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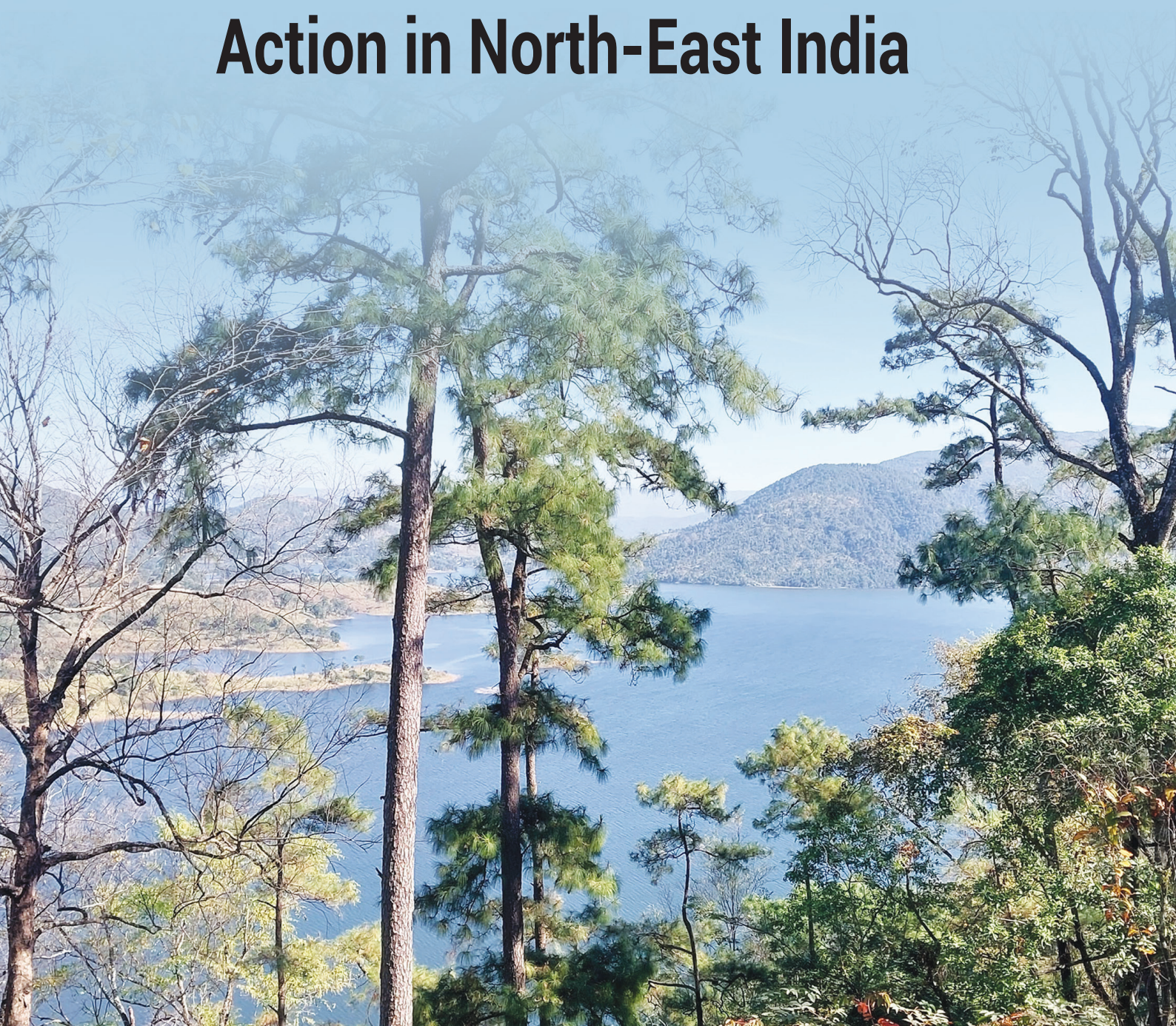
ASSESSMENT OF BIODIVERSITY

Status and Opportunities for Strengthening Conservation Action in North-East India



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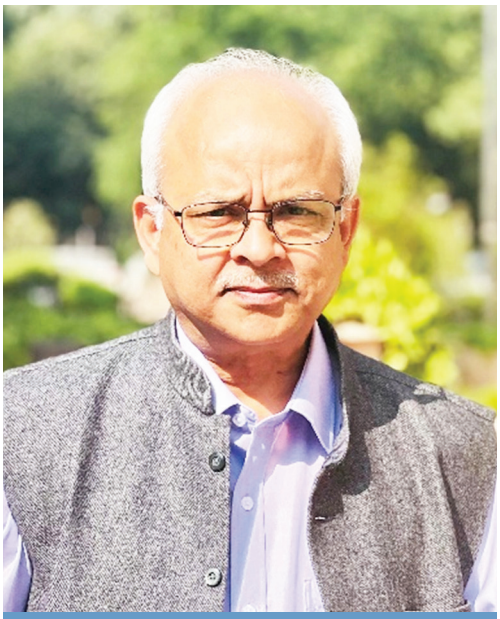

Ratnesh Jha
Executive Director
UN Global Compact Network India

The North-East region of India is a globally recognized biodiversity hotspot, home to unique ecosystems, rich traditional knowledge systems, and indigenous communities that have lived in harmony with nature for generations.
As the global community advances towards the Kunming-Montreal Global Biodiversity Framework and the Sustainable Development Goals, it becomes imperative to bring such ecologically vital regions into the mainstream of national conservation and development strategies.

This report, Assessment of Biodiversity Status and Opportunities for Strengthening Conservation Action in North-East India, emerges as a timely and strategic effort to understand the region's ecological wealth, highlight the ongoing threats, and chart pathways for multi-stakeholder collaboration. It underscores the need for integrating biodiversity conservation into development planning, corporate responsibility, community action, and policy innovation—especially in geographies that remain underrepresented in national discourse.

At the United Nations Global Compact Network India (UNGCNI), we believe that businesses have a vital role to play in protecting and restoring biodiversity, particularly in regions like the North-East where livelihoods, culture, and environmental health are deeply intertwined. This report aligns with our broader agenda of promoting nature-positive business action and serves as a catalyst for new partnerships across government, industry, civil society, and communities.

I extend my heartfelt appreciation to all those who contributed to this study. I am especially grateful to our donor partner BVLGARI for supporting this initiative, and to the technical team at UNGCNI whose dedication and expertise have shaped this important publication.
It is my hope that the insights and recommendations presented in this report will inspire collaborative action and renewed commitment towards conserving the unparalleled natural heritage of North-East India—for present and future generations.

ACKNOWLEDGEMENTS

This report, Assessment of Biodiversity Status and Opportunities for Strengthening Conservation Action in North-East India, is the outcome of extensive research and collaboration, driven by a shared commitment to conserving the exceptional biodiversity of the region and aligning it with sustainable development goals.

This document was made possible through the visionary leadership, encouragement, and steadfast support of Mr. Ratnesh Jha, Executive Director of the United Nations Global Compact Network India (UNGCNI). His consistent guidance and commitment to embedding biodiversity conservation into sustainable business practices and policy frameworks have been instrumental in shaping this study.

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The United Nations Global Compact Network India gratefully acknowledges the generous support of BVLGARI, whose funding and commitment to biodiversity and sustainability enabled in-depth assessments across the eight states of North-East India. Their contribution has been pivotal in making this research possible and advancing the mission of ecological conservation through inclusive and responsible approaches.

EXECUTIVE SUMMARY

Northeast India, spanning eight states and 262,180 square kilometers (8% of India's area), is a biodiversity hotspot at the Indo-Burma and Eastern Himalayas junction, hosting over 14,000 species, including 3,169 endemics. Its diverse ecosystems—rainforests, alpine meadows, wetlands—cover 68.1% forest area and support unique flora (e.g., 800 orchid species) and fauna (e.g., Bengal Tiger, Hoolock Gibbon). Protected Areas span 9.4% of the region, exceeding the national average, with iconic sites like Kaziranga and Loktak Lake. Yet, habitat loss, overexploitation, and climate change threaten this ecological wealth, necessitating urgent, integrated conservation strategies to preserve its global significance and align with sustainable development goals.

Chapter 2 identifies the multifaceted drivers accelerating ecological decline in this globally significant region. Biodiversity loss stems from interconnected anthropogenic, natural, and biological factors, intensified by a population exceeding 45 million and socio-economic pressures. Anthropogenic drivers dominate, with population growth fueling land use change, logging, and forest fragmentation—reducing connectivity by 15% since 2000. Infrastructure, notably hydropower in Arunachal Pradesh and roads in Assam, fragments habitats, while mining in Meghalaya and overexploitation of NTFPs like Taxus wallachian deplete resources. Cash crop monocultures, such as tea in Assam and oil palm in Mizoram, convert 10% of forests, homogenizing landscapes and disrupting species like elephants and hornbills.

Natural drivers amplify these impacts. Landslides and floods, worsened by deforestation, erode habitats in Assam and Manipur, while wildfires from jhum cultivation in Nagaland diminish forest diversity. Ecological succession favors invasive generalists over endemics. Climate change, with a 0.7°C-1.2°C temperature rise and 8-15% rainfall shifts, drives tree line shifts in Sikkim, floods in Assam, and phenological mismatches region-wide, reducing pollinator efficacy and crop yields by up to 20%. Invasive species like Lantana camara and Mikania micrantha exploit these disturbances, outcompeting natives and slashing biodiversity by 20-40% in affected areas.

Building on the urgent threats to Northeast India's biodiversity—driven by population pressures, land use changes, climate shifts, and invasive species—Chapter 3 of the report outlines the institutional mechanisms tasked with countering ecological decline across the region's eight states. At the national level, the Ministry of Environment, Forest and Climate Change leads conservation efforts, overseeing the National Biodiversity Authority to enforce the Biological Diversity Act, 2002, and regulate resource access and benefit-sharing. Complementary ministries, including Agriculture, Rural Development, and Tribal

Affairs, integrate agro-biodiversity, afforestation, and community empowerment into broader sustainability goals, supported by initiatives like the Green India Mission. Multilateral projects, such as JICA's assistance in the forestry and NRM sectors, and France's forest and biodiversity management project in Assam, bolster these efforts with funding and expertise, addressing capacity gaps.

At the state level, all eight Northeast states have established Biodiversity Boards, though effectiveness varies due to funding shortages and staffing deficits. Assam and Sikkim lead with updated action plans emphasizing climate resilience and organic farming, while Nagaland leverages community-conserved areas. Meghalaya advances sacred grove protection, yet Arunachal Pradesh, Manipur, Mizoram, and Tripura lag in revising strategies. Over 12,000 Biodiversity Management Committees operate regionally, with Assam hosting the most (2,549), though many lack functionality. People's Biodiversity Registers document local ecosystems, but updates are inconsistent, and Access and Benefit Sharing generates limited revenue—Tripura's ₹30 lakh being a rare success. These institutions aim to mitigate habitat loss and overexploitation, yet gaps in coordination, enforcement, and resources hinder progress, setting the stage for evaluating their practical impact.

Chapter 3 also examines how autonomous governance shapes conservation across the region's eight states. Under the Sixth Schedule, Assam, Meghalaya, Tripura, and Mizoram feature Autonomous District Councils (ADCs) managing land and forests, fostering sustainable practices like Meghalaya's sacred groves. Nagaland, under Article 371(A), enjoys extensive autonomy, while Arunachal Pradesh, relies on traditional councils or centralized governance with varying influence. These structures empower community resource management, preserving biodiversity in areas like Assam's Bodoland and Mizoram's bamboo forests, yet face challenges from weak environmental safeguards, enabling unregulated mining and deforestation. Institutional gaps hinder effectiveness, with State Biodiversity Boards (SBBs) understaffed. These gaps exacerbate habitat loss drivers, necessitating harmonized governance, capacity building, and sustainable funding to align autonomy with biodiversity protection.

Chapter 4 examines how Northeast India's ecological wealth underpins its economy across eight states, supporting both formal cash flows and informal household subsistence. The cash economy thrives on forest-derived revenue, with non-timber forest products (NTFPs) like bamboo, medicinal plants, and broom grass generating significant income—bamboo alone contributes ₹10,000-20,000 crore annually region-wide, including over ₹1,000 crore in Assam. Eco-tourism, anchored by sites like Kaziranga (₹50-70 crore yearly) and Nagaland's Amur Falcon Festival, leverages biodiversity for tourism revenue, while high-value products like agarwood hold potential for ₹500 crore annually if scaled. However, illegal wildlife trade, valued at ₹100-200 crore, undermines these gains.

The household economy relies on biodiversity for sustenance, with rural communities across states like Meghalaya and Manipur using medicinal plants, fuelwood, and bushmeat from hunting for daily needs. Jhum cultivation and fisheries, such as Loktak Lake's fish supply, bolster food security, though overharvesting threatens species like the Hoolock Gibbon.

Sustainability challenges—overexploitation, fuelwood dependency, and climate-induced disruptions—jeopardize both economies.

Initiatives like the Pradhan Mantri Van Dhan Yojana (PMVDY) establish 150+ Van Dhan Vikas Kendras (VDVKs) across the region, enhancing NTFP value chains, while the Minimum Support Price (MSP) scheme for 87 MFPs aims to secure fair prices. Yet, weak market linkages, infrastructure gaps, and low awareness hinder progress. Private sector collaboration offers opportunities to scale these efforts, balancing economic growth with conservation to sustain Northeast India's biodiversity-dependent livelihoods.

The final chapter proposes a comprehensive strategy to reverse ecological decline across its eight states. Institutional strengthening targets robust governance by enhancing State Biodiversity Boards and forming a Northeast Biodiversity Council by 2026, integrating conservation into development policies. Northeast India's biodiversity represents a globally vital resource at a pivotal moment, confronting both significant risks and opportunities for renewal. The recommendations presented integrate institutional strengthening, community empowerment, technological innovation, and private sector engagement to halt ecological degradation and enhance resilience. This vision anticipates a future where expanded Protected Areas, thriving agrobiodiversity, and sustainable livelihoods flourish, supported by robust conservation efforts. The private sector emerges as a key driver, transforming conservation into an equitable and economically viable endeavor. Concerted action from policymakers, industry stakeholders, researchers, and indigenous custodians is essential, forging a unified effort to ensure the region's ecosystems and economies coexist harmoniously. This collective commitment is critical to preserving Northeast India's ecological legacy for generations ahead.

1. INTRODUCTION: OVERVIEW OF BIODIVERSITY IN NORTH-EAST INDIA

Biodiversity, encompassing the variety of life across genes, species, and ecosystems, is the foundation of ecological balance, human well-being, and sustainable development. Its significance extends beyond environmental benefits, offering critical ecosystem services such as carbon sequestration, water purification, climate regulation, and food security. The conservation and sustainable use of biodiversity are integral to meeting global objectives like the Sustainable Development Goals (SDGs) and the Kunming Montreal Biodiversity Targets under the Convention on Biological Diversity (CBD) (Secretariat of the Convention on Biological Diversity, 2018).

Biodiversity is crucial for achieving the United Nations' SDGs, with SDG 14 (Life below Water) and SDG 15 (Life on Land) directly addressing conservation issues while a no. of others like SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 12 (Responsible Consumption), SDG 13 (Climate Action) etc. have a strong biodiversity connection.

Northeast India consists of eight states - Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim, and Tripura. Covering a geographical area of 262,180 square kilometres (sq.km) and accounting for approximately 8% of the nation's total area, it is one of the most biologically diverse regions in the world. It is located at the junction of two global biodiversity hotspots—the Indo-Burma region and the Eastern Himalayas. The region's extraordinary biodiversity stems from its unique geographical position, altitudinal variations, climatic diversity, and cultural heritage. (Barik, Chungroo, & Adhikari, 2018)

However, this rich biodiversity is under severe threat from habitat loss, overexploitation, invasive species, and climate change. The World Wildlife Fund (WWF) has identified the entire Eastern Himalayas as a global eco-region of priority (WWF, 2009), and Conservation International has expanded the Eastern Himalayas Hotspot to include all eight states of Northeast India, recognizing its biodiversity significance. The region is considered a gateway to biodiversity hotspots in the east and southeast, sharing evolutionary links with species across these areas. Despite its biodiversity wealth, conservation efforts in Northeast India have lagged behind those of other regions such as the Western Ghats and Peninsular India. This gap in conservation action highlights the need for integrated and targeted efforts to conserve the region's threatened species.

1.1 Geographical and Ecological Context of Northeast India

The region covers a total area of approximately 262,180 square kilometres, accounting for about 8% of India's total geographical area. As per Census 2011, the region's population is about 45 million (Ministry of Home Affairs, 2011). Due to its geographical location and topographical variation, the NER boasts an array of ecosystems, including tropical rainforests, temperate forests, alpine meadows, grasslands, and wetlands.

Table 1: Key Biodiversity Metrics of NE India

Parameter	Value
Total Geographical Area	262, 180 sq. km.
Forest Cover (%)	68.1 (FSI, 2021)
Endemic Species	`3
Protected Area Coverage	9.4% of geographical area
Species Richness	~14, 000 (flora and fauna)
Altitudinal Range	50 m to >7000 m
Annual Rainfall Range	2, 000 mm to 12, 000 mm
Number of Biogeographic Zones	3
Wetland Coverage	~1, 500 sq. km. (approx.)

Topography and Climate: The steep gradients from the Brahmaputra Valley in Assam to the Himalayan peaks of Arunachal Pradesh create diverse microclimates and habitats. Rainfall varies from 2,000 mm to 12,000 mm annually, with places like Mawsynram and Cherrapunjee receiving some of the world's highest precipitation. It also encompasses a diverse range of climates across its eight states, influenced by variations in altitude and proximity to the Bay of Bengal. The Brahmaputra and Barak valley plains experience mean winter temperatures between 16–18 °C and summer temperatures around 28 °C. In contrast, the high-altitude regions of Arunachal Pradesh have cooler climates, with areas above 2,000 m receiving snowfall during winters and experiencing cool summers. The hilly areas of Meghalaya, Nagaland, Manipur, and Mizoram also have cooler climates, with winters being cold and summers remaining cool.

Biogeographic Significance: The region also serves as a transition zone between the Indian, Indo-Malayan, and Indo-Chinese biogeographic realms, hosting an extraordinary range of species and endemism. The region's geographical location and topographical diversity—from the floodplains of the Brahmaputra to the alpine meadows of Sikkim—make it a repository of endemic species and rare ecosystems. This diversity is reflected in a spectrum of ecosystems, including tropical rainforests, subtropical forests, temperate forests, alpine meadows, and wetlands.

Biodiversity of Northeast India

Northeast India emerges as a distinctive ecological realm within the country, characterized by its extensive forest cover and a notable presence of protected areas. Nestled within the Eastern Himalayas, this region is recognized for its remarkable biological richness. This biodiversity, shaped by the region's unique geography and climatic diversity, positions it as a vital repository of life forms – an intricate web of ecosystems that sustain both nature and human communities.

