moisture Retention and Oxygen Release: Bamboo forests, while having lower tree-related attributes, still play a significant role in moisture retention and oxygen release, showcasing their ecological importance.
      ii. Adaptability: Bamboo's ability to grow quickly and retain moisture makes it a valuable resource for ecosystem services, particularly in areas where traditional forests may not thrive.

Chapter VII

MONETARY VALUES ASSIGNED TO DIFFERENT SERVICES, NAV and COMPARISON WITH PREVIOUS STUDIES

MONETARY VALUES ASSIGNED TO DIFFERENT SERVICES

To evaluate the economic value of each Forest Ecosystem Service (FES) for the fiscal year 2023-24, a comprehensive economic valuation framework is applied. This involves quantifying the monetary worth of various ecosystem services provided by forest ecosystems over a one-year period. ***(Costs are based on prices during Dec/2023)***

1. **<u>Water Consumption</u>**

According to data from the Guwahati Metropolitan Drinking Water and Sewerage Board (GMDWSSB), the average cost incurred by each household in Guwahati for water supply is ₹ 25.00 per 1,000 L. The total water consumption by the community residing within the Garbhanga Reserve Forest (RF) is recorded at **9,49,89,060** L.

Sl No	Villages	Total No. of Households	Average No. of Family Member Per Households	Total Population	Yearly Domestic Consumption of Water (Ltr)	Yearly Per Capita Consumption of Water (Ltr)	Per Capita Monetary Value (₹) of Water Consumption for 2023-24
1	Amring	42	6	252	82,47,540	32,728.33	₹ 818.21
2	Natun Garbhanga	26	5	130	50,01,230	38,471.00	₹ 961.78
3	Doloipaham	66	7	462	1,32,97,680	28,782.86	₹ 719.57
4	Natun Jalukpaham	09	4	36	17,24,625	47,906.25	₹1,197.66
5	Matang	45	4	180	86,55,975	48,088.75	₹1,202.22
6	Narlong	21	4	84	40,85,445	48,636.25	₹1,215.91
7	Kayampathar	09	5	45	17,18,055	38,179.00	₹ 954.48
8	Old Garbhanga	37	6	222	70,76,620	31,876.67	₹ 796.92
9	Ulubari	20	4	80	40,51,500	50,643.75	₹1,266.09
10	Jalukpaham	36	7	252	70,95,600	28,157.14	₹ 703.93
11	Garbhanga	28	7	196	53,75,720	27,427.14	₹ 685.68
12	Pahamjila	44	5	220	84,79,680	38,544.00	₹ 963.60
13	Garbhanga Nepali Basti	04	5	20	8,17,600	40,880.00	₹1,022.00
14	Borpani	04	4	16	8,13,220	50,826.25	₹1,270.66
15	Latumpaham	14	6	84	27,84,950	33,154.17	₹ 828.85

16	Numalipa thar	36	5	180	70,16,760	38,982.00	₹ 974.55
17	Thekerak uchi	08	4	32	15,24,240	47,632.50	₹1,190.81
18	Dekapath ar	12	6	72	23,95,860	33,275.83	₹ 831.90
19	Nautari	24	5	120	48,26,760	40,223.00	₹1,005.58
		485		**2683**	**9,49,89,060**	**39,179.73**	**₹979.49**

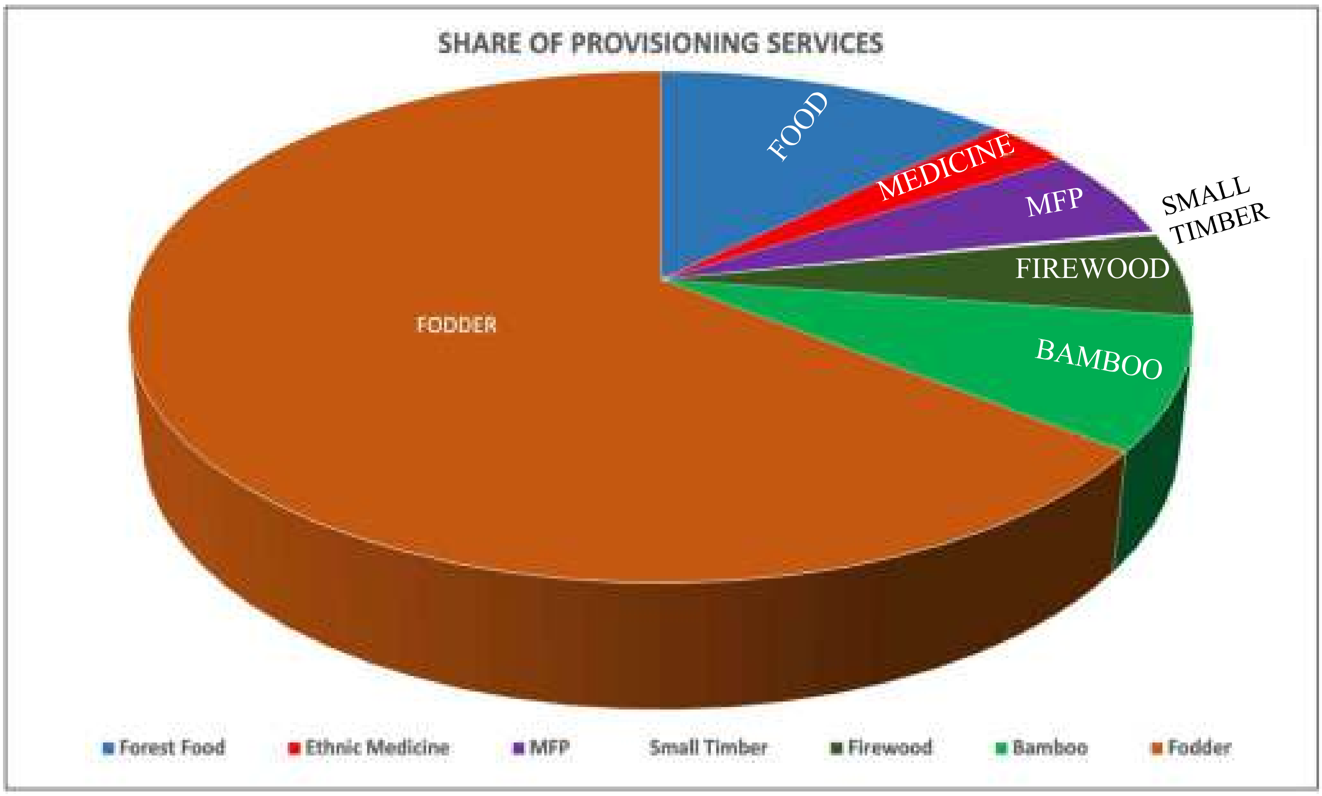
Hence total cost of consumption of water in one year = **9,49,89,060** L x ₹25/1000 L = **₹23,74,726.50**
Average per capita monetary value of water consumption is **₹979.49**

2. **Forest food, Ethnic medicine, MFPs, Small timbers, Bamboo, Fodder etc.:**
To ascertain the economic value of products consumed by communities within Garbhanga Reserve Forest (RF), a detailed market analysis was conducted. The market rates for these products were collected from local markets in the vicinity of Garbhanga RF. This analysis offers valuable insights into the economic dynamics of the Garbhanga RF communities.

Sl. no	Product	Consumption / Sale per year	Unit	Rate/Unit in Rs	Economic value/year in ₹
Forest Food					
1	Kolful	1,27,116	Nos.	50.00	₹63,55,800.00
2	Dhekia	81,108	Bundles	10.00	₹8,11,080.00
3	Kosu loti	15,392	Bundles	30.00	₹4,61,760.00
4	Pani kosu	15,120	Bundles	20.00	₹3,02,400.00
5	Sojina	7,453	KG	100.00	₹7,45,300.00
6	Bet gaaj	15,072	Nos.	20.00	₹3,01,440.00
7	Gondh kosu	42,384	Bundles	10.00	₹4,23,840.00
8	Baah gaaj	28,640	Nos.	10.00	₹2,86,400.00
9	Tokomar phool	14,560	Bundles	20.00	₹2,91,200.00
10	Meteka phool	12,012	Bundles	10.00	₹1,20,120.00
11	Miri tenga	12,012	Bundles	10.00	₹1,20,120.00
12	Mushroom	7,801	KG	240.00	₹18,72,240.00
13	Tita bhekuri	806	KG	60.00	₹48,360.00
14	Owtenga	9,660	Nos.	10.00	₹96,600.00
15	Mosondori	10,432	Bundles	10.00	₹1,04,320.00
16	Leteku	557	KG	40.00	₹22,280.00
17	Kosu	10,800	Bundles	10.00	₹1,08,000.00

18	Honey	180	Litres	150.00	₹27,000.00
19	Mechka tenga	2,400	KG	40.00	₹96,000.00
20	Kothal	1,630	Nos.	80.00	₹1,30,400.00
21	Kothal guti	3,640	KG	60.00	₹2,18,400.00
22	Gos aloo	864	KG	20.00	₹17,280.00
23	Korobi kosu thuri	1,020	Bundles	10.00	₹10,200.00
24	Kola kosu	4,320	Bundles	10.00	43,200.00
25	Amara	688	KG	50.00	₹34,400.00
26	Jaam	22	KG	80.00	₹1,760.00
27	Gar jibha	34,080	Bundles	10.00	₹3,40,800.00
28	Dudh kosu	4,992	Bundles	10.00	₹49,920.00
29	Nil kosu	2,808	Bundles	10.00	₹28,080.00
30	Nilaji	800	KG	60.00	₹48,000.00
31	Nol tenga	48	Bundles	20.00	₹960.00
32	Garo kosu	75,000	KG	40.00	₹30,00,000.00
33	Bangi/Bami	4,000	KG	60.00	₹2,40,000.00
34	Kordoi	988	KG	60.00	₹59,280.00
35	Panjari tenga	1,560	Nos.	10.00	₹15,600.00
		1,040	Bundles	40.00	₹41,600.00
				Sub-Total	**₹1,68,74,140.00**
Ethnic Medicine					
1	Bhedai lota	9,516	Bundles	20.00	₹1,90,320.00
2	Amlokhi	14,553	KG	150.00	₹21,82,950.00
3	Bhomora	156	KG	90.00	₹14,040.00
4	Bahaka phool	468	KG	50.00	₹23,400.00
5	Hilikha	14,405	KG	100.00	₹14,40,500.00
6	Pepper	616	KG	100.00	₹61,600.00
7	Bih dhekia	260	KG	200.00	₹52,000.00
8	Hansum	780	KG	50.00	₹39,000.00
9	Kasi dira	1,040	Bundles	20.00	₹20,800.00
10	Manimuni	1,620	Bundles	10.00	₹16,200.00
12	Mehek paat	4,440	Bundles	20.00	₹88,800.00
13	Surat paat phool	832	KG	30.00	₹24,960.00
				Sub-Total	**₹41,54,570.00**
MFP					
1	Jharu	86,271	KG	80.00	₹69,01,760.00
2	Paan	37,622	Bundles	15.00	₹5,64,330.00

				Sub-total	**₹74,66,090.00**
Small Timber					
1	Small Timber	485	Cft	700.00	**₹3,39,500.00**
Firewood					
1	Firewood	70,812	Moottha	100.00	**₹70,81,200.00**
Bamboo					
1	Bamboo	72,750	Nos.	150.00	**₹1,09,12,500.00**
Fodder					
1	Cow Fodder	29,20,000	KG	25.00	₹7,30,00,000.00
2	Goat Fodder	5,84,000	KG	20.00	₹1,16,80,000.00
				Sub-Total	**₹8,46,80,000.00**
				Grand Total	**₹13,15,08,000.00**
Per Capita Monetary Value for the Year 2023-24					**₹49,015.28**



3. **Carbon Sink:**

The Garbhanga Reserve Forest (RF), spanning 18,200 hectares, has sequestered a total of 48,52,001.80 MG of carbon over the past 20 years. For the fiscal year 2023-24, the carbon sequestration is calculated to be 2,42,600.090 MG.

Using the current global carbon trading rate of \$4.00 MG^{-1}, equivalent to ₹334.00 per Carbon Credit (1.0 MG), the value of the carbon sink for the year 2023-24 is **₹8,10,28,430.06.**
The estimated value of carbon sink = **₹4,452.11 $Ha^{-1}Yr^{-1}$**

Strata Wise Carbon Sink and Respective Monetary Value Ha^{-1}

Sl No	Strata	Average Carbon for 20 years (±5%) MG Ha^{-1}	Average Carbon for the year 2023-24 MG H^{-1}	Monetary Value of Carbon for the year 2023-24 ₹ Ha^{-1}
1	Scrub Forest	269.920	13.496	4,507.66
2	Open Forest	272.217	13.611	4,546.07
3	Moderate Dense Forest	270.171	13.508	4,511.67
4	Very Dense Forest	274.187	13.709	4,578.81
5	Bamboo	173.385	8.669	2,895.45
6	Forest Blank	219.464	10.973	3,664.98
7	Plantation	260.071	13.003	4,343.00
8	Kharif	170.658	8.533	2,850.02

4. **Water Retention:**

The economic value of water retention in Garbhanga Reserve Forest (RF) for the fiscal year 2023-24 has been meticulously assessed based on data provided by the Public Health Engineering (PHE) department. The analysis encompasses both the water bodies and the water retained within biomass and soil.

Water Bodies:

Least Quantity of water retained in water bodies, biomass and soil = 1.644 x 10^{11} Ltr Ha^{-1} Yr^{-1}

Economic Valuation:

Data on cost pumping and storage of 60,000 Litres of water in underground reservoir per day as provided by the PHE Department –

Cost					Cost/Litres
Power	Disinfection	Manpower	Maintenance	Total	
₹225.00	₹4.30	₹1,050.00	₹6.12	₹1,285.42	₹0.021423

Cost of Ground Water Extraction, Treatment and Storage: Say, ₹0.020 Ltr^{-1}

Hence, Monetary Value of Water Retention = (1.644 x 10^{11} Ltr Ha^{-1} Yr^{-1} x ₹0.020 Ltr^{-1} = **₹3,28,96,15,502.12 Ha^{-1} Yr^{-1}**

5. **Temperature Regulation:**

To maintain a temperature difference of 2.93°C during the summer months in an urban area, the energy consumption required to run an air conditioner (AC) for one hour inside a room is 0.624 kWh. Over the summer months, equivalent to 1080 hours (6 hours per day), the total energy consumption for the air volume equivalent to the total volume of air trapped inside Garbhanga RF is calculated to be 77,83,14,27,021.50 kWh

Given the average cost of energy is ₹10.00 kWh^{-1}, the total cost for this energy consumption is: 77,83,14,27,021.50 kWh ×₹10.00 kWh^{-1} = **₹7,78,31,42,70,215.00**

Therefore, the cost involved in maintaining the desired temperature difference Ha^{-1} during the summer months equivalent to the year 2023-24 against 42,76,452 kWh Ha^{-1} = **₹4,27,64,520.34 Ha^{-1} Yr^{-1}**

6. **Cultural Service:**
Total Economic Impact:
The cumulative economic impact of these forest-based recreational activities for the year 2023-24 amounts to **₹6,02,69,683.00** This valuation underscores the significant contribution of forest ecosystems to recreational and educational pursuits, providing substantial economic benefits through tourism and related activities.

Sl. No.	Purpose of visit	No. of persons	Average no. of days visited per year per person	Total Mandays	Average Monetary value per day per person	Total value per year under each category	Value per year ₹ Ha-1
1	Adventure Outing	79	45	3555	7125	25329375	1,391.72
2	Photography and Bird Watching	57	27	1539	7285	11212068	616.05
3	Picnic	93	1	93	400	37200	2.04
4	Field Study	262	15	3930	6028	23690040	1301.65

Hence economic value of cultural services in terms of Ha-1 = **₹3,311.46 Ha^{-1}**

7. **Soil Nutrient:**
The economic value of the forest soil from Garbhanga Reserve Forest (RF) has been determined using a market-based valuation approach. This method involved collecting data on the prices of similar soil types currently available in the local markets as well as in e-Commerce websites. By analysing these market prices, we derived a precise economic valuation for the soil within the Garbhanga RF.

Total volume of soil considering 30 cm depth against 18200 ha of Garbhanga RF is 5,46,60,000 Cum
Market price of forest soil is ₹ 300.00 Cum^{-1}
Hence, economic value of forest soil **= ₹16,39,80,00,000.00**

Volume of Soil = 2,999.99 Cum Ha^{-1}
Market Price of Soil **= ₹8,99,997.00 Ha^{-1}**

8. **Release of Oxygen:**
Total Oxygen released by Trees during 20 years *(Refer Page – 51)* = 2,866,54,57,42,782.680 Ltr
Oxygen released by Trees during 2023-24 = **1,43,32,72,87,139.134 Ltr**
Oxygen released by Trees Ha^{-1} during 2023-24 = **78,75,125.67 Ltr Ha^{-1}**

Market price of refill of Oxygen is ₹350.00/Ltr
Therefore, economic value of Oxygen released during 2023-24 is ₹5,01,64,55,04,98,696.90
Economic Value of Oxygen released during 2023-24 = ₹2,75,62,93,983.00 Ha^{-1} Yr^{-1}

Strata wise Monetary Value of the Ecosystem Services Ha^{-1} $Yr^{-1}$are displayed below:

SF	OF	MDF	VDF	FOREST BLANKS	KHARIF	PLANTATION	BAMBOO	ATTRIBUTES
0.22	0.26	0.32	0.39	0.27	0.35	0.29		AVG DBH m
5	14	23	19	2	3	13		AVG TREE NO. PER PLOT
400	3,800	7,400	5,400	100	100	200	300	AREA ALLOTED Ha
4	38	74	54	1	1	2	8	NO. OF SAMPLE POINT
50	141	233	295	20	30	125		EXTRAPOLATED NO. OF TREES Ha^{-1}
1.840	7.481	18.384	35.483	1.450	2.889	8.057		BASAL AREA m^2 Ha^{-1}
15.801	13.862	14.888	16.352	15.285	17.346	11.590		AVG CROP HT m
0.621	1.382	2.728	6.890	0.207	0.765	2.480	0.145	TREE CARBON MG $Ha^{-1}Yr^{-1}$
27,50,333.80	4,85,128.68	3,55,036.75	1,24,248.34	24,24,117.81	52,82,512.24	0.00	5,23,605.81	WATER BODY MOISTURE RETENTION Ltr Ha^{-1} Yr^{-1}
62.765	296.282	562.933	1,468.433	27.860	139.369	544.439	542.700	STEM MOISTURE RETENTION Ltr Ha^{-1} Yr^{-1}
16.843	81.418	160.745	340.770	26.365	20.831	99.131		CROWN MOISTURE RETENTION Ltr Ha^{-1} Yr^{-1}
34.146	30.489	32.655	33.891	69.575	37.675	13.778	6.156	GROUND BIOMASS MOISTURE IN Ltr Ha^{-1} Yr^{-1}
2.373	3.268	3.779	3.742	2.582	4.881	2.747	0.334	DEADWOOD BIOMASS MOISTURE IN Ltr Ha^{-1} Yr^{-1}
13,333.333	15,000.000	16,666.667	18,888.889	12,222.222	13,333.333	17,222.222	15,555.556	SOIL MOISTURE IN ltr Ha^{-1} Yr^{-1}
11,58,756.422	25,78,870.204	50,92,374.528	1,28,60,432.342	3,87,220.180	14,27,559.160	46,29,589.348	2,69,919.996	OXYGEN RELEASED IN Ltr Ha^{-1} Yr^{-1}
₹40,56,20,230.59	₹90,26,60,347.70	₹1,78,23,87,351.12	₹4,50,12,09,042.11	₹13,55,82,580.25	₹49,97,01,238.97	₹1,62,04,12,464.46	₹9,45,27,375.72	MONETARY VALUE ₹ Ha^{-1} Yr^{-1}

ECONOMIC ANALYSIS ON FOREST ECOSYSTEM SERVICES AND STATE GDP:

1. **Detailed Analysis of Forest Categories and Economic Contributions:**
   a. **Scrub Forest (SF): ₹40,56,20,230.59**
   Ecological Role: Scrub forests are typically found in semi-arid regions and play a crucial role in biodiversity conservation. They support a variety of plant and animal species adapted to dry conditions, contributing to regional ecological diversity.
   Economic Activities: Economic activities in scrub forests include sustainable harvesting of medicinal plants, collection of non-timber forest products (like gums, resins, and tannins), and grazing lands for livestock. These activities provide livelihoods for local communities and generate income through small-scale enterprises.

   b. **Open Forest (OF): ₹90,26,60,347.70**
   Ecological Role: Open forests have a more developed tree canopy than scrub forests but are less dense compared to dense forests. They serve as important habitats for wildlife, including game species and migratory birds, contributing to biodiversity conservation.
   Economic Activities: Economic activities in open forests encompass sustainable timber harvesting, collection of non-timber forest products (such as honey, nuts, and mushrooms), and eco-tourism ventures. These activities support rural economies, provide employment opportunities, and promote conservation-oriented land management practices.

   c. **Medium Dense Forest (MDF): ₹1,78,23,87,351.12**
   Ecological Role: Medium dense forests have a moderate tree canopy cover and support diverse flora and fauna. They play a critical role in watershed management, soil erosion control, and carbon sequestration, contributing to ecosystem stability.
   Economic Activities: Economic activities in MDFs include sustainable timber harvesting for high-value hardwoods, eco-tourism development around scenic areas and wildlife habitats, and conservation programs aimed at preserving endemic species and forest ecosystems. These activities generate revenue, create jobs in forestry and hospitality sectors, and promote sustainable forest management practices.

d. **Very Dense Forest (VDF): ₹4,50,12,09,042.11**
Ecological Role: Very dense forests have a dense tree canopy with high biodiversity and are critical for maintaining ecological balance. They provide habitat for endangered species, regulate local climate, and support nutrient cycling in ecosystems.
Economic Activities: Economic activities in VDFs focus on sustainable timber harvesting of rare and valuable hardwoods, wildlife-based tourism including birdwatching and safaris, and research initiatives in forest ecology and conservation biology. These activities contribute significantly to the economy through revenue from tourism, and scientific research grants.

e. **Forest Blanks: ₹13,55,82,382.25**
Ecological and Economic Potential: Forest blanks may include areas undergoing forest regeneration, mixed land-use zones, or transitional habitats. These areas have potential for restoration projects, agroforestry initiatives, and community-based conservation efforts.
Economic Activities: Economic activities in forest blanks could involve reforestation programs, sustainable agriculture practices integrating trees, community forestry enterprises, and ecosystem restoration projects funded through environmental grants and corporate social responsibility initiatives.

f. **Plantation: ₹1,62,04,12,464.46**
Ecological Role: Plantation forests are cultivated for commercial purposes and often include fast-growing species for timber production, pulpwood, and biomass energy.
Economic Activities: Economic activities in plantation forests include intensive silviculture practices, timber harvesting for industrial use, biomass energy production, and carbon offset projects. These activities support the forestry sector, create jobs in planting and harvesting operations, and contribute to industrial supply chains for wood-based products.

g. **Bamboo: ₹9,45,27,375.72**
Ecological and Economic Importance: Bamboo forests provide versatile resources for construction, handicrafts, paper-making, and sustainable agriculture practices.
Economic Activities: Economic activities in bamboo cultivation include plantation management, bamboo harvesting for handicrafts and industrial products, and sustainable harvesting practices that support rural livelihoods and promote environmental sustainability. Bamboo forests also play a role in soil conservation, erosion control, and carbon sequestration, enhancing their ecological and economic value.