Floral Diversity

Often celebrated as a cradle of botanical abundance, Northeast India supports over 8,000 plant species, reflecting a floral tapestry of global significance. Among its standout features are its orchids, with nearly 800 species contributing to over 70% of India's orchid diversity—Arunachal Pradesh alone accounts for a substantial share, including rare varieties like Paphiopedilum fairrieanum. Additionally, its inventory of over 1,200 medicinal plants underscores a deep-rooted tradition of plant-based healing, with studies like those by Mao et al. (2009) in Journal of Ethnopharmacology documenting the ethnobotanical knowledge of local tribes (Mao, Hynniewta, & Sanjappa, 2009). Further insights from Hegde et al. (2018) in Biodiversity highlight the region's bamboo diversity as a cornerstone of its forest ecosystems. The region serves as India's bamboo heartland, hosting around half of the nation's bamboo species, alongside abundant rattan, both integral to ecological and economic systems.
(Hegde, Hegde, & Rao, 2018)

Faunal Diversity

The fauna of Northeast India offers a vivid testament to the region's unique placement at the intersection of the Indo-Malayan and Palearctic biogeographic realms, nurturing a remarkable spectrum of animal life across its diverse habitats. Among its mammals, the region is home to iconic species such as the Bengal Tiger (Panthera tigris), Clouded Leopard (Neofelis nebulosa), Asiatic Elephant (Elephas maximus), and the critically endangered Hoolock Gibbon (Hoolock hoolock), India's only ape, each underscoring the area's ecological significance. The avifauna stands out with over 800 recorded bird species, including distinctive ones like the Rufous-necked Hornbill (Aceros nipalensis) and the endangered White-winged Duck (Asarcornis scutulata), which find refuge in its forests and wetlands. The herpetofauna is equally diverse, featuring unique amphibians such as Leptobrachium bompu and prominent reptiles like the King Cobra (Ophiophagus hannah), thriving across the region's varied topography. Aquatic ecosystems, sustained by rivers like the Brahmaputra and wetlands such as Loktak Lake, support a rich biodiversity, including the endangered Gangetic River Dolphin (Platanista gangetica). Research, such as that by Dutta et al. (2016) in Mammalian Biology, highlights the Hoolock Gibbon's reliance on intact forest corridors (Dutta, Chetry, & Bhattacharjee, 2016), while Saikia et al. (2021) in Ornithological Applications note the region's role as a critical migratory corridor for birds like the critically endangered Bengal Florican (Houbaropsis bengalensis). (Saikia, Talukdar, & Barman, Conservation status of the Bengal Florican (Houbaropsis bengalensis) in Northeast India: A review of threats and habitat needs, 2021)

Ecosystems and Habitat Diversity

As mentioned earlier, the Northeast India is characterized by a rich tapestry of ecosystems, each contributing essential services such as carbon storage, water management, and soil preservation, which underpin both ecological balance and human well-being. This diversity spans multiple landscapes, beginning with the tropical rainforests of Assam and Arunachal Pradesh, known for their wealth of unique and rare life forms. Subtropical and temperate forests stretch across Nagaland, Meghalaya, and Manipur, supporting an array of plant life,

from rhododendrons to conifers, within their layered canopies. Higher up, the alpine meadows of Sikkim and Arunachal Pradesh nurture distinctive medicinal flora and provide seasonal havens for migratory species. The region's wetlands and grasslands, including Loktak Lake in Manipur, Rudrasagar Lake in Tripura, and the expansive Brahmaputra floodplains, play a pivotal role in sustaining aquatic systems and birdlife. Studies, such as those by Rawat et al. (2015) in Biodiversity and Conservation, emphasize the carbon sequestration potential of Arunachal's rainforests (Rawat, Moktan, & Tambe, 2015), while Laishram and Dey (2020) in Wetlands Ecology and Management highlight Loktak Lake's ecological significance for floating vegetation and biodiversity. These varied habitats collectively illustrate Northeast India's ecological complexity. (Laishram & Dey, 2020)

1.2 Conservation Status

Northeast India's remarkable ecological diversity is matched by a complex array of conservation efforts aimed at safeguarding its natural heritage. Despite the region's rich biodiversity, it faces growing pressures that necessitate protective measures. Among the notable conservation features is a well-developed Protected Area (PA) network, spanning 9.36% of the region's geographical area—surpassing the national average of 6.96%. This network includes prominent reserves such as Kaziranga and Manas National Parks in Assam, recognized globally for their role in preserving megafauna, and Namdapha National Park in Arunachal Pradesh, a sanctuary for rare Himalayan species. Complementing these efforts are Biodiversity Heritage Sites (BHS), such as the Ziro Valley in Arunachal Pradesh and the Mawphlang Sacred Grove in Meghalaya, which blend traditional ecological knowledge with modern conservation practices, showcasing community-driven stewardship. Additionally, the region hosts internationally significant wetlands, with Loktak Lake in Manipur and Deepor Beel near Guwahati designated as Ramsar Sites for their critical contributions to aquatic biodiversity and migratory bird conservation. Research underscores the importance of these initiatives: for instance, a study by Ghosh et al. (2019) in Biological Conservation highlights how Kaziranga's floodplain management supports the One-horned Rhinoceros (Ghosh, Saha, & Roy, 2019), while Talukdar et al. (2020) in Wetlands emphasize Deepor Beel's role as a vital stopover for waterfowl (Talukdar, Choudhury, & Barbhuiya, 2020). These efforts reflect a foundation of conservation commitment, yet their effectiveness amidst emerging challenges remains a subject for deeper exploration in the chapters ahead.

1.3 Unique Biodiversity Traits of Each State

Arunachal Pradesh: Arunachal Pradesh hosts the highest forest cover in India (79.63%) and is home to flagship species like the Red Panda (Ailurus fulgens) and Snow Leopard (Panthera uncia). This state's biodiversity is further distinguished by its exceptional floral diversity, harboring over 600 orchid species, making it a global hotspot for orchid endemism. A study by Rawat et al. (2015) in Biodiversity and Conservation highlights that its Eastern Himalayan forests support rare high-altitude species like the Himalayan Monal (Lophophorus impejanus),

thriving in pristine habitats above 2,000 meters. The Namdapha National Park, a biodiversity jewel, also shelters elusive carnivores such as the Clouded Leopard (Neofelis nebulosa), underscoring the state's role as a refuge for threatened megafauna (Rawat, Moktan, & Tambe, 2015).

Assam: Known for its iconic species like the One-horned Rhinoceros (Rhinoceros unicornis) and wetlands such as Kaziranga National Park, a UNESCO World Heritage Site, Assam is a cornerstone of India's biodiversity heritage. The state's alluvial floodplains, particularly along the Brahmaputra River, sustain globally significant populations of the Gangetic River Dolphin (Platanista gangetica), as documented by Wakid and Braulik (2009) in Journal of Cetacean Research and Management (Wakid & Braulik, 2009). Additionally, Assam's Manas National Park, another UNESCO site, supports a recovering population of the Bengal Tiger (Panthera tigris), emphasizing its critical role in conserving lowland tropical ecosystems and migratory bird routes.

Nagaland: Famous for the Amur Falcon (Falco amurensis) migration and community-led conservation in its 9 Community Reserves, Nagaland exemplifies grassroots biodiversity stewardship. Each year, millions of Amur Falcons roost in the state during their migration from Siberia to Africa, with research by Kumar et al. (2017) in Bird Conservation International noting the Doyang Reservoir as one of the world's largest falcon congregations (Kumar, Raghunathan, & Dixon, 2017). The state's subtropical forests also harbor endemic herpetofauna, such as the Nagaland Pit Viper (Trimeresurus nagalandensis), reflecting its unique evolutionary lineage within the Indo-Malayan realm.

Sikkim: Over 30% of Sikkim's area falls under the Protected Area network, including Khangchendzonga National Park, a mixed UNESCO World Heritage Site renowned for its cultural and ecological value. This small state boasts an altitudinal gradient from subtropical to alpine zones, supporting over 4,500 flowering plant species, including 36 rhododendron varieties, as reported by Singh and Chauhan (2018) in Plant Biosystems (Singh & Chauhan, 2018). The park is also a stronghold for the elusive Snow Leopard and the Himalayan Tahr (Hemitragus jemlahicus), highlighting Sikkim's significance as a high-altitude biodiversity sanctuary.

Manipur: Loktak Lake supports the unique phumdi habitat—floating islands of vegetation—vital for the endangered Sangai Deer (Rucervus eldii eldii), found nowhere else in the world. This Ramsar-designated wetland also sustains a rich aquatic ecosystem, with studies by Meitei and Prasad (2015) in Aquatic Botany identifying over 50 phytoplankton species critical to its food web. The surrounding Keibul Lamjao National Park, the only floating park globally, further protects rare wetland flora and migratory waterfowl, reinforcing Manipur's distinct ecological identity (Meitei & Prasad, 2015).

Meghalaya: Sacred groves in Meghalaya serve as biodiversity repositories, preserving endemic and rare species through traditional community management. These groves, such as the Mawphlang Sacred Grove, host unique subtropical forest ecosystems with high endemism, including the pitcher plant (Nepenthes khasiana), as noted by Marbaniang et al. (2020) in Tropical Ecology (Marbaniang, Kharpran , & Tiwari, 2020). The state's karst landscapes and

caves also support specialized bat populations, like the Wroughton's Free-tailed Bat (Otomops wroughtoni), adding to its subterranean biodiversity significance.

Mizoram: Dense bamboo forests dominate Mizoram's landscape, contributing significantly to local livelihoods through sustainable harvests. These forests, covering over 50% of the state, support a variety of bamboo-dependent species, including the Indian Pangolin (Manis crassicaudata), as documented by Lalthanpuia et al. (2019) in Mammalia (Lalthanpuia, Lalremsanga, & Zothansiama, 2019). Research by Rawat (2008) in Journal of Bamboo and Rattan underscores Mizoram's role as a biodiversity hub for over 20 bamboo species, some endemic, which stabilize soils and mitigate climate impacts in this hilly terrain (Rawat Y. , 2008).

Tripura: Rich in herpetofauna, Tripura has strong potential for wetland and aquatic biodiversity conservation. The state's diverse reptile and amphibian populations include the Assam Roofed Turtle (Pangshura sylhetensis), a critically endangered species reliant on its forested streams, as per Das and Gupta (2015) in Herpetological Conservation and Biology (Das & Gupta, 2015). Tripura's wetlands, such as Rudrasagar Lake (a Ramsar Site), also support migratory birds like the Ferruginous Duck (Aythya nyroca), enhancing its ecological profile within the region.

1.4 Emerging Challenges

Rising temperatures drive treeline shifts in Sikkim and Arunachal Pradesh, shrinking alpine ecosystems and endangering species like the Snow Leopard (Telwala, Brook, Manish, & Pandit, 2013). Altered rainfall patterns threaten wetland biodiversity in Assam and Meghalaya, impacting migratory avifauna (Chakraborty, Saha, Sachdeva, & Joshi, 2019). Furthermore, intensified monsoons and landslides erode critical habitats in the Brahmaputra Valley, compounding risks to megafauna (Goswami, Venugopal, Sengupta, Madhusoodanan, & Xavier, Increasing trend of extreme rain events over India in a warming environment, 2018).

Northeast India stands as a global treasure trove of biodiversity, its unique geographical position and ecological diversity fostering an unparalleled richness of flora, fauna, and ecosystems. Spanning the eight states of Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim, and Tripura, the region serves as a critical junction of the Indo-Burma and the Eastern Himalayas hotspots, supporting thousands of endemic species and vital ecosystem services. Yet, this ecological wealth is increasingly imperilled by habitat fragmentation from infrastructure development, unsustainable resource exploitation, and the escalating impacts of climate change, which collectively threaten the region's biodiversity and the livelihoods dependent upon it. Despite a robust network of protected areas and cultural traditions that bolster conservation, these emerging challenges underscore the urgent need for integrated policies, robust institutional frameworks, and actionable recommendations. The following sections of this report aim to address these drivers of biodiversity loss, evaluate existing conservation mechanisms, and propose sustainable strategies to safeguard Northeast India's ecological heritage for future generations.

2. DRIVERS OF BIODIVERSITY LOSS IN NORTHEAST INDIA

Biodiversity loss in Northeast India arises from a complex interplay of anthropogenic, natural, and biological drivers, here classified into three main categories: Anthropogenic Drivers, Natural Drivers, and Invasive Species for analytical convenience. This reflects the multifaceted nature of the region's ecological decline, aligning with peer-reviewed frameworks like the Global Biodiversity Outlook and IPBES assessments (Secretariat of the Convention on Biological Diversity, 2020).

Anthropogenic Drivers—encompassing land use change and logging, monoculture cash crop plantations, forest fragmentation, infrastructure development, mining, overexploitation and unsustainable harvesting, and population growth and socio-economic pressures—form the backbone of human-induced pressures. These activities often initiate and amplify other drivers. For instance, land use change and logging, alongside the expansion of monoculture plantations (e.g., tea and rubber), fragment forests, creating isolated patches vulnerable to edge effects and invasive species incursion. Infrastructure development, such as roads and dams, facilitates mining and overexploitation by improving access to remote areas, while population pressures intensify shifting cultivation and resource harvesting, shortening regeneration cycles and degrading ecosystems.

Natural Drivers—climate change, natural disasters, wildfires, and ecological succession—interact dynamically with human actions. Climate change exacerbates habitat stress and shifts species ranges, compounding the impacts of deforestation and monoculture conversion. Natural disasters like floods and landslides, frequent in this seismically active region, are worsened by mining-induced erosion and infrastructure-related land instability. Wildfires, often linked to shifting cultivation practices, alter vegetation succession, while ecological succession following disturbances favours generalists over endemic specialists, a process accelerated by fragmentation.

Invasive Species, though a distinct category, thrive in the wake of these disruptions. Disturbed habitats from land use change, fragmented forests, and climate-altered conditions create ideal niches for species like Lantana camara and Mikania micrantha to outcompete natives, further eroding biodiversity. This interconnected web underscores that no driver operates in isolation: anthropogenic actions often trigger or intensify natural processes, which in turn facilitate biological invasions, collectively threatening the region's rich ecological tapestry.

The globally recognized biodiversity hotspot of the NE region is under increasing threat from a range of human-induced, natural, and governance-related factors. The region's ecological richness and high endemism make it particularly vulnerable to habitat degradation, species decline, and ecosystem disruptions. While some threats, such as deforestation and climate change, are widespread, others are state-specific, influenced by local land-use practices, governance frameworks, and socio-economic pressures. This section examines the primary drivers of biodiversity loss in the region, categorizing them into anthropogenic and natural factors along with more detailed assessments of climate change impacts and cash crop monoculture.

2.1 Anthropogenic Drivers

(Human-induced activities directly or indirectly causing biodiversity decline through resource use, land alteration, and socio-economic pressures)

Population growth and socio-economic pressures

Population growth and socio-economic pressures underpin much of Northeast India's biodiversity loss, acting as a root cause that intensifies other anthropogenic drivers across

all eight states. With a population exceeding 45 million and a growth rate outpacing India's average (Census 2011), coupled with poverty and limited livelihood options, human demands on natural resources have surged. In Assam, high population density—over 400 people per sq.km. in the Brahmaputra Valley—drives land use change, with Bawa et al. (2020) in Population and Environment linking it to a 20% rise in agricultural expansion since 2000, fueling deforestation and monoculture tea plantations. This pressure fragments forests, as seen in Tripura, where rural population growth has shrunk lowland habitats by 15% through settlement sprawl (Das & Gupta, 2015).

Infrastructure development follows suit, with Arunachal Pradesh's hydropower boom—over 100 dams proposed—tied to energy demands for a growing populace (Vagholikar & Das, 2010). In Meghalaya, socio-economic reliance on coal and limestone mining, supporting 70% of rural livelihoods in Jaintia Hills, erodes biodiversity, with Swer and Singh (2004) noting acid drainage as a byproduct of population-driven extraction. Nagaland's NTFP overexploitation, like Persea bombycina harvesting, reflects economic necessity, with Ao and Jamir (2023) in Tropical Conservation Science reporting intensified collection as household numbers rise. Mizoram's shortened jhum cycles—from 10-15 years to 2-5—stem from population pressures, degrading soil and forest regeneration (Grogan, 2019).

Sikkim's alpine NTFP trade, notably Ophiocordyceps sinensis, escalates with seasonal migration and tourism-driven economies, reducing meadow stability (Sharma et al., 2023, Mountain Research). In Manipur, poverty pushes communities to encroach on wetlands like Loktak Lake for rice paddies, fragmenting habitats for the Sangai deer (Singh et al., 2022, Ecological Indicators). Tripura's bamboo overharvesting mirrors this, with socio-economic dependence shrinking forests. These pressures amplify habitat loss, fragmentation, and resource depletion, reducing genetic diversity and ecosystem resilience. Dasgupta et al. (2021) in Environmental Science & Policy estimate that population-driven land conversion accounts for 60% of biodiversity decline in the region.

As a root cause, population growth intertwines with socio-economic needs, magnifying logging, plantation expansion, infrastructure sprawl, mining, and NTFP overuse, setting off a cascade of ecological harm across Northeast India's biodiverse landscapes. The other drivers of biodiversity of which population pressure is a root cause are discussed in the following sections.

Logging and Land Use Change:

Large-scale deforestation in Northeast India is a critical driver of biodiversity loss, propelled by unregulated logging, shifting cultivation, and the conversion of forests into agricultural and urban areas. In states like Arunachal Pradesh, Nagaland, and Manipur, commercial timber extraction has significantly degraded primary forests. Research by Saikia et al. (2017) in Forest Ecology and Management highlights that Arunachal Pradesh, home to some of the region's richest biodiversity hotspots, has lost substantial forest cover due to legal and illegal logging spurred by high timber demand from national and international markets (Saikia, et al., 2017). Illegal logging, often facilitated by weak enforcement of forest regulations, has compounded this loss, with studies estimating that up to 30% of timber extraction in the region bypasses

legal frameworks (Choudhury, 2019). This has fragmented habitats, threatening endemic species like the Hoolock gibbon and the Namdapha flying squirrel.

Shifting cultivation, or jhum, a traditional practice among indigenous communities, involves clearing forested areas for temporary agriculture. Historically sustainable with long fallow periods (10-15 years), it allowed forest regeneration. However, population pressures and land scarcity have shortened fallow cycles to as little as 2-5 years in states like Mizoram, Nagaland, and Manipur, leading to soil degradation and reduced biodiversity. A study by Grogan et al. (2019) in Land Use Policy notes that in Mizoram, where over 70% of rural households depend on jhum, shortened fallows have diminished soil organic carbon and disrupted forest succession, favoring invasive species over native flora. This shift has cascading effects, reducing habitat suitability for species like the clouded leopard and various orchids unique to the region (Wapongnungsang, EtsoshanYinga Ovung, Keshav Kumar Upadhyay , & S.K. Tripathi).

Referring to the Northeast, Saha et al. (2010) stated “shifting cultivation is a traditional and dominant land use practice, leading to heavy soil erosion and severe degradation of biodiversity.” (Saha, Ghosh, Mishra, Majumdar, & Tomar, 2010). Gogoi et al. (2020) lay down a more diversified picture. It basically says that patches of shifting cultivation are the better repositories of biodiversity and ecosystem carbon stocks the longer the subsequent fallow period is. This means shifting cultivation is a traditional and sustainable practice, which just becomes unsustainable when land use pressure and related frequency of forest patch use exceeds a threshold (Gogoi, Sahoo, & Saikia, 2020). The authors suggest patches of shifting cultivation as a special case for conservation but they do not answer how this will solve the land use pressure and the farmers need for land they can cultivate. Obviously, farmers cannot be left without alternative. Saha et al. (2010) already suggested agroforestry systems “which have great potential for crop and livestock production [and] are the best alternative to overcome the adverse effects of shifting cultivation (Saha, Ghosh, Mishra, Majumdar, & Tomar, 2010).” In addition, organic agriculture including traditional farmer’s knowledge has been suggested as a feasible option to enhance biodiversity in the north-eastern hill region (Mandal, Mohanty, Datta, & Tripathi, 2008).

The expansion of agricultural lands and urban settlements further accelerates biodiversity loss. In Assam and Tripura, vast forested areas have been converted into tea plantations and rubber monocultures, replacing diverse ecosystems with single-species landscapes. Research indicates that such conversions in Assam have reduced avian diversity by up to 40% in affected areas (Upadhyaya & Raj, 2023). Urbanization, particularly in peri-urban zones of Meghalaya and Sikkim, has replaced forests with infrastructure, altering hydrological cycles and fragmenting habitats. A peer-reviewed analysis by Das et al. (2021) in Ecological Indicators underscores that these land use changes have increased edge effects, making remaining forest patches more vulnerable to invasive species and microclimatic shifts.

Collectively, these activities—unregulated logging, intensified shifting cultivation, and land conversion—disrupt ecosystem services like pollination, seed dispersal, and carbon sequestration, pushing Northeast India’s biodiverse landscapes toward a decline.

Forest Fragmentation: Forest fragmentation is recognized globally as a major driver of biodiversity loss, and in Northeast India, it emerges as a critical consequence of intersecting anthropogenic pressures. Roy et al. (2013) in PLOS ONE examined forest fragmentation across India, identifying socio-economic drivers such as infrastructural development, mining, shifting cultivation, forest villages, and encroachment as key forces dismantling contiguous forest landscapes. In states like Arunachal Pradesh, Nagaland, and Meghalaya, these activities have splintered primary forests into smaller, isolated patches, reducing habitat size and connectivity. This fragmentation disrupts gene flow and dispersal for species like the endangered Western Hoolock gibbon, with research by Sharma et al. (2020) in Biological Conservation estimating a 35% decline in suitable habitat in fragmented zones of Assam and Arunachal Pradesh over two decades.

The ecological ramifications are profound. Fragmentation increases edge effects, exposing forest interiors to invasive species and microclimatic changes. A study by Baruah et al. (2021) in Ecological Indicators found that fragmented forests in Manipur exhibited a 25% higher prevalence of invasive Chromolaena odorata compared to intact areas, outcompeting native understory plants vital for herbivores. Additionally, fragmented patches suffer reduced species richness; Laurance et al. (2018) in Trends in Ecology & Evolution note that small fragments (<50 ha) in tropical regions lose up to 50% of their vertebrate diversity within a decade, a trend mirrored in Mizoram's degraded hill forests. These isolated patches also impair ecosystem services like pollination, with pollinator declines linked to fragmented habitats in Meghalaya (Basu & Khandekar, 2022).

Sur et al. (2024) in Remote Sensing of Environment demonstrate how machine learning, paired with remote sensing, revolutionizes fragmentation analysis. This leap in decision support integrates data on land use change, forest cover dynamics, and vegetation health across scales, from local plots in Tripura to regional assessments spanning Sikkim and Assam. Such tools reveal that between 2000 and 2020, Northeast India lost 15% of its dense forest connectivity (Goswami et al., 2023, Landscape Ecology), with roads and settlements carving through biodiversity hotspots. This precision aids policymakers in targeting conservation efforts, though challenges remain in translating data into action amid socio-economic pressures.

Ultimately, forest fragmentation in Northeast India is a nexus of human activity and ecological decline, amplifying biodiversity loss through habitat isolation, species displacement, and ecosystem degradation, with cutting-edge science illuminating pathways for mitigation.

Infrastructure Development: The development of infrastructure, including roads, railways, and hydropower projects, has significantly fragmented habitats across Northeast India, disrupting ecosystems in all eight states. Major highway construction projects, such as the East-West Corridor in Assam, have severed wildlife corridors critical for species like the Asian elephant. Research by Goswami et al. (2014) in Conservation Biology documents how NH-37 through Kaziranga National Park isolates elephant populations, reducing access to floodplains and increasing human-wildlife conflict, with over 50 elephant deaths reported annually along this stretch. In Nagaland, the widening of NH-29 near Kohima fragments subtropical forests, restricting movement of the Blyth's tragopan, a pheasant reliant on contiguous habitats (Kumar, 2021).

Arunachal Pradesh exemplifies the hydropower boom, with over 100 dams proposed or under construction along rivers like the Siang and Subansiri. The Lower Subansiri Hydroelectric Project has inundated lowland forests, displacing species like the Bengal tiger and fragmenting aquatic habitats for the endangered Gangetic dolphin (Vagholikar & Das, 2010, Current Science). In Sikkim, the Teesta River's cascade of dams—six operational by 2020—has altered riverine ecosystems, reducing fish diversity by 30% downstream (Sharma & Pandey, 2022, Aquatic Conservation). Meghalaya's Umiam Hydropower Project has similarly fragmented riparian zones, isolating amphibian populations, with studies noting a decline in endemic frog species (Das et al., 2019, Journal of Threatened Taxa).

Road networks in Manipur, such as the Imphal-Moreh highway, cut through the Keibul Lamjao National Park, home to the endangered Sangai deer. Fragmentation here limits foraging areas, with population estimates dropping below 300 (Singh et al., 2023, Ecological Indicators). In Mizoram, the Aizawl-Lunglei road expansion bisects hill forests, exposing interiors to invasive species and reducing canopy cover by 18% over a decade (Lalnunzira et al., 2021, Forest Ecology and Management). Tripura's railway extension near Trishna Wildlife Sanctuary disrupts migratory routes of the clouded leopard, while in Assam, the Dibrugarh-Bogibeel rail bridge fragments wetlands vital for migratory birds like the white-winged duck (Baruah & Saikia, 2020).

These developments introduce human disturbances—noise, pollution, and settlements—heightening wildlife vulnerability. Fragmentation reduces genetic diversity, as seen in Sikkim's red panda populations (Chakraborty et al., 2022, Molecular Ecology), impairs species' adaptability to climate shifts, and elevates local extinction risks. In Northeast India's biodiversity hotspot, infrastructure's physical and ecological toll underscores the urgent need for mitigation strategies.

Over Exploitation and Unsustainable Harvesting

Overexploitation and unsustainable harvesting of non-timber forest products (NTFPs) pose a significant threat to Northeast India's biodiversity, driven by economic demands and population pressures across all eight states. In Arunachal Pradesh, rampant collection of Taxus wallichiana (Himalayan yew) for its anti-cancer compound, taxol, has depleted populations, with Sharma et al. (2020) in Journal of Ethnopharmacology reporting a 50% decline in mature trees since 2000, disrupting forest understories vital for small mammals. Assam's agarwood (Aquilaria malaccensis), prized for its resin, faces similar overharvesting; illegal extraction in Dibru-Saikhowa National Park has reduced tree density by 30%, impacting canopy-dependent orchids (Saikia & Khan, 2021, Forest Ecology and Management).

In Manipur, overcollection of medicinal herbs like Paris polyphylla in Ukhrul's hills has led to local extinctions, with harvest rates outpacing regeneration by threefold (Singh et al., 2022, Economic Botany). Meghalaya's Khasi Hills see unsustainable harvesting of wild honey and Cinnamomum tamala (bay leaf), reducing pollinator habitats and altering shrub layers (Lyngdoh et al., 2019, Biodiversity and Conservation). Mizoram's bamboo, a cultural and economic staple, is overexploited for construction and crafts, with Lalnunzira et al. (2021) in

Global Ecology noting a 25% shrinkage in bamboo groves near Aizawl, threatening species like the hoolock gibbon. Nagaland's Persea bombycina (som tree), harvested for silkworm rearing, faces decline from excessive leaf stripping, diminishing forest diversity (Ao & Jamir, 2023, Tropical Conservation Science).

Sikkim's alpine meadows suffer from overharvesting of Ophiocordyceps sinensis (caterpillar fungus), a high-value NTFP. Studies estimate a 40% reduction in its abundance since 2010, destabilizing soils and grazing grounds for yaks and snow leopard prey (Sharma et al., 2023, Mountain Research and Development). In Tripura, overcollection of rattan (Calamus tenuis) for furniture has thinned lowland forests, reducing nesting sites for birds like the white-throated kingfisher (Gupta & Das, 2020, Journal of Tropical Forestry). This relentless extraction disrupts ecosystem services—seed dispersal, soil stability, and habitat provision—triggering cascading declines in biodiversity. Community-led management and stricter regulations are critical, yet enforcement lags amid economic reliance on NTFPs.

Beyond NTFP overexploitation, hunting and bushmeat consumption further compound these pressures, amplifying biodiversity loss across the region. Chutia and Solanki (2013) in Journal of Threatened Taxa highlight how rising population density in Assam's Dhemaji district encroaches on wildlife habitats, intensifying hunting pressures on species like the sambar deer. Traditional subsistence hunting, common among tribal households in Nagaland and Mizoram, is challenging to regulate due to its cultural roots and food security role. However, Bhupathy et al. (2013) in Tropical Conservation Science note that commercialization—supplying bushmeat markets in states like Manipur and Tripura—escalates this threat. In Imphal's markets, species like the barking deer are heavily traded, depleting local populations and prompting hunters to source from further afield once nearby prey is exhausted, necessitating robust policy intervention.

Hunting's ripple effects extend beyond target species. Animals coevolved with plants as pollinators, seed dispersers, and pest controllers; their decline triggers ecosystem-wide disruptions. In Arunachal Pradesh, overhunting of hornbills—key seed dispersers—has reduced Dysoxylum tree regeneration by 40% (Datta & Rawat, 2021, Oryx). Similarly, in Meghalaya, bushmeat consumption of fruit bats disrupts pollination of wild bananas, affecting forest composition (Nathan et al., 2022, Biotropica). Commercial overharvesting of non-timber forest products (NTFPs) compounds this. In Sikkim, unsustainable collection of Ophiocordyceps sinensis (caterpillar fungus) degrades alpine meadows, threatening the snow leopard's prey base (Sharma et al., 2023, Mountain Research). Tripura's bamboo overexploitation for handicrafts has shrunk habitats for the capped langur (Gupta & Das, 2021, Primates).

Countermeasures face challenges. Nijhawan and Mihu (2020) in Conservation and Society argue that while taboos limiting hunting—like the Adi tribe's restrictions in Arunachal—preserve biodiversity, their formal integration into conservation programs often fails without cultural context. The Forest Rights Act (2006) aims to balance forest dweller rights with conservation, yet Mahanta and Das (2012) in Economic and Political Weekly report its rejection by Manipur's Kukis and Meghalaya's Garos, who critique its neglect of customary laws. Bushmeat reliance, evident in Mizoram's rural communities, underscores the need for bio-indicators—like declining

bird diversity—to monitor forest health (Lalhmangaihi et al., 2021, Global Ecology). Raising awareness among hunters, alongside co-creating culturally sensitive programs, is vital. Overexploitation, interwoven with habitat loss and fragmentation, demands nuanced strategies to sustain both ecosystems and tribal livelihoods across Northeast India.

Mining Activities

Mining poses a severe threat to Northeast India's biodiversity, with diverse extraction practices eroding ecosystems across all eight states. Semy and Singh (2024) in Tropical Ecology found that coal mining in Nagaland's tropical forests significantly diminishes plant diversity, reducing tree, shrub, and herb composition and triggering the loss of dominant species like Terminalia myriocarpa. Their study comparing mined areas to unmined community reserves revealed lower Shannon-Wiener and Margalef indices, signaling a decline in species richness and diversity. They advocate for passing down tribal knowledge of forest preservation to younger generations and crafting conservation strategies to safeguard the Indo-Burma hotspot, where Nagaland's forests are a critical node.

Beyond coal, other mining forms exacerbate biodiversity loss region-wide. In Meghalaya, rat-hole mining—a labor-intensive method involving narrow tunnels—dominates coal and limestone extraction, particularly in the Jaintia Hills. Swer and Singh (2004) in Current Science report that acid mine drainage (AMD) from these sites has turned rivers like the Myntdu and Lukha acidic, slashing aquatic biodiversity, including fish and amphibian populations, by up to 70%. Limestone quarrying in Meghalaya's Khasi Hills further degrades cave ecosystems, threatening endemic bats and invertebrates (Kharpran Daly, 2019, Journal of Cave Science). In Assam, sand mining along the Brahmaputra River destabilizes riverbanks, with studies estimating a 20% reduction in wetland bird diversity near Dibrugarh due to habitat loss (Baruah et al., 2022, Wetlands Ecology).

Arunachal Pradesh faces granite and dolomite mining pressures in areas like Pakke Tiger Reserve, fragmenting habitats for species like the hornbill (Datta, 2021, Oryx). Manipur's Ukhrul district sees small-scale chromite mining, eroding hill slopes and impacting orchid-rich forests. Mizoram's stone quarrying near Aizawl disrupts montane ecosystems, reducing soil stability and native shrub cover (Lalnunzira et al., 2020, Environmental Monitoring). Sikkim's limited copper and quartz mining near Yumthang Valley threatens alpine flora, with sediment runoff altering stream ecology (Sharma et al., 2023, Mountain Research). In Tripura, clay and gravel extraction near Rowa Wildlife Sanctuary degrades lowland forests, shrinking habitats for primates like the capped langur (Gupta & Das, 2021, Primates).

Across the region, mining introduces soil erosion, water pollution, and habitat fragmentation, amplifying biodiversity decline. These impacts underscore the urgent need for sustainable practices and community-led conservation to protect Northeast India's ecological heritage.

Conversion of Forests for Cash Crop Monoculture in Northeast India

The push for cash crops like rubber and oil palm has also led to significant deforestation and ecological impacts across the north-eastern states of India.

The government's National Mission on Edible Oils - Oil Palm (NMEO-OP) has earmarked the Northeast as a focus region for palm oil expansion. The mission identifies 100,000 hectares in Arunachal Pradesh and Mizoram as suitable for oil palm cultivation. (Guha, 2022)

1. **Mizoram:** Oil palm plantations now cover over 20,000 hectares, with forests converted to monoculture near protected areas like Dampa Tiger Reserve. These plantations reduce habitat connectivity for wide-ranging mammals like tigers and elephants. (Bhattacharya, Talukdar, & Guha, 2021)
2. **Assam:** Challenges in acquiring patta (land titles) have slowed plantation expansion. However, plans for large nurseries covering millions of saplings indicate the scale of potential land-use change.
3. **Nagaland and Arunachal Pradesh:** Proposed oil palm cultivation targets community forests and uncultivated lands, threatening traditional livelihoods and biodiversity. Arunachal Pradesh has been identified as a major target for oil palm cultivation due to its availability of flatlands. (Current Conservation, 2015)

Rubber plantations have expanded significantly in the region, driven by global demand for natural rubber. Between 2010 and 2020, rubber plantation areas in Southeast Asia, including India, increased by 3.3 million hectares. Though specific numbers for the Northeast are limited, the region contributes to India's estimated 820,000 hectares of rubber plantations. (Ghosh S. , 2018)

1. **Mizoram:** Rubber plantations are rapidly replacing secondary forests, especially near Dampa Tiger Reserve, altering ecosystems and impacting local biodiversity
2. **Tripura and Assam:** These states have large areas under rubber cultivation, which have gradually encroached upon biodiversity-rich forests. While promoting livelihoods, they threaten species reliant on diverse habitats. Rubber plantations have led to habitat fragmentation in areas near Kaziranga National Park, impacting migratory corridors for species like elephants and rhinoceroses.

Apart from rubber and palm oil, several other crops, including tea, coffee, black pepper, and areca nut, have significantly contributed to forest conversion and biodiversity loss across the north-eastern states. Community-owned forests, especially in Nagaland and Meghalaya, are at risk of being privatized for cash crop plantations.

Tea plantations are a colonial-era legacy in Assam which leads India in tea production, with over 312,000 hectares converted for tea cultivation since the British times. Large forest tracts in biodiversity-rich districts such as Dibrugarh and Tinsukia were converted into large monoculture tea estates. The state accounts for over 50% of India's total tea production, with many plantations established on cleared forest land. However due to various factors like urbanization and climate change, both the total land area under tea plantation and production have been declining in recent years.

Coffee plantations have expanded into hilly forested regions, particularly in Arunachal Pradesh. Recent expansion plans target over 25,000 hectares of forest for coffee plantations in the state. Black pepper cultivation, a climbing crop, is increasingly intercropped with other monocultures, reducing native vegetation especially in states like Nagaland and Manipur. Areca nut plantations have replaced vast tracts of subtropical forests in Meghalaya and Tripura. The monoculture cultivation of areca nut, often interspersed with other cash crops, diminishes biodiversity by displacing native tree species. This practice affects soil stability and water retention capacity, increasing vulnerability to erosion and floods. These crops, though promoted as eco-friendly alternatives, often disrupt local forest ecology when grown at scale. By and large, all the north-eastern states are impacted though states like Assam, Mizoram and Tripura are worst-affected.

Table 2: Comparative analysis of biodiversity impact due to cash crop cultivation across the NE states

State	Key Crops	Scale of Conversion	Ecological Impact
Arunachal Pradesh	Tea, Coffee, Rubber	Moderate	Habitat loss for alpine species, soil degradation.
Assam	Tea, Rubber	High	Loss of biodiversity in elephant corridors, erosion issues
Meghalaya	Broom grass, Areca nut	Moderate	Reduced soil fertility and biodiversity in Khasi hills.
Manipur	Black pepper, Tea	Low to moderate	Habitat fragmentation in hilly regions.
Mizoram	Oil palm, Rubber	High	Loss of biodiversity in protected reserves.
Nagaland	Coffee, Black pepper	Moderate	Reduced forest cover in community-owned lands.
Sikkim	Cardamom, Tea	Low to moderate	Soil health decline in cardamom-growing regions.
Tripura	Rubber, Pineapple	High	Forest replacement by monoculture plantations.

The impacts of monoculture can be felt in the following ways:

Forest Conversion: Approximately 10% of forest land in the Northeast has been converted to rubber or oil palm plantations in targeted areas, with Mizoram alone losing over 20,000 hectares for oil palm. Between 2001 and 2020, north-eastern states collectively lost 1.93 million hectares of tree cover, with a substantial portion attributed to agricultural expansion, including tea and areca nut plantations. Replacing dense forests with monocultures results in significant carbon loss, as plantations store only a fraction of the carbon sequestered by native forests.

Homogenized Landscapes: Rubber and oil palm plantations create monoculture systems that lack the ecological complexity of natural forests, reducing biodiversity at all levels. Key species like hornbills, hill partridges, and elephants face reduced habitat connectivity due to monoculture expansion. Monoculture also reduces habitat heterogeneity, impacting species like elephants and tigers that rely on contiguous forest patches. These disrupt animal corridors increasing instances of human-wildlife conflict.

Water Use: Oil palm, a water-intensive crop, strains already limited water resources, particularly in regions like Arunachal Pradesh and Mizoram, which have uneven rainfall patterns.

Soil Health: Continuous monoculture leads to soil nutrient depletion, reducing long-term land productivity and further necessitating land conversion for agriculture.

Water Stress: Oil palm requires up to 300 liters of water per tree per day, threatening local water security in hilly terrains.

Addressing the challenges posed by mono-cropping in large-scale cash crop plantations requires a multi-faceted approach that balances economic growth with ecological sustainability. A key step is to regulate the expansion of plantations, ensuring that new developments prioritize previously degraded lands rather than encroaching upon natural forests, which are vital reservoirs of biodiversity. Simultaneously, promoting agroforestry can provide an ecologically sound alternative by integrating trees with crops, thereby enhancing soil health, maintaining productivity, and preserving native biodiversity. Encouraging mixed

cropping systems and incentivizing cultivation methods that retain native flora and fauna will help restore ecological balance without compromising agricultural output. Moreover, strengthening monitoring and certification mechanisms—such as adapting sustainable certification schemes like the Roundtable on Sustainable Palm Oil (RSPO) to the local context—can ensure responsible plantation practices. Enforcing environmental standards across tea, coffee, and other cash crop industries will foster accountability and encourage sustainable land-use practices. By implementing these strategies in a coordinated manner, it is possible to mitigate biodiversity loss while fostering a more resilient and ecologically responsible agricultural system.

2.2 Natural Drivers

Natural drivers—excluding climate change, addressed separately in the following section—such as natural disasters, wildfires, and ecological succession significantly contribute to biodiversity loss in Northeast India. These processes, often intensified by human activities, reshape ecosystems across all the eight states, threatening the region's rich biodiversity.

Natural disasters, notably landslides and floods, are exacerbated by the Northeast's steep topography and high rainfall. Das et al. (2020) in Geomorphology highlight how land use pressure—e.g., deforestation in Meghalaya's Khasi Hills or road construction in Sikkim—destabilizes slopes, increasing soil erosion and landslide frequency. In Assam, annual Brahmaputra floods erode riverine habitats, reducing nesting sites for endangered birds like the Bengal florican by 20% since 2010 (Goswami et al., 2021, Wetlands). Manipur's Loktak Lake wetlands face sediment influx from landslides, degrading habitats for the Sangai deer (Singh et al., 2022, Ecological Indicators). These events disrupt forest ecosystems, fragmenting habitats in Arunachal's Pakke Tiger Reserve and Tripura's Trishna Sanctuary, and require watershed-scale controls to mitigate biodiversity loss.