2. **Policy Implications and Strategic Development:**

a. Sustainable Forest Management: Policies should prioritize sustainable practices that balance economic development with environmental conservation goals. This includes promoting certified forestry practices, restoring degraded forest landscapes, and enhancing biodiversity conservation measures.

b. Enhancing Market Access: Facilitating market linkages for forest products, promoting value-added processing industries, and supporting certification schemes that ensure sustainable sourcing practices.

b. Community Engagement and Livelihoods: Investing in community-based natural resource management initiatives, enhancing access to training and technology for sustainable forest management practices, and promoting alternative livelihoods that reduce dependency on unsustainable forest practices.

3. **Socio-economic Impact and Future Directions:**
    a. Rural Development: Forest-related activities provide livelihood opportunities for rural communities, contributing to poverty alleviation and social equity.

    b. Climate Resilience: Enhancing the role of forests in climate change mitigation and adaptation strategies through carbon sequestration, watershed management, and resilience-building measures.

    c. Inclusive Growth: Ensuring that economic benefits from forest resources are equitably distributed among local communities, indigenous peoples, and marginalized groups, promoting inclusive growth and sustainable development.

12. Integration into State GDP

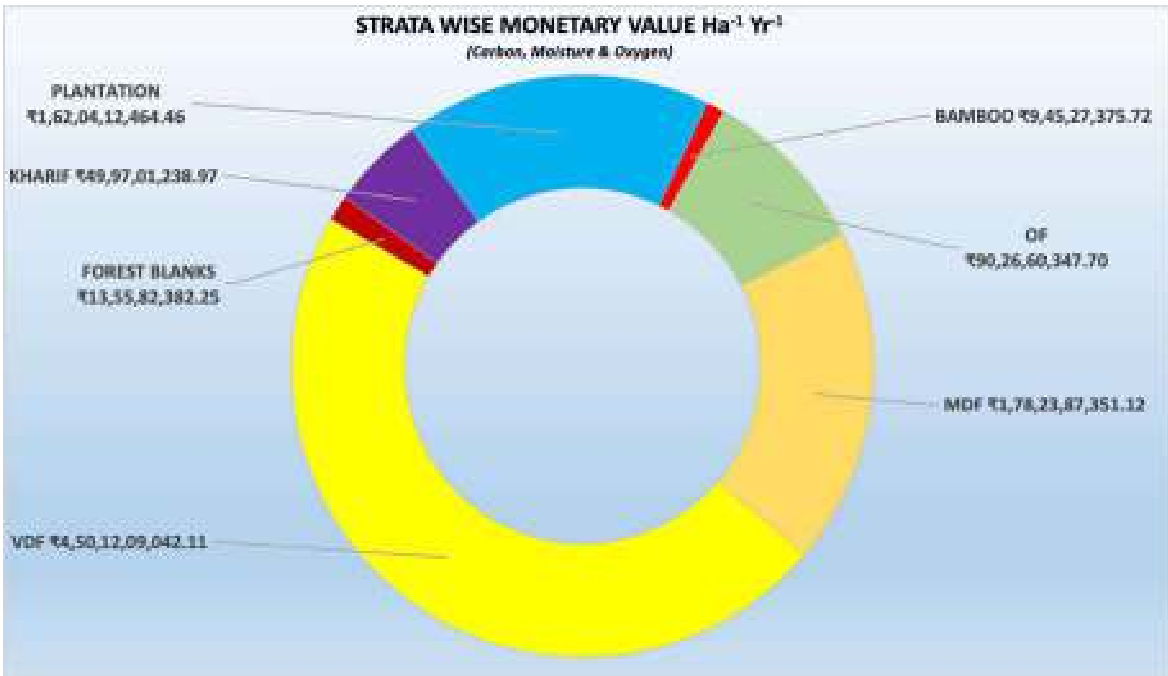
a. Monetary Valuation

The economic values of these ecosystem services can be derived from their direct and indirect contributions to the economy. For instance, carbon sequestration values can be monetized using carbon trading markets, water retention can be valued based on infrastructure cost savings, and soil moisture's impact on agriculture can be quantified through increased crop yields.

b. Aggregation and Inclusion

The total economic contribution of these ecosystem services can be aggregated by multiplying the per hectare values by the total forest area in the state. These aggregated values can then be included in the State GDP, providing a more comprehensive and accurate representation of the state's economic health and environmental sustainability.

The provided data underscores the significant economic contributions of forest ecosystem services to the state. By valuing these services and integrating them into the State GDP, policymakers can better appreciate the forests' role in supporting the economy and human well-being. This holistic approach promotes sustainable forest management, environmental conservation, and resilience against climate change, ultimately enhancing the state's economic and environmental prosperity.



SERVICES	MONETARY VALUE
WATER CONSUMPTION Ha^{-1} Yr^{-1}	₹5,219.18
FOREST FOOD Ha^{-1} Yr^{-1}	₹927.15
ETHNIC MEDICINE Ha^{-1} Yr^{-1}	₹228.27
MFP and NTFP Ha^{-1} Yr^{-1}	₹410.22
BAMBOO CONSUMPTION Ha^{-1} Yr^{-1}	₹599.59
FODDER Ha^{-1} Yr^{-1}	₹4,652.75
SMALL TIMBER Ha^{-1} Yr^{-1}	₹18.65
FIREWOOD Ha^{-1} Yr^{-1}	₹389.08
CARBON SINK Ha^{-1} Yr^{-1}	₹4452.11
WATER RETENTION Ha^{-1} Yr^{-1}	₹3,28,96,15,502.12
TEMPERATURE REGULATION Ha^{-1} Yr^{-1}	₹4,27,64,520.34
CULTURAL SERVICE Ha^{-1} Yr^{-1}	₹3,311.46
SOIL NUTRIENT RETENTION Ha^{-1} Yr^{-1}	₹8,99,997.00
OXYGEN RELEASE Ha^{-1} Yr^{-1}	₹2,75,62,93,983.00
TOTAL	₹6,08,95,94,210.92

The detailed monetary valuation of ecosystem services in the Garbhanga Reserved Forests underscores the multifaceted benefits these forests provide, spanning scientific, economic, and land valuation perspectives.

Scientific Perspective:
The significant valuation of water consumption at ₹5,219.18 per hectare per year (Ha^{-1} Yr^{-1}) highlights the forest's role in maintaining the hydrological cycle, crucial for sustaining local biodiversity and water quality. The valuation of water retention at ₹3,28,96,15,502.12 Ha^{-1} Yr^{-1} further emphasizes the forest's ability to prevent flooding and recharge groundwater. The role of forests in regulating temperature is underscored by the substantial valuation of temperature regulation services at ₹4,27,64,520.34 Ha^{-1} Yr^{-1}, reflecting their critical function in mitigating climate change and maintaining local climate stability. The extraordinary value assigned to oxygen release at ₹2,75,62,93,983.00 Ha^{-1} Yr^{-1} highlights the immense contribution of forests to air purification and carbon sequestration, vital for sustaining life and combating global warming.

Economic Perspective:
The provisioning services such as forest food (₹927.15 Ha^{-1} Yr^{-1}), ethnic medicine (₹228.27 Ha^{-1} Yr^{-1}), minor forest products (MFP) and non-timber forest products (NTFP) (₹410.22 Ha^{-1} Yr^{-1}), bamboo consumption (₹599.59 Ha^{-1} Yr^{-1}), fodder (₹4,652.75 Ha^{-1} Yr^{-1}), small timber (₹18.65 Ha^{-1} Yr^{-1}), and firewood (₹389.08 Ha^{-1} Yr^{-1}) illustrate the direct economic benefits derived from forest resources. These values reflect the forest's capacity to provide essential goods that support local livelihoods and economies, contributing to food security, healthcare, and raw materials. The valuation of cultural services at ₹3,311.46 Ha^{-1} Yr^{-1} signifies the non-material benefits forests provide, including recreational, spiritual, and aesthetic values, which enhance human well-being and societal welfare.

Land Valuation Perspective:
The high value attributed to soil nutrient retention at ₹8,99,997.00 Ha^{-1} Yr^{-1} signifies the crucial role of forests in maintaining soil fertility and preventing erosion, thereby sustaining agricultural productivity in surrounding areas. This service is essential for long-term land sustainability and

agricultural output. The comparative scale of these values indicates the forest's extensive role in ecosystem stability, economic sustenance, and climate regulation. The cultural services, valued at ₹3,311.46 Ha^{-1} Yr^{-1}, reflect the intrinsic and non-material benefits forests provide.

Overall, the comprehensive valuation of these ecosystem services provides a robust framework for recognizing the true economic worth of forest ecosystems. By highlighting their multifaceted contributions, this analysis underscores the necessity of integrating forest ecosystem services into national and state-level GDP calculations, ensuring their conservation and sustainable management for future generations.

Scale Comparison:
The values provided vary significantly due to the different types of ecosystem services considered and their economic impacts:

High-Value Services: Services like Temperature Regulation, Water Retention and Soil Nutrient Retention show exceptionally high values due to their critical roles in supporting agricultural productivity, reducing energy costs, and enhancing environmental quality.

Moderate-Value Services: Services like Water Consumption, Forest Food, and Cultural Services have moderate values, reflecting their direct and indirect benefits to human well-being and cultural practices.

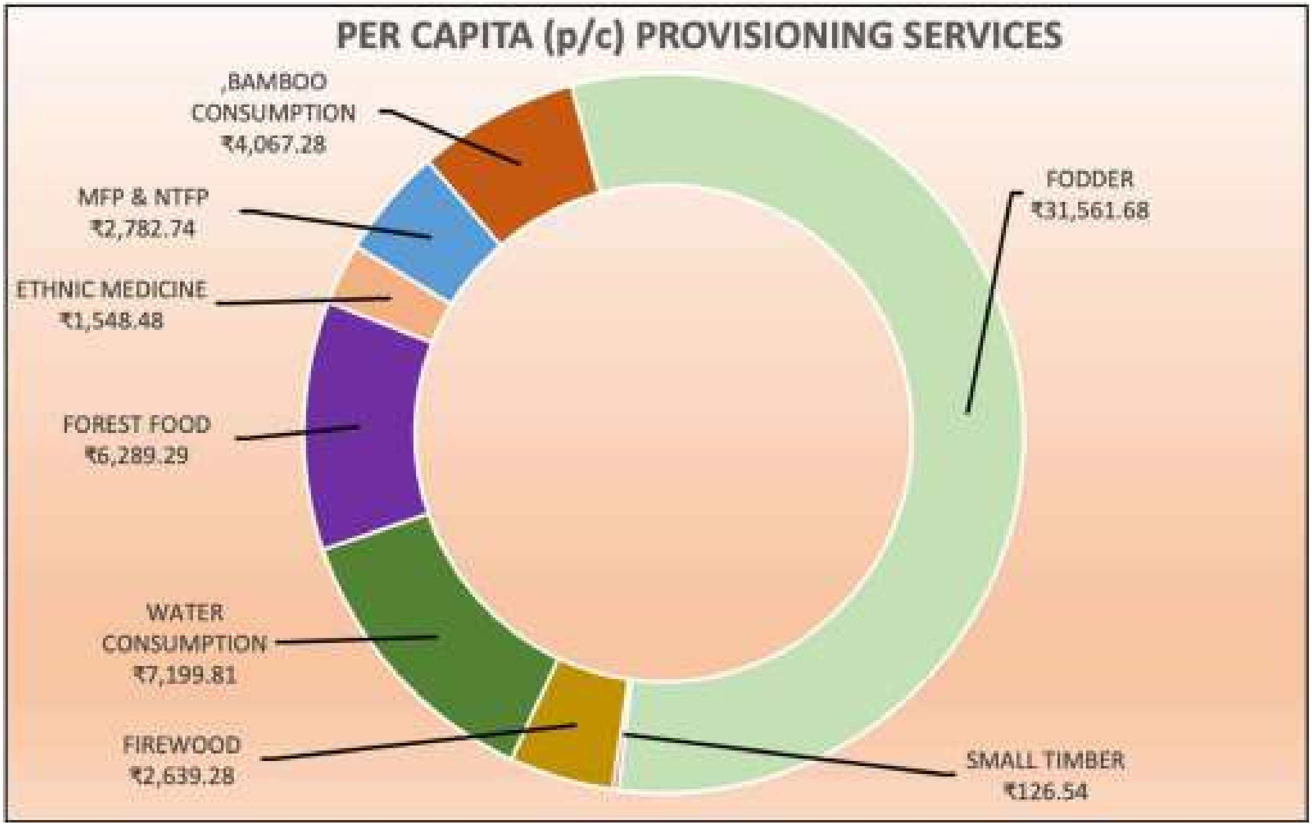
Low-Value Services: Services such as Small Timber and Firewood, while important, contribute relatively less to the overall economic value compared to other services.

Reasoning for Scale:
The scale of these values is determined by several factors:
Demand and Supply: Economic value reflects the demand for these services and their scarcity or abundance.
Substitute Costs: Values often consider the costs that would be incurred if these services were replaced or simulated by human-made alternatives.
Environmental Impact: The ecological contributions and resilience provided by forests influence their economic value, especially in terms of risk mitigation and sustainability.

Economic value of p/c per year provisioning services:
In summary, these values underscore the multifaceted economic contributions of forests beyond conventional timber extraction, highlighting their critical role in sustaining human well-being and environmental health.
In economic terms, the values provided per capita annually illustrate the significant contributions of forests to human welfare and economic activity. Water consumption (₹7,199.81 p/c Yr^{-1}) reflects the value of forests in regulating water cycles and ensuring clean water availability, crucial for both domestic and industrial use, thereby reducing infrastructure costs for water purification. Forest food (₹6,289.29 p/c Yr^{-1}) and ethnic medicine (₹1,548.48 p/c Yr^{-1}) underscore the forest's role in providing nutritional diversity and medicinal resources, contributing to public health and potentially reducing healthcare expenditures. Minor Forest Produce (MFP) and Non-Timber Forest Products (NTFP) (₹2,782.74 p/c Yr^{-1}) include a range of products like resins, fibres, and natural dyes, supporting local economies through employment and trade opportunities. Bamboo consumption (₹4,067.28 p/c Yr^{-1}) reflects its versatile use in construction, crafts, and industry, contributing to economic diversification and sustainable development. Fodder (₹31,561.68 p/c Yr^{-1}) is crucial for livestock rearing, supporting rural livelihoods and agriculture, while small timber (₹126.54 p/c Yr^{-1}) and firewood (₹2,639.28 p/c Yr^{-1}) provide essential materials for construction, heating, and cooking in rural areas, reducing energy costs and enhancing resilience against fuel price fluctuations.

SERVICES	MONETARY VALUE
WATER CONSUMPTION p/c CAPITA Yr^{-1}	₹7,199.81
FOREST FOOD p/c Yr^{-1}	₹6,289.29
ETHNIC MEDICINE p/c Yr^{-1}	₹1,548.48
MFP & NTFP p/c Yr^{-1}	₹2,782.74
BAMBOO CONSUMPTION p/c Yr^{-1}	₹4,067.28
FODDER p/c Yr^{-1}	₹31,561.68
SMALL TIMBER p/c Yr^{-1}	₹126.54
FIREWOOD p/c Yr^{-1}	₹2,639.28
TOTAL MONETARY VALUE p/c Yr^{-1}	₹56,215.10

From a social perspective, these values highlight the direct benefits forests provide to communities, particularly in rural and indigenous contexts. Access to forest resources supports traditional livelihoods and cultural practices, fostering social cohesion and preserving cultural heritage. Moreover, the availability of forest products like food, medicine, and fodder enhances food security, health outcomes, and resilience to economic shocks, thereby promoting social equity and reducing vulnerability among marginalized populations. Sustainable management of these resources ensures their continued availability, contributing to long-term social stability and community resilience against environmental and economic changes. Overall, the economic and social analysis of these per capita values underscores the critical importance of forests not only for economic growth but also for sustainable development and societal well-being.



The monetary valuation of forest ecosystem services in Garbhanga Reserved Forest (RF) is crucial for incorporating these vital natural assets into the State GDP, thereby reflecting their true economic contribution. Services such as carbon sequestration, water retention, moisture regulation, and oxygen release provide substantial economic benefits that extend far beyond the forest boundaries. For instance, Garbhanga RF's dense vegetation plays a pivotal role in carbon sequestration, directly contributing to climate change mitigation and enhancing the state's environmental credentials. Water retention services reduce the need for costly artificial water infrastructure, while soil moisture maintenance supports agricultural productivity, underpinning food security and rural livelihoods. Furthermore, oxygen release and air quality improvements from these forests translate into significant public health benefits, reducing healthcare costs and boosting overall productivity. By quantifying and integrating these ecosystem services into the State GDP, policymakers can make informed decisions that recognize the full economic value of forests, leading to more sustainable development strategies, enhanced environmental conservation efforts, and a stronger, more resilient economy.

Moreover, there is a significant scope for augmenting fund provisions to maintain and increase the quantum of forest ecosystem services in Garbhanga RF and other recorded forest areas of Assam. Investing in forest management and conservation can amplify these benefits, ensuring long-term ecological balance and economic prosperity. Enhanced funding can support reforestation projects, sustainable harvesting practices, and community-based forest management programs, thereby increasing the forest's capacity to provide critical ecosystem services. This approach not only aligns with global sustainable development goals but also fosters a robust framework for environmental stewardship, economic development, and social well-being. By prioritizing the allocation of resources towards the preservation and enhancement of forest ecosystems, the state can secure a healthier, more sustainable future for its citizens, while positioning itself as a leader in innovative environmental governance.

Additionally, the aspect of carbon trading presents a lucrative opportunity to gather funds for such activities. Public Sector Undertakings (PSUs) and corporates can be engaged in carbon trading initiatives under the purview of Carbon Credit Trading Scheme (CCTS) , where they invest in carbon credits generated by the forest's carbon sequestration capabilities. This not only provides a revenue stream for conservation activities but also allows these entities to meet their corporate social responsibility (CSR) goals and regulatory requirements for carbon emissions. By creating a market for carbon credits, Assam can attract significant investments from both national and international stakeholders, further enhancing its efforts in forest conservation and sustainable development. This strategy not only ensures the financial sustainability of forest ecosystem services but also positions Assam as a leader in innovative climate finance and environmental governance.

NET ASSET VALUE

Assessing the net asset value (NAV) of forest ecosystem services (FES) has been deemed essential for determining their economic value for inclusion in the state's GDP. The Garbhanga Reserved Forest (RF) had provided significant FES, which had been historically overlooked in economic calculations. To accurately reflect their contribution, the Gross Asset Value (GAV) of the Garbhanga RF had been determined. This valuation had encompassed various ecosystem services such as carbon sequestration, water retention, soil nutrient retention, and biodiversity conservation. However, to derive the true economic value, the NAV had been calculated by subtracting liability expenditures and other related costs. These costs had included infrastructure development, protection measures, salaries of forestry staff, timber salvage operations, plantation activities, boundary demarcation, and research initiatives. By accounting for these expenditures, the net contribution of Garbhanga RF to the state's economy had been accurately assessed. This precise valuation had not only highlighted the critical importance of FES as an additional economic resource but had also underscored their potential to enhance the state's GDP. Including FES in economic assessments had fostered a more comprehensive understanding of natural assets and their sustainable management. Furthermore, it had aligned with global trends of incorporating environmental values into economic frameworks, promoting ecological sustainability, and ensuring that natural capital had been preserved for future generations. This approach had provided policymakers with robust data to make informed decisions regarding forest management and conservation strategies. By recognizing the economic value of FES, increased investment in forest conservation and sustainable practices had been justified, ultimately contributing to the state's economic growth and environmental well-being. This paradigm shift towards including FES in GDP calculations had marked a progressive step in valuing and preserving our natural heritage.

The Gross Asset Value of Garbhanga RF are furnished as:

Sl No	Forest ES	Monetary Value
Gross Asset Value (GAV) Ha^{-1} Yr^{-1} 2023-24		
1	Provisioning Services	₹12,444.89 $Ha^{-1}Yr^{-1}$
2	Regulating Services	₹3,33,23,84,474.57 $Ha^{-1}Yr^{-1}$
3	Cultural Services	₹3,311.46 $Ha^{-1}Yr^{-1}$
4	Supporting Services	₹2,75,71,93,980.00 $Ha^{-1}Yr^{-1}$
A. Total		**₹6,08,95,94,210.92 $Ha^{-1}Yr^{-1}$**
Liabilities and Expenditure 2023-24 Ha^{-1}		
1	Salary of staff	₹57,974.07 $Ha^{-1}Yr^{-1}$
2	Infrastructure	₹52.20 $Ha^{-1}Yr^{-1}$
3	Creation and maintenance of plantation including nursery	₹55,444.49 $Ha^{-1}Yr^{-1}$
4	Amenities to the forest staffs	₹16.68 $Ha^{-1}Yr^{-1}$
5	Protection of Forest	₹77.47 $Ha^{-1}Yr^{-1}$
6	Timber dragging cost	₹47.73 $Ha^{-1}Yr^{-1}$
7	Research	₹109.90 $Ha^{-1}Yr^{-1}$
B. Total		**₹1,13,722.54 $Ha^{-1}Yr^{-1}$**
C. Net Asset Value (NAV) $Ha^{-1}Yr^{-1}$		**₹ 6,08,94,80,488.38 $Ha^{-1}Yr^{-1}$**

High Contribution of Regulating Services:
Regulating services form the largest part of the GAV at **₹6,08,95,94,210.92 $Ha^{-1}Yr^{-1}$**. This is likely due to the forest's significant role in carbon sequestration, climate regulation, and water retention. Given the hilly topography of Garbhanga Reserved Forest, these services are essential for maintaining environmental stability and preventing natural disasters like landslides and floods.

Modest Contribution of Provisioning, Cultural, and Supporting Services:
Provisioning services, cultural services, and supporting services contribute comparatively less to the GAV. Provisioning services, which include tangible products like forest food, small timbers, and bamboo, are valued at ₹12,442.18 Ha^{-1} Yr^{-1}. Cultural services, such as tourism and recreational activities, contribute ₹3,311.46 Ha^{-1} Yr^{-1}. Supporting services, essential for ecosystem functioning like soil nutrient retention, add ₹27,56,29,398.00 Ha^{-1} Yr^{-1}. Despite their lower monetary values, these services are crucial for local communities and biodiversity.

Expenditure Breakdown:
The total expenditure for maintaining the forest is ₹1,13,722.54. The largest expenditure is the salary of staff at ₹57,974.07, indicating the importance of human resources in forest management. Significant amounts are also allocated to the creation and maintenance of plantations, infrastructure, and protection measures, reflecting ongoing efforts to sustain and enhance forest health and productivity.

High Net Asset Value (NAV):
The NAV stands at **₹ 6,08,94,80,488.38 $Ha^{-1}Yr^{-1}$**, indicating the substantial net economic value of the Garbhanga Reserved Forest after accounting for liabilities and expenditures. This high NAV underscores the forest's potential contribution to the state's GDP if recognized in economic assessments. It highlights the economic importance of FES, which have traditionally been undervalued or ignored.

Reasons for High NAV:
Ecological Significance: The Garbhanga Reserved Forest's rich biodiversity and dense vegetation contribute to its high regulating and supporting service values. The forest's ability to sequester carbon, regulate water cycles, and maintain soil fertility is vital for environmental sustainability.

Topographical Influence: The forest's hilly terrain enhances its ecosystem service value. The steep slopes and varied elevation increase the importance of water retention, erosion control, and climate regulation services.

Comprehensive Management: The expenditures indicate a well-rounded approach to forest management, including staffing, infrastructure, protection, and research. This comprehensive management strategy helps maintain the forest's health and productivity, ensuring the continued provision of valuable ecosystem services.

In conclusion, the Garbhanga Reserved Forest's substantial NAV reflects its critical role in providing essential ecosystem services. This valuation emphasizes the importance of including FES in state GDP calculations, recognizing them as valuable economic resources.

COMPARISON WITH PREVIOUS STUDIES

Summary Qualitative Comparison of Forest Ecosystem Services (ES) Assessment

A. **Previous Exercises:**

1. Western Ghats Biodiversity Hotspot:
   Number of ES Considered: Multiple ES including water regulation, climate regulation, soil conservation, and carbon sequestration.
   Methodology: Holistic ecosystem approach emphasizing biodiversity and regional climate patterns.
   Use of Modern Technology: Limited mention, focus on traditional ecological knowledge and field studies.

2. Sundarbans Mangrove Forests:
   Number of ES Considered: Coastal protection, carbon sequestration, fisheries support, and livelihoods.
   Methodology: Case studies on natural barrier function and support for local fisheries.
   Use of Modern Technology: Emphasis on traditional ecological functions and community-based observations.

3. Western Himalayan Region:
   Number of ES Considered: Water provisioning, carbon storage, soil conservation, and tourism.
   Methodology: Emphasis on water sources and tourism activities.
   Use of Modern Technology: Traditional methods with limited technological integration.

4. Agroforestry in Andhra Pradesh:
   Number of ES Considered: Soil fertility, carbon sequestration, water regulation, biodiversity conservation.
   Methodology: Integration of agroforestry practices in local farming.

Use of Modern Technology: Community-based practices with minimal technological input.

5. Urban Green Spaces in Bengaluru:
   Number of ES Considered: Heat island mitigation, air purification, recreation, mental well-being.
   Methodology: Evaluation of urban parks and gardens.
   Use of Modern Technology: Limited; reliance on direct observational data.

6. Kaziranga National Park:
   Number of ES Considered: Habitat preservation, biodiversity conservation, water regulation, cultural values.
   Methodology: Focus on wildlife conservation and support for local communities.
   Use of Modern Technology: Traditional conservation techniques with limited technological application.

7. Brahmaputra River Basin:
   Number of ES Considered: Water provisioning, irrigation, flood regulation, sediment retention, fishery support.
   Methodology: Case studies on water management and flood control.
   Use of Modern Technology: Traditional water management practices.

8. Assam Tea Plantations:
   Number of ES Considered: Soil conservation, carbon sequestration, biodiversity support, economic livelihoods.
   Methodology: Focus on sustainable tea farming practices.
   Use of Modern Technology: Traditional farming techniques with some sustainable management practices.

9. Manas National Park:
   Number of ES Considered: Habitat preservation, biodiversity conservation, water regulation, cultural values.
   Methodology: Emphasis on conservation of endangered species and ecotourism.
   Use of Modern Technology: Traditional methods with limited technological input.

10. Community Forest Management in Assam:
    Number of ES Considered: Carbon sequestration, biodiversity conservation, watershed protection, livelihood support.
    Methodology: Community-based forest management initiatives.
    Use of Modern Technology: Traditional community management practices.

B. **Present Exercise (Garbhanga Forest Ecosystem):**
   Number of ES Considered: Major focus valuation of carbon sequestration and oxygen production, temperature regulation potential, all tangible provisioning services including food, medicine, MFP, small timber, Bamboo, fodder , comprehensive water retention potential, Soil nutrient capacity, comprehensive carbon sink assessment and cultural services.
   Methodology: Utilized Land Use, Land Use Change, and Forestry maps; stratified random sampling for biomass and carbon estimation; detailed socio-economic and ecological data collection.
   Use of Modern Technology: Advanced mapping techniques (LULC), stratified sampling, precise carbon sink calculations, and modern data collection methods.

a. Comparison:

Number of Forest ES Taken into Consideration:

Previous Exercises: Broader range of ES including water regulation, climate regulation, soil conservation, coastal protection, habitat preservation, and more.

Present Exercise: Narrower focus on carbon sequestration and oxygen production, specifically from mature trees.

Methodology:

Previous Exercises: Emphasis on holistic, ecosystem-based approaches relying on traditional methods and community involvement.

Present Exercise: Methodological rigor with stratified random sampling, use of LULC maps, and comprehensive socio-economic surveys.

Use of Modern Technology:

Previous Exercises: Limited use of modern technology, predominantly traditional methods and field studies.

Present Exercise: Integration of modern technology including advanced mapping, precise sampling techniques, and comprehensive data analysis.

In summary, the present exercise employs a more focused and technologically advanced approach compared to previous assessments, which considered a broader range of ecosystem services using more traditional methods.

Understanding the economic value of forest ecosystem services necessitates a comprehensive comparison of methodologies employed by diverse agencies globally and at the national level. Globally, agencies utilize varying frameworks to assess these values, reflecting different ecological and economic contexts across continents. These comparisons provide a nuanced understanding of the multifaceted contributions of forests, ranging from carbon sequestration and climate regulation to biodiversity conservation and recreational opportunities. Each of these ecosystem services holds distinct economic implications, shaping global policies and strategies for sustainable development.

At the national level, such as in the context of Garbhanga Reserved Forest in Assam, India, economic valuation takes on a more localized and specific dimension. Here, the valuation process considers not only the tangible benefits like timber production and watershed protection but also the intrinsic values tied to cultural heritage and community livelihoods dependent on forest resources. Comparing these local valuations with global standards offers insights into how different economic values are assigned to ecosystem services based on local needs and priorities. This comparison informs targeted conservation strategies and policy frameworks tailored to safeguarding both ecological integrity and socio-economic resilience.

By conducting these comparative exercises, agencies can refine their methodologies, enhance data accuracy, and ultimately support evidence-based decision-making. This approach ensures that the economic contributions of forests, whether on a global scale or within specific regions like Garbhanga RF, are accurately quantified and integrated into broader socio-economic planning efforts, fostering sustainable development and equitable resource management practices.

Comparing exercises conducted by different agencies on the economic valuation of forest ecosystem services is crucial for several reasons. Firstly, it allows for the assessment of methodological strengths and weaknesses across different approaches, fostering improvement and refinement of valuation techniques. By understanding how different methodologies quantify the economic benefits of forests, policymakers can adopt best practices suited to their specific environmental and socio-economic contexts, optimizing resource allocation and conservation strategies.

Secondly, such comparisons provide a broader perspective on the diverse values forests contribute globally and nationally. For instance, studies like Costanza's on tropical forest biomes emphasize global ecological services like carbon sequestration, while localized studies such as Mizoram University's focus on cultural and biodiversity values specific to a region. This diversity of perspectives enriches our understanding of the multifaceted roles forests play in supporting livelihoods, enhancing resilience to climate change, and preserving biodiversity.

Moreover, comparing exercises from varied geographical locations, such as Uttarakhand by IIFM and Garbhanga RF by the Assam Forest Department, helps identify common challenges and successful strategies in valuing ecosystem services. This cross-regional analysis promotes knowledge sharing and collaboration among stakeholders, leading to more effective conservation policies and sustainable development practices tailored to local needs.

	MONETORY VALUE ASSIGNED			
	FOREST DEPT., ASSAM (Garbhanga Reserved Forests-2023 ₹ Ha^{-1} Yr^{-1}	**MIZORAM UNIVERSITY (Forests of Mizoram-2020) ₹ Ha^{-1} Yr^{-1}** (*Using the actual CPI values from the U.S. Bureau of Labor Statistics, the equivalent value of $1 in 1997 is approximately $1.90 in 2023*) ***Dec'23: $1=*** **₹83.28**	**IIFM, BHOPAL (Forests of Uttarakhand-2007) ₹ Ha^{-1} Yr^{-1}**	**COSTANZA (Tropical Forest Biome – 1997) ₹ Ha^{-1} Yr^{-1}** (*Using the actual CPI values from the U.S. Bureau of Labor Statistics, the equivalent value of $1 in 1997 is approximately $1.90 in 2023*) ***Dec'23: $1=*** **₹83.28**
Valuation Technique	*a.Market based approach* *b.Stated preference approach* *c.Revealed preference approach - (Market transactions analysis, Hedonic pricing analysis, Travel cost method)*	*State of Environment report of Mizoram (2020)*	*a.Market based approach* *b.Stated preference approach* *c.Revealed preference approach - (Market transactions analysis, Hedonic pricing analysis, Travel cost method)* *d.Tropical Forest Ecosystem Services by Costanza,1997*	*a.Market based approach* *b.Stated preference approach* *c.Revealed preference approach*

Water consumption	5,219.18	-	427.00	316.46
Forest food, ethnic medicine, MFPs, Small timbers, Bamboo, Fodder	7,225.71	6,053.31	27,966.00	31,146.72
Carbon Sink	4452.11	154.51	1,28,594.24	-
Water Retention	₹3,28,96,15,502.12	68.81	570.00	474.69
Temperature Regulation	4,27,64,520.34	-	1,61,863.00	-
Cultural Service	3,311.46	13.23	8,211.68	10,759.77
Soil Nutrient Retention	8,99,997.00	-	66,103.00	57,121.75
Oxygen Release	2,75,62,93,984.00	-	-	-

<u>The discrepancies in the monetary value assigned to ecosystem services across different studies can be attributed to several factors:</u>

1. **Number of Components of Ecosystem Services Under Consideration**
   Different studies might consider varying components of ecosystem services within each major category. For example:
   i. Garbhanga Reserved Forests (2023): Comprehensive valuation, including diverse ecosystem services.
   ii. Forests of Mizoram (2020): Might have considered fewer components, leading to lower overall values.
   iii. Forests of Uttarakhand (2007): Specific services might have been emphasized, with some components underrepresented.
   iv. Costanza (1997): An early comprehensive study but with possible limitations in the number of services considered due to data availability at the time.

2. **Scale**
   The scale of analysis significantly impacts the valuation:
   i. Garbhanga Reserved Forests (2023): Large-scale, specific regional study leading to detailed valuation.
   ii. Forests of Mizoram (2020): Regional focus but possibly on a bigger scale compared to Garbhanga RF.
   iii. Forests of Uttarakhand (2007): Regional but might have used broader assumptions.
   iv. Costanza (1997): Global scale with general estimates, possibly less precise for specific regions.

3. **Area of Interest**
   The geographical characteristics and ecological significance of the study area play a crucial role:
   i. Garbhanga Reserved Forests: Rich biodiversity, dense vegetation, hilly terrain leading to high ecosystem service values.
   ii. Forests of Mizoram: Different topography and forest type, potentially influencing the valuation.
   iii. Forests of Uttarakhand: Varied ecological zones, impacting the valuation differently.
   iv. Costanza's Tropical Forest Biome: Generalized biome-level analysis, not specific to any particular area.

4. **Timeline Considered**
   The period of study and valuation affects the monetary estimates:

i. Garbhanga Reserved Forests (2023): Latest data and methodologies, reflecting current ecological and economic conditions.
ii. Forests of Mizoram (2020): Recent but slightly older data compared to Garbhanga.
iii. Forests of Uttarakhand (2007): Over a decade old, possibly outdated valuation methods and economic parameters.
iv. Costanza (1997): Early valuation with significant temporal difference, requiring adjustment for inflation and economic changes.

6. Data Collection Methodology

Different data collection methodologies lead to varying results:

i. Garbhanga Reserved Forests (2023): Likely used extensive ground surveys, remote sensing, GIS mapping, and direct field data collection to capture a detailed and accurate representation of ecosystem services.
ii. Forests of Mizoram (2020): Might have relied more on secondary data sources and less intensive field surveys, leading to less precise valuation.
iii. Forests of Uttarakhand (2007): Data collection might have been limited due to time and resource constraints, possibly relying more on literature of Costanza valuation report 1997 and less on direct field data.
iv. Costanza (1997): Relied heavily on existing global data and estimates, with limited direct data collection specific to the region.

7. Valuation technique

Different valuation techniques lead to varying results:

i. Market-based approach: Relies on market prices, possibly leading to higher valuations where markets for ecosystem services are well-developed.
ii. Stated preference approach: Based on surveys and willingness to pay, reflecting perceived value.
iii. Revealed preference approach: Uses actual behavior and market transactions, providing more realistic estimates but limited by available market data.

7. Ground Truthing

The extent of ground truthing influences the accuracy of the valuation:

i. Garbhanga Reserved Forests: Involved extensive field surveys and data collection, leading to precise valuation.
ii. Forests of Mizoram: Possibly involved some ground truthing but may be less extensive.
iii. Forests of Uttarakhand: Ground truthing might have been limited due to time and resource constraints.
iv. Costanza (1997): Early study with limited ground truthing, relying more on existing data and broad assumptions.

<u>Specific Reasons for Discrepancies</u>

a. Water Consumption:

The valuation for Garbhanga includes more detailed components such as water purification and storage, while others may only consider basic consumption.

b. Forest Food, Ethnic Medicine, MFPs, Small Timbers, Bamboo, Fodder:

Different studies may emphasize various components, such as medicinal plants, food, and small timbers, impacting the overall value.

c. Carbon Sink:

Methodology differences in estimating carbon sequestration and pricing carbon credits.

d. Water Retention:
Differences in hydrological modelling and the importance of water retention in hilly terrains versus flat regions. Inclusion of the water retention value of the water body network in Garbhanga RF, leading to a higher valuation, which might not have been explicitly considered in other exercises, resulting in lower overall values.

e. Temperature Regulation:
Extensive valuation in Garbhanga due to its critical role in regulating local climate, which may not have been as significant in other studies.

f. Cultural Services:
Differences in the valuation of recreational, spiritual, and cultural benefits.

g. Soil Nutrient Retention:
Variations in soil types, fertility, and the methodology used for assessing nutrient retention.

h. Oxygen Release:
This component might have been overlooked or undervalued in other studies.

In conclusion, the discrepancies in the monetary value of ecosystem services arise due to differences in the number of components considered, scale, area of interest, timeline, methodology, and ground truthing efforts. Each study's unique focus and methodology lead to varying valuations, reflecting the complexity and multifaceted nature of ecosystem services.

Chapter VIII

UNCERTAINTY ASSESSMENT

UNCERTAINTY ASSESSMENT

Assessing uncertainty is a critical component of evaluating the reliability and accuracy of our biomass estimation and ecosystem service quantification. Uncertainty in biomass estimation and ecosystem service quantification arises from multiple sources, including measurement errors, model assumptions, variability in biological and environmental factors, and human activities. Understanding and quantifying these uncertainties are essential for improving the reliability of our assessments.

A. Provisional Services:

- **Water Consumption**

  This section evaluates the potential uncertainties in the reported domestic water consumption data for various villages. Each source of uncertainty is identified and its impact on the reliability of the data is discussed.

  1. Measurement Errors on Daily Domestic Water Consumption per Household: The average daily domestic water consumption per household is given with a ±5% uncertainty. This variability can arise from differences in household size, water usage habits, and measurement inaccuracies. Variations in individual household water usage and the precision of measurement tools.

  2. Population Data Variability in total Number of Villages and Households: The counts of villages and households are critical for calculating total water consumption. Possible errors in population census data or changes in household numbers due to migration or demographic shifts.