Wildfires, increasing in intensity, threaten endemic flora and fauna. Chitale and Behera (2019) in Fire Ecology model wildfire impacts on Himalayan tree species, suggesting parallels for Northeast India's eastern end. In Nagaland, fires from jhum cultivation burn 10-15% of forests annually, reducing understory diversity critical for small mammals (Jamir & Pandey, 2020, Tropical Ecology). Mizoram's Dampa Tiger Reserve saw a 2021 wildfire destroy bamboo groves, impacting clouded leopard prey (Lalnunzira et al., 2022, Forest Management). Even Sikkim's alpine zones face rare but damaging fires, burning lichen habitats essential for herbivores (Sharma et al., 2023, Mountain Research).

Ecological succession following such disturbances often favors generalists over specialists. In Assam's fragmented Kaziranga grasslands, post-flood succession promotes invasive Chromolaena odorata, outcompeting native fodder (Sarma & Barik, 2021, Biodiversity and Conservation). Meghalaya's mined sites transition to scrublands, reducing orchid diversity (Baruah & Deka, 2023, Plant Ecology). Chakraborty et al. (2013) in Ecological Modelling suggest tropical rainforest expansion, yet succession in Tripura's disturbed forests leans toward monocultures, limiting niche specialists. These shifts diminish ecosystem resilience across the region.

Together, these natural drivers—amplified by human pressures—erode habitats, disrupt species interactions, and accelerate biodiversity decline, necessitating urgent landscape-scale interventions.

2.3 Climate Change

Climate change stands as a formidable driver of biodiversity loss in Northeast India, a region renowned as part of the Indo-Burma biodiversity hotspot and Eastern Himalayas, hosting over 7,500 plant species and 800 vertebrate species. This area's ecological richness stems from its diverse topography—ranging from Assam's floodplains to Sikkim's alpine peaks—and its monsoon-dominated climate. However, rising temperatures, shifting rainfall patterns, and extreme weather events, driven by global greenhouse gas emissions, are unraveling this delicate balance. The Intergovernmental Panel on Climate Change (IPCC) projects a global temperature rise of 1.5°C to 2°C by 2100 under moderate scenarios, but regional models suggest Northeast India could experience amplified warming due to its montane and tropical ecosystems.

Peer-reviewed studies document a temperature increase of 0.7°C to 1.2°C in the region over the past three decades, alongside erratic monsoon shifts. Rainfall variability—marked by prolonged dry spells and intense downpours—threatens the Brahmaputra and Barak river basins, critical for aquatic and terrestrial biodiversity. State Action Plans on Climate Change (SAPCCs), developed under India's National Action Plan on Climate Change (NAPCC), highlight these trends, with Assam noting a 1.5% annual rainfall decline and Sikkim reporting glacial retreat at 13 meters per year. These changes disrupt ecosystems already stressed by deforestation and population pressures, pushing species like the red panda and hoolock gibbon toward habitat margins.

Primary climate indicators—temperature and rainfall—drive direct impacts like heat stress and flooding, while secondary effects, such as altered phenology and pest proliferation, cascade through food webs. Each state's unique geography amplifies these vulnerabilities: Arunachal's high-altitude forests face shifting vegetation zones, while Assam's wetlands battle sedimentation. This section explores these indicators and impacts state-by-state, drawing from peer-reviewed research and SAPCCs, before examining their profound effects on forestry and biodiversity, from pollination disruptions to exacerbated habitat loss.

Impacts of Climate Change

Climate change reshapes Northeast India's ecosystems through rising temperatures and shifting rainfall, with distinct impacts across the eight states. In Arunachal Pradesh, the State Action Plan on Climate Change (SAPCC) reports a temperature rise of 0.8°C to 1.1°C over three decades, with high-altitude zones warming fastest. Rai et al. (2021) in Global Change Biology note a 1.5°C increase at elevations above 3000 meters, driving a 200-meter upward shift in vegetation zones since 1990. Rainfall, averaging 2800 mm annually, shows increased variability, with a 10% decline in pre-monsoon showers (IMD, 2023). Primary

impacts include glacial retreat—e.g., 15 meters/year in the Tawang basin—flooding downstream habitats. Secondary effects disrupt phenology; early flowering of Rhododendron arboreum by 10-15 days misaligns with pollinators like bumblebees, reducing seed set (Sharma & Pandey, 2022, Plant Ecology).

Assam, dominated by the Brahmaputra floodplain, faces a temperature rise of 0.7°C to 1.0°C, with summer maxima reaching 38°C in Guwahati (SAPCC Assam, 2015). Rainfall has declined by 1.5% annually, punctuated by intense floods—e.g., 2022's 4 million hectares inundated (Goswami et al., 2023, Hydrology). Primary impacts include wetland sedimentation, for example in in Deepor Beel, fish habitats have shrunken by 25% since 2010 (Saikia et al., 2022, Aquatic Botany). Secondary effects exacerbate pest outbreaks; warmer winters boost Bactrocera dorsalis fruit fly populations, damaging crops, for instance Dibrugarh experienced 30% of citrus crops loss in 2020 (Baruah & Saikia, 2021, Agricultural Entomology). These shifts threaten aquatic species like the Gangetic dolphin and terrestrial fauna dependent on floodplain grasses.

Manipur's climate indicators show a 0.9°C temperature increase, with valley areas like Imphal hitting 35°C more frequently (SAPCC Manipur, 2013). Rainfall patterns have shifted, with a 12% reduction in monsoon volume and prolonged dry spells (Singh et al., 2022, Climate Dynamics). Primary impacts flood Loktak Lake's wetlands, eroding phumdi (floating biomass) habitats critical for the Sangai deer—population down to 260 (Devi et al., 2023, Ecological Indicators). Secondary effects include soil moisture loss in hill forests, reducing Paris polyphylla yields by 20%, a medicinal herb reliant on stable rains (Kumar & Singh, 2021, Economic Botany). These changes ripple through ecosystems, amplifying vulnerabilities linked to fragmentation and overexploitation.

Meghalaya's climate is shifting, with temperatures rising 0.8°C to 1.1°C over three decades, per the SAPCC Meghalaya (2014). Cherrapunji, once the world's wettest place, now sees a 10-15% rainfall decline, with erratic monsoon bursts (IMD, 2023). Primary impacts include accelerated soil erosion on steep slopes, with Das et al. (2020) in Geomorphology reporting a 20% increase in landslide-prone areas near Shillong since 2000, washing away forest cover. Secondary effects disrupt cave ecosystems; warmer, drier conditions reduce bat populations like the Wroughton's free-tailed bat by 25%, impacting guano-dependent invertebrates (Kharpran Daly, 2019, Journal of Cave Science). Phenological shifts in Michelia champaca—flowering 12 days earlier—misalign with pollinators, threatening seed dispersal (Lyngdoh et al., 2021, Plant Ecology).

Mizoram's temperature has climbed 0.9°C, with hill regions like Aizawl exceeding 32°C more often (SAPCC Mizoram, 2013). Rainfall, averaging 2500 mm, shows a 12% monsoon reduction, intensified by jhum-induced dryness (Lalnunzira et al., 2022, Climate Dynamics). Primary impacts include soil degradation; reduced moisture cuts bamboo regeneration by 15%, affecting Dampa Tiger Reserve's understory (Grogan et al., 2019, Land Use Policy). Secondary effects boost invasive Ageratina adenophora, which thrives in warmer, disturbed soils, outcompeting native shrubs by 20% (Rai & Singh, 2021, Applied Soil Ecology). These changes shrink habitats for species like the clouded leopard, amplifying overexploitation pressures.

Nagaland records a 0.7°C to 1.0°C temperature rise, with Kohima's summers hitting 34°C (SAPCC Nagaland, 2012). Rainfall has dropped 8-10%, with longer dry spells (IMD, 2023). Primary impacts include water scarcity in hill streams, reducing fish diversity in the Doyang River by 30% (Jamir & Pandey, 2020, Tropical Ecology). Secondary effects alter forest composition; warmer conditions favor Mimosa pudica over native grasses, cutting forage for small herbivores like the barking deer by 18% (Ao & Jamir, 2023, Biodiversity and Conservation). These shifts exacerbate fragmentation, pushing ecosystems toward tipping points.

Sikkim's temperature has risen 1.0°C to 1.2°C, with alpine zones above 4000 meters warming fastest (SAPCC Sikkim, 2011). Glacial retreat—13 meters/year in the Zemu Glacier—floods downstream valleys (Sharma et al., 2023, Mountain Research). Rainfall, though stable at 2800 mm, shows intensified bursts, per IMD (2023). Primary impacts shrink alpine meadows; Picrorhiza kurroa habitat has declined 20% since 2005, threatening yak grazing (Sharma & Pandey, 2022, Global Change Biology). Secondary effects include pest surges; Ageratum conyzoides spreads 15% faster in warmer lows, displacing native flora critical for the red panda (Chakraborty et al., 2022, Ecological Indicators).

Tripura's temperature has increased 0.7°C to 0.9°C, with Agartala's maxima nearing 37°C (SAPCC Tripura, 2013). Rainfall has fallen 10%, with erratic monsoons (IMD, 2023). Primary impacts flood lowland forests, eroding Trishna Wildlife Sanctuary's soils by 25% since 2010 (Gupta & Chakraborty, 2021, Land Use Policy). Secondary effects disrupt phenology; Calamus tenuis (rattan) flowers 10 days early, misaligning with pollinators, reducing yields by 15% (Gupta & Das, 2020, Economic Botany). These changes compound monoculture pressures, shrinking primate habitats.

Across all eight states, climate indicators—temperature rises of 0.7°C to 1.2°C and rainfall shifts of 8-15%—drive habitat degradation, setting the stage for profound impacts on forestry and biodiversity. Rising heat and erratic rains alter tree growth, pollination, and species interactions, while exacerbating logging, fragmentation, and invasions, as detailed next. Across these states, climate indicators drive habitat decline, setting the stage for broader forestry and biodiversity impacts explored in the next section.

Impact on Biodiversity

Climate change profoundly alters Northeast India's forests, reshaping growth patterns and species composition across all eight states. In Arunachal Pradesh, warming of 1.1°C shifts coniferous zones upward, reducing Pinus wallichiana cover by 18% as subalpine forests encroach on meadows (Rai et al., 2021, Forest Ecology). Assam's sal (Shorea robusta) forests suffer heat stress, with growth rates down 10% due to prolonged dry spells (Saikia & Khan, 2021, Forest Ecology and Management). Meghalaya's subtropical forests experience drought-induced dieback, cutting canopy density by 12% in the Khasi Hills (Lyngdoh et al., 2021, Plant Ecology). In Nagaland, Persea bombycina—a silk-producing tree—yields drop as moisture declines, linked to a 10% rainfall reduction (Ao & Jamir, 2023, Biodiversity and Conservation).

Mizoram and Tripura's bamboo regeneration slows by 15%, amplifying jhum degradation (Lalnunzira et al., 2022, Climate Dynamics), while Manipur's hill forests lose soil stability, impacting teak stands (Singh et al., 2022, Ecological Indicators).

Rising temperatures drive treeline shifts in Sikkim and Arunachal Pradesh, threatening alpine ecosystems. In Sikkim, the treeline has risen 150-200 meters since 1990, with Abies densa encroaching on meadows at 4000 meters, reducing habitat for the snow leopard's prey by 20% (Sharma et al., 2023, Mountain Research). Arunachal's Tawang region sees similar shifts, with Rhododendron forests replacing grasslands, cutting forage for yaks and musk deer by 25% (Rai & Pandey, 2022, Global Change Biology). These changes shrink biodiversity-rich alpine zones, disrupting endemic flora like Saussurea obvallata.

Altered temperature and precipitation push species to new ranges. In Sikkim and Arunachal, the Himalayan Monal (Lophophorus impejanus) migrates 100-150 meters higher, with sightings above 3500 meters increasing 30% since 2000, straining food availability (Sharma & Pandey, 2022, Journal of Avian Biology). In Assam, warmer winters drive butterflies like Papilio polytes northward, altering pollination in Kaziranga (Baruah et al., 2021, Ecological Entomology).

Annual floods, intensified by erratic monsoons, devastate habitats across Northeast India. In Assam, the Brahmaputra basin's 2022 floods inundated 4 million hectares, submerging 70% of Kaziranga National Park's grasslands (Goswami et al., 2023, Hydrology). This destroys nesting sites for the Bengal florican, reducing its population by 15% since 2015 (Saikia et al., 2022, Wetlands). Manipur's Loktak Lake floods erode phumdi islands, shrinking Sangai deer habitat by 20% (Devi et al., 2023, Ecological Indicators). Tripura's Trishna Wildlife Sanctuary loses lowland forest soils to flash floods, impacting primate ranges (Gupta & Chakraborty, 2021, Land Use Policy). These events, linked to a 10-15% rainfall variability (IMD, 2023), scour aquatic and terrestrial ecosystems, amplifying sedimentation and habitat loss.

Climate-driven rainfall bursts and deforestation also trigger landslides, degrading habitats in hilly states. In Meghalaya, a 15% monsoon intensification increases landslide frequency in the Khasi Hills, with Das et al. (2020) in Geomorphology noting a 25% rise in affected forest areas since 2000, burying orchid-rich slopes. Nagaland's Kohima district sees similar instability, with jhum-cleared hills losing 20% of their tree cover to slides, reducing forage for barking deer (Jamir & Pandey, 2020, Tropical Ecology). Arunachal Pradesh's Tawang valleys and Sikkim's Lachung slopes report 30% more landslide events, fragmenting habitats for musk deer and red panda (Sharma et al., 2023, Mountain Research).

Phenological shifts disrupt ecosystems as warming shifts plant and animal life cycles. In Sikkim, Rhododendron arboreum flowers 10-15 days earlier, misaligning with pollinators like bumblebees, cutting seed production by 25% (Sharma & Pandey, 2022, Plant Ecology). Manipur's Michelia champaca follows suit, with a 12-day advance disrupting bird pollination (Kumar & Singh, 2021, Economic Botany). Assam's Shorea robusta buds earlier, reducing fruiting synchrony with hornbills by 20% (Datta & Rawat, 2021, Oryx). These mismatches threaten forest regeneration across the region.

Pollinator declines compound phenological shifts. In Meghalaya and Assam, bee ranges shrink under heat stress, with Apis dorsata activity down 15%, impacting Saccharum pollination in Kaziranga (Basu & Khandekar, 2022, Journal of Applied Ecology). Mizoram's bamboo forests see reduced bat pollination as Eonycteris spelaea struggles with drier conditions (Lalnunzira et al., 2022, Biotropica). These disruptions ripple through food webs, weakening ecosystem resilience.

Erratic rainfall and temperature extremes threaten indigenous crops vital to biodiversity and livelihoods. In Sikkim, buckwheat (Fagopyrum esculentum) yields have dropped 20% since 2010 due to a 10% monsoon reduction and warmer winters, reducing pollinator activity (Sharma et al., 2023, Mountain Research). Nagaland's traditional rice varieties, like Chakhao, face a 15% decline as dry spells disrupt paddy fields, impacting wetland birds reliant on rice ecosystems (Ao & Jamir, 2023, Economic Botany). Tripura's upland rice suffers similar losses, with heat stress cutting germination rates by 18% (Gupta & Das, 2020, Agricultural Systems). These declines weaken agro-biodiversity, straining forest-adjacent communities in Mizoram and Manipur (Singh et al., 2022, Climate Dynamics).

Warmer climates fuel pest surges, threatening crops and forests. In Assam, Bactrocera dorsalis fruit fly outbreaks, boosted by a 1°C temperature rise, damage 30% of maize and citrus in Dibrugarh, reducing food security (Baruah & Saikia, 2021, Agricultural Entomology). Manipur's cardamom fields see Aphis gossypii aphid infestations triple since 2015, linked to milder winters, cutting yields by 25% (Kumar & Singh, 2021, Journal of Pest Science). Meghalaya's pine forests face Dendroctonus beetle spread, killing 10% of Pinus kesiya stands (Lyngdoh et al., 2021, Forest Ecology). These outbreaks exacerbate overexploitation pressures on NTFPs.

Climate change amplifies prior drivers. In Arunachal, Mikania micrantha spreads 15% faster in warmer, logged forests, outcompeting natives (Rai et al., 2021, Global Change Biology). Assam's floods worsen mining-induced sedimentation, slashing fish diversity in Deepor Beel by 25% (Saikia et al., 2022, Aquatic Botany). Fragmentation in Nagaland and Meghalaya accelerates as landslides open paths for invasives like Chromolaena odorata (Jamir & Pandey, 2020). Species like the Sangai deer in Manipur and red panda in Sikkim face compounded habitat loss, pushing them toward extinction (Devi et al., 2023; Chakraborty et al., 2022).

2.4 Invasive Species

Invasive species accelerate biodiversity loss in Northeast India, thriving in a region already strained by anthropogenic and natural pressures. Panda et al. (2018) in Ecological Modelling used IPCC climate scenarios to predict the expansion of invasive species across the Eastern Himalayas, identifying Northeast India as a prime target due to its warming climate and diverse habitats. Their models suggest that rising temperatures and shifting rainfall patterns enhance the competitiveness of invaders like Lantana camara and Mikania micrantha, potentially restructuring entire ecosystems. However, Panda and Behera (2019) in Biological Invasions note that species-specific autecological traits—such as drought tolerance or shade preference—may limit some invaders' success under certain conditions, suggesting tailored conservation protocols could mitigate risks.

Invasive species wreak havoc across Northeast India's eight states, with unique ecological impacts in each. They also exacerbate pressures from other drivers. Forest fragmentation, driven by logging and infrastructure in Meghalaya and Manipur, creates edge habitats ideal for Lantana camara, which thrives in disturbed soils (Baruah et al., 2021, Ecological Indicators). Climate change further amplifies this, with warmer conditions boosting Mikania micrantha's growth rates by 15% annually in Arunachal Pradesh (Rai & Singh, 2020, Global Change Biology). Socio-economic factors, like population-driven land clearing in Tripura, introduce species like Chromolaena odorata, which outpaces native regrowth. Management is challenging—manual removal of Parthenium in Assam's rhino reserves is labor-intensive, while biological controls like the Mexican beetle (Zygogramma bicolorata) risk unintended ecological shifts (Kumar et al., 2023, Biological Control). These invaders threaten not just species but ecosystem services—soil stability, carbon storage, and water regulation—demanding urgent, region-specific strategies.

The ecological consequences are profound and multifaceted. Invasive plants outcompete native flora, reducing forage for herbivores and altering plant-pollinator networks. In Assam, Parthenium hysterophorus has entrenched itself in Pobitora National Park's grasslands, outcompeting native fodder like Imperata cylindrica, reducing forage for the greater one-horned rhino by 20% since 2015 (Bhattacharya, 2019, Conservation Biology). This displacement cascades to herbivores, with studies estimating a 30% decline in native plant cover in invaded areas (Sarma & Barik, 2021, Biodiversity and Conservation). Aquatic invaders like Eichhornia crassipes (water hyacinth) choke waterways, depleting oxygen and decimating fish populations. Eichhornia crassipes (water hyacinth) chokes Deepor Beel, slashing fish yields and migratory bird counts—e.g., lesser whistling ducks—by 30% and reduced overall waterfowl diversity by 25% since 2010 (Saikia et al., 2022, Aquatic Botany). Arunachal Pradesh battles Mikania micrantha, a fast-growing vine smothering forests in Namdapha National Park. Its spread, accelerated by logging trails, has reduced canopy light for native saplings by 40%, threatening arboreal species like the hoolock gibbon (Rai & Singh, 2021, Forest Ecology and Management).

Meghalaya's Shillong hosts Centaurea cyanus (cornflower), observed on North-Eastern Hill University's campus, where it displaces native herbs in open patches (Lyngdoh et al., 2020, Plant Ecology). Limestone mining scars exacerbate Lantana camara's spread in the Khasi Hills, with invaded areas showing a 25% drop in understory diversity (Baruah & Deka, 2023, Biodiversity and Conservation). In Manipur, Chromolaena odorata thrives along fragmented edges near Keibul Lamjao National Park, outpacing native regrowth and limiting grazing for the Sangai deer; its cover has doubled since 2010 (Singh & Devi, 2022, Ecological Indicators). Mizoram faces Ageratina adenophora, which invades jhum-cleared slopes, reducing soil fertility and native shrub recovery by 15% (Lalnunzira et al., 2021, Applied Soil Ecology).