  3. Data Collection Methods for Survey and Reporting: The data might have been collected through surveys or self-reported by households, introducing biases. Respondent inaccuracies, misunderstanding of survey questions, or deliberate misreporting.

  vi. Temporal Variability regarding Yearly Domestic Water Consumption: Consumption can vary seasonally due to changes in water availability, climate, and household needs. Fluctuations in water use during different times of the year, such as increased usage in summer or during festivals.

  vii. Estimation and Calculation Errors in Conversion from Daily to Yearly Consumption: The conversion from daily to yearly water consumption assumes consistent daily usage throughout the year. Day-to-day variations in water use and potential errors in annualizing daily consumption figures.

  6. Data Aggregation and Reporting in Averaging and Summarizing Data: Aggregating data from individual households to village totals may introduce rounding errors or miscalculations. Inaccuracies in data processing or spreadsheet calculations.

- **Food, Medicine, Firewood, Small timber, Bamboo, MFP and Fodder**

  Assessing the uncertainty in the estimation of consumption and sale of forest products is crucial to ensure the accuracy and reliability of the data. The following sections outline potential sources of uncertainty and their impacts on the estimates provided.

  1. Measurement and Reporting Errors

     i. Survey Accuracy: The data on consumption and sale were collected through surveys. Respondent bias, recall errors, and misunderstanding of questions can introduce inaccuracies.

     ii. Sampling Bias: If the survey sample is not representative of the entire population, it could lead to biased estimates. Efforts to survey all relevant households and institutions are necessary to mitigate this risk.

iii. Measurement Units: Variability in the units of measurement (e.g., bundles, kg, nos.) could lead to inconsistencies, especially if conversions between units are required.

2. Temporal Variability
   i. Seasonal Changes: Consumption and availability of forest products can vary seasonally. For example, certain forest foods may only be available in specific seasons, affecting annual estimates.
   ii. Yearly Fluctuations: Annual variations due to climatic conditions, natural disturbances, or socio-economic changes can affect the accuracy of yearly estimates.

3. Spatial Variability
   i. Geographical Differences: Consumption patterns and resource availability may differ significantly between villages. Aggregating data across villages without accounting for these differences can introduce errors.
   ii. Resource Distribution: The distribution of forest resources might not be uniform across the area, leading to uneven consumption rates.

4. Human Impact and Disturbances
   i. Logging and Land Use: Human activities such as logging, agriculture, and urbanization can affect the availability and quality of forest products, leading to changes in consumption patterns.
   ii. Population Dynamics: Changes in population size and structure in the villages can impact the demand and consumption of forest products.

5. Statistical and Model Uncertainties
   i. Estimation Methods: The methods used to estimate consumption (e.g., average consumption per household) can introduce errors, especially if the underlying assumptions are not accurate.
   ii. Data Extrapolation: Extrapolating data from a sample to the entire population can introduce uncertainty, particularly if the sample size is small or not representative.

6. Market Dynamics
   i. Price Fluctuations: Changes in the market price of forest products can influence the sale and consumption rates. Economic factors such as inflation and market demand can lead to variability in estimates.
   ii. Trade Restrictions: Policies and regulations affecting the trade of forest products can impact their availability and consumption.

B. Regulating Service:

- **Carbon Estimation**

  This is a qualitative assessment of uncertainties associated with the calculation of carbon stocks in various forest strata. The sources of uncertainty and their potential impacts on the reliability of the carbon stock estimates are discussed.

  1. Measurement Errors in Average Carbon per Sample Plot: The average carbon stock per sample plot is reported with a ±5% uncertainty. This could be due to variability in tree biomass measurements, sampling errors, or instrument precision. Differences in tree sizes, species composition, and human error in measurements.

  2. Area Assignment against Each Strata: The area assigned to each strata is a crucial factor in determining the total carbon stock. Errors in mapping or delineating these areas can lead to inaccuracies. Use of outdated or inaccurate maps, satellite imagery interpretation errors, or changes in land use.

3. Data Collection Methods and Sampling Techniques: The carbon stock data is based on sample plots, and the representativeness of these samples can affect the overall estimates. Non-random sampling, insufficient sample size, or unrepresentative plots.

4. Natural Variability in Forest Dynamics: Natural variability in forest growth rates, mortality, and disturbances (e.g., fires, pests) can affect carbon stock estimates. Temporal changes in forest conditions and unexpected environmental events.

5. Estimation and Calculation Errors in Calculation of Total Carbon: The conversion from per plot carbon stock to total carbon stock involves multiple steps, each introducing potential erro₹ Rounding errors, miscalculations, or incorrect application of conversion facto₹

- **Water Retention**

The primary sources of uncertainty in the reported data include measurement errors, conversion inaccuracies, estimation variability, and calculation errors. These uncertainties highlight the need for precision in data collection, robust conversion methodologies, and careful consideration of moisture content variability in biomass components. Addressing these factors can significantly improve the reliability of water volume and retention estimates during the dry season.

i. Measurement Errors: Errors in measuring the volume of water, either in cubic meters or litres, could result from inaccuracies in instruments or methods used. This includes the daily average volume and the total volumes calculated for the dry season. Measurement errors can cause variability in the reported average volume per second and the total volume for the dry season.

j. Conversion Errors: Errors in converting measurements from cubic meters to litres could introduce uncertainties, especially when dealing with large values. Conversion inaccuracies may lead to incorrect estimations of water volumes.

k. Estimation Errors: The average volume per second is given with a ±10% uncertainty. This estimation error reflects the natural variability in water flow and potential inaccuracies in the data collection process. The ±10% uncertainty impacts all derived values, including the total volumes for the dry season.

l. Calculation Errors: Calculating the total volume retained over 180 days involves multiple steps and potential accumulation of minor calculation error. Errors in intermediate steps can propagate, leading to significant discrepancies in the final results.

m. Biomass Moisture Content: Each biomass component has a specified moisture loss percentage with an associated uncertainty (±5% to ±10%). These values affect the calculation of water retained in biomass. The variability in moisture loss percentages directly impacts the estimated water retention in biomass, potentially leading to over- or under-estimation.

n. Biomass Mass Measurements: Inaccuracies in measuring the mass of various biomass components can lead to errors in calculating the water retained. Incorrect biomass mass measurements affect the accuracy of water retention estimates.

- **Temperature Regulation**

This section evaluates the potential sources of uncertainty in the temperature data provided for Garbhanga RF and Guwahati City, focusing on the average monthly temperatures and the temperature differences between the two locations. Each source of uncertainty is identified and its impact on the data is discussed.

1. Data Collection Methods: The precision of the thermometers and other equipment used to measure the temperatures can introduce uncertainties. Inaccuracies in temperature readings due to instrument calibration, placement, and maintenance.

2. Temporal Variability on Daily and Monthly Fluctuations: Temperature can vary significantly within a month, and the reported average may not capture short-term anomalies. Day-to-day weather variations, unusual weather events, and differences in time of day when measurements are taken.

3. Geographical Variability: Garbhanga RF and Guwahati City may have microclimates that affect temperature readings differently within each area. Local geographic features such as altitude, vegetation cover, and urban heat islands.

4. Data Entry and Processing Errors: Mistakes during data entry or processing can lead to incorrect temperature values. Typographical errors, incorrect formula application in calculations, and data misinterpretation.

5. Sampling Errors: Limited sampling points within Garbhanga RF and Guwahati City may not represent the entire area's temperature accurately. Spatial coverage of temperature sensors and representativeness of chosen sampling locations.

6. Environmental Influences: Guwahati City may experience higher temperatures due to urbanization, while Garbhanga RF may have cooler temperatures due to forest cover. Differences in land use, surface materials, and anthropogenic heat sources.
7. Measurement Error: There could be errors in measuring the average volume of air within each house and the power rating of the AC. Variations in measurement techniques, equipment precision, or human error could contribute to this uncertainty.

8. Variability in Environmental Conditions: The effectiveness of the AC in cooling the room may vary depending on factors like ambient temperature, humidity, insulation of the house, and presence of windows or doo₹ These factors may not be consistent across all houses within Garbhanga RF.

9. Assumptions and Estimations: The calculations may rely on certain assumptions or estimations, such as the average temperature reduction achieved by the AC or the total number of households. Variability or inaccuracies in these assumptions could introduce uncertainty.
10. Seasonal Variations: The data provided for power consumption during cooling is specified for the months from April to September, implying a certain seasonal context. However, variations in weather patterns or usage patterns within this timeframe may introduce uncertainty.

11. Sampling Variability: The data might represent a sample of houses within Garbhanga RF rather than the entire population. Variability within the sample or differences between the sample and the population could affect the generalizability of the results.

12. Modelling Assumptions: The calculation of total power consumption for cooling may involve certain modelling assumptions or simplifications. Variability or inaccuracies in these assumptions could contribute to uncertainty.

13. Reporting Precision: The ±10% uncertainty range provided for the average volume of air and total volume of air represents a level of precision in the measurements. However, the actual uncertainty could be higher or lower than this stated range.

C. Cultural Services:

- This assessment is based on the assumption that the identified sources of uncertainty represent typical challenges encountered during field studies. Actual deviations may vary depending on specific project circumstances and mitigation strategies employed.

1. Variability in Field Conditions: This factor could lead to fluctuations in the time required for data collection and analysis, potentially resulting in a deviation from the estimated man-days.

2. Changes in Research Objectives: Given the dynamic nature of research environments, alterations in research objectives may necessitate additional time for planning, execution, and analysis, resulting in a deviation.

3. Unforeseen Challenges: Unexpected obstacles such as adverse weather conditions, equipment failures, or logistical issues may significantly disrupt field activities, leading to a deviation.

D. Supporting Services:

- **Soil Nutrient Retention**

Uncertainty assessment involves identifying and quantifying uncertainties associated with the data provided. Here's how you could carry out an uncertainty assessment for the given data:

1. Measurement Uncertainty: Determination of the precision of the measurement devices used to collect the data induces uncertainty. If the pH meter, for example, has a margin of error of ±0.1 pH units, then each pH value should be considered accurate within that range.

2. Analytical Uncertainty: This involves uncertainties associated with the laboratory analysis. Errors in equipment calibration, methodological biases, and human errors during analysis can all contribute to analytical uncertainty.

3. Natural Variability: Natural systems inherently have variability. Soil properties can vary even within a small area due to factors like micro-topography, parent material, and biological activity. This variability may generate uncertainty when interpreting the data.

4. Data Reporting: Accuracy and complete data collection is an important factor here. Any missing values or misinterpretations can introduce uncertainty into the analysis.

5. Expert Judgment: Sometimes, it's necessary to rely on expert judgment to assess uncertainties that cannot be quantified through other means. Experts familiar with the study area and the data collection methods can provide valuable insights into potential sources of uncertainty.

- **Oxygen Release**

It's important to acknowledge that the ±5% margin of error provided may not fully capture the overall uncertainty in the assessment. There could be additional uncertainties stemming from factors such as variability in environmental conditions, measurement techniques, and the complexity of ecosystem dynamics. To carry out an uncertainty assessment, we'll evaluate the potential sources of uncertainty in the data and calculations provided. Here's a breakdown:

1. Measurement Uncertainty: The data provided states that the values are given with a margin of ±5%. This indicates that there is a potential error of up to 5% in both the total carbon sink of trees and the total oxygen released.

2. Extrapolation Uncertainty: The average age of the tree crop is given as 20 years There might be uncertainty associated with extrapolating this average age to estimate the total carbon sink and oxygen released over 20 years, as it assumes a constant rate of growth and carbon/oxygen production which may not be entirely accurate.

3. Exclusion of Components: The decision to exclude shrubs, herbs, litter, and soil organic carbon introduces uncertainty regarding the total carbon sink and oxygen release. While mature trees may contribute significantly, these excluded components could also contribute to the ecosystem's overall carbon sequestration and oxygen production.

4. Data Availability: The lack of readily accessible data for certain components (shrubs, herbs, litter, and SOC) introduces uncertainty into the analysis. It's unclear how significant their contributions could be, and not accounting for them may underestimate the total carbon sink and oxygen release.

5. Model Assumptions: The assessment relies on established growth patterns and age-volume relationships, which could introduce uncertainty if these patterns don't fully capture the variability within the Garbhanga Forest ecosystem.

Chapter IX

DISCUSSION, INTERPRETATION, COMPARISON, IMPLICATIONS and CONCLUSION

DISCUSSION

Forests provide essential ecosystem services crucial for societal well-being, yet their value often remains underestimated in economic indicators. Despite their significant contributions, current economic indicators overlook the value of forest ecosystem services. For instance, the Gross State Domestic Product (GSDP) of Assam for 2023-24 does not include the substantial value derived from forests, which cover approximately 36% of the state's landmass. This research aims to quantify and value forest ecosystem services, informing sustainable management and policy. Key objectives include establishing benchmarks, implementing monitoring programs, engaging stakeholders, reviewing best practices, designing standardized protocols, providing capacity building, pilot testing, and disseminating findings. By assessing ecosystem service magnitude, understanding drivers of change, refining quantification methods, estimating economic values, informing policymakers, enhancing stakeholder engagement, and contributing to knowledge sharing, the research bridges the gap between science and policy for effective forest conservation and management.

The report explores the methodologies for assessing Forest Ecosystem Services (ES), focusing on the Millennium Ecosystem Assessment (MA), The Economics of Ecosystems and Biodiversity (TEEB), and the Common International Classification of Ecosystem Services (CICES). While MA offers a holistic view, TEEB emphasizes economic valuation, and CICES provides a standardized framework. Aligning with MA and TEEB principles, methodologies were chosen for the Garbhanga Reserved Forest Project, ensuring credibility and comparability. This strategic alignment underscores a commitment to rigorous ES assessment, enhancing project effectiveness and relevance.

This report outlines the methodology used to quantify ecosystem services in the Garbhanga Reserved Forest. Pre-survey activities involved using Land Use, Land Use Change, and Forestry maps to delineate various forest types and land uses. Sample points were assigned for biomass and carbon estimation based on stratified random sampling, and data collection points for water flow and retention were chosen along rivers and streams. The locations of ethnic villages and local markets were identified for socio-economic data collection. Survey activities included laying out sample plots for tree biomass data collection and sub-plots for ground biomass and soil data. These methods provide a comprehensive understanding of ecosystem services in the Garbhanga RF.

The research report focuses on valuing forest ecosystem services, employing market-based, stated preference, and revealed preference approaches. It examines provisioning services like forest food, medicine, and firewood, emphasizing their economic worth. Bamboo, a versatile resource, is highlighted for its carbon sequestration potential and socioeconomic significance. Additionally, Minor Forest Produce (MFP) and various valuation techniques are discussed, aiming to comprehensively assess the economic value of forest ecosystem services. The report lists a variety of ecosystem services considered for quantification and valuation at Garbhanga RF, ranging from provisioning to cultural and supporting services.

The research report provides information on –

1. Domestic water consumption across 19 villages in the Garbhanga Forest ecosystem. It includes information such as the total number of villages, households, and average daily domestic water consumption per household with a margin of ±5%. The yearly domestic water consumption for each village is calculated based on these figures. The total yearly domestic water consumption for all villages combined is 95,239,450 litres, with an average daily consumption per household of 538 litres.
2. Consumption patterns of various forest products in the Garbhanga Forest region. Products such as forest food, ethnic medicine, minor forest produce (MFP), small timber, firewood, bamboo, and fodder are consumed across multiple villages. The data presents annual consumption/sale figures

with a ±10% margin of uncertainty, showcasing the significant reliance on forest resources for sustenance and livelihoods in the area. The findings highlight the importance of sustainable forest management practices to ensure the continued availability of these vital resources for local communities.

3. Water retention in the Garbhanga Forest ecosystem during the dry season. With an average volume of 0.632 cubic meters per second (±10%), the total volume of water retained over 180 days of the dry season is estimated at 1.477×10^{13} cubic meters (±10%), equivalent to 1.477×10^{16} litres (±10%). The daily water retention during the dry season is calculated at 8.215×10^{13} litres (±10%), with the minimum quantity retained throughout the year estimated at 1.647×10^{12} Ltr Ha^{-1} Yr^{-1} (±10%). Components contributing to water retention include stem biomass, crown biomass, litter, deadwood, and soil, with varying masses, moisture loss percentages, and corresponding water retention values. These findings provide valuable insights into the hydrological dynamics of the Garbhanga Forest ecosystem, aiding in conservation and management efforts.
4. Temperature variations between Garbhanga RF and Guwahati City, indicating a consistent temperature difference throughout the year, with Garbhanga generally cooler by approximately 3.27°C annually. Additionally, the volume of air within the forests in Garbhanga RF considering area of reserved forest 18,200 Ha and crop height 14.65 meters is outlined, estimating a total volume of approximately 2,66,64,47,036.854 cum. Power consumption data for cooling using 1.5-ton AC units suggests an estimated requirement of 77,83,14,27,021.50 kWh for cooling by 2.93°C from April to September in Garbhanga RF.
5. Various purposes of visits to the Garbhanga RF. Adventure outings, photography, and bird watching were common activities, with 79, 57, and 93 individuals respectively engaging in them. Field studies were the most frequent purpose, with 262 individuals spending an average of 15 days each, totalling 3930 man-days.
6. Soil characteristics data for different density classes within the Garbhanga Forest ecosystem. Soil pH ranges from very strongly acidic to strongly acidic across the classes. Organic carbon content is consistently very high, with variation in C:N ratios and soil nutrient levels. The majority of the area comprises sandy loam texture. The total volume of soil sampled for estimation within Garbhanga RF is 5,46,60,000 cubic meters.

   Total carbon sink and oxygen release attributed to mature trees within the Garbhanga Forest ecosystem over a 20-year period. The total carbon sink of trees is estimated to be approximately 15,35,649.527 metric tons, with a margin of error of ±5%. Over the same timeframe, trees are projected to release a total oxygen of approximately 28,66,54,57,42,782.680 Litres, also with a margin of error of ±5% and discounting the intake of Oxygen during respiration by trees. Hence, Oxygen released during the year 2023-24 is estimated to be approximately 78,75,125.67 Ltr Ha^{-1}. While this analysis focuses solely on mature trees due to data availability constraints, it provides valuable insights into their significant contribution to carbon sequestration and oxygen production within the ecosystem. However, it's important to note that the exclusion of other ecosystem components may introduce limitations to the scope of the study.
7. Comprehensive qualitative assessment of uncertainty across various ecosystem services within the Garbhanga Forest ecosystem. Assessing uncertainty is crucial for ensuring the reliability and accuracy of biomass estimation and ecosystem service quantification. The following key points summarize the findings:
   i. Provisional Services: Uncertainty in estimating consumption and sale of forest products arises from measurement errors, temporal and spatial variability, human impacts, statistical uncertainties, and market dynamics.
   ii. Regulating Services: Uncertainties stem from measurement errors, data collection methods, natural variability, estimation errors, and model assumptions. Addressing these uncertainties is crucial for enhancing the reliability of ecosystem service quantification.
   iii. Cultural Services: Variability in field conditions, changes in research objectives, and unforeseen challenges can impact the estimation of cultural services provided by the ecosystem.

iv. Supporting Services: Uncertainties arise from measurement errors, analytical uncertainties, natural variability, data reporting, and expert judgment. Addressing these uncertainties is vital for improving the accuracy of supporting service quantification.

ECONOMIC VALUATION OF ECOSYSTEM SERVICES AGAINST THE YEAR 2023-24

- Provisioning Services: Water consumption (valued at ₹ 979.49 per capita Yr^{-1} and ₹ 5219.18 $Ha^{-1}Yr^{-1}$), forest produce (₹49,015.28 per capita Yr^{-1} and ₹ 7,225.71 $Ha^{-1}Yr^{-1}$).
- Regulating Services: Carbon sink (₹ 4452.11 Ha^{-1} Yr^{-1}) which includes all 8 strata of the forest), temperature regulation (₹ 4,27,64,520.34 $Ha^{-1}Yr^{-1}$), water retention (valued at ₹ 3,28,96,15,502.12 Ha^{-1} Yr^{-1}).
- Cultural Services: Cultural services (₹3,311.46 Ha^{-1} Yr^{-1}).
- Supporting Services: Soil nutrient provision (₹ 8,99,997.00 Ha^{-1} Yr^{-1}), oxygen release (₹ 2,75,62,93,983.00 Ha^{-1} Yr^{-1}).
- A comparison analysis was carried out to assess the economic value of ES among various studies carried out globally, nationally by Costanza, IIFM Bhopal and Mizoram University.
- The NAV of the ES of Garbhanga RF for the year 2023 was calculated by discounting liabilities and expenses for maintaining the ecosystem from Gross Asset value (GAV) of the ES for the year 2023-24. The NAV of Garbhanga RF stands at ₹ 6,08,94,80,488.38 $Ha^{-1}Yr^{-1}$.

In summary, the economic value of the forest ecosystem services is indispensable for sustainable development, emphasizing the critical interdependence between nature and human well-being. Recognizing and quantifying these values are essential for informed decision-making and policy formulation aimed at conserving and sustainably managing ecosystems for present and future generations.

INTERPRETATION OF FINDINGS IN RELATION TO RESEARCH OBJECTIVES

The research report endeavours to interpret its findings in relation to the stated research objectives, which aim to comprehensively assess the economic value of forest ecosystem services in the Garbhanga RF. The research uncovers critical insights into the significance of forest ecosystem services for societal well-being, despite their often-underestimated economic value. By quantifying and valuing these services, the research aims to inform sustainable management and policy, bridging the gap between science and policy for effective forest conservation.

The report highlights the utilization of various methodologies aligned with established frameworks such as the Millennium Ecosystem Assessment (MA), The Economics of Ecosystems and Biodiversity (TEEB), and the Common International Classification of Ecosystem Services (CICES). Through rigorous assessment methods, the research ensures credibility and comparability, enhancing project effectiveness and relevance.

Key findings include detailed analyses of domestic water consumption, consumption patterns of forest products, water retention dynamics, temperature variations, purposes of visits, soil characteristics, and the carbon sink and oxygen release attributed to mature trees. However, uncertainties persist across various ecosystem services, necessitating meticulous attention to measurement errors, data collection methods, natural variability, and model assumptions for enhanced reliability and accuracy.

In essence, the research findings underscore the invaluable contribution of forest ecosystem services to societal well-being and economic prosperity. By shedding light on their economic worth and underlying uncertainties, the research lays a foundation for informed decision-making, sustainable management practices, and policy formulation aimed at safeguarding and enhancing the invaluable resources of the Garbhanga Forest ecosystem.

IMPLICATIONS FOR FOREST MANAGEMENT AND POLICY

The findings from the quantification and valuation of ecosystem services in Garbhanga RF have significant implications for forest management and policy. By providing a comprehensive understanding of the ecosystem services offered by the forest, this study underscores the need for informed and strategic management practices. Effective forest management should prioritize the preservation and enhancement of these services, recognizing their critical role in supporting biodiversity, regulating climate, and sustaining local communities.

From a policy perspective, the valuation of ecosystem services highlights the substantial economic contributions of Garbhanga RF to the State GDP, particularly through services such as carbon sequestration, water purification, and ecotourism. This economic valuation can justify increased investment in conservation efforts and the development of incentive-based mechanisms, such as payments for ecosystem services (PES), Carbon financing which reward local communities and stakeholders for their role in preserving the forest.

Additionally, the study provides a benchmark for future research, establishing a methodological framework for the assessment of forest ecosystem services in other regions. Policymakers can use this framework to formulate and implement more effective conservation policies that are grounded in empirical data. These policies should incorporate adaptive management practices that address the impacts of climate change, ensuring the long-term sustainability and resilience of forest ecosystems.

Educational outreach and public awareness campaigns are also crucial, as they foster community engagement and support for forest conservation initiatives. By involving local communities in the management process and recognizing their traditional knowledge and practices, policies can be more inclusive and effective.

Overall, the implications of this study for forest management and policy are profound, advocating for a holistic approach that integrates ecological, economic, and social dimensions. This integrated approach not only enhances the sustainability of forest resources but also contributes to the broader goals of environmental conservation and economic development.

CONCLUSION

The comprehensive evaluation of Garbhanga RF's ecosystem services, derived from extensive surveys and field data, underscores its significant ecological, social, and economic value. By estimating the number of visitors benefiting from cultural services, calculating biomass and carbon sequestration through precise measurements of tree dimensions and densities, and analysing domestic water consumption patterns, we have quantified the forest's contributions to carbon storage, climate regulation, and community water supply. Comparative temperature data between Garbhanga RF and

Guwahati City highlights the forest's cooling effects, emphasizing its role in mitigating urban heat. Addressing potential uncertainties in data collection and analysis has strengthened the reliability of these findings. Overall, this study affirms the critical importance of preserving Garbhanga RF for its diverse and invaluable ecosystem services. The implications of these findings are far-reaching, advocating for enhanced conservation strategies, sustainable forest management, and policy interventions that recognize and protect the forest's multifaceted benefits. Such measures will ensure the continued provision of these essential services, fostering environmental sustainability and improving the well-being of local communities.

Chapter X

RECOMMENDATIONS FOR FUTURE RESEARCH AND POLICY

RECOMMENDATIONS FOR FUTURE RESEARCH AND POLICY

To build on the findings of this research and enhance the conservation and sustainable management of Garbhanga RF, we recommend the following:

1) **Longitudinal Studies:** Conduct long-term monitoring of forest ecosystem services to understand temporal changes and trends, particularly in response to climate change and human activities.

2) **Biodiversity Assessments:** Implement comprehensive biodiversity surveys to document species diversity and abundance, which are critical for maintaining ecosystem resilience and functionality.

3) **Water Resource Management:** Investigate the impacts of forest cover on water quality and quantity to develop integrated water management strategies that support both ecosystem health and community needs.

4) **Socio-economic Research:** Explore the socio-economic benefits of ecosystem services to local communities, including non-timber forest products, and develop community-based conservation programs that align with local livelihoods.

5) **Educational Outreach:** Enhance public awareness and education initiatives to foster community engagement and stewardship of forest resources.

6) **Technological Integration:** Utilize advanced technologies such as remote sensing, GIS, and AI for more accurate data collection, analysis, and real-time monitoring of forest health and ecosystem services.

7) **Climate Adaptation Strategies:** Develop and promote adaptive management practices that mitigate the impacts of climate change on forest ecosystems, ensuring their long-term sustainability and productivity.

8) **Benchmarking for Future Studies:** Recognize the importance of this study as a benchmark for future research. It provides a foundational understanding of ecosystem services in Garbhanga RF, offering a model for similar studies in other regions.

9) **Protection from Erosion:** Forests are essential for preventing soil erosion, a critical service that sustains land productivity and ecological balance. This research focuses on quantifying and valuing the erosion protection provided by the Garbhanga Reserved Forest (RF) in Assam, emphasizing its economic significance is a vibrant research option.

10) **Assessment of Anthropogenic Pressure:** Understanding the complexity of tree stand composition and anthropogenic pressure dynamics is essential for effective forest management and conservation. This observation opens avenues for future research to explore the specific traits conferring resilience, the impact of habitat fragmentation, and the efficacy of conservation measures. Further studies will enhance our knowledge of forest ecosystems and inform sustainable management practices.

11) **Policy Development:** Formulate and implement policies that incentivise conservation, such as payment for ecosystem services (PES) schemes, and strengthen enforcement mechanisms

to prevent illegal activities like deforestation and poaching. Modification of wildlife management plans for restoration of habitat and conservation of wildlife.

12) **Economic Augmentation:** Quantify the economic contributions of forest ecosystem services to the State GDP, highlighting the financial benefits of conservation and sustainable management. This can include the valuation of ecosystem services such as carbon sequestration, water purification, and ecotourism.

13) **Economic Valuation of Other Forest Types**: This research will serve as a benchmark for future studies on the economic valuation of other forest types.

14) **Stakeholder Consultation**: Engage with stakeholders, including government agencies, NGOs, local communities, and academic institutions, to develop a standard protocol for quantification and valuation of forest ecosystem services in Assam. Ensure that the protocol reflects the needs and priorities of diverse stakeholder.

15) **Best Practices Review:** Review existing protocols and guidelines for ecosystem service quantification and valuation from relevant national and international sources. Identify best practices and lessons learned that can be adapted to the context of Assam.

16) **Capacity Building:** Provide training and capacity-building programs to forest managers, researchers, and other stakeholders on the use of the standard protocol. Offer hands-on workshops, technical assistance, and educational materials to enhance skills and knowledge in ecosystem service assessment.

17) **Pilot Testing:** Pilot test the standard protocol in selected forest areas to evaluate its effectiveness, feasibility, and applicability in real-world settings. Solicit feedback from participants and stakeholders to identify areas for improvement and refinement.

18) **Finalization and Dissemination**: Finalize the standard protocol based on feedback from pilot testing and stakeholder input. Disseminate the protocol widely through workshops, seminars, publications, and online platforms to ensure its uptake and adoption by practitioners.

By pursuing these recommendations, future research and policy can significantly contribute to the preservation and enhancement of Garbhanga RF's ecosystem services, ensuring that they continue to benefit both the environment and local communities while augmenting the State's GDP. This study will act as a crucial benchmark, guiding subsequent research efforts and policy decisions aimed at sustainable forest management.

Chapter XI

ADDITIONAL INFERENCES

ADDITIONAL INFERENCES FROM THE STUDY

A. MAXIMUM CARBON SEQUESTERING TREE SPECIES IN GARBHANGA RF:

The Garbhanga Reserve Forest (RF) plays a crucial role in carbon sequestration, which is essential for mitigating climate change. During the analysis of the field survey data on tree enumeration in sample plots it was found that among the diverse flora in Garbhanga RF, some tree species sequester more carbon in comparison to others which can guide us to determine the higher carbon storage capability of certain species of trees. This study aims to identify the maximum carbon-sequestering tree species in Garbhanga RF and to quantify their contributions to carbon storage for more effective forest management and climate change mitigation strategies as furnished below.

Following the survey conducted in Garbhanga Reserve Forest (RF), the carbon sink of each tree species has been calculated. Considering a specific DBH range of trees i.e., up to 27cm which is attained at an approximate age of 20 years (Refer: - Page 52), for determining carbon sequestration potential for obtaining more targeted and specific results. Younger trees have faster growth and carbon sequestration rates compared to mature trees. By focusing on this age range, we can better understand the carbon sequestration potential during the critical growth phases of tree development. Trees typically experience rapid growth during their juvenile and early mature stages, generally up to around 20 years Hence the tree species which does not have data < 27cm is not considered for the analysis. During the period up to 20 years of age, they sequester carbon more efficiently as they are building biomass at a faster rate compared to their later stages of maturity when growth slows down. Younger trees have higher photosynthetic rates and, consequently, a higher rate of carbon uptake. They allocate significant amounts of carbon to both above-ground and below-ground biomass, enhancing their overall carbon sequestration potential.

Si = Carbon sequestration potential of tree species
N_i = Number of trees of species i with DBH ≥ 27 cm
B_{ij} = Biomass of tree j of species i with DBH ≥ 27 cm
Cij = Carbon content of tree j of species i with DBH ≥ 27 cm
f_c = Carbon fraction of biomass (typically 0.48)
DBH_{ij} = Diameter at breast height of tree j of species i

The biomass, $B_{ij} = a_i * DBH_{ij} \pm b_i$
Where, a_i and b_i are species-specific slope and intercept coefficients.

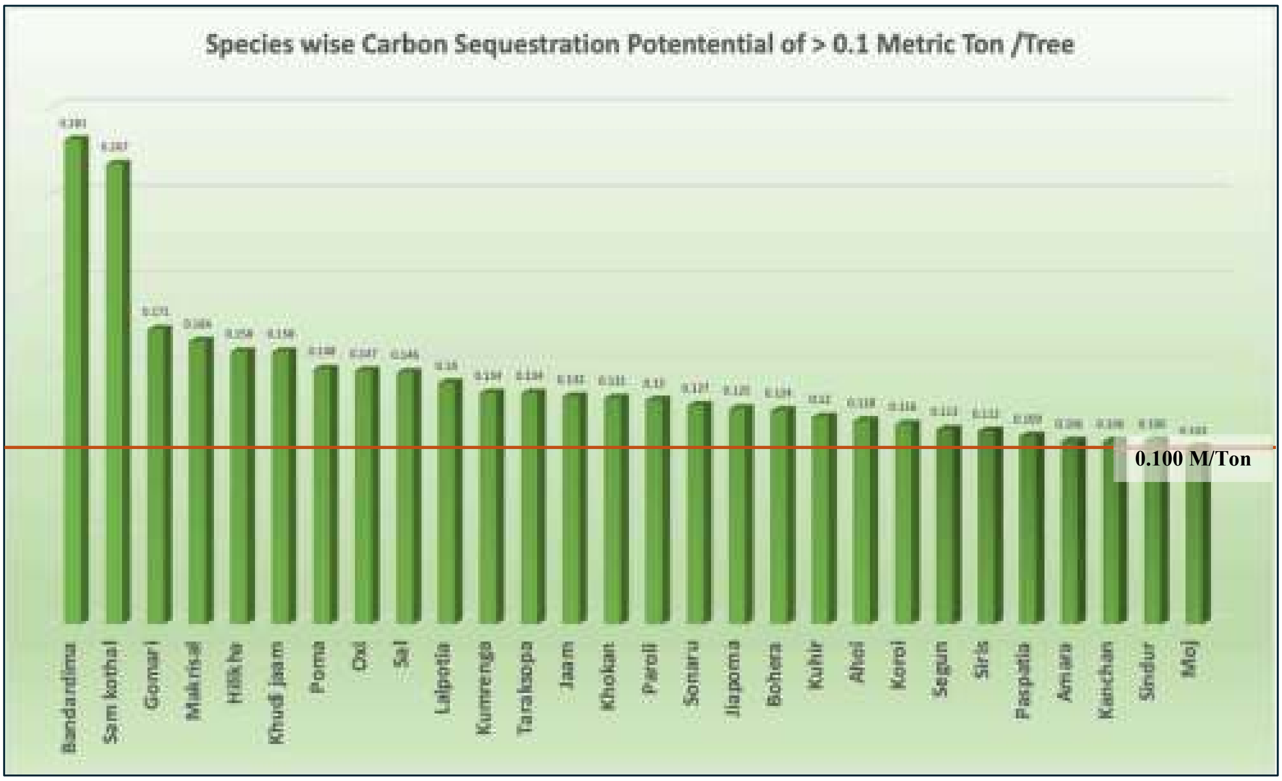
The carbon content, C_{ij} of each tree j of species i is $C_{ij} = f_c * B_{ij}$

The total carbon sequestration potential $S_i = \sum_{j=1}^{Ni} Cij$

Sl. No.	Species with >0.100 M/ton Carbon Sequestration Potential		Average carbon sink value against one tree in M/Ton
	Local name	Scientific name	
1	Bandardima	*Dysoxylum binectariferum*	0.281
2	Sam kothal	*Artocarpus chaplasa*	0.267
3	Gomari	*Gmelina arborea*	0.171
4	Makrisal	*Schima wallichii*	0.164
5	Hilikha	*Terminalia chebula*	0.158
6	Khudi jaam	*Syzygium fruticosum*	0.158
7	Poma	*Chukrasia tabularis*	0.148

8	Oxi	*Dilenia pentagyna*	0.147
9	Sal	*Shorea robusta*	0.146
10	Lalpotia	*Euphorbia pulcherrina*	0.140
11	Kumrenga	*Carya arborea*	0.134
12	Taraksopa	*Haldina cordifolia*	0.134
13	Jaam	*Syzygium cumini*	0.132
14	Khokan	*Duabanga grandiflora*	0.131
15	Paroli	*Stereospermum tetragonum*	0.130
16	Sonaru	*Cassia fistula*	0.127
17	Jiapoma	*Lannea coromandelica*	0.125
18	Bohera	*Terminalia bellirica*	0.124
19	Kuhir	*Bridelia retusa*	0.120
20	Ahoi	*Vitex altissima*	0.118
21	Koroi	*Albizia procera*	0.116
22	Segun	*Tectona grandis*	0.113
23	Siris	*Albizia lebbek*	0.112
24	Paspatia	*Vitex canescens*	0.109
25	Amara	*Spondius mangifera*	0.106
26	Kanchan	*Bauhinia variegata*	0.106
27	Sindur	*Bixa orellana*	0.106
28	Moj	*Pithecellobium monadelphum*	0.102

In assessing the carbon sequestration capabilities of various tree species from the data collected from sample points, a threshold of 0.100 metric tons of carbon per tree was established as the benchmark for high carbon sequestration after analysis *(Red horizontal line in bar graph below)*. Based on this criterion, 28 species have been identified as exceptional in their ability to act as carbon sinks, playing a crucial role in mitigating climate change through their enhanced carbon absorption and storage capacities. These species surpass the established threshold, indicating their significant potential in contributing to environmental sustainability and carbon reduction efforts. Consequently, these high carbon-sequestering tree species should be prioritized in afforestation and reforestation projects to maximize the benefits of carbon capture and contribute to global climate change mitigation strategies.



By prioritizing the identified 28 tree species in Artificial Regeneration and Assisted Natural Regeneration programs, forest management can significantly enhance carbon sequestration capabilities. This strategic approach not only helps in countering climate change but also promotes biodiversity, supports ecosystem services, and fosters sustainable development. Implementing these recommendations will position similar forest areas to Garbhanga RF at the forefront of climate change mitigation efforts.

B. ANTHROPOGENIC PRESSURE ON SPECIES:

Anthropogenic activities, particularly illegal logging, have profound impacts on Garbhanga Reserved Forest ecosystems. These activities disrupt natural regeneration processes, resulting in altered forest structures characterized by younger, smaller trees. This study aims to quantify the impact of such pressures on tree species by analysing their average basal area (BA). A BA value < 0.07065 square meters corresponding to DBH < 0.30 metres *(Refer – Page 52)* serves as an indicator of significant anthropogenic pressure. The analysis focuses on the average basal area of various tree species to assess the impact of anthropogenic pressure, specifically illegal felling and regeneration issues.

By employing a threshold BA of 0.07065 square meters, the study identifies species under tremendous pressure. Species with BA values below this threshold exhibit significant disturbances over the last decades. These disturbances have manifested in younger tree compositions with diameters at breast height (DBH) of less than 30 centimetres, indicating a lack of mature, larger trees. This matrix highlights the extent of illegal logging activities and their long-term effects on forest regeneration and structure, underlining the importance of effective conservation strategies to mitigate such impacts.

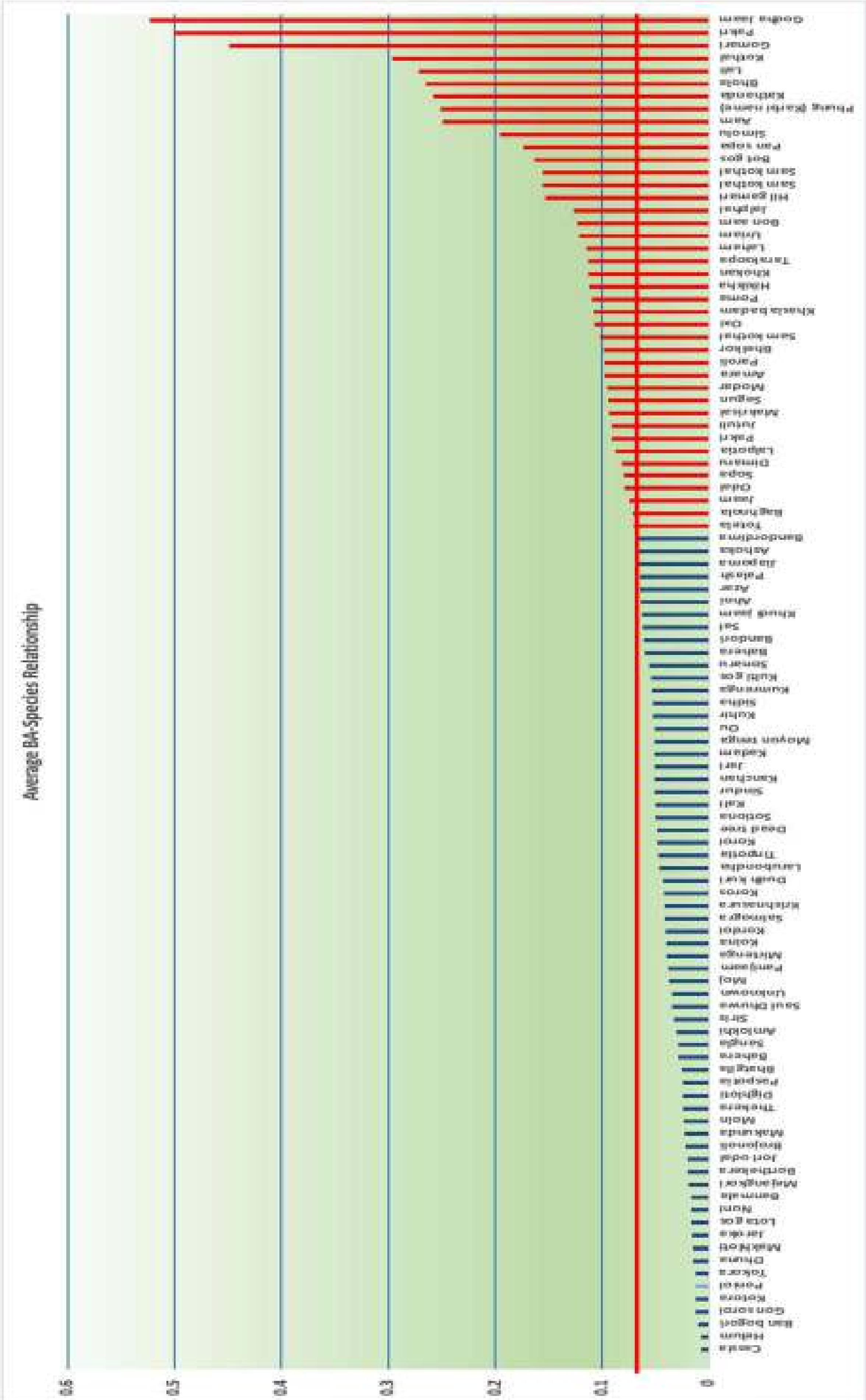
<u>Data Collection:</u> Basal area measurements were obtained for a range of tree species across different forest regions. The diameter at breast height (DBH) was recorded, and BA was calculated using the formula: BA = $\pi \times (\frac{DBH}{2})^2$

Threshold Determination: An average BA of 0.07065 square meters was established as the critical threshold. Tree species with BA values below this threshold were identified as being under tremendous anthropogenic pressure.