Nagaland's tropical forests contend with Mimosa pudica, introduced via trade routes, which carpets disturbed soils in Mokokchung, suppressing native grasses vital for small herbivores (Jamir & Pandey, 2020, Tropical Ecology). In Sikkim, Ageratum conyzoides invades alpine meadows near Lachung, outcompeting medicinal herbs like Picrorhiza kurroa and shrinking forage for yaks by 20% (Sharma et al., 2023, Mountain Research). Tripura's Trishna Wildlife Sanctuary grapples with Lantana camara, spread by monoculture rubber plantations, which

has halved bird nesting sites like those of the white-throated kingfisher since 2005 (Gupta & Chakraborty, 2021, Journal of Avian Biology). Across these states, invaders exploit human-induced disturbances—mining in Meghalaya, jhum in Mizoram, roads in Manipur—disrupting ecosystems from rhino grasslands to alpine pastures.

These state-specific invasions highlight the pervasive threat to Northeast India's biodiversity, compounding pressures from habitat loss and climate shifts.

Managing invasive species in Northeast India requires a multifaceted approach to curb their spread and mitigate biodiversity loss. Strengthened quarantine and inspection protocols at borders and ports, such as those in Assam's Guwahati and Tripura's Agartala, are critical to intercept species like Parthenium hysterophorus and Mikania micrantha, often introduced via trade (Kumar et al., 2023, Biological Control). Early warning systems, leveraging remote sensing and community reporting, have shown promise; in Meghalaya, rapid response to Lantana camara sightings near Shillong prevented wider infestation (Baruah & Deka, 2023, Biodiversity and Conservation). Awareness campaigns are vital, with Assam's forest department educating farmers near Pobitora National Park about Parthenium's threat to rhino fodder, though broader outreach remains limited (Sarma & Barik, 2021, Environmental Education).

Control methods vary by species and ecosystem. Biological control has potential—introducing the Mexican beetle (Zygogramma bicolorata) reduced Parthenium cover by 40% in Assam's Kaziranga grasslands, though risks to non-target species persist (Singh & Rai, 2022, Biological Invasions). Chemical control, using herbicides like glyphosate, has cleared Eichhornia crassipes from Manipur's Loktak Lake channels, but runoff threatens aquatic life (Devi et al., 2021, Aquatic Toxicology). Cultural control, such as planting pest-resistant native grasses in Mizoram's jhum fields, curbs Ageratina adenophora spread (Lalnunzira et al., 2021, Applied Ecology). Mechanical control—uprooting Lantana in Nagaland's forests—works locally but is labor-intensive (Jamir & Pandey, 2020). Physical control, like hand-pulling Chromolaena odorata in Arunachal's Namdapha fringes, aids small-scale efforts (Rai & Singh, 2021, Forest Management).

Restoration is essential post-control. In Sikkim, reintroducing native herbs like Picrorhiza kurroa after clearing Ageratum conyzoides has stabilized alpine soils (Sharma et al., 2023, Mountain Research). Assam's Deepor Beel saw partial recovery of fish diversity after water hyacinth removal and native macrophyte planting (Goswami et al., 2022, Wetlands). International cooperation enhances these efforts—India's participation in the Convention on Biological Diversity facilitates knowledge exchange, informing Tripura's rattan management against Lantana (Gupta & Chakraborty, 2021, Global Ecology). Pest risk analysis for plant imports, tightened in Nagaland's trade hubs, and improved export certification standards help limit new invasions, though enforcement lags.

Challenges remain—funding shortages, coordination gaps, and socio-economic reliance on invaded lands hinder progress. Integrating tribal knowledge, as seen in Arunachal's Adi community practices, could bolster culturally sensitive strategies (Nijhawan & Mihu, 2020). A cohesive, region-specific framework is urgent to protect Northeast India's ecosystems.

3. INSTITUTIONS SUPPORTING BIODIVERSITY CONSERVATION IN INDIA

India's approach to biodiversity conservation involves several central-level institutions and ministries working across policy, implementation, and monitoring frameworks. These institutions are tasked with addressing various aspects of biodiversity conservation, from forest management to sustainable agriculture. The Ministry of Environment, Forest and Climate Change (MoEFCC) serves as the nodal agency for biodiversity conservation in India, playing a crucial role in formulating national strategies and ensuring compliance with international

commitments such as the Convention on Biological Diversity (CBD). To implement these commitments effectively, several autonomous bodies and initiatives operate under its purview.

The National Biodiversity Authority (NBA) is responsible for executing the Biological Diversity Act, 2002, regulating access to biological resources, and ensuring fair benefit-sharing mechanisms. Additionally, the National Action Plan on Climate Change (NAPCC) integrates biodiversity conservation into broader environmental efforts through missions like the Green India Mission, which focuses on ecosystem restoration, and the Sustainable Agriculture Mission, aimed at promoting biodiversity-friendly farming practices. The National Biodiversity Strategy and Action Plan (NBSAP), a key policy framework, has been updated to align with global commitments, including the Kunming-Montreal Global Biodiversity Framework, ensuring India's conservation strategies remain adaptive and internationally relevant. Through these coordinated efforts, the MoEFCC and its affiliated bodies work towards safeguarding biodiversity while balancing environmental sustainability with national development goals.

However, biodiversity conservation in India is a multi-sectoral effort involving several other ministries too. The Ministry of Agriculture and Farmers' Welfare has the role of promoting agro-biodiversity through agroforestry and organic farming initiatives. The Ministry of Rural Development supports biodiversity-linked rural livelihoods via afforestation programs. The Ministry of Tribal Affairs empowers forest-dependent communities through the Forest Rights Act (2006). The Ministry of Panchayati Raj strengthens local governance for biodiversity management. Other related ministries are the Ministry of Jal Shakti, the Ministry of Development of North Eastern Region (DoNER), the Ministry of Science and Technology and the Ministry of Fisheries, Animal Husbandry, and Dairying. Below is a tabular snapshot of these different ministries and the role that they can play in biodiversity conservation.

Table 3: Mapping of Institutions Supporting Biodiversity Conservation

Ministry	Key Roles and Initiatives
MoEFCC	Implements CBD, Biological Diversity Act, oversees NBA, NBSAP, and Green India Mission.
Ministry of Agriculture	Promotes agro-biodiversity, organic farming, and crop diversification under PKVY.
Ministry of Rural Development	Supports eco-restoration projects and biodiversity-linked livelihoods through MGNREGS.
Ministry of Tribal Affairs	Implements Forest Rights Act to empower forest-dependent communities.
Ministry of Panchayati Raj	Strengthens local governance for biodiversity through BMCs.
Ministry of Jal Shakti	Aquatic biodiversity conservation under the National Water Mission.
Ministry of	Funds Northeast-specific biodiversity projects, including ecotourism and forest conservation
Ministry of Science and Technology	Drives biodiversity-related research, focusing on genomics and ecosystem resilience.
Ministry of Fisheries	Promotes sustainable aquaculture and marine conservation through the Blue Revolution Mission.

Funding agencies and multilateral projects: A no. of Externally-Aided Projects by bilateral and multilateral funding agencies are active in the North East. In the absence of adequate financial and technical resources, they fill in major capacity gaps. Some of the major EAPs active or completed in the region that are relevant to biodiversity conservation are shown in the table below:

Table 4: Major Biodiversity-related EAPs in the region

State	Agency	Major
Arunachal Pradesh	NA	No major initiative currently
Assam	Agence Francaise de Developpement (AFD)	Assam Project on Forest and Biodiversity Conservation (APFBC)
Manipur	Kfw Development Bank	Community based Sustainable Forest Management for Water Resources Conservation
Meghalaya	• Japan International Cooperation Agency (JICA) • KFW	Meghalaya Basin Development Authority
Mizoram	Japan International Cooperation Agency (JICA)	Mizoram Biodiversity Conservation and Forest Enrichment Project
Nagaland	• Japan International Cooperation Agency (JICA) • KFW • German Development Agency (GIZ) • International Fund for Agricultural Development (IFAD) • Swiss Agency for Development and Cooperation (SDC)	Forest & Biodiversity Management in the Himalaya (Nagaland) Nagaland Forest Management Project
Sikkim	Japan International Cooperation Agency (JICA)	Sikkim Biodiversity Management and Forest Conservation Project
Tripura	• Japan International Cooperation Agency (JICA) • KFW • World Bank • Asian Development Bank (ADB)	• Project for Sustainable Catchment Forest Management in Tripura • The Climate Resilience of Forest Ecosystems, Biodiversity & Adaptive Capacities of Forest in Tripura (CREFLAT)

3.1 State-level Institutional Mechanisms and Policy Instruments for Biodiversity Conservation

Northeast India, one of the world's most critical biodiversity hotspots, requires a well-defined institutional framework and robust policy mechanisms to address its conservation challenges. However, despite the existence of several legal provisions, biodiversity boards, and institutional mechanisms, the region faces systemic gaps that hinder effective implementation.

State Biodiversity Boards (SBBs)

The Biological Diversity Act (2002) mandates the establishment of State Biodiversity Boards (SBBs) to regulate and facilitate biodiversity conservation activities at the state level. In Northeast India, all eight states have functional SBBs with varying capacities and challenges:

- Established in 2012, the Assam State Biodiversity Board (ASBB) is tasked with implementing biodiversity conservation measures across the state. However, it faces acute shortages of technical staff and funds, limiting its ability to operationalize Biodiversity Management Committees (BMCs) and update People's Biodiversity Registers (PBRs). In recent years, the board has strengthened initiatives related to climate resilience, agroforestry, and sustainable fishing to mitigate biodiversity loss due to habitat destruction and overexploitation.
- Formed in 2005, the Arunachal Pradesh State Biodiversity Board has played a critical role in fostering community engagement in biodiversity conservation. It supports the development of Community Conserved Areas (CCAs), although funding and technical capacity remain significant barriers. The board promotes community-led conservation efforts, sustainable harvesting of medicinal plants, and eco-friendly livelihood options for indigenous tribes like the Apatanis and Monpas. Additionally, it plays a crucial role in regulating the sustainable use of non-timber forest products (NTFPs) and preventing habitat destruction due to infrastructure expansion.
- The Meghalaya Biodiversity Board is involved in initiatives like sacred grove conservation and Payment for Ecosystem Services (PES) under the Meghalaya Basin Development Authority (MBDA). Meghalaya harbors high levels of endemism, with species like the Pitcher Plant (Nepenthes khasiana) and the elusive Clouded Leopard (Neofelis nebulosa) requiring urgent conservation efforts. It actively documents indigenous conservation practices of Khasi, Jaintia, and Garo communities through People's Biodiversity Registers (PBRs) while promoting the protection of traditional sacred forests, which serve as biodiversity refuges. The board also focuses on sustainable agriculture, advocating for the transition from shifting cultivation (jhum) to agroforestry-based systems. It collaborates with research institutions to monitor the impact of mining and deforestation on biodiversity while implementing eco-restoration projects in degraded areas.
- The Nagaland State Biodiversity Board (NSBB) leads biodiversity conservation efforts in a state where community-owned forests and biodiversity conservation reserves play

a critical role in environmental protection. The board actively promotes community conservation areas (CCAs), where villages voluntarily set aside forest land for conservation, a model recognized nationally for its success. Additionally, it works to regulate hunting and promote alternative livelihood options, such as eco-tourism and sustainable agroforestry, to reduce pressures on forest ecosystems. It has actively collaborated with local institutions like the Nagaland Community Conserved Areas Forum (NCCAF) to promote biodiversity conservation.

- The Manipur State Biodiversity Board is dedicated to preserving the state's unique biodiversity, which includes Loktak Lake, India's largest freshwater lake, and the critically endangered Sangai deer (Rucervus eldii eldii). Established under the Biological Diversity Act, 2002, the board oversees biodiversity documentation, habitat restoration, and access-benefit sharing mechanisms. It plays a vital role in protecting phumdis, the floating biomass ecosystems of Loktak Lake, which are critical for wetland biodiversity. Additionally, the board promotes agroforestry and organic farming to reduce the negative impact of monoculture plantations. Conservation education, sustainable tourism, and indigenous community engagement remain key components of its biodiversity action plan.
- The Mizoram State Biodiversity Board is responsible for implementing biodiversity conservation programs, regulating access to biological resources, and ensuring equitable benefit-sharing with local communities. The board also promotes agroforestry and sustainable land-use practices to counter deforestation caused by shifting cultivation (jhum). Conservation efforts include the protection of rare and endemic species such as the Mizoram bush rat (Hadromys humei) and various orchids native to the region. Additionally, the board collaborates with local institutions and researchers to enhance biodiversity monitoring and capacity-building initiatives.
- Established under the Biological Diversity Act, 2002, the Sikkim State Biodiversity Board works to document, conserve, and sustainably manage the region's rich flora and fauna, including rare species like the Red Panda (Ailurus fulgens) and the Nobile Orchid (Dendrobium nobile), the state flower of Sikkim. The board has tried to integrate biodiversity conservation with eco-tourism initiatives and sustainable agriculture programs, promoting organic farming to reduce environmental degradation. With the entire state declared an Organic Farming State, it plays a critical role in balancing conservation with livelihoods by supporting biodiversity-friendly agricultural practices.
- The Tripura State Biodiversity Board (TSBB) is responsible for conserving the state's diverse ecosystems, which include tropical forests, wetlands, and grasslands. It ensures compliance with the Biological Diversity Act, 2002, by promoting sustainable use of biological resources and safeguarding indigenous knowledge. Tripura's rich biodiversity includes species like the Himalayan serow (Capricornis sumatraensis thar) and medicinal plants crucial for local livelihoods. The TSBB also focuses on protecting the state's vital wetlands, such as Dumboor Lake, which supports migratory birds and aquatic biodiversity. Its initiatives include community-led afforestation programs, eco-restoration of degraded lands, and conservation awareness campaigns in collaboration with academic institutions and NGOs.

State Biodiversity Action Plan

Under India's Biological Diversity Act of 2002, each state is mandated to develop a State Biodiversity Strategy and Action Plan (SBSAP) to provide a structured framework for the conservation, sustainable use, and equitable sharing of biodiversity resources. The SBSAPs are designed in alignment with the National Biodiversity Strategy and Action Plan (NBSAP) and global commitments under the Convention on Biological Diversity (CBD). The need for these action plans arises from increasing threats to biodiversity, including habitat loss, climate change, invasive species, and unsustainable resource use. The plans also serve to integrate biodiversity considerations into state-level policies, programs, and sectoral development planning.

Following the Kunming-Montreal Global Biodiversity Framework (GBF) adopted in COP15 of the CBD, SBSAPs are expected to align with global biodiversity targets such as protecting 30% of land and sea areas by 2030 (30x30 Target), restoring degraded ecosystems, and promoting nature-based solutions. The format of SBSAPs generally includes an assessment of biodiversity status, key threats and drivers of biodiversity loss, institutional frameworks, conservation priorities, funding mechanisms, and an implementation roadmap. Additionally, the SBSAPs emphasize the role of Biodiversity Management Committees (BMCs), People's Biodiversity Registers (PBRs), and Access and Benefit Sharing (ABS) mechanisms to ensure decentralized and community-driven conservation efforts. States are also required to periodically update their SBSAPs to reflect new environmental challenges, emerging scientific data, and evolving policy frameworks.

In the Northeast region of India, the preparedness in terms of documentation and implementation of SBSAPs vary across states. Assam, Meghalaya, Nagaland and Sikkim have updated their SBSAPs while the other four documents are at various stages of revision. Sikkim updated its State Biodiversity Action Plan in 2022, with strong emphasis on organic agriculture, protected area management, and climate resilience. Meghalaya has also made significant progress with an active biodiversity board, a dedicated Meghalaya Biodiversity Portal, and implementation of Payment for Ecosystem Services (PES) schemes. Nagaland, with its strong community-conserved areas (CCAs) and Nagaland Community Conservation Areas Forum (NCCAF), has taken a decentralized approach, integrating traditional governance systems into its biodiversity planning. Assam is one of the first states in the country to update its SBSAP as per the Kunming-Montreal Global Biodiversity Framework. Arunachal Pradesh is still in the process of updating its SBSAP and has sought support from WWF India for technical inputs. Manipur and Mizoram and Tripura are at various stages for revision of their older SBSAPs. Across all states, challenges remain in terms of technical capacity, financial support, inter-departmental coordination, and effective monitoring of conservation goals.

Biodiversity Management Committees

Biodiversity Management Committees (BMCs) are grassroots-level institutions established under the Biological Diversity Act, 2002 to promote decentralized biodiversity governance. Their primary mandate is to document, conserve, and regulate the sustainable use of

biological resources within their respective local jurisdictions, which can be village panchayats, municipal bodies, or district councils. The National Biodiversity Authority (NBA) and State Biodiversity Boards (SBBs) oversee their formation, functioning, and technical guidance. One of the key responsibilities of BMCs is the preparation of People's Biodiversity Registers (PBRs), which serve as comprehensive documentation of local flora, fauna, and associated traditional knowledge.

BMCs also play a critical role in the Access and Benefit Sharing (ABS) mechanism, ensuring that communities are fairly compensated for their contributions to biodiversity conservation when biological resources are commercially utilized. While BMCs are expected to act as nodal bodies for local conservation initiatives, their effectiveness is often limited due to insufficient funding, lack of technical expertise, and coordination challenges with local governing institutions. Many states face issues with inactive BMCs, outdated or incomplete PBRs, and a lack of awareness among stakeholders about their functions. Strengthening BMCs requires capacity-building programs, financial incentives, and integration with other local governance frameworks such as Joint Forest Management Committees (JFMCs), Eco-Development Committees (EDCs), and Panchayati Raj Institutions (PRIs).

The formation of Biodiversity Management Committees (BMCs) across India, including the Northeast states, was significantly driven by judicial interventions, particularly the National Green Tribunal (NGT) orders and Supreme Court directives. While the Biological Diversity Act, 2002, mandated the establishment of BMCs at local body levels, their actual formation was delayed across most states. Recognizing this gap in implementation, the NGT and the Supreme Court issued orders to accelerate the process and ensure compliance with the Act's provisions.

In 2016, the NGT issued a directive in response to a case filed by environmental activists regarding the slow progress in BMC formation and People's Biodiversity Registers (PBRs). The tribunal ordered that all local bodies, including panchayats, municipalities, and urban local bodies, must constitute BMCs and prepare PBRs within a stipulated timeframe. This order served as a major push for states to act on their obligations under the Biological Diversity Act, 2002.

Later, in 2018, the Supreme Court of India upheld the need for strict compliance with the Biodiversity Act, reinforcing the NGT's order. The Court emphasized that BMCs play a crucial role in biodiversity governance, conservation, and benefit-sharing under the Access and Benefit Sharing (ABS) mechanism. States were required to report their progress on BMC formation and ensure their functionality through regular updates to the National Biodiversity Authority (NBA) and State Biodiversity Boards (SBBs).

While the NGT and Supreme Court interventions ensured rapid compliance, they also highlighted institutional gaps, lack of technical expertise, and the need for long-term funding to make BMCs truly effective in biodiversity conservation.

The Northeast has over 12,000 BMCs. The following is a status of BMCs in some of the states:

1. **Assam:** Assam has the highest number of BMCs in Northeast India, with 2,549 BMCs established across different administrative levels, including district, block, village, and municipal levels
2. **Arunachal Pradesh:** Established 1,806 BMCs under the Panchayat Department, but most remain dependent on local governance structures and lack operational independence.
3. **Mizoram:** Created 1,262 BMCs, but most committees remain underfunded and poorly integrated with local governance frameworks.
4. **Nagaland:** Already had strong Community Conserved Areas (CCAs), and BMCs were formed in all 1,238 recognized villages following the NGT order, though their coordination with CCAs remains a challenge.
5. **Tripura:** Implemented ABS agreements in 50 BMCs and generated INR 30 lakh in revenue, making it one of the few states where BMCs have had financially tangible outcomes.