Analysis: The distribution of BA values was analysed to determine the extent of anthropogenic pressure on each species. Comparisons were made between species with BA values above and below the threshold.

The average basal area of all the tree species studied was 0.07065 square mete₹ Species with BA values below this threshold was considered significant anthropogenic pressure. These species predominantly exhibited younger tree compositions with DBH <30 cm, indicating a lack of mature, larger trees.

The primary drivers of this pressure include illegal felling and inadequate regeneration. Over the past decades, these activities have prevented the natural development of mature trees, leading to forests dominated by younger, smaller trees. Continuous illegal logging activities have led to the removal of mature trees, reducing the average DBH and BA of the affected species. Post-logging regeneration has been insufficient to replace the removed mature trees, resulting in younger forest stands with smaller DBH values.


Average BA-Species Relationship
0.6
0.5
0.4
0.3
0.2
0.1
0

Analysis of the Bar Graph:
Y-Axis: Represents the average BA (Basal Area or another relevant metric).

Threshold Application:
The red line at BA = 0.07 marks the threshold for tremendous anthropogenic pressure. Species with bars below this red line are considered under high pressure.

Species Below Threshold (BA < 0.07):
The species ***Cassia, Helum, Ban Bogori, Gondhsoroi, Kotora, Poniol, Tokora, Dhuna, Makhioti, Jarka, Lotagos, Banmala Nuni, Mejangkori, Borthekera, Jori Odal, Brojonoli, Makunda, Moin, Thekera, Dighloti, Paspatia, Bhatgila, Bohera, Sangla, Amlokhi, Siris, Unknown, Sauldhowa, Moj, Panijaam, Mirtenga, Koina, Kordoi, Salmogra, Krishnasura, Dudh kuri, Koros, Larubondha, Tinpotia, Koroi, Sotiona, Kali, Sindur, Kanchan, Jari, Kadam, Moyon tenga, Ou, Kuhir, Sidha, Kumrenga, Kulti gos, Sonaru, Bandori, Sal, Khudi jaam, Ahoi, Azar, Palash, Jiapoma, Ashoka, Bandardima,*** possibly face significant anthropogenic pressures such as habitat destruction, pollution, climate change, and overexploitation. Conservation efforts should be prioritized for these species to mitigate the negative impacts of human activities.

Species Above Threshold (BA ≥ 0.07):
The species ***Baghnola, Totela, Jaam, Odal, Sopa, Dimaru, Lalpotia, Pakri, Jutuli, Makrisal, Segun, Modar, Amara, Paroli, Bhelkor, Samkothal, Oxi, Khasia Badam, Poma, Hilikha, Khokan, Taraksopa, Laham, Uriam, Bon Aam, Jalphai, Hil Gomari, Botgos, Pan Sopa, Simolu, Aam, Kathanda, Bhola, Lali, Kothal, Gomari, Pakri, Godhajaam,*** may be more resilient to anthropogenic pressures or inhabit regions with lower human impact. While not under immediate threat, ongoing monitoring and conservation are still important.

Further, from the tree enumeration data analysis it was inferred that few species which are scarcely available are having higher BA. Following reasons may be attributed against the availability of tree species that are scarcely available exhibiting higher average basal area (BA), it indicates several potential ecological and anthropogenic dynamics at play –

Ecological and Anthropogenic Implications:
Low Competition:
Scarcely available species with higher average BA may benefit from reduced competition for resources such as light, water, and nutrients. With fewer individuals competing for the same resources, each tree has more access to what it needs to grow larger.

Habitat Fragmentation:
These species might be growing in isolated or fragmented habitats where human activity is minimal. Fragmentation can create small, isolated populations that are less subjected to logging and other anthropogenic pressures

Resilience to Anthropogenic Pressure:
Higher BA in scarcely available species could indicate that these species have inherent resilience to anthropogenic pressures. They might possess traits that allow them to survive in conditions that are less favourable for other species, thus growing larger over time.

Survival of Mature Trees:
The presence of larger, mature trees among scarcely available species suggests that these trees have not been subjected to recent felling activities. It could indicate a historical period of low anthropogenic interference, allowing these trees to reach maturity.

Selective Logging:
If the scarcely available species have higher economic value or are targeted less frequently by illegal logging, they might be left standing while other, more valuable or preferred species are removed. This selective logging results in the survival of larger, mature trees of these less targeted species.
Conservation Efforts:
It may also be indicative of successful conservation efforts that have protected these species from anthropogenic pressures. Areas with effective conservation measures often retain larger, older trees, reflecting lower levels of human disturbance.

Climate Change effects on seed germination:
Changes in soil chemistry and microbial activity, influenced by climate change, also play a crucial role. Insects, acting as seed predators or vectors for pests and diseases, can increase seed predation and reduce seed availability. Pathogenic fungi and mycorrhizal fungi, both influenced by climate change, affect seed viability and seedling success. Additionally, phenological shifts can cause seeds to germinate at suboptimal times, disrupting the balance of plant communities. Decline in population of certain plant species suitable as food for birds due to climate change may induce birds to feed over seeds of alternative species.

C. BIODIVERSITY INDEX:

To calculate the biodiversity index for the listed tree species, we first need to determine the relative abundance of each species in the list totalling 4079 trees. The biodiversity index can be calculated using the Shannon-Wiener diversity index formula:

$H' = -\sum_{i=1}^{S} p_i * \ln(p_i)$

Where,
H' is the Shannon-Wiener diversity index.
p_i is the proportion of individuals belonging to the i_ith species.
S is the total number of species

Species	Count	Proportion(p_i)	ln(p_i)	Proportion (p_i)*ln(p_i)
Aam	1	0.00025	-8.31361	-0.002038
Ahoi	100	0.02452	-3.70844	-0.090915
Amlokhi	27	0.00662	-5.01777	-0.033214
Amara	14	0.00343	-5.67455	-0.019476
Ashoka	3	0.00074	-7.21499	-0.005306
Ajar	1	0.00025	-8.31361	-0.002038
Bandori	2	0.00049	-7.62046	-0.003736
Bandardima	6	0.00147	-6.52185	-0.009593
Baghnola	18	0.00441	-5.42324	-0.023932
Bon Bogori	3	0.00074	-7.21499	-0.005306
Bhatgila	9	0.00221	-6.11638	-0.013495
Bhelkor	7	0.00172	-6.36770	-0.010928
Bhola	2	0.00049	-7.62046	-0.003736
Bonmala	22	0.00539	-5.22256	-0.028168
Bohera	31	0.00760	-4.87962	-0.037085
Bon Aam	2	0.00049	-7.62046	-0.003736
Borthekera	1	0.00025	-8.31361	-0.002038

Brojonoli	1	0.00025	-8.31361	-0.002038
Bot gos	2	0.00049	-7.62046	-0.003736
Cassia	1	0.00025	-8.31361	-0.002038
Dead Tree	2	0.00049	-7.62046	-0.003736
Dhuna	2	0.00049	-7.62046	-0.003736
Dimaru	9	0.00221	-6.11638	-0.013495
Dighloti	5	0.00123	-6.70417	-0.008218
Dudh kuri	224	0.05492	-2.90196	-0.159362
Goda Jaam	1	0.00025	-8.31361	-0.002038
Gomari	16	0.00392	-5.54102	-0.021735
Gondhsoroi	2	0.00049	-7.62046	-0.003736
Helum	1	0.00025	-8.31361	-0.002038
Hil gomari	2	0.00049	-7.62046	-0.003736
Hilikha	4	0.00098	-6.92731	-0.006793
Howra	12	0.00294	-5.82870	-0.017147
Jaam	45	0.01103	-4.50694	-0.049721
Jalphai	7	0.00172	-6.36770	-0.010928
Jari	1	0.00025	-8.31361	-0.002038
Jaroka	1	0.00025	-8.31361	-0.002038
Jiapoma	55	0.01348	-4.30627	-0.058064
Jori Odal	1	0.00025	-8.31361	-0.002038
Jutuli	1	0.00025	-8.31361	-0.002038
Kadam	1	0.00025	-8.31361	-0.002038
Kali	2	0.00049	-7.62046	-0.003736
Kanchan	115	0.02819	-3.56868	-0.100612
Kathanda	1	0.00025	-8.31361	-0.002038
Khudi jaam	14	0.00343	-5.67455	-0.019476
Khasia Badam	40	0.00981	-4.62473	-0.045352
Khokon	45	0.01103	-4.50694	-0.049721
Kulti gos	2	0.00049	-7.62046	-0.003736
Kanchan	115	0.02819	-3.56868	-0.100612
Koina	1	0.00025	-8.31361	-0.002038
Kordoi	2	0.00049	-7.62046	-0.003736
Koroi	26	0.00637	-5.05551	-0.032224
Koros	2	0.00049	-7.62046	-0.003736
Kothal	2	0.00049	-7.62046	-0.003736
Kotora	2	0.00049	-7.62046	-0.003736
Kumrenga	91	0.02231	-3.80275	-0.084837
Kuhi	28	0.00686	-4.98140	-0.034194
Kumrenga	96	0.02354	-3.74926	-0.088239
Krishnasura	2	0.00049	-7.62046	-0.003736
Kulti gos	3	0.00074	-7.21499	-0.005306
Laham	1	0.00025	-8.31361	-0.002038
Lali	10	0.00245	-6.01102	-0.014737
Lalpotia	29	0.00711	-4.94631	-0.035166

Larubondha	25	0.00613	-5.09473	-0.031225
Lotagos	3	0.00074	-7.21499	-0.005306
Makhioti	2	0.00049	-7.62046	-0.003736
Mirtenga	38	0.00932	-4.67602	-0.043562
Modar	16	0.00392	-5.54102	-0.021735
Makrisal	847	0.20765	-1.57191	-0.326405
Makunda	42	0.01030	-4.57594	-0.047117
Mejangkori	1	0.00025	-8.31361	-0.002038
Moin	11	0.00270	-5.91571	-0.015953
Moj	5	0.00123	-6.70417	-0.008218
Moyon tenga	1	0.00025	-8.31361	-0.002038
Nuni	2	0.00049	-7.62046	-0.003736
Odal	105	0.02574	-3.65965	-0.094205
Ou	2	0.00049	-7.62046	-0.003736
Oxi	114	0.02795	-3.57741	-0.099982
Pakri	3	0.00074	-7.21499	-0.005306
Palash	1	0.00025	-8.31361	-0.002038
Panijaam	3	0.00074	-7.21499	-0.005306
Pan Sopa	3	0.00074	-7.21499	-0.005306
Paspatia	7	0.00172	-6.36770	-0.010928
Phung	3	0.00074	-7.21499	-0.005306
Poma	30	0.00735	-4.91241	-0.036130
Poniol	1	0.00025	-8.31361	-0.002038
Paroli	72	0.01765	-4.03694	-0.071258
Sal	814	0.19956	-1.61165	-0.321618
Salmogra	4	0.00098	-6.92731	-0.006793
Sam kothal	15	0.00368	-5.60556	-0.020614
Sangla	1	0.00025	-8.31361	-0.002038
Sauldhowa	2	0.00049	-7.62046	-0.003736
Segun	274	0.06717	-2.70048	-0.181400
Simolu	4	0.00098	-6.92731	-0.006793
Sidha	145	0.03555	-3.33687	-0.118619
Sindur	8	0.00196	-6.23417	-0.012227
Siris	11	0.00270	-5.91571	-0.015953
Sonaru	17	0.00417	-5.48039	-0.022841
Sopa	35	0.00858	-4.75826	-0.040828
Sotiona	6	0.00147	-6.52185	-0.009593
Taraksopa	10	0.00245	-6.01102	-0.014737
Thekera	4	0.00098	-6.92731	-0.006793
Tinpotia	56	0.01373	-4.28826	-0.058873
Tokora	1	0.00025	-8.31361	-0.002038
Totela	1	0.00025	-8.31361	-0.002038
Urium	11	0.00270	-5.91571	-0.015953
Unknown	50	0.01226	-4.40158	-0.053954
Total	**4079**			-3.090031

i.e., Shannon-Weiner Biodiversity Index is 3.09

A Shannon-Wiener index (also known as Shannon entropy or Shannon diversity index) of 3.09 indicates a relatively high level of biodiversity within the ecosystem under consideration. The Shannon-Wiener index measures both species richness (the number of different species present) and species evenness (how evenly the individuals are distributed among the species). A higher Shannon-Wiener index suggests greater diversity because it takes into account not only the number of species but also their relative abundances. In the context of list of tree species, a Shannon-Wiener index of 3.09 would imply that there is considerable diversity among the tree species present, with a relatively even distribution of individuals across the different species. This could indicate a healthy and ecologically balanced ecosystem.

The list of Tree species count as per availability in the sample plots –

Local Name	Scientific Name	Nos observed in 182 sample plots				
		Very Scarce (1-5)	Scarce (6-20)	Moderate (21-50)	High (51-100)	Very High >100
Aam	*Mangifera indica*	1				
Ashoka	*Saraca asoca*	3				
Ajar	*Lagerstromea speciosa*	1				
Bandori		2				
Bon Bogori	*Ziziphus rugosa*	3				
Bhola	*Semecarpus anacardium*	2				
Bon Aam	*Magifera sylvatica*	2				
Borthekera	*Garcinia pedungculata*	1				
Brojonoli	*Zanthoxylum retusum*	1				
Bot gos	*Ficus bengalensis*	2				
Cassia	*Cassia siamea*	1				
Dead Tree		2				
Dhuna	*Canarium resiniferum*	2				
Godha Jaam	*Sygizium fruticosum*	5				
Gondhsoroi	*Cinnamomum glaucescens*	1				
Helum		2				
Hil gomari	*Premna milieflora*	1				
Jari	*Ficus tinctoria*	2				
Jaroka		4				
Jori Odal	*Sterculia colorata*	1				
Jutuli	*Altingia excelsa*	1				
Kadam	*Neolamarckia cadamba*	1				
Kali		1				
Kathanda	*Trabernaemontana divaricata*	1				
Kulti gos		2				
Koina		1				
Kordoi	*Averrhoa carambola*	2				
Koros	*Pongamia pinnata*	1				
Kothal	*Artocarpus integrifolia*	2				
Kotora	*Cordia myxa*	2				
Krishnasura	*Delonnix regia*	2				
Laham	*Baliospearmum montanum*	2				

Lotagos	*Ficus maclellandii*	3				
Makhioti	*Flemingia strobilifera*	1				
Mejangkori	*Litsiea citrata*	3				
Moyon tenga	*Canthium glabrum*	2				
Nuni	*Morus alba*	1				
Ou	*Dillenia indica*	5				
Pakri	*Ficus rumphii*	1				
Palash	*Butea monosperma*	2				
Panijaam	*Syzigium malaccense*	2				
Pan Sopa	*Magnolia grifithii*	3				
Uriam	*Bischofia javanica*	1				
Poniol	*Flacourtia jangomas*	3				
Sangla		3				
Sauldhowa	*Glycosomis arborea*	3				
Tokora	*Margarateria indica*	1				
Totela		4				
Bandardima	*Dysoxylum binectariferum*		6			
Baghnola	*Litsea glutinosa*		18			
Sotiona	*Alstonia scholaris*		6			
Bonmala	*Callicarpa arborea*			22		
Kuhir	*Bridelia retusa*			28		
Unknown				50		
Ahoi	*Vitex altissima*				100	
Jiapoma	*Laanea coromandelica*				55	
Dudh kuri	*Holarrhena antidysenterica*					224
Kanchan	*Bauhenia purpuraa*					115
Makrisal	*Schima wallichi*					847
Odal	*Sterculia villosa*					105
Oxi	*Dillenia pentagyna*					114
Sal	*Shorea robbusta*					814
Segun	*Tectona grandis*					274
Sidha	*Lagerstroemia parviflora*					145

D. REGRESSION MODELS OF STEM VOLUME and AGB OF TREES:

Stem biomass and above-ground biomass (AGB) for the listed species in the Garbhanga Reserved Forest are calculated using comprehensive field data that includes measurements of diameter at breast height (DBH) in meters, bole height, tree height, and crown shape. To estimate stem biomass, a form factor (0.68) is applied to calculate top diameter of the clean bole trunk, ensuring accuracy in the measurement of the trunk's volume. For crown biomass, different geometric shapes are utilized based on the specific crown shape of each species, allowing for precise calculation of the crown's volume. Both stem and crown biomass values are then adjusted by multiplying them by the wood density and the weight of a unit volume (1.0 cum) of crown biomass respectively, yielding the final biomass values for each species. Utilizing these detailed data points, a regression model has been developed for the 41 major species available in the Garbhanga Reserved Forest, providing a reliable method for estimating biomass. However, the lack of sufficient data for the remaining species has impeded the development of regression models for those species, highlighting the need for further data collection to ensure comprehensive biomass estimation for all species within the region. This underscores the importance of ongoing research and data acquisition to refine biomass estimations and support effective forest management and conservation efforts. Higher R-Squared value indicates high veracity of data.

l.	Species	Standing tree Clean Bole Volume in Cum	R-Squared Value	AGB in KG	R-Squared Value
1	Ahoi	V = 6.9796*DBH - 1.0833	R^2 = 0.91	AGB = 5283.9*DBH - 838.67	R^2 = 0.89
2	Amara	V = 4.3124*DBH - 0.5997	R^2 = 0.97	AGB = 2144.2*DBH - 270.37	R^2 = 0.97
3	Amlokhi	V = 4.5916*DBH - 0.545	R^2 = 0.84	AGB = 3895*DBH - 460.25	R^2 = 0.84
4	Baghnala	V = 8.5294*DBH - 1.5158	R^2 = 0.90	AGB = 3667.8*DBH - 629.43	R^2 = 0.91
5	Banmala	V = 1.5604*DBH - 0.1343	R^2 = 0.97	AGB= 1167.7*DBH - 99.175	R^2 = 0.98
6	Bhatgila	V = 5.7535*DBH - 0.6816	R^2 = 0.93	AGB = 1954.5*DBH - 229.45	R^2 = 0.93
7	Bhelkor	V = 30.607*DBH - 9.5814	R^2 = 0.89	AGB = 10107*DBH - 3057	R^2 = 0.90
8	Bohera	V = 7.4599*DBH - 1.198	R^2 = 0.85	AGB = 5691.2*DBH - 908.5	R^2 = 0.84
9	Dimaru	V = 13.068*DBH - 2.0168	R^2 = 0.77	AGB = 5640.1*DBH - 842.42	R^2 = 0.73
10	Dudh kuri	V = 3.762*DBH - 0.5104	R^2 = 0.80	AGB = 2193.2*DBH - 278.06	R^2 = 0.82
11	Gomari	V = 8.077*DBH - 1.6037	R^2 = 0.91	AGB = 5421.2*DBH - 986.47	R^2 = 0.92
12	Howra	V = 2.4559*DBH - 0.2286	R^2 = 0.90	AGB = 2101.3*DBH - 194.95	R^2 = 0.97
13	Jaam	V = 0.6504*DBH + 0.1329	R^2 = 0.82	AGB= 1782.7*DBH - 112.13	R^2 = 0.91
14	Jiapoma	V = 8.4164*DBH - 1.4636	R^2 = 0.80	AGB = 5490.9*DBH - 922.04	R^2 = 0.83
15	Kanchan	V = 3.0586*DBH - 0.3674	R^2 = 0.92	AGB = 2303*DBH - 252.82	R^2 = 0.94
16	Khasia Badam	V = 3.3737*DBH - 0.634	R^2 = 0.91	AGB = 2407.4*DBH - 425.93	R^2 = 0.93
17	Khokan	V = 6.3678*DBH - 1.2502	R^2 = 0.92	AGB = 3210.2*DBH - 585.71	R^2 = 0.93
18	Khudi Jaam	V = 4.0077*DBH - 0.4797	R^2 = 0.89	AGB = 2928.2*DBH - 329.39	R^2 = 0.88
19	Koroi	V = 7.2311*DBH - 0.9842	R^2 = 0.87	AGB = 4043.8*DBH - 535.44	R^2 = 0.82
20	Kuhir	V = 7.4078*DBH - 1.2138	R^2 = 0.87	AGB = 6122.6*DBH - 969.47	R^2 = 0.83
21	Kumrenga	V = 4.4711*DBH - 0.6161	R^2 = 0.90	AGB = 4036.8*DBH - 499.36	R^2 = 0.91
22	Lali	V = 13.205*DBH - 3.0047	R^2 = 0.69	AGB = 10701*DBH - 2436.6	R^2 = 0.71
23	Lalpotia	V = 8.8525*DBH - 1.4355	R^2 = 0.93	AGB = 6164.3*DBH - 975.38	R^2 = 0.91
24	Larubondha	V = 3.0369*DBH - 0.3209	R^2 = 0.96	AGB = 2089*DBH - 192.31	R^2 = 0.89
25	Makrisal	V = 9.6247*DBH - 1.8152	R^2 = 0.84	AGB = 8482.2*DBH - 1580.3	R^2 = 0.78
26	Makunda	V = 1302.5*DBH - 104.58	R^2 = 0.93	AGB = 1302.5*DBH - 104.58	R^2 = 0.82
27	Mirtenga	V = 3.0641*DBH - 0.3699	R^2 = 0.83	AGB = 2735.2*DBH - 324.34	R^2 = 0.79
28	Odal	V = 5.5987*DBH - 0.9392	R^2 = 0.88	AGB = 1834.5*DBH - 287.84	R^2 = 0.82
29	Oxi	V = 7.9077*DBH - 1.5229	R^2 = 0.89	AGB = 5075.6*DBH - 942.71	R^2 = 0.87
30	Paroli	V = 8.0244*DBH - 1.4892	R^2 = 0.84	AGB= 5385.6*DBH - 985.98	R^2 = 0.78
31	Poma	V = 9.8866*DBH - 1.8073	R^2 = 0.92	AGB= 6168*DBH - 1097.1	R^2 = 0.92
32	Sal	V = 12.846*DBH - 2.2348	R^2 = 0.76	AGB = 9619.9*DBH- 1651.4	R^2 = 0.70
33	Sam kothal	V = 11.486*DBH - 2.4835	R^2 = 0.97	AGB = 7372.8*DBH - 1591.1	R^2 = 0.90
34	Segun	V = 34.987*DBH - 9.1198	R^2 = 0.73	AGB = 20169*DBH - 5183.6	R^2 = 0.64
35	Sidha	V = 6.0706*DBH - 0.9664	R^2 = 0.84	AGB = 3840.4*DBH - 601.35	R^2 = 0.81
36	Siris	V=3.3403*DBH - 0.4155	R^2=0.82	AGB= 2725.4*DBH - 307.48	R^2=0.81
37	Sonaru	V=4.5147*DBH- 0.6788	R^2 = 0.92	AGB=3555.6*DBH- 484.77	R^2 = 0.93
38	Sopa	V=8.3133*DBH- 1.4348	R^2 = 0.91	AGB=4192.7*DBH- 695.36	R^2 = 0.92

39	Taraksopa	V=8.2553*DBH- 1.6816	R^2 = 0.92	AGB=5297.4*DBH - 1015.8	R^2 = 0.92
40	Tinpotia	V=4.0949*DBH - 0.5239	R^2 = 0.93	AGB=3665.1*DBH - 468.42	R^2 = 0.92
41	Urium	V=17.425*DBH - 3.8788	R^2 = 0.84	AGB=9568.3*DBH - 2002.8	R^2 = 0.88

E. CHECKLIST OF BIODIVERSITY:

This list is compiled by identifying the species from the secondary source of publication of reports on bird watching available both online and offline and periodic field visits.

1. ORCHIDS

Sl. No.	Scientific Name
1	*Cymbidium aloefolium*
2	*Papilionanthe teres*
3	*Rhyncostylis retusa*
4	*Aerides odoratum*
5	*Acampe multiflora*
6	*Dendrobium aphyllum*
7	*Dendrobium densiflorum*
8	*Pholidota imbricata*
9	*Bulbophyllum careyanum*
10	*Aerides multiflora*
11	*Bulbophyllum umbellatum*
12	*Phalaenopsis mannii*
13	*Pholidota articulata*
14	*Cymbidium bicolour*
15	*Dendrobium jenkinsii*
16	*Malaxis densiflora*

2. BAMBOO/CANE

Sl. No.	Common Name	Scientific Name
1	Kako Bah	*Dendrocalamus hamiltoni*
2	Dolu Bah	*Schizostachyum dwlooa (syn-Teinostachyum dullosa)*
3	Jati Bah	*Bambusa tulda (Planted)*
4	Bijuli Bah	*Bambusa pallid (probably planted)*
5	Jati Bet	*Calamus tennuis*
6	Raiding Bet	*Calamus flagellum*

3. BUTTERFLY

Sl. No.	English Name	Scientific Name
1	Yellow Zezebel	*Delias agastina*
2	Indian Cabbage White	*Pieris conidia*
3	Common Gull	*Cepora nerissa*
4	Coomon Emigrant	*Catopsila Pomona*
5	Yellow Helen	*Princeps nepheulus*

6	Great Mormon	*Princeps memon*
7	Common Jay	*Graphium doson*
8	Common Blue Battle	*Graphium sarpedon*
9	Plain Bush brown	*Mycalesis malsarida*
10	Red Lacewing	*Cethosa bibles*
11	Plain Tiger	*Danaus chrysippus*
12	Peacock Pancy	*Precis almana*
13	Lemon Pancy	*Precis lemonias*
14	Nigger	*Orsotrioena medus*
15	Painted Lady	*Cynthia cardui*
16	Knight	*Lebadea martha*
17	Grey Pancy	*Precis atlites*
18	Grey Count	*Tanaccia lepidea*
19	Great Ant Fly	*hypolimnus bolina*
20	Angled Red Forester	*Lethe chandica*
21	Bamboo Tree Brown	*Lathe europa*
22	Banded Tree Brown	*Neope confusa*
23	Common Fourring	*Ypthiama haldus*
24	Dark Caerulean	*Jamides bochus*
25	Common Raven	*Princeps nephelus*
26	Common Bush Brown	*Mycalesis perseus*
27	Common Castor	*Ariadne merione*
28	Common Crow	*Eupoea care*
29	Common Earl	*Tanaecia Julii*
30	Yellow Pancy	*Poluura hierta*
31	Common Evening Brown	*Melanitis Leda*
32	Common Maplet	*Chersonesis Risa*
33	Common Lascar	*Pantoparia Hardonia*
34	Common Jester	*Symbrenthia Liaea*
35	Black Vein Segant	*Parathyma ranga*
36	Common Segant	*Parathyma nefle*
37	Dark Evening Brown	*Melanitis Phedima*
38	Angle Caster	*Aridne Aradne*
39	Glassy Tiger	*Parantica Aglea*
40	Anglet Pierrot	*Caleta caleta*
41	Banded Blue Pierrot	*Castalius Ethion*
42	Common Hedge Blue	*Acetolepsis Puspa*
43	Common onyx	*Horaga onyx*
44	Common Pierrot	*Castilus rosemen*
45	Lime Blue	*Chilades Laius*
46	Opaque 6 Line Blue	*Nacaduba beroe*
47	Purple Sapphire UP	*Heliophorus epicles*
48	Striped pierrot	*Tarucus Nara*

4. BIRD

SL. No.	Local Name	Scientific Name
1	White browed Picufet	*Sasia ochracea*
2	Speckled Piculet	*Picumnus innominatus*
3	Grey-capped Pygmy Woodpecker	*Dendrocopos canicapillus*
4	Fulvous-breasted Woodpecker	*Dendrocopos mecei*

5	Rufous woodpecker	*Celeus brachyurus*
6	Lesser yellow nape	*Picus chlorolophus*
7	Streak-throated Woodpecker	*Picus xanthopygaeus*
8	Grey headed woodpecker	*Picus canus*
9	Black-rumped Flameback	*Dinopium benghalense*
10	Greater Flameback	*Chrysocolaptes guttacristatus*
11	Bay woodpecker	*Blythipicus pyrrhotis*
12	Lineated Barbet	*Megalaima lineata*
13	Blue-throated Barbet	*Megalaima asiatica*
14	Blue-eared Barbet	*Megalaima australis*
15	Coppersmith Barbet	*Megaliaima haemacephala*
16	Oriental Pied Hornbill	*Anthracoceros albirostris*
17	Common Hoopoe	*Upupa epops*
18	Red-headed Trogon	*Harpactes erythrocephalus*
19	Indian Roller	*Coracias benghalensis*
20	Common Kingfisher	*Alcedo atthis*
21	Blue-eared kingfisher	*Alcedo meninting*
22	Oriental dwarf kingfisher	*Ceyx erithacus*
23	Stork billed Kingfisher	*Pelargopsis capensis*
24	White throated kingfisher	*Halcyon smyrnensis*
25	Blue-bearded Bee-eater	*Nyctyornis athertoni*
26	Green Bee-eater	*Merops orientalis*
27	Blue-tailed Bee-eater	*Merops philippinus*
28	Chestnut headed Bee-eater	*Merops leschenaultia*
29	Pied cuckoo	*Clamator jacobinus*
30	Common Hawk cuckoo	*Hierococcyx varius*
31	Indian cuckoo	*Cuculus micropterus*
32	Banded Bay cuckoo	*Cacomantis sonneratii*
33	Plaintive cuckoo	*Cacomantis merulinus*
34	Asian Koel	*Eudynamys scolopacea*
35	Green-billed Malkoha	*Phaenicophaeus tristis*
36	Greater coucal	*Centropus sinensis*
37	Lesser coucal	*Centropus bengalensis*
38	Rose-ringed Parakeet	*Psittacula krameri*
39	Grey-headed Parakeet	*Psittacula finschii*
40	Blossom-headed Parakeet	*Psittacula roseate*
41	Red-breasted Parakeet	*Psittacula alexandri*
42	Himalayan swiftlet	*Aerodramus brevlrostris*
43	Asian Palm swift	*Cypsiurus balasiensis*
44	Barn owl	*Tylo alba*
45	Oriental scops owl	*Otus sunia*
46	Collared sops owl	*Otus bakkamoena*
47	Dusky Eagle owl	*Bubo coromandus*
48	Asian Barred owlet	*Glaucidium cuculoides*
49	Spotted owlet	*Athene brama*
50	Brown Hawk owlet	*Ninox scutulata*
51	Spot billed Eagle owl	*Bubo nipalensis*
52	Grey Nightjar	*Caprimulgus indicus*
53	Large-tailed Nightjar	*Caprimulgus macrurus*
54	Blue Rock Pigeon	*Columba livla*
55	Oriental turtle Dove	*Streptopelia orientalis*
56	Spotted Dove	*Streptopelia chinensis*
57	Emerald Dove	*Chalcophaps indica*
58	Pompadour Green Pigeon	*Treron pompadore*

59	Thick-billed Green Pigeon	*Treron curvirostre*
60	Yellow-footed Green Pigeon	*Treron phoenicoptera*
61	Green Imperial Pigeon	*Ducula aenea*
62	Brown crake	*Amaurornis akool*
63	White-breasted waterhen	*Amauromis phoenicurus*
64	Red-wattled lapwing	*Vanellus indicus*
65	Jerdon's Baza	*Aviceda jerdoni*
66	Black Baza	*Aviceda leuphotes*
67	Oriental Honey-buzzard	*Pernis ptilorhynchus*
68	Black kite	*Milvus migrans*
69	Black-eared Kite	*Milvus migrans lineatus*
70	White-rumped vulture	*Gyps bengalensis*
71	Long-billed vulture	*Gyps indicus*
72	Himalayan Griffon	*Gyps himalayensis (on flight)*
73	Crested sepent Eagle	*Spilornis cheela*
74	Crested Goshawk	*Accipiter trivirgatus*
75	Shikra	*Accipiter badius*
76	Whlte-eared Buzzard	*Butastur teesa*
77	Common Buzzard	*Buteo buteo*
78	Lesser spotted Eagle	*Aquila pomarina*
79	Greater Spotted Eagle	*Aquila Clanga*
80	Steppe Eagle	*Aquila nipalensis*
81	Rufous-bellied Eagle	*Hieraaetus kienerii*
82	Changeable Hawk Eagle	*Spizaetus cirrhatus*
83	Eurasian sparrowhawk	*Accipiter nisus*
84	Pied falconet	*Microhierax melanoleucos*
85	Oriental Hobby	*Falco severus*
86	Peregrine falcon	*Falco peregrinus*
87	Red-necked Falcon	*Falco chicquera*
88	Common kestrel	*Falco tinnunculus*
89	Little cormorant	*Phalacrocorak niger*
90	Little Egret	*Egretta garzetta*
91	Intermediate Egret	*Mesophoyx intermedia*
92	Cattle Egret	*Bubulcus ibis*
93	Indian Pond Heron	*Ardeola grajii*
94	Little Heron	*Butorides straitus*
95	Black-crowned Night Heron	*Nycticorak nycticorak*
96	Asian openbill	*Anastomus oscitans*
97	Lesser Adjutant	*Leptoptilos javanicus*
98	Hooded pitta	*Pitta sordida*
99	Long-tailed Broadbill	*Psarisomus dulhousiae*
100	Asian fairy Bluebird	*Irena puella*
101	Blue-winged Leafbird	*Chloropsis cochinchinesis*
102	Golden fronted leafbird	*Chloropsls aurifrons*
103	Orange-bellied leafbird	*Chloropsls hardwlckii*
104	Brown shrike	*Lanius cristatus*
105	Grey-backed shrike	*Lanius tephronotus*
106	Long-tailed shrike	*Zoothera monticola*
107	Rufous treepie	*Dendrocitta vagabunda*
108	Housecrow	*Corvus splendens*
109	large-billed crow	*Corvus macrorhynchos*
110	Ashy-wood swallow	*Artamus fuscus*
111	Slender-billed oriole	*Oriolus tenuirostrus*
112	Black-hooded Oriole	*Oriolus xanthornus*
113	Maroon oriole	*Oriolus traillii*

114	Large cuckoo shrike	*Coracina macei*
115	Black-winged cuckooshrike	*Coracina melaschistos*
116	Rosy minivet	*Pericrocotus roseus*
117	Small Minivet	*Pericrocotus cinnamomeus*
118	Long-tailed minivet	*Pericrocotus ethologus*
119	Scarlet minivet	*Pericrocotus flammeus*
120	Bar-winged Flycatcher shrike	*Hemipus picatus*
121	White-throated fantail	*Rhipidura albicollis*
122	Black drongo	*Dicrurus macrocercus*
123	Ashy drongo	*Dicrurus leucophaeus*
124	Crow-billed drongo	*Dicrurus annectans*
125	Bronze Drongo	*Dicrurus aeneus*
126	Lesser Racket-tailed Drongo	*Dicrurus remifer*
127	Greater Racket-tailed Drongo	*Dicrurus paradiseus*
128	Spangled Drongo	*Dicrurus hottentottus*
129	Black-naped Monarch	*Hypothymis azurea*
130	Common lora	*Aegithina tiphla*
131	Large woodshrlke	*Tephrodornis gularis*
132	Blue rock Thrush	*Monticola solitarious*
133	Blue-whistling Thrush	*Myophonus caeruleus*
134	0range-headed Thrush	*Zoothera citrina*
135	Dark-sided Thrush	*Zoothera marginata*
136	Dark-throated Thrush	*Turdus rufiollis*
137	Red-throated Flycatcher	*Ficedula parva*
138	Snowy-browed Flycatcher	*Ficedula hyperythra*
139	Little pied Flycatcher	*Ficedula westermanni*
140	Verditer Flycatcher	*Eumyias thalassina*
141	Small Niltava	*Niltava macgrigoriae*
142	Pale-chinned Flycatcher	*Cyornis poliogenys*
143	Pygmy blue Flycatcher	*Muscicapella hodgsoni*
144	Tickll's blue Flycatcher	*Cuornis tickelliae*
145	Grey-headed Canary Flycatcher	*Culicicapa ceylonensis*
146	Bluethroat	*Luscinia svecica*
147	Firethroat	*Luscinia pectardens*
148	Small Niltava	*Niltava macgrigoriae*
149	Oriental Magpie Robin	*Copsychus saularis*
150	White-rumpedshama	*Copsychus mala baricus*
151	Daurian red start	*Phoenicurus auroreus*
152	White capped redstart	*Chaimarrornis leucocephalus*
153	Black-backed Forktail	*Enicurus immaculatus*
154	Common stonechat	*Saxicola torquata*
155	Grey stonechat	*Saxicola ferrea*
156	Chestnut-tailed starling	*Sturnus malabaricus*
157	Asian pied starling	*Sturnus contra*
158	Common Myna	*Acriddotheres tristis*
159	Jungle Myna	*Acriddotheres fuscus*
160	White-vented Myna	*Acriddotheres cinereus*
161	Hill Myna	*Gracula religiosa*
162	Chestnut-bellied Nuthatch	*Sitta castanea*
163	Velvet-fronted Nuthatch	*Sitta frontalis*
164	Great Tit	*Parus major*
165	Barn swallow	*Hirundo rustica*
166	Crested Finchbill	*Spizixos canifrons*
167	Black-crested Bulbul	*Pycnonotus melanicterus*
168	Red-whiskered Bulbul	*Pycnonotus jocosus*

169	Black-headed Bulbul	*Pycnonotus atriceps*
170	Red-vented Bulbul	*Pycnonotus cafer ·*
171	Flavescent Bulbul	*Pycnonotus flavescens*
172	White-throated Bulbul	*Lole virescens*
173	Olive Bulbul	*Hypsipetes leucocephalus*
174	Striated Prinia	*Prinia criniger*
175	Rufescen·Prinia	*Prinia rufescens*
176	Grey-breasted Prinia	*Prinia hodgsonii*
177	Ashy Prinia	*Prinia socialis*
178	Oriental white-eye	*Zosterops palpebrosus*
179	Aberrant Bush Warbler	*Cettia flavolivacea*
180	Brownish flanked Bush Warbler	*Cettia fartipas*
181	Common tailor bird	*Orthotomus sutorius*
182	Dark necked tailor bird	*Orthotomus atrogularis*
183	Dusky warbler	*Phylloscopus fuscatus*
184	Tickell's leaf warbler	*Phylloscopus affinis*
185	Yellow-browed warbler	*Phylloscopus inornatus*
186	Burne's warbler	*Phylloscopus humei*
187	Greenish warbler	*Phylloscopus trochiloides*
188	Grey-hooded Warbler	*Phylloscopus xanthoschistos*
189	White-spectacled Warbler	*Seicercus affinis*
190	Yellow-belled Warbler	*Abroscopus superciliaris*
191	Lesser Necklaced laughing thrush	*Garrulax monileger*
192	Greater-Necklaced laughing thrush	*Garrulax pectoralis*
193	Moustached laughing thrush	*Garrulax cineraceus*
194	Rofous necked Laughing thrush	*Garrulax ruficollis*
195	Spot-breasted Laughing thrush	*Garrulax merulinus*
196	Abbott's Babbler	*Malacocincla abbotti*
197	Puff-throated Babbler	*Pellorneum ruficeps*
198	White-brewed scimiter Babbler	*Pomatorhinus schisticep*
199	Buff-breasted Babbler	*Trichastoma tickelli*
200	Spot-throated Babbler	*Pellorneum albiventre*
201	Rufous-fronted Babbler	*Stachyridopsis rufifrons*
202	Grey-throated Babbler	*Stachyris nigriceps*
203	Striped Tit Babbler	*Macronus gularis*
204	Jungle Babbler	*Turdoides striata*
205	White-hooded Babbler	*Gampsorhynchus rufulus*
206	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*
207	Fire-breasted Flowerpecker	*Dicaeum ignipectus*
208	Plain Flowerpecker	*Dicaeum concolor*
209	Scarlet-backed flowerpecker	*Dicaeum cruentatum*
210	Purple sunbird	*Nectarinia asiatica*
211	Crimson sunbird	*Aethopyga siparaja*
212	Black-throated sunbird	*Aethopyga saturala*
213	House sparrow	*Passer domesticus*
214	Eurasian Tree sparrow	*Passer hispaniolensis*
215	Forest wagtail	*Dendronathus indicus*
216	Grey wagtail	*Motacilla cinerea*
217	Olive backed Pitpit	*Anthus hodgsoni*
218	Paddyfield pippit	*Anthus rufutus*
219	Oriented skylark	*Alauda gulgula*
220	Yellow Wagatail	*Motacilla cinerea*
221	Beya Weaver	*Ploceus philippinus*
222	Scaly-breasted Munia	*Lonchura punctulata*
223	White rumped Munia	*Lonchura striata*

224	Black francolin	*Francolinus francolinus*
225	Whitecheeked partridge	*Arporophila atrogularis*
226	Red jungle foul	*Galas galas*
227	Kalij Pheasant	*Lophura laucomelanos*