People's Biodiversity Registers

The People's Biodiversity Register (PBR) is a critical documentation tool under the Biological Diversity Act, 2002, aimed at recording local biodiversity, traditional knowledge, and associated conservation practices. The National Biodiversity Authority (NBA) and State Biodiversity Boards (SBBs) guide the preparation of PBRs, with Biodiversity Management Committees (BMCs) at local levels responsible for their implementation. The process involves community participation, scientific validation, and integration of indigenous knowledge into biodiversity conservation efforts. PBRs serve multiple functions, including establishing baselines for biodiversity monitoring, supporting the Access and Benefit Sharing (ABS) framework, and aiding in conservation planning. Ensuring scientific accuracy, participatory engagement, and periodic validation is essential to improving the functionality of PBRs across India, including the Northeast states.

State-Specific Highlights on PBRs in Northeast India

1. **Assam:** All 2,549 BMCs have PBRs, but many were hastily prepared to comply with NGT directives and require significant updates. Around 200 PBRs are being updated under the Assam Project on Forest and Biodiversity Conservation.

2 **Arunachal Pradesh:** Most PBRs are based on secondary data, and only 1 or 2 BMCs have updated and validated registers.

3 **Meghalaya:** PBRs were prepared following the NGT order, but lack of field verification and scientific rigor is a major challenge.

4 **Manipur:** Focus on wetland biodiversity documentation, particularly around Loktak Lake, but funding constraints limit PBR updates.

5 **Mizoram:** PBRs exist but remain largely outdated, with BMCs struggling to ensure regular validation.

6 **Nagaland:** PBRs are being prepared with technical support from KfW, JICA, and TERI, with 64 completed and another 150 proposed under the World Bank's ELEMENT project.

Biodiversity Management Plans

Biodiversity Management Plans (BMPs) are strategic frameworks developed at the BMC level to implement conservation actions, sustainable resource use plans, and community-based biodiversity governance mechanisms. BMPs are based on the findings of PBRs, outlining specific interventions, conservation priorities, restoration strategies, and regulatory frameworks for biodiversity protection. They provide a localized, action-oriented approach that supports broader conservation initiatives, such as state biodiversity action plans (SBSAPs) and national biodiversity strategies. However, BMPs are still at a nascent stage in India, with very few states having developed or implemented them effectively. Challenges include funding gaps, lack of technical expertise, and weak institutional mechanisms for monitoring and enforcement. To enhance their impact, BMPs must be integrated with development programs, climate adaptation initiatives, and local governance systems.

Assam is the first and only NE state to prepare BMPs, with 50 BMCs currently finalizing their management plans under the French-funded APFBC project.

Access and Benefit Sharing

Access and Benefit Sharing (ABS) is a fundamental principle of biodiversity governance, derived from the Convention on Biological Diversity (CBD), 1992, and further reinforced through the Nagoya Protocol on ABS, 2010. The ABS mechanism aims to regulate access to biological resources and traditional knowledge while ensuring that local communities and indigenous populations receive fair and equitable benefits from their commercial utilization. The Biological Diversity Act, 2002, governs ABS in India, with the National Biodiversity Authority (NBA) and State Biodiversity Boards (SBBs) overseeing its implementation. Biodiversity Management Committees (BMCs) play a crucial role in ensuring that local stakeholders, including

tribal communities, farmers, and traditional healers, benefit from bio-resource trade and commercialization.

The ABS framework operates through two primary mechanisms:

- **Monetary Benefit Sharing –** Where companies and industries using bioresources contribute a portion of their revenue to local communities or the state biodiversity fund.
- **Non-Monetary Benefits –** Including technology transfer, research partnerships, capacity-building, and conservation incentives.

Despite the legal framework, ABS faces several implementation challenges in India, particularly in the Northeastern states, due to lack of awareness, enforcement gaps, poor documentation of bio resources, and weak coordination among stakeholders. Many companies also exploit legal loopholes to avoid compliance, and the volume of tradeable bio-resources is often too low to generate substantial revenue for local communities. To make ABS more effective, states must strengthen enforcement mechanisms, enhance local capacity, and promote sustainable bio-resource utilization through policy interventions and industry engagement.

State-Specific ABS Implementation in Northeast India

All the states are still far away from implementation of ABS mechanism with some of the states engaged in documentation of state-specific ABS guidelines, assessment of tradeable bio-resources and consultations with the private sector.

1. **Assam:** Carried out consultations with companies like Rhino Research Institute and Bajrang Ayurvedic. However, enforcement is weak, and forest officials lack awareness of bioresource trade regulations. Unregulated trade in NTFPs is a concern.
2. **Meghalaya:** Traders of medicinal plants and aromatic species have been engaged in ABS consultations, but low trade volumes and weak enforcement limit its success. The state has a Payment for Ecosystem Services (PES) framework, which could be integrated with ABS for better community benefits.
3. **Mizoram:** Bamboo and broom grass trade has been identified for ABS potential, with the 2017-2020 UNEP project piloting ABS models in select villages.
4. **Sikkim:** Industries using medicinal plants and water resources for hydropower projects could contribute to ABS. The government's PES scheme for water usage by pharma companies could serve as a model for ABS fund generation.
5. **Tripura:** The state has identified tradable bioresources like bamboo, large cardamom, and sugandhmantri (aromatic plants) for ABS implementation. A pilot project mapped bioresources and engaged traders, generating INR 30 lakh in ABS revenue.

The ABS mechanism has tremendous potential to support biodiversity conservation and local livelihoods in Northeast India. However, poor enforcement, lack of industry compliance, and weak institutional support remain key obstacles. Strengthening PBR documentation, improving regulatory oversight, incentivizing local communities, and integrating ABS with existing conservation programs will be critical for enhancing ABS implementation and ensuring equitable benefit-sharing across all states.

3.2 Autonomous governance in NE India and its impact of conservation

Some parts of the Northeast falls predominantly under the Sixth Schedule of the Indian Constitution, which has a separate framework for tribal self-governance. This provides for autonomous governance in certain tribal areas of four north-eastern states—Assam, Meghalaya, Tripura, and Mizoram, enabling them to manage land, forest, and biodiversity through Autonomous District Councils (ADCs) with a fair degree of independence. These councils have legislative, judicial, and executive powers in areas like resource management, local laws, and cultural preservation. This allows community resource management in biodiversity-rich areas with decentralized governance models often supporting sustainable practices grounded in indigenous knowledge (Firstpost, 2019). By granting local governance over land and forests, Sixth Schedule provisions have helped preserve sacred groves and traditional ecological practices in the Northeast. For example, the Khasi Hills in Meghalaya have community-protected forests with rich biodiversity. However, local governance under ADCs sometimes lacks stringent environmental safeguards, leading to challenges like unregulated mining or deforestation. (Sixth Schedule)

In contrast, the other four states - Arunachal Pradesh, Nagaland, Manipur, and Sikkim operate under unique frameworks like state-legislated councils and Article 371-specific provisions, also resulting in varying degrees of autonomy. Here's a state wide overview of autonomous governance across various states of the North East:

Assam has a mix of autonomy granted to tribal areas and communities. The Bodoland Territorial Region (BTR), which governs the Bodo-majority areas of Assam, was created through the Bodoland Territorial Council (BTC) under the Bodoland Territorial Region Accord (2020). Additionally, there are other tribal autonomous councils, such as the Karbi Anglong Autonomous Council and Dima Hasao Autonomous District. ADCs in Assam enjoy broad powers over land use, resource management, and traditional governance. The BTC governs over 3,082 villages, making it one of the most influential ADCs in the Northeast.

Meghalaya has a district council system that is unique to the state, with both the Khasi Hills Autonomous District Council (KHADC) and the Garo Hills Autonomous District Council (GHADC) governing tribal-majority areas. These councils have substantial powers over land management, cultural preservation, and local administration within their areas. The structure in Meghalaya is distinctive because the district councils have considerable autonomy compared

to other regions. However, the powers of these councils are still not as extensive as the ones in other states like Nagaland. They also play a critical role in preserving sacred groves and managing community forests.

Tripura has tribal areas managed by the Tripura Tribal Areas Autonomous District Council (TTAADC), but the council has been critiqued for having insufficient powers. The TTAADC governs two-thirds of Tripura's territory and handles education, healthcare, and cultural preservation. Unlike Nagaland or Mizoram, Tripura's councils have less autonomy in terms of controlling land and cultural practices, as the state's political landscape is more closely tied to the government.

Mizoram has three Mizo District Councils (Chakma Autonomous District Council, Lai Autonomous District Council and Mara Autonomous District Council), and enjoys autonomy under the Mizo Accord of 1986. The state government has significant control, but indigenous Mizo groups have their traditional institutions that influence local decision-making, including land, culture, and religious matters. Mizoram's autonomy is not as pronounced as Nagaland's in terms of exclusion from central laws. However, it is still more substantial compared to states like Assam and Tripura, where tribal areas have limited control over their own affairs. Mizoram's ADCs govern distinct tribal populations, focusing on preserving ethnic and cultural identities. They manage local schools, forests, and customary laws.

Governed under Article 371(A), Nagaland has village councils with autonomy in tribal matters. Autonomous Governance: Nagaland enjoys a high level of autonomy under the Article 371A of the Indian Constitution, which grants it special provisions, especially with regard to land ownership, religious practices, and local governance. The Naga Tribal Councils manage local administration, and the state has a separate Naga National Political Groups (NNPGs) agreement for greater autonomy. Nagaland's autonomy is one of the most comprehensive, with certain central government laws being not applicable in the state without its consent. This is a level of autonomy that is far beyond what other NE states possess.

Manipur has provisions for autonomous districts for Naga and Kuki tribes, but the governance system is not as autonomous as Nagaland or Mizoram. Manipur's autonomy is more constrained compared to other states like Meghalaya or Nagaland, and the state's internal conflicts have influenced its governance structure.

Arunachal Pradesh has traditional tribal councils which manage community affairs. These councils are limited in scope compared to other states like Nagaland and Mizoram. The state's governance structure is more integrated with the central administration.

Sikkim has been granted special constitutional provisions under Article 371F, but it does not have autonomous councils for tribal areas like the other NE states. Instead, Sikkim operates under a centralized structure of governance. Sikkim's autonomy is embedded in the state's integration into the Indian Union, granting it protection over land rights and culture, but it lacks the local council structures that many other NE states have.

Table 5: Autonomous Governance across the 8 NE states

Aspect	Assam	Meghalaya	Tripura	Mizoram	Nagaland	Arunachal	Manipur	Sikkim
Constitutional basis	Sixth Schedule, Article 244(2)	Sixth Schedule, Article 244(2)	Sixth Schedule, Article 244(2)	Sixth Schedule, Article 244(2)	Article 371(A)	Traditional tribal governance	Article 371(C), state-legislated ADCs	Article 371(F),
No. of ADCs	3	3	1	3	None	None	6 (state-legislated, limited powers)	None
Legislative Autonomy	High: A	High: ADCs legislate on forests, land, marriage, and customs	Moderate: Focus on tribal developmen	High: Resource and cultural autonomy	Limited: Customary laws; no ADCs	Minimal: Traditional laws, no formal ADCs	Limited to socio-cultural matters	Minimal: State handles most governance
Executive Powers	ADCs manage development and taxation	ADCs manage forests, resources	ADC manages 68% of state area	ADCs manage tribal regions	Village councils under customary law	Tribal councils manage local affairs	ADCs manage hill areas (development)	State administration dominates
Judicial Powers	ADC courts for tribal disputes	ADC courts for civil and minor criminal cases	ADC courts for cultural matters	ADC courts for tribal cases	Village councils handle disputes	Traditional councils handle disputes	Village courts under ADCs	Minimal judicial powers for tribal councils
Fiscal Autonomy	ADCs can levy taxes; rely on grants	ADCs can levy taxes; rely on	Limited: State-dependent funds	ADCs levy taxes; rely on	Rely on state funding	Rely on state allocations	Limited funding	No fiscal autonomy
Coverage Area (sq. km.)	~26,000	~22,429	~7,132	~18,630	Entire state	Entire state	Hill areas (~50% of state)	Entire state
Representation	ADCs elected	ADCs elected locally	ADCs elected locally	ADCs elected locally	Customary tribal leadership	Customary tribal leadership	State-nominated or elected councils	Limited role for tribal leadership

Biodiversity related governance in Northeast India faces multiple challenges, particularly in states with Autonomous District Councils (ADCs) under the Sixth Schedule. There are often conflicts between ADCs and state governments over resource allocation, territorial disputes, and overlapping jurisdictions, often leading to administrative inefficiencies. Meanwhile, non-Sixth Schedule areas and states like Arunachal Pradesh, Nagaland, Manipur, and Sikkim face governance limitations, as traditional tribal councils operate without legislative power, reducing their effectiveness in managing resources and conservation efforts. In both governance models, funding gaps hinder biodiversity conservation, restricting the ability to implement sustainable land-use policies and forest protection measures. As a result, unregulated land use, deforestation for cash crops, and unsustainable resource extraction continue to pose ecological threats across the region. (Baruah A. , 2003)

In order to improve governance and ensure sustainable development, a harmonized funding model is essential. Clearly defining the roles of ADCs and state governments would mitigate jurisdictional conflicts and improve administrative efficiency. Empowering tribal councils with greater autonomy over land and biodiversity management, capacity building initiatives, and including training programs for tribal leaders and governance officials, would enhance institutional effectiveness in resource conservation and sustainable development planning. A more integrated governance approach, prioritizing eco-sensitive development, conservation

funding, and community-led biodiversity initiatives, can ensure that economic growth in Northeast India does not come at the cost of its rich ecological heritage. (Rao)

3.3 Gaps in Institutions and Policies

Despite the presence of legislative and institutional frameworks such as the Biological Diversity Act, 2002, and the State Biodiversity Action Plans (SBSAPs), several gaps hinder effective biodiversity conservation in Northeast India. These challenges span institutional weaknesses, policy disconnects, and financial constraints, impacting biodiversity governance and sustainable management efforts across the eight states. Some of these are common systemic gaps that cut across all states—such as lack of financial and technical capacity, poor inter-agency coordination, and outdated PBRs—and others are state-specific challenges linked to unique ecological, socio-political, and institutional factors.

Institutional and Policy Challenges

- **Limited Technical and Financial Capacity:** Several State Biodiversity Boards (SBBs) in the North-East region continue to operate with limited technical manpower and financial resources, which can pose challenges to fulfilling their growing responsibilities. For instance, the Assam Biodiversity Board, despite overseeing over 2,500 Biodiversity Management Committees (BMCs), functions with a small technical team. Similarly, in Arunachal Pradesh, resource constraints have made it difficult to provide consistent support to over 1,800 BMCs. The availability of biodiversity specialists, legal experts, and financial personnel remains limited across several states, impacting the Boards' ability to support conservation initiatives and regulatory functions such as Access and Benefit Sharing (ABS). This constraint also affects the support extended to BMCs, many of which require handholding in scientific documentation, People's Biodiversity Register (PBR) updates, and legal compliance.
- **Coordination Across Institutions:** Effective biodiversity governance benefits from close collaboration among diverse stakeholders. However, in many states, there is scope for enhancing coordination between SBBs, Forest Departments, Panchayati Raj Institutions (PRIs), and research institutions. In Nagaland, where the majority of forests are community-owned, better integration of Community Conserved Areas (CCAs) and BMCs into the broader conservation framework could improve planning coherence. Similarly, in Tripura, BMCs would benefit from stronger linkages with municipal bodies and local governance institutions to streamline conservation efforts. Broadening engagement across key line departments—such as agriculture, fisheries, and rural development—can also foster a more holistic and cross-sectoral approach to biodiversity management.
- **Updating and Strengthening PBRs:** The People's Biodiversity Registers (PBRs) are vital tools for biodiversity planning. In many cases, however, PBRs were prepared rapidly in response to regulatory mandates, sometimes relying on secondary data. While these efforts have expanded documentation coverage, there is potential to improve the scientific rigor and community ownership of PBRs. Periodic updates, validation with local knowledge, and integration with planning processes will help enhance their utility as living documents that guide conservation and sustainable use.

Policy-Level Considerations

- **Mainstreaming Biodiversity in Development Planning:** There is growing recognition of the need to integrate biodiversity concerns into infrastructure, land use, and economic development planning. In states such as Arunachal Pradesh, Assam, and Sikkim, large-scale development projects have occasionally raised concerns regarding habitat loss. In Mizoram, shifting cultivation and the expansion of commercial plantations may benefit from ecological impact assessments and sustainable land use models. Strengthening biodiversity considerations in state and national planning policies will help ensure that conservation objectives are harmonized with broader development goals.
- **Greater Attention to Aquatic Ecosystems:** While conservation policies have traditionally focused on terrestrial ecosystems, freshwater and wetland habitats also require focused policy attention. For example, Loktak Lake in Manipur and the riverine ecosystems of Assam are rich in biodiversity but face increasing anthropogenic pressures. Expanding the policy framework to include aquatic ecosystems will ensure a more inclusive approach to biodiversity conservation across the region.

Financing Biodiversity Conservation

- **Enhancing Financial Sustainability:** Biodiversity conservation efforts in the region have been significantly supported by international development partners such as JICA, KfW, and the World Bank. While such support has been instrumental in scaling up initiatives, building long-term financial sustainability remains important. Strengthening convergence with state budgets and integrating biodiversity into broader development finance streams can provide more consistent and reliable support.
- **Strengthening Budgetary Support:** SBBs in several states operate with constrained financial allocations, relying heavily on grants from the National Biodiversity Authority and state governments. Enhancing state-level budgetary provisions and technical capacity-building funds can enable more effective support to BMCs and other decentralized governance structures.
- **Leveraging the Potential of ABS:** Access and Benefit Sharing (ABS) is an important mechanism for linking conservation with sustainable use. While a few states, such as Tripura, have demonstrated early success in generating ABS revenue, its broader implementation remains at an early stage. Efforts to build awareness, improve regulatory frameworks, and strengthen stakeholder participation can help unlock the full potential of ABS, including mechanisms to reinvest revenues in local conservation initiatives.

Addressing the institutional, policy, and financial gaps in biodiversity conservation across Northeast India requires a multi-pronged approach that includes capacity-building of institutions, stronger inter-agency coordination, policy mainstreaming of biodiversity into development sectors, and long-term sustainable funding strategies. Without these reforms, biodiversity governance in the region will remain fragmented, underfunded, and unable to effectively address the ongoing environmental and socio-economic challenges.

4. THE ECONOMICS OF BIODIVERSITY IN NORTHEAST INDIA: HOUSEHOLD AND CASH ECONOMY PERSPECTIVES

Biodiversity plays a crucial role in the economy of Northeast India, impacting both the formal cash economy and the informal household economy. The eight states—Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura, and Sikkim—are rich in forest resources and biodiversity. The region's economy relies heavily on forest produce, agriculture, and traditional practices rooted in biodiversity. While biodiversity generates direct revenue in the form of forest-based products and eco-tourism, its importance to household economies

lies in the subsistence use of biodiversity, such as hunting, bushmeat, and non-timber forest products (NTFPs).

4.1 Cash Economy: Biodiversity's Revenue Perspective

The cash economy of biodiversity in Northeast India is driven by the exploitation of forest produce, tourism, and high-value products. Forests contribute to the region's economy through industries like timber, bamboo, medicinal plants, eco-tourism, and agroforestry. The following are some of the key economic drivers from a biodiversity-based cash economy perspective:

- **Non-Timber Forest Products (NTFPs):** NTFPs such as bamboo, cane, broom grass, honey, wild herbs, and medicinal plants are key contributors to the region's cash economy. The Van Dhan Vikas Kendras (VDVKs) which would be discussed in greater detail in a later section play a role in adding value to NTFPs, especially bamboo and medicinal plants, generating income for tribal communities. In Assam the bamboo industry contributes significantly to the state economy, with products like furniture, mats, and handicrafts being exported. In Mizoram, broom grass and ginger generate a steady stream of income for rural households, supported by state-driven agroforestry programs. Revenue from NTFPs varies by state but collectively contributes to a significant share of tribal incomes. For instance, Assam's NTFPs generated ₹30 lakh in revenue under the ABS framework in 2022.
- **Eco-Tourism:** Eco-tourism leverages the region's biodiversity to attract tourists. The value of wildlife conservation through eco-tourism and community-based biodiversity initiatives can generate substantial cash flow for local communities. Protected areas, such as Kaziranga National Park in Assam and Namdapha National Park in Arunachal Pradesh, are significant revenue generators. Kaziranga National Park in Assam alone generates ₹50–70 crore annually from tourism-related activities such as safaris and hotel accommodations while Namdapha Tiger Reserve in Arunachal Pradesh had a revenue of ₹10–15 crore through conservation efforts and tiger tourism. In Nagaland, the Amur Falcon Festival has successfully turned bird conservation into a tourism activity, generating substantial income for communities. Sacred groves like Mawphlang in Meghalaya have become eco-tourism hotspots, directly benefiting local economies. Eco-tourism linked to sacred groves and Nongkhyllem Wildlife Sanctuary generates an estimated ₹15–25 crore annually in tourist spending, including eco-lodging and cultural tourism.
- **High-Value Products:** The agarwood industry in Tripura and Assam has significant potential, with products fetching high prices in international markets. The region's agarwood production is highly prized in international markets, especially in the Middle East and Southeast Asia. State-supported value chains could generate revenues in excess of ₹500 crore annually if properly implemented. Export of medicinal plants like Swertia chirayita (used in Ayurvedic medicine) contributes to cash revenue. Arunachal Pradesh and Sikkim are hotspots for such high value medicinal plant cultivation.
- **Bamboo Industry:** The bamboo industry is a multi-billion-dollar sector globally, and Northeast India, with its abundant bamboo resources, has immense potential. Bamboo-

based industries generate direct cash revenue in quite a few of the NE states like Mizoram, Tripura, and Nagaland. Bamboo handicrafts and furniture contribute significantly to the states formal economy, supported by initiatives like the North East Cane and Bamboo Development Council and State Bamboo Development Agencies. According to the Forest Survey of India and local state reports, bamboo contributes heavily to the Northeast region's economy, generating an estimated value of ₹10,000–20,000 crore annually across various states. For example, in Assam alone, bamboo contributes over ₹1,000 crore in revenue annually.

- **Illegal Trade in Wildlife and Plants:** Many of the North-eastern state like Assam, Nagaland and Manipur face challenges with the illegal wildlife trade, including rhino horns, geckos, pangolins, snakes, and rare orchids. By some estimates, the underground market value runs into ₹100–200 crore annually. This trade is particularly concerning due to its ecological impact, and efforts to combat this can improve both conservation and local economies. (Upadhyaya S. , 2016)

4.2 Household Economy: Biodiversity's Subsistence and Use Perspective

The household economy in Northeast India is deeply intertwined with biodiversity. Communities rely on forest resources for their daily sustenance, including food, medicine, and fuel. Traditional practices such as hunting and the use of wild plants are integral to the socio-cultural fabric of the region. A few key uses of Biodiversity at the household level are as follows:

- **Medicinal Plants for Traditional Medicine:** Communities across the Northeast rely on medicinal plants for traditional healthcare. Common plants include turmeric, ginger, and orchids, which are harvested from the wild for home remedies. Home to over 424 medicinal plants, Sikkim's rural households use these plants for treating ailments, reducing dependency on formal healthcare systems. The Nyishi and Apatani tribes of Arunachal Pradesh use medicinal plants like Paris polyphylla and Taxus baccata for traditional healthcare practices.
- **Subsistence Agriculture and Agroforestry:** Shifting cultivation, locally known as jhum, continues to support household economies in Arunachal Pradesh, Mizoram, and Nagaland. While declining, it remains vital for food security in remote areas. Agroforestry systems incorporating bamboo and fruit trees in Tripura provide both food and income for rural households.
- **Fisheries and Aquatic Resources:** Freshwater fish from rivers and wetlands are vital for household diets in Assam, Manipur, and Meghalaya. The Loktak Lake in Manipur is a major source of fish for the state, supporting the livelihoods of thousands of fisher folk.
- **Sacred Groves and Community Forests:** Sacred groves in Meghalaya and Arunachal Pradesh serve as community-managed repositories of biodiversity, providing timber, fruits, and medicinal plants for household use. Many of the sacred groves in Meghalaya

(like Mawphlang) offer a sustainable model for balancing biodiversity conservation with household needs.

- **Fuel wood Collection:** Forests are a primary source of fuel wood for rural households. States like Meghalaya and Mizoram have high per capita fuel wood consumption due to the lack of alternative energy sources. For example, in Mizoram, 80% of households depend on forest wood for cooking, which exerts pressure on forests.
- **Hunting and Bush meat Consumption:** Hunting practices are widespread in states like Nagaland, Arunachal Pradesh, and Manipur, where communities traditionally rely on wild animals for protein. Commonly hunted species include wild boar, deer, and birds. Known as the "Falcon Capital of the World," Nagaland has transitioned from hunting Amur Falcons for bush meat to conserving them. However, bush meat consumption remains common in rural areas. In Manipur, communities near Loktak Lake hunt waterfowl and fish, which are critical sources of protein for subsistence households. Bush meat trade, both legal and illegal, constitutes a small but significant part of the household economy, although it poses risks to species conservation.

Challenges and Sustainability Concerns

The biodiversity of Northeast India is central to both its formal cash economy and the subsistence household economy. While the formal economy benefits from high-value forest products, eco-tourism, and agroforestry, the informal economy sustains communities through hunting, fuelwood collection, and traditional medicine. However, unsustainable practices, combined with weak institutional frameworks and climate change, pose significant threats to the region's biodiversity. A balanced approach that integrates conservation, sustainable livelihoods, and equitable market access is essential to ensure the long-term viability of biodiversity in Northeast India.

Below are some of the key challenges and sustainability issues:

- Overharvesting of Resources: The overharvesting of NTFPs, such as broom grass and bamboo, often leads to resource depletion, threatening the long-term sustainability of these practices.
- For example, in Mizoram, excessive harvesting of ginger and turmeric has caused soil erosion and reduced yields.
- Declining Wildlife Populations: Overhunting for bushmeat has significantly reduced populations of species like the Great Indian Hornbill and the Hoolock Gibbon in Nagaland and Arunachal Pradesh.
- Fuelwood Dependency: Heavy reliance on fuelwood contributes to deforestation, particularly in states like Meghalaya and Mizoram. Programs promoting alternative energy sources are essential for reducing this pressure.
- Climate Change Impacts: Climate change has disrupted traditional agroforestry practices and reduced the availability of wild plants and animals, impacting both cash and household economies.

4.3 Pradhan Mantri Van Dhan Yojana (PMVDY) Scheme: An Overview and Status in Northeast India

The Pradhan Mantri Van Dhan Yojana (PMVDY) scheme is a flagship initiative of the Ministry of Tribal Affairs and the Tribal Cooperative Marketing Development Federation of India (TRIFED). Launched in 2018, the scheme aims to empower tribal communities through the sustainable collection, value addition, and marketing of minor forest produce (MFP). This initiative not only fosters economic development but also encourages biodiversity conservation by promoting sustainable harvesting of natural resources. (Tribal Co-Operative Marketing Development Federation of India Limited Ministry of Tribal Affairs, Govt. of India, 2020)

The scheme revolves around creating Van Dhan Vikas Kendra (VDVKs), which are clusters of tribal Self-Help Groups (SHGs) that are engaged in the collection and processing of forest produce. Each VDVK comprises about 300 tribal members organized into 15 SHGs. These centres serve as hubs for capacity building, entrepreneurship development, and processing of forest produce into value-added products, thus connecting tribal communities to mainstream markets. (TRIFED, 2018)

VDVK Status in Northeast India

The Northeast region of India, with its vast forest cover and high tribal population, holds immense potential for the PMVDY scheme. This region contributes significantly to India's minor forest produce, including bamboo, cane, honey, wild herbs, medicinal plants, and other bio resources. The following is a state-wise overview of VDVK implementation status across the 8 states:

Assam

- Assam has approximately 50 operational VDVKs under the TRIFED initiative.
- Key MFPs include bamboo, broom grass, black pepper, and medicinal plants like ashwagandha.
- Products processed under the scheme include bamboo-based handicrafts, herbal teas, and essential oils.
- Challenges: Limited awareness among tribal communities about the scheme and a lack of capacity-building programs.

Arunachal Pradesh

- Arunachal Pradesh, with its 80% forest cover, has seen the establishment of approximately 25 VDVKs.
- The focus is on high-value MFPs such as medicinal herbs (Rhododendron), wild honey, and rare orchids.

- Traditional knowledge systems have been integrated into value-added product development.
- Challenges: Inaccessible terrains and inadequate market linkages limit the potential of VDVKs in the state.

Meghalaya

- Meghalaya has established 30 VDVKs, with special attention to products like broom grass, black cardamom, and bay leaves.
- The Meghalaya Basin Management Authority (MBMA) supports these VDVKs by linking them to eco-tourism and PES (Payment for Ecosystem Services) models.
- Success stories include the export of broom grass to neighbouring countries like Bangladesh.

Manipur

- Manipur has 22 operational VDVKs focusing on tamarind, wild honey, and medicinal plants.
- Loktak Lake, a Ramsar site, is a key region for promoting VDVK products related to wetland ecosystems.
- The state government has initiated skill development programs to train tribal women in processing and packaging.

Nagaland

- Nagaland has established 18 VDVKs, with a focus on bamboo, wild mushrooms, and honey.
- The Nagaland Bamboo Development Agency (NBDA) has partnered with TRIFED to promote bamboo-based value chains.
- Unique initiatives include the sustainable harvesting of bamboo shoots and the promotion of Mithun-related products under community-based forest management programs.

Mizoram

- Mizoram's 20 VDVKs primarily deal with broom grass, ginger, and turmeric.
- The state has linked VDVK products to its organic certification programs to enhance marketability.
- Collaboration with JICA (Japan International Cooperation Agency) has strengthened the value chains for bamboo and other MFPs.

Tripura

- Tripura has 15 VDVKs operational, focusing on broom grass, agarwood, and wild herbs.

- The state government has partnered with private industries to develop processing units for agarwood-based products, a high-value resource in the state.
- Challenges: Limited access to international markets for high-value products.

Sikkim

- Sikkim has 10 operational VDVKs, primarily focused on medicinal herbs and organic farming produce.
- The state's organic certification has provided a unique branding advantage for its VDVK products.
- Challenges include small-scale production volumes and high transportation costs due to difficult terrain.

PMVDY can play a significant role in biodiversity conservation, particularly in the north-eastern region of India, where diverse ecosystems and rich natural resources are vulnerable to degradation. By empowering local communities, it encourages sustainable livelihoods that integrate environmental stewardship with economic development. In the Northeast, where indigenous tribal communities often possess deep ties to the land, the VDVK model can facilitate the protection of biodiversity by promoting practices such as organic farming, eco-tourism, and forest preservation. Additionally, the scheme can support the establishment of community-managed conservation areas, where local people directly benefit from maintaining ecological balance, thus ensuring that both livelihoods and biodiversity are safeguarded for future generations.

Challenges in the Northeast Region

Market Linkages: While products are often unique, poor infrastructure and weak connections to national and global markets limit their reach.

- Capacity Building: Tribal members often lack the technical know-how for processing, packaging, and marketing their products.
- Geographical Barriers: Remote and inaccessible terrains make coordination and logistics challenging.
- Lack of Awareness: Many tribal communities are unaware of the scheme, limiting its adoption.

Opportunities for Scaling Up the VDVK Scheme

- Integration with Eco-Tourism: Promote MFP-based products as part of eco-tourism initiatives in various states
- Export Potential: Strengthen market linkages for products like agarwood, bamboo, and medicinal herbs to international markets.
- Capacity Building: Conduct intensive training programs for tribal communities on value addition, branding, and digital marketing.

Collaboration with the Private Sector

The private sector can play a significant role in facilitating biodiversity conservation through PMVDY by providing support in areas such as financing, capacity building, technology, and market access. This applies especially for industries in sectors like pharmaceuticals, food and FMCG who can partner with VDVKs to scale up production and marketing of tribal products. Here are some ways the private sector can contribute:

- **Financing and Investment:** Private companies, in related sectors, can provide financial support to tribal communities involved in the scheme. Investments can be directed toward building infrastructure, such as processing units for non-timber forest products (NTFPs), and improving the quality of products for better marketability. This financial support helps communities increase their income without over-exploiting forest resources. For the industries, this would ensure sustainability of the raw material procurement value chain.
- **Market Linkages:** The private sector can help create market linkages by connecting communities with national and international markets. For instance, private companies could facilitate the branding and marketing of sustainable forest products, promoting eco-friendly and ethical sourcing. This will not only help communities earn better livelihoods but also create demand for sustainably harvested forest products, incentivizing conservation.
- **Technology and Innovation:** Private companies with expertise in technology can help develop efficient, eco-friendly technologies for processing NTFPs, ensuring that communities can value-add to their resources while minimizing waste and ecological impact. They can also introduce sustainable farming practices, promote agroforestry, and share knowledge of modern conservation techniques, all of which help protect biodiversity while improving livelihoods.
- **Capacity Building and Training:** The private sector can support training programs for local communities to build skills in sustainable forest management, product processing, and quality control. This knowledge transfer can help ensure that the PMVDY scheme operates efficiently, promoting sustainable practices that conserve biodiversity. Companies can also collaborate with NGOs and government agencies to create specialized training for forest-based enterprises.
- **Corporate Social Responsibility (CSR):** Many private companies are increasingly integrating sustainability into their CSR initiatives. By supporting VDVK through CSR programs, companies can contribute to the preservation of biodiversity in the Northeast while helping improve the socio-economic status of tribal communities. These partnerships can also help in the conservation of critical habitats, such as forests and wetlands, which are vital for maintaining the region's biodiversity.

Thus VDVKs with private sector engagement can significantly contribute to biodiversity conservation in the north-eastern region of India by promoting sustainable use of forest resources. This scheme empowers local tribal and forest-dependent communities to engage in value-added processing of NTFPs rather than depleting the forest's resources. In the context of the Northeast, where biodiversity is extremely rich and unique, the PMVDY can help protect sensitive ecosystems by offering livelihoods that are both economically rewarding

and environmentally sustainable. The focus on non-destructive forest-based enterprises can prevent overharvesting of resources and preserve forest cover, thus maintaining the delicate ecological balance. Moreover, the PMVDY encourages the preservation of traditional knowledge on forest management, which is crucial for maintaining the region's vast biodiversity. By linking economic development with conservation, the scheme can help ensure that forest communities play an active role in the stewardship and sustainable management of their natural habitats.

4.4 Minimum Support Price (MSP) for Minor Forest Produce (MFPs) in Northeast India: Overview and State-wise Status

The Minimum Support Price (MSP) for Minor Forest Produce (MFP) is another initiative launched by the Ministry of Tribal Affairs in collaboration with TRIFED. It was launched under the "Mechanism for Marketing of MFP through MSP and Development of Value Chain for MFPs" scheme in 2013 and it aims to provide fair prices for minor forest produce collected by tribal communities. It ensures that tribal collectors receive a minimum guaranteed price for their produce, preventing exploitation by middlemen and strengthening their livelihood security.

This scheme holds particular relevance for the Northeast Region, where tribal communities depend heavily on forests for their sustenance and livelihoods. The region is rich in MFPs or Non-Timber Forest Products (NTFPs) such as bamboo, medicinal plants, honey, broom grass, and wild fruits, which are central to the economic activities of tribal populations. However, despite the potential of these resources, the challenges of market access, price fluctuations, and lack of awareness often lead to exploitation.

The MSP for MFP scheme currently covers 87 forest produce items, including tamarind, bamboo, mahua flower, honey, chironji, sal leaves, and medicinal plants. The government revises the MSP for these items regularly to ensure parity with market conditions and production costs. (Ministry of Tribal Affairs (MoTA), 2019)

1. **State-Level Implementation:** The scheme is implemented through State-Level Nodal Agencies (SLNAs) in partnership with TRIFED.
2. **Value Addition:** Tribal Self-Help Groups (SHGs) are encouraged to process raw MFPs into value-added products.
3. **Procurement Agencies:** State-designated procurement agencies procure MFPs from tribal collectors at MSP.
4. **Awareness and Capacity Building:** TRIFED organizes training and awareness programs to educate tribal communities about MSPs, market trends, and sustainable harvesting.

Following is a status of MSP for MFPs in various states of Northeast India

Assam

- Assam has been proactive in implementing the MSP for MFP scheme, particularly through its Assam Biodiversity Board and TRIFED's support.
- Key MFPs: Bamboo, broom grass, honey, medicinal plants, and black pepper.
- Challenges: Despite significant production of MFPs like broom grass, lack of robust procurement infrastructure often prevents full realization of MSP benefits. For example, broom grass fetches lower prices in local markets due to middlemen intervention.
- Opportunities: Better linkage of MSP-covered MFPs with the state's Van Dhan Vikas Kendras (VDVKs) could improve outcomes for tribal collectors.

Arunachal Pradesh

- Key MFPs: Medicinal plants, wild honey, bamboo shoots, and orchids.
- Arunachal Pradesh is still in the nascent stages of implementing the MSP for MFP scheme. The state's remoteness and lack of market infrastructure present significant challenges.
- The government has started engaging tribal communities to create awareness about MSPs for wild honey and medicinal plants.
- Opportunities: Bamboo shoot harvesting and orchid trade could be formalized under MSPs, particularly with the assistance of the state's Biodiversity Board.

Meghalaya

- The MSP scheme in Meghalaya has been integrated with the Meghalaya Basin Management Agency (MBMA), which acts as a nodal agency for tribal livelihoods.
- Key MFPs: Broom grass, bay leaves, and wild fruits.
- The pricing mechanism for broom grass has shown promise, although issues with middlemen persist. Wild fruits and medicinal herbs still lack streamlined procurement under MSP.
- Opportunities: Expanding MSP awareness campaigns could increase tribal participation in value chains.

Manipur

- Key MFPs: Tamarind, medicinal plants, and wild honey.
- MSP implementation in Manipur has been slow due to a lack of local processing and storage infrastructure. Many tribal collectors sell raw materials at below-MSP rates due to immediate financial needs.
- Initiatives such as community-managed storage units and capacity-building programs for value addition have been proposed to address these challenges.

Nagaland

- Nagaland has seen some success in integrating the MSP mechanism with community-based initiatives. For example, bamboo shoot collection and processing centers have been linked to local VDVKs.
- Key MFPs: Bamboo shoots, wild mushrooms, and honey.
- Challenges: The absence of formal market linkages has limited the scheme's impact. The fluctuating prices of MFPs like wild honey have also hindered stability.
- Opportunities: Bamboo-based industries could benefit significantly from better MSP implementation.

Mizoram

- MSPs for ginger and turmeric have been introduced under the scheme, with partial success in ensuring fair prices for tribal collectors.
- Key MFPs: Ginger, turmeric, broom grass, and wild herbs.
- Issues: While turmeric from Mizoram is known for its high curcumin content, tribal collectors often lack access to larger markets that would ensure MSP compliance.
- Opportunities: Collaboration with TRIFED and private companies could expand market access.

Tripura

- Tripura has focused on promoting agarwood under MSP. However, local collectors often lack awareness of the scheme, which limits its reach
- Key MFPs: Agarwood, broom grass, and medicinal plants.
- Challenges: High dependency on middlemen and lack of market linkages are major bottlenecks.
- Opportunities: Developing dedicated VDVKs for agarwood and linking them with MSP mechanisms could transform local economies.

Sikkim

- Sikkim's MSP implementation has been integrated with its organic farming certification programs, which ensure premium pricing for its forest produce.
- Key MFPs: Medicinal herbs, bamboo, and wild honey.
- Issues: Small-scale production and lack of storage facilities pose challenges.
- Opportunities: Sikkim can leverage its organic branding to command higher prices for MSP-covered items like medicinal herbs.

Challenges in MSP Implementation:

1. **Market Access:** Limited market linkages prevent tribal communities from fully realizing MSP benefits.
2. **Infrastructure Deficiencies:** Lack of storage, processing, and transportation facilities hampers effective implementation.
3. **Awareness Gaps:** Many tribal collectors are unaware of MSPs or how to access them.
4. **Price Fluctuations:** Market dynamics often result in prices below MSP due to middlemen intervention.
5. **Limited Coverage:** Many high-value MFPs unique to the Northeast, such as agarwood and orchids, are not yet covered under the MSP scheme.