6. MAMMAL

Sl. No.	English Name	Scientific Name
1	Indian Elephant	*Elephas maximus*
2	Leopard	*Panthera pardus*
3	Jungle Cat	*Felis chaus*
4	Leopard Cat	*Felis bengalensis*
5	Large Indian Civet Cat	*Viverrazibentha*
6	Small Indian Civet cat	*Viverricula indica*
7	Palm Civet Cat	*Paradoxurus hermaphroditus*
8	Himalayan Palm Civet	*Pagumalarvata*
9	Yellow Throated Marten	*Martis flavigula*
10	Jackel	*Canis aureus*
11	Sloth Bear	*Ursus ursinus*
12	Barking Deer	*Muntiacus muntjak*
13	Shamber	*Carvusunicolar*
14	Rhesus macaque	*Macaca mulatta*
15	Capped Langur	*Presbytis pilllcatus*
16	Hoolock Gibbon	*Hoolock hoolock*
17	Slow Loris	*Nycticebuscoucang bengalensis*
18	Serow	*Capricornissumatraansis*
19	Binturong	*Arctitis binturong*
20	Brush tailed Porqupine	*Artherurusmacrourus*
21	Red Giant flying Squirrel	*Petauristapetaurista*
22	Orange bellied Himalayan Squirrel	*Dremomyslokriah*
23	Malayan Giant Squirrel	*Patifabicolar*
24	Hoory Bellied Squirrel	*Callosciuruspygerythus*
25	Indian Flying Fox	*Pteropus giganteus*
26	Pipistrelle Bat	*Pipistrellus caromandra*
27	Horseshoe Bat	*Rhinolophus rouxii*
28	Small Indian Mongoose	*Herpestesjavanicus*
29	Chinese Pangolin	*Manis pentadactyla*
30	Wild Boar	*Sus scrofa*
31	Grey musk shrew	*Suncus murinus*
32	Yellow house Bat	*Scotophiluskuhlii*
33	Lesser Bandicoot Rat	*Bandicota bengalensis*
34	Long tailed tree Mouse	*Vandeleuria oleracea*
35	Greater short nosed fruit Bat	*Cynopterus sphinx*
36	Horney Bamboo Rat	*Rhizomyspruinosus*
37	Mithun	*Bos gaurus*

N.B: *However, no record of serow and Binturong for last ten-to-eleven-year Last sightingduring 2011 and 2012. There are unconfirmed reports of Himalayan black Bear.*

**** These species list were identified/compiled by Sri Mrigen Barua, AFS, ACF, Genetic Cell Division, Guwahati.**

DATA COLLECTION FORMS

Provisioning Service

[illegible]

Date:

Name of the Market

Name of Team leader

Market Survey

Product name								
Vernacular Name	Local name	Scientific Name	Sl. No. of persons selling the products from forest	Place of collection of products	Quantity of products sold per day	No. of days of selling	Selling Unit price	remarks

Regulating Service

WATER											
Date:											
Time:											
Name of the person collecting data:											
Sl.No.	Location	Retention of water in waterbodies									
		Name of water body	Type of water body	Dimensions of water body						Average Water velocity	Volume of water retained during dry season
				Total Length	Average width of water body	Average depth of water body			Total Volume		

For one particular water body						
Sl. No.	Point at which width is recorded Geo-coordinate	Width at each recording point	Depth of the bed			
			Depth at right bank	Depth at left bank	Depth at center	Average depth
	Average width of water body				Average depth of water body	

Sl. No.	Date	Name	Name of water body	Point at which width is recorded with Geo-coordinate		Width at each recording point (m)	Depth of the bed			Time taken to cover 100 m of flowing water body (min)	Volume of water flow per 100 m length per unit time
				Lat	Long		Depth at right bank (m)	Depth at left bank (m)	Depth at center (m)		

Date:

Name of the Industry

Name of Team leader

Water consumption by industries

Amount of water used per day	Source of water	No. of days water is used per year	Cost involved in collection and supply of water	Total amount spent for use of water per year

Regulating Service Continued….

Date:
Name of the Industry
Name of Team leader

Government Enterprise

Qty of water supplied during winter	Qty of water supplied during summer	Cost incurred per litre	Total amount spent in a year

TEMPERATURE DATA

Date	Latitude	Longitude	Strata	Temperature inside Garbhanga					Temperature in Guwahati city				
				10:00 AM	12:00	18:00	22:00:00	Avg Daily temp	10:00 AM	12.00 noon	18:00	22:00:00	Avg Daily temp

Date:
Name of the industry
Name of Team leader

Power Consumption

Name of appliances	Time required to reduce 1 degree Celsius temperature in 30-35 degree Celsius range	Total power consumption for 1 degree C reduction in temperature in 30-35 degree range	Time required to reduce 1 degree Celsius temperature in 35-40 degree Celsius range	Total power consumption for 1 degree C reduction in temperature in 35-40 degree range	Time required to reduce 1 degree Celcius temperature in 40-45 degree Celsius range	Total power consumption for 1 degree C reduction in temperature in 40-45 degree range	Average of 2, 4 and 6	Cost involved in reduction of 1 Degree Celcius temperature for 14ftx14ftx10.5ft (2058 cft) room	Cost involved in reduction of 1 Degree Celcius temperature for 1ft x 1ft x 1 ft room	Average temperature in Guwahati City throught the year	Average temperature in Garbhanga throught the year	Average temperature difference between garbhanga RF and Guwahati city	Total cost of Power consumption per year	Shared Capital expenditure	Total Amount Spent per year
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AC 1.5 Ton															
AC 2 Ton															

Supporting Service

CROWN CHARACTERISTICS FOR CARBON ASSESSMENT	
Plot No:	
Date:	
Temperature:	
Humidity:	
Name of the Recorder:	
Sample plot GPS coordinate *(degree decimal format)*:	

Tree No.	Species	GBH in mtrs	DBH in mtrs	Height upto top of crown	Clean bole height	Crown height	Crown width			Shape of crown	Crown volume	Stem volume	Branch biomass <10cm of the 1mX1mX1m sample	Branch biomass <10cm of the tree	Foliage Biomass of the 1mX1mX1m sample	Foliage Biomass of the tree
							1	2	Avg							

SOC

Latitude	Longitude	Assigned density class	Calculated density class	NE fresh wt. of soil (kg)	SW fresh wt. of soil (kg)	Total wt. (kg)	Average fresh wt. (kg) (30cm x 30cm)	Average dry weight kg (30cm x30 cm)	Sample Fresh Wt. (kg)	Sample Dry wt. (kg)	Difference of sample wt. (M-N) in kg	% difference of wt per kg	LAB SOC %	SOC OF DRY SOIL SAMPLE (kg)	SOC for 30x30cm sample plot (kg)	SOC per plot (m ton)	SOC per plot (KG)	SOC PER KG DRY WT (kg)	SOC PER PLOT IN M/Ton	Total Soil carbon in bamboo area M/Ton

CARBON ASSESMENT	
Plot No:	
Date:	
Temperature:	
Humidity:	
Name of the Recorder:	
Sample plot size:	

Above Ground Biomass (AGB)	Below Ground Biomass (BGB)	Carbon	Wt. of Soil (30cm x 30cm x 30cm)		Carbon mass	Wt. of litter (1m x 1m)		Carbon mass	Wt. of Dead wood <5cm GBH (3m x 3m)		Carbon mass	Wt. Dead wood >5cm GBH (5m x 5m)		Carbon mass	Total Carbon/sample plot	Total carbon /ha
			North-east corner	South-west corner		North-east corner	South-west corner		North-east corner	South-west corner		North-east corner	South-west corner			

Supporting Service continued

Total Carbon Sink of Trees in M/Tons in 20 years (±5%)	Total Oxygen Released in M/tons in 20 years (±5%)	Total Oxygen Released in Litres in 20 years (±5%)	Total Oxygen released in Litres per day by trees

Plot No:
Date:
Temperature:
Humidity:
Name of the Recorder:
Sample plot GPS coordinate/degree

Species name	Clump dia	Green sound culm								Green damaged culm								Dry sound culm				Dry damaged culm				Decayed culm	Total no. of culms
		1-2 years				Over 2 years				1-2 years				Over 2 years													
		1x2 cm	2x5 cm	5x8 cm	8+ cm	1x2 cm	2x5 cm	5x8 cm	8+ cm	1x2 cm	2x5 cm	5x8 cm	8+ cm	1x2 cm	2x5 cm	5x8 cm	8+ cm	1x2 cm	2x5 cm	5x8 cm	8+ cm	1x2 cm	2x5 cm	5x8 cm	8+ cm		

Bamboo weight form

Plot No:
Date:
Temperature:
Humidity:
Name of the Recorder:
Sample plot GPS coordinate/degree

Species		1x2 cm			2x5 cm			5x8 cm			8+ cm			Dry weight			
Name	code	dia in mm	total length in m	wt in gm	dia in mm	total length in m	wt in gm	dia in mm	total length in m	wt in gm	dia in mm	total length in m	wt in gm	1x2 cm	2x5 cm	5x8 cm	8+ cm

SOIL

Date:
Time:
Location:
Name of the person collecting data:

Location	Area	Soil sample	Carbon content	Nitrogen content	Phosphorus content	Potassium content	Cost of the media in market

Cultural Service

Sl. No.	Institution	No. of persons	Purpose of visit	No. of days visited per year per person	Monetary value per day per person	Total value per year under each category

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MOMENTS CAPTURED DURING WHOLE EXERCISE

STAFFS GEARING UP AFTER TRAINING and DISTRIBUTION OF FIELD KIT

ATTENTIVE TEAM MEMBERS DURING DEBRIEFING SESSIONS

<u>PHOTO SESSION BEFORE COMMENCEMENT OF FIELD EXERCISE</u>

MANEUVERING TOUGH TERRAIN

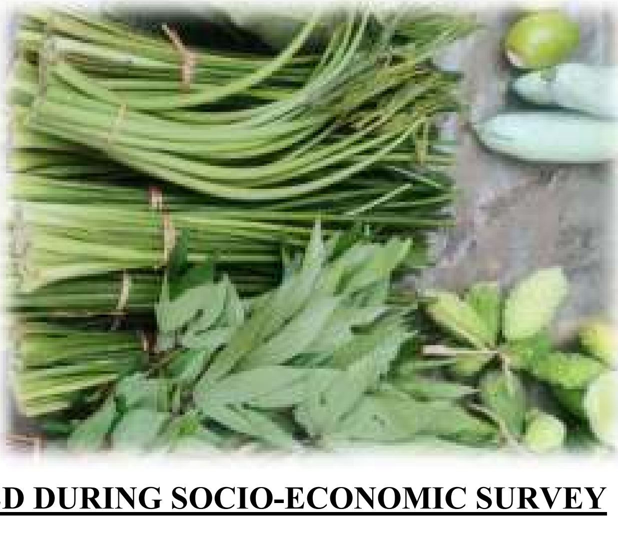
ABSTRACTED IN RIGOROUS FIELD EXERCISE

DEEP INTO WATERS FOR EXECISE ON MEASURING VOLUME OF DISCHARGE

<u>SAMPLES BEING COLLECTED and PACKED FOR LAB ANALYSIS</u>

<u>ENJOYING MOMENTS OF BRIEF RECESS IN BETWEEN FIELD WORK SESSIONS</u>

ENGAGED IN CONVERSATION WITH VILLAGERS DURING SOCIO-ECONOMIC SURVEY



<u>NTFP and MFP COMMONLY OBSERVED DURING SOCIO-ECONOMIC SURVEY</u>

FOREST FOOD PRODUCT OBSERVED DURING LOCAL MARKET SURVEY

DISCUSSING THE VALUE OF CULTURAL SERVICES OF GARBHANGA RF WITH VISITORS, TOUR OPERATORS and NGOS



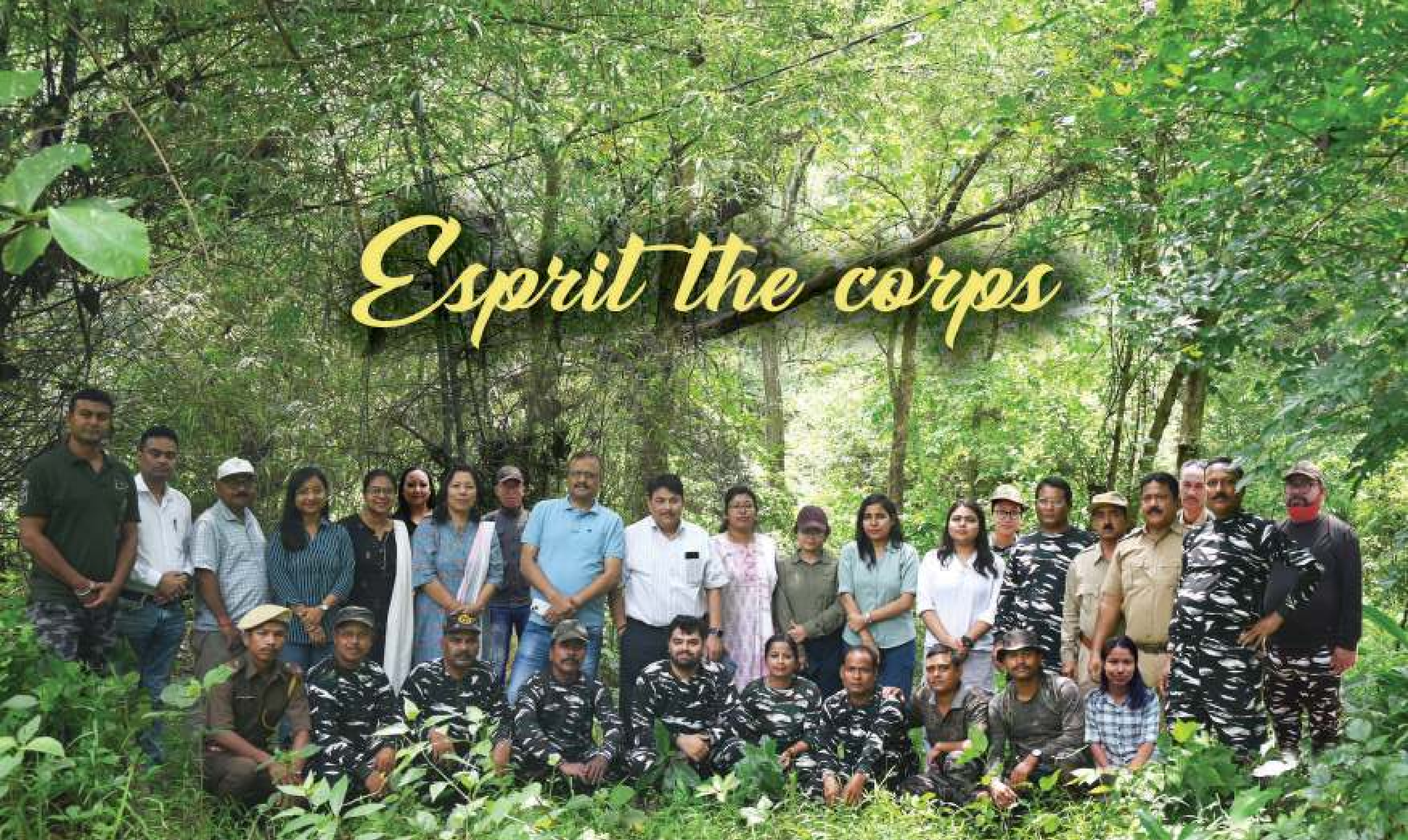

INTERNS FOCUSSED ON DRYING and WEIGHT ANALYSIS

UNDERSTANDING THE PESPECTIVE ON VALUE OF CULTURAL SERVICES FROM UNIVERSITY and SCHOOL STUDENTS

DATA COLLECTION FROM GOVT. and CORPORATE OFFICES ON VALUATION OF WATER STORAGE and USE

GLIMPSES OF FEW FLORA and FAUNA ENCOUTERED IN THE FIELD

Author & Co-Authors

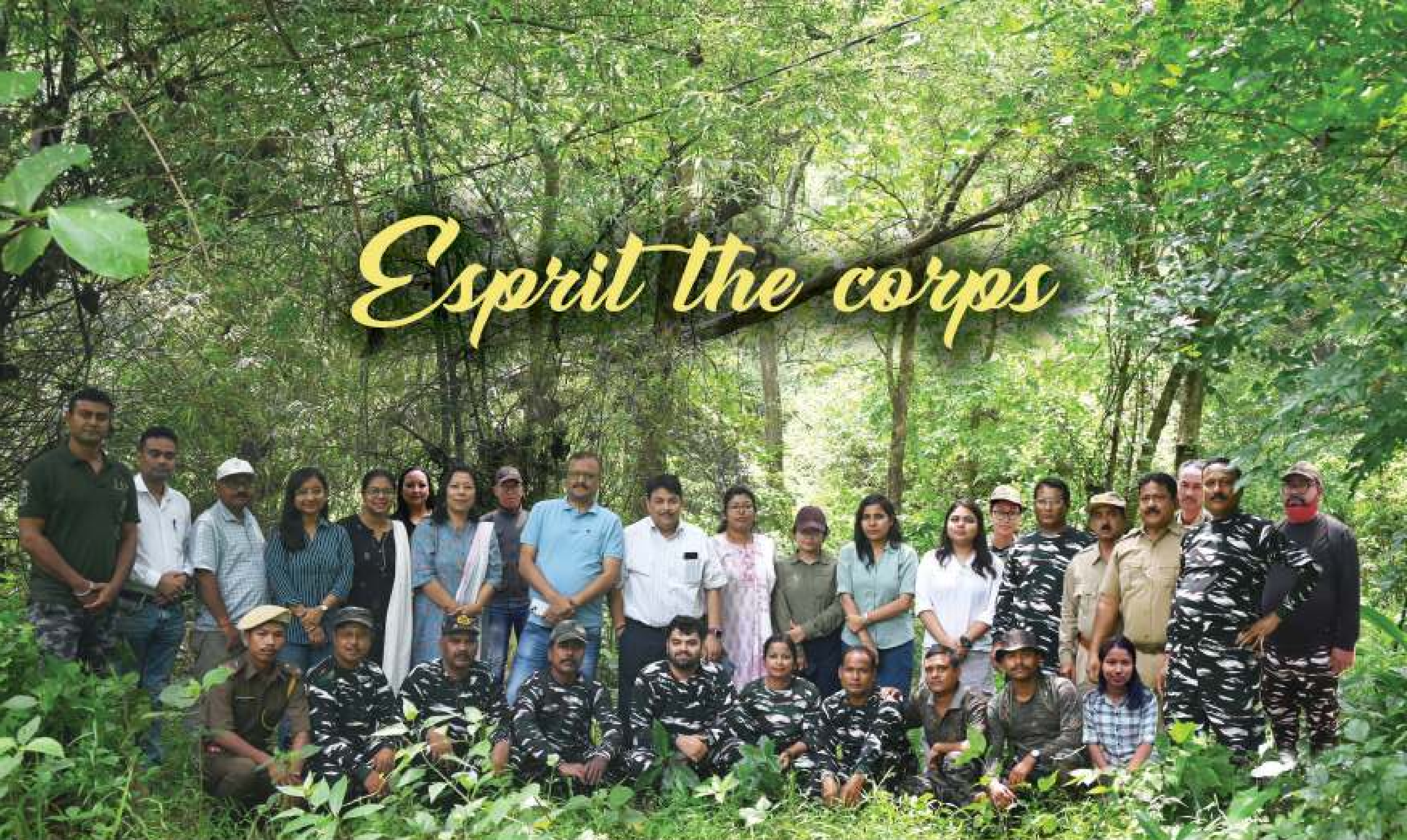


Sitting from left to right

Asim Teron (Fgd.), Dilip Kalita (Fr-1), Tazimullah(Fgd.), Jiten Kalita(Fgd.), Himangshu Bhattacharya (Fr-1), Nirupama Baruah(Fr-1), Phukon Das (Fgd.), Bipul Das (Fr-1), Dibyajyoti Baruah(Fgd.), Monalisa Kali (Fr-1)

Standing From Left to right

Pranjal Prakash Das (Fr-1), Manash Pratim Mahanta (Dy. R) , Dharmeswar Nath (FR), Panchali Hazarika (FR), Kasturi Goswami (FR), Gayatri Gogoi (Fr-1), Himamoni Handique (Research Officer) Abhijit Dolley (FR), Dibakar Deb (Silviculturist, Assam), Mrigen Baruah (ACF), Preeti Buragohain (DCF), Munmi Gogoi (FR), Pallabi Das (FR), Nigar Sultana (FR), Beauty Owary (Fr-1), Jan Ali Borah (Fgd.), Hitesh Kalita (Fgd.), Moidul islam (Fr-II), Bishon Basumatary (Fr-1), Pradip Mahanta (Fr-II), Pranab Deka (Fr-1)



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