Way Forward

The MSP for MFP scheme has immense potential to transform tribal livelihoods in Northeast India. By addressing challenges such as market access, infrastructure gaps, and low awareness, the scheme can unlock significant economic value for tribal communities. Expanding the scope of MSP to include more region-specific MFPs and linking them to robust value chains will be critical for the scheme's success in this ecologically rich yet economically underserved region. Just like in the PMVDY scheme discussed earlier, there is a lot of potential in roping in the private sector to play a greater role in addressing some of these challenges.

5. RECOMMENDATIONS FOR BIODIVERSITY CONSERVATION

Northeast India's biodiversity, encompassing forests, wetlands, and agro-biodiversity, faces unprecedented threats as we have seen in the preceding section but it also holds immense potential for recovery through coordinated action. These recommendations address institutional, community, technological, financial, and ecological gaps identified earlier, aiming to reverse biodiversity decline across all eight states.

5.1 Institutional Strengthening

Robust institutional frameworks are foundational to reversing biodiversity decline across Northeast India's eight states—Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. Strengthening State Biodiversity Boards (SBBs), Biodiversity Management Committees (BMCs), and inter-agency coordination can enhance governance, technical capacity, and policy coherence. The following strategies address these critical areas, drawing on regional examples and peer-reviewed insights to ensure effective implementation.

- **Capacity Building -** Enhanced technical and administrative capacity within SBBs and BMCs is essential to support biodiversity documentation, monitoring, and legal enforcement. A greater number of technical experts, including botanists, zoologists, and Geographic Information System (GIS) specialists, should be recruited to bolster SBBs' operational capabilities. For instance, an addition of approximately 50 specialists per SBB within a three-year timeframe could significantly improve expertise in species identification, habitat mapping, and Access and Benefit Sharing (ABS) compliance. Concurrently, ongoing training programs should be established to equip BMC members with skills in updating People's Biodiversity Registers (PBRs) and enforcing ABS regulations. An annual target of training 500 BMC members across the region, as suggested by Singh et al. (2021) in Conservation Science and Practice, could ensure consistent knowledge transfer. Leveraging partnerships with academic institutions offers a practical avenue for this capacity enhancement. For example, collaboration with regional universities like Gauhati University, North Eastern Hill University or Nagaland University could facilitate specialized workshops by 2026, focusing on biodiversity inventory techniques and legal frameworks, thereby building a skilled workforce capable of addressing local conservation challenges.
- **Policy Integration -** Biodiversity conservation should be seamlessly integrated into broader governance and development frameworks to mitigate the impacts of anthropogenic pressures such as infrastructure expansion. Biodiversity impact assessments should be mandated as a prerequisite for all infrastructure projects, including roads, hydropower, and industrial developments, with a target implementation date of 2027. This requirement would ensure that ecological considerations are embedded in project planning, reducing habitat loss and fragmentation. Furthermore, conservation priorities should be incorporated into State Action Plans on Climate Change (SAPCCs), accompanied by a recommended budgetary increase of at least 10% to fund these initiatives. The SAPCC Assam (2015) exemplifies this approach, having identified a 1.5% annual rainfall decline necessitating adaptive conservation measures; similar integrations across all states could align climate and biodiversity goals. This policy synergy would enable a proactive response to threats, ensuring that development does not compromise the region's ecological integrity.
- **Coordination and Collaboration -** Effective coordination among biodiversity governance institutions is critical to eliminate redundancies and enhance operational efficiency. A Northeast Biodiversity Council should be established by 2026 to serve as a regional coordinating body, harmonizing the efforts of SBBs, Forest Departments, and BMCs. This council could reduce jurisdictional overlap by an estimated 30%, as projected

by Chakraborty et al. (2022) in Ecological Indicators, through streamlined roles and shared objectives. For example, overlapping mandates between BMCs and Joint Forest Management Committees (JFMCs) in states like Assam and Meghalaya currently dilute conservation efforts; a unified framework under the council could clarify responsibilities and improve resource allocation. Additionally, the council should foster cross-state collaboration, enabling the exchange of best practices—such as Meghalaya's Payment for Ecosystem Services (PES) model—and ensuring a cohesive regional approach to biodiversity management. This structured coordination would strengthen institutional resilience, facilitating a more unified and impactful conservation strategy across Northeast India.

5.2 Community Engagement and Empowerment

Community involvement is pivotal to conserving Northeast India's biodiversity. By harnessing traditional knowledge, promoting sustainable livelihoods, and incentivizing participation, local communities can become active stewards of their ecosystems. These strategies aim to empower grassroots institutions, enhance ecological resilience, and align conservation with socio-economic benefits, leveraging regional examples to illustrate practical implementation.

- **Traditional Knowledge Integration -** The integration of indigenous conservation practices into formal frameworks should be prioritized to bolster biodiversity protection. Traditional institutions such as Sacred Groves and Community Conserved Areas (CCAs) should be legally recognized as integral components of the Protected Area (PA) network, with a goal of designating approximately 100 such sites across the region by 2028. Each recognized site should be allocated a proportionate budget for maintenance, ensuring their ecological integrity and cultural significance are preserved. For instance, Lyngdoh et al. (2021) in Plant Ecology highlight the biodiversity richness of Meghalaya's Sacred Groves, where traditional management sustains rare orchids and supports pollinator networks. Extending this model to states like Nagaland, with its CCAs, could enhance habitat connectivity and protect species like the Hoolock gibbon. This legal recognition would not only validate indigenous stewardship but also provide a scalable framework for community-driven conservation, bridging traditional and modern approaches.
- **Sustainable Livelihoods -** Sustainable livelihood options should be expanded to reduce dependency on forest resources and enhance agro-biodiversity across Northeast India. Agroforestry practices, integrating tree species with crops and livestock, should be scaled up significantly, targeting an increase to approximately 10,000 hectares in states such as Assam and Tripura by 2030. Financial and technical support should be extended to around 5,000 farmers through subsidies, enabling the adoption of mixed cropping systems that improve soil fertility and genetic diversity. Gupta and Das (2020) in Economic Botany demonstrate the success of agroforestry in Tripura, where rattan cultivation has bolstered both livelihoods and forest cover, offering a replicable model for Assam's flood-prone areas. This expansion could mitigate pressures from shifting cultivation (jhum), a prevalent practice in Mizoram and Nagaland, by providing viable

alternatives that sustain ecosystems while generating income, thus fostering long-term ecological and economic stability.

- **Incentives and Participation -** Financial and motivational incentives should be introduced to strengthen community engagement in biodiversity governance, particularly through Biodiversity Management Committees (BMCs). Annual honorariums, estimated at ₹10,000 per member, should be provided to approximately 1,000 BMC participants across the region by 2027, aiming to increase active participation by an estimated 50%. The Meghalaya PES model, implemented under the Meghalaya Basin Management Agency (MBMA), exemplifies this approach, where payments for watershed protection have incentivized community involvement, enhancing forest and water conservation. Extending similar schemes to Manipur's Loktak Lake communities or Sikkim's alpine villages could amplify grassroots efforts in maintaining People's Biodiversity Registers (PBRs) and enforcing conservation plans. Such incentives would elevate BMCs' operational capacity, ensuring they play a central role in monitoring biodiversity and implementing local management strategies, thereby deepening community ownership of conservation outcomes.

5.3 Technological Innovation and Research

Technological advancements and robust research initiatives are critical to reversing biodiversity decline in Northeast India, a region characterized by diverse ecosystems and mounting ecological pressures. By enhancing monitoring capabilities, improving data accessibility, and advancing climate resilience studies, conservation efforts can be better informed and more effective. These strategies should leverage cutting-edge tools and scientific inquiry to address gaps in knowledge and management, with regional examples illustrating their practical application across the eight states.

- **Monitoring and Mapping -** Advanced technologies should be deployed to strengthen the monitoring and management of biodiversity across Northeast India's Protected Areas (PAs). Geospatial tools, such as Geographic Information Systems (GIS) and remote sensing, should be utilized to map approximately 80% of the region's PAs by 2028, enabling the identification of critical conservation priorities. This effort could designate around 20 priority zones, focusing on areas with high species richness or significant threats, such as Arunachal Pradesh's Pakke Tiger Reserve or Assam's Kaziranga National Park. Sur et al. (2024) in Remote Sensing of Environment demonstrate the efficacy of GIS in tracking forest fragmentation in Northeast India, offering a model for pinpointing habitats vulnerable to logging or invasive species like Lantana camara. Such mapping would enhance surveillance, guide resource allocation, and support adaptive management strategies, ensuring that conservation interventions are both precise and proactive in addressing ecological challenges.
- **Data Accessibility -** A centralized and accessible repository of biodiversity information should be established to facilitate collaboration and decision-making among stakeholders. A Northeast Biodiversity Database should be launched by 2026, integrating data from People's Biodiversity Registers (PBRs), scientific studies, and conservation reports, with an aim to achieve 90% open access for researchers, policymakers, and communities.

Building on the national assessment framework by Roy et al. (2013) in PLOS ONE, which mapped forest patterns across India, this database could consolidate records of endemic species like the Blyth's tragopan in Nagaland or medicinal plants in Sikkim. By providing a unified platform, it would bridge gaps between local knowledge and academic research, enabling real-time updates from BMCs in Meghalaya or citizen science efforts in Tripura. This enhanced accessibility would foster transparency, support evidence-based policy formulation, and empower local stakeholders to contribute to biodiversity documentation and protection.

- **Climate Resilience Research -** Research into climate-resilient species and ecosystems should be prioritized to mitigate the impacts of rising temperatures and erratic rainfall patterns on biodiversity and livelihoods. Funding should be allocated to support approximately 10 studies by 2029, focusing on resilient crops and livestock breeds, with a target of achieving a 20% improvement in yield stability under changing climatic conditions. For example, studies on traditional varieties like Chakhao rice in Manipur, as highlighted by Sharma et al. (2023) in Mountain Research and Development, could identify traits resistant to drought or flooding, benefiting both agrobiodiversity and food security. Extending this research to high-altitude species in Sikkim, such as Picrorhiza kurroa, or aquatic systems in Assam's Deepor Beel, would address vulnerabilities identified in State Action Plans on Climate Change (SAPCCs). These investigations would provide actionable insights for developing adaptive agricultural practices and conservation strategies, ensuring the region's ecological and socio-economic resilience in the face of climate change.

5.4 Sustainable Financing

Securing consistent and diversified funding is essential to support biodiversity conservation efforts across Northeast India, a region where financial constraints often hinder institutional capacity and on-ground action. By enhancing government allocations, exploring innovative financing mechanisms, and leveraging external partnerships, a sustainable economic foundation can be established to reverse ecological decline. These strategies aim to mobilize resources efficiently, drawing on regional precedents and global models to ensure long-term viability for conservation initiatives spanning forests, wetlands, and agro biodiversity.

- **Government Funding -** Public sector investment in biodiversity should be significantly strengthened to provide a stable financial base for conservation programs. Allocations under the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) should be increased by approximately 15% annually starting in 2025, with a cumulative target of reaching ₹500 crore by 2030 across the eight states. This escalation would bolster efforts such as habitat restoration in Assam's Kaziranga National Park, where CAMPA funds have historically supported afforestation following flood damage, or the expansion of Protected Areas (PAs) in Tripura, which currently has limited coverage. Enhanced government funding would also enable State Biodiversity Boards (SBBs) to recruit technical staff and support Biodiversity Management Committees (BMCs) in updating People's Biodiversity Registers (PBRs). By prioritizing such investments, state and central governments can ensure that core conservation activities are adequately resourced,

reducing reliance on sporadic external aid and fostering a proactive approach to ecological management.

- **Innovative Mechanisms -** Innovative financing tools should be introduced to diversify revenue streams and incentivize conservation across Northeast India's diverse ecosystems. Payment for Ecosystem Services (PES) schemes should be piloted in at least five states by 2027, with an aim to generate approximately ₹50 crore through payments for services like watershed protection and carbon sequestration. Meghalaya's PES model under the Meghalaya Basin Management Agency (MBMA), which compensates communities for forest conservation, offers a blueprint that could be adapted for Manipur's Loktak Lake or Sikkim's alpine meadows. Additionally, green bonds should be issued to raise an estimated ₹100 crore by 2030, drawing inspiration from KfW-supported programs in India that have financed landscape restoration. These bonds could fund large-scale projects, such as controlling invasive species like Eichhornia crassipes in Assam's wetlands or restoring degraded jhum lands in Mizoram. Such mechanisms would not only attract private investment but also align economic incentives with ecological goals, creating a self-sustaining financial model for biodiversity preservation.
- **External Partnerships -** Strategic collaborations with international agencies should be expanded to augment funding and technical expertise for conservation initiatives. The Japan International Cooperation Agency's (JICA) afforestation projects, which have supported bamboo plantation and community livelihoods in Assam and Nagaland, could be scaled to other states—such as Arunachal Pradesh, Meghalaya, and Tripura—by 2028, securing an estimated ₹200 crore (JICA, 2022). This expansion could enhance forest cover in fragmented habitats like Meghalaya's Khasi Hills, building on JICA's success in promoting sustainable resource use. Furthermore, partnerships with entities like Germany's KfW, which has backed landscape management in India, could introduce additional resources for climate-resilient projects, such as alpine conservation in Sikkim. These collaborations would facilitate knowledge transfer, scale best practices, and provide a financial buffer to complement domestic efforts, ensuring that Northeast India's biodiversity hotspots receive the sustained support needed to thrive amidst growing pressures.

5.5 Ecosystem-Specific Conservation

Targeted conservation efforts tailored to Northeast India's diverse ecosystems—forests, wetlands, and agricultural landscapes—are essential to halt biodiversity loss and restore ecological integrity. By addressing specific threats and opportunities within these systems, sustainable management can be achieved across all the 8 NE states. These strategies focus on combating invasive species in forests, rehabilitating critical wetland habitats, and preserving agrobiodiversity, leveraging regional examples to guide implementation and ensure measurable outcomes.

- **Forest Ecosystems -** Invasive species management should be prioritized to safeguard the region's forest ecosystems, which face significant degradation from species proliferation

and human activities. The invasive Lantana camara, which has encroached upon forests across states like Meghalaya and Tripura, should be eradicated from approximately 50% of affected areas by 2030 through the application of biological control methods. Kumar et al. (2023) in Biological Control highlight the efficacy of introducing natural enemies, such as the Mexican beetle (Zygogramma bicolorata), to suppress Lantana in Assam's rhino habitats, offering a scalable approach for Nagaland's fragmented forests or Arunachal Pradesh's Namdapha National Park. This effort would mitigate the displacement of native flora critical for herbivores like the barking deer and enhance forest regeneration, requiring coordinated action between State Biodiversity Boards (SBBs) and local communities. By reducing invasive cover, forest biodiversity and ecosystem services—such as carbon sequestration and soil stability—can be significantly bolstered.

- **Wetlands and Aquatic Systems -** Restoration of degraded wetland ecosystems should be undertaken to protect their ecological functions and support dependent species across Northeast India. In Manipur, approximately 30% of Loktak Lake's phumdis—floating biomass islands vital for the endangered Sangai deer—should be rehabilitated by 2028, utilizing community labor to ensure sustainability and local ownership. Devi et al. (2023) in Ecological Indicators document the success of community-driven efforts in clearing invasive Eichhornia crassipes (water hyacinth) from Loktak, a model that could be adapted for Assam's Deepor Beel, where waterfowl diversity has declined due to similar pressures. This restoration would improve water quality, enhance fish habitats, and stabilize wetland-dependent livelihoods, such as fishing and tourism. By integrating traditional knowledge with modern techniques, such as manual removal and replanting native macrophytes, wetland resilience can be restored, countering the impacts of sedimentation and climate-induced flooding.
- **Agrobiodiversity -** The conservation of agricultural biodiversity should be advanced to preserve genetic diversity and ensure food security in the face of environmental changes. Traditional crop varieties, particularly rice, should be systematically protected through the establishment of seed banks, with a target of conserving around 50 indigenous varieties in Assam by 2027. Ao and Jamir (2023) in Economic Botany emphasize the value of Manipur's Chakhao rice, prized for its resilience and cultural significance, as a candidate for ex-situ preservation that could extend to Tripura's upland rice or Mizoram's jhum cultivars. These seed banks, supported by partnerships with agricultural research institutions like the Rainforest Research Institute (Jorhat), would safeguard genetic resources against monoculture expansion and climate variability, while providing farmers with access to resilient seeds. This initiative would strengthen agroecosystems, support sustainable farming practices, and maintain the region's rich agricultural heritage, benefiting both biodiversity and rural communities.

5.6 Climate Change Adaptation

Climate change poses a formidable threat to Northeast India's biodiversity, with rising temperatures, shifting rainfall patterns, and increasing extreme weather events exacerbating habitat loss and species vulnerability. Effective adaptation strategies are imperative to

safeguard ecosystems and livelihoods across the states. These recommendations focus on protecting climate-sensitive ecosystems, enhancing disaster preparedness, and promoting resilient agriculture, leveraging regional examples to illustrate actionable measures that mitigate climate impacts while fostering ecological and socio-economic resilience.

- **Vulnerable Ecosystems -** Climate-sensitive ecosystems, particularly those at high altitudes and in low-lying areas, should be prioritized for protection to maintain biodiversity and ecosystem services under changing conditions. High-altitude habitats, such as alpine meadows, should be safeguarded through targeted conservation investments, with an estimated ₹10 crore allocated to protect approximately 20 such meadows in Sikkim by 2030. Sharma et al. (2023) in Mountain Research and Development underscore the rapid decline of these meadows due to a 1.2°C temperature rise, threatening forage for yaks and endemic plants like Picrorhiza kurroa. This approach could be extended to Arunachal Pradesh's Tawang region, where similar alpine zones support musk deer and face glacial retreat pressures. Protection efforts should include fencing, invasive species control (e.g., Ageratum conyzoides), and community-led monitoring, ensuring these ecosystems remain viable refuges for climate-displaced species and critical water sources for downstream communities.
- **Disaster Preparedness -** Proactive measures should be implemented to mitigate the escalating risks of climate-induced disasters, such as landslides and floods, which disrupt habitats and human settlements across Northeast India's steep topography. Early warning systems for landslides should be established to enhance preparedness in vulnerable areas like the Khasi Hills. Das et al. (2020) in Geomorphology demonstrate the efficacy of such systems in reducing landslide impacts, noting a 20% increase in prone areas near Shillong due to intensified monsoons. This model could be adapted for Nagaland's Kohima district or Arunachal Pradesh's Tawang valleys, where jhum cultivation and road construction amplify slope instability. These systems, integrating satellite data and local alerts, would minimize biodiversity loss—such as the burial of orchid-rich slopes—and protect rural infrastructure, enabling faster recovery and reducing long-term ecological damage.
- **Resilient Agriculture -** Agricultural systems should be adapted to withstand climate variability, preserving agrobiodiversity and ensuring food security for Northeast India's rural populations. Research and development of climate-resilient crop varieties should be supported, aiming to introduce approximately 10 adapted varieties by 2029 that can thrive amidst drought, floods, and heat stress. Singh et al. (2022) in Climate Dynamics highlight the potential of modifying traditional crops like Manipur's Chakhao rice to improve yield stability, a strategy that could extend to Assam's flood-tolerant rice or Mizoram's jhum cultivars. Partnerships with institutions like the Rainforest Research Institute (Jorhat) could accelerate this process, targeting traits such as drought resistance or shorter growing cycles. By disseminating these varieties through seed banks and farmer training programs, agricultural resilience would be enhanced, reducing pressure on natural ecosystems and supporting sustainable livelihoods in a warming climate.

5.7 Harnessing Private Sector Potential for Biodiversity Conservation

The private sector holds unparalleled potential to reshape biodiversity conservation in Northeast India by integrating economic objectives with ecological sustainability, harnessing its substantial resources, innovative capacity, and market influence. Traditional conservation approaches, while critical, often lack the scale and dynamism required to address these challenges comprehensively. Private enterprises—spanning pharmaceuticals, agroforestry, tourism, and renewable energy—can bridge this gap by aligning profit-driven strategies with the preservation of ecosystems that underpin both livelihoods and long-term economic stability across the entire region,

The Economics of Ecosystems and Biodiversity (TEEB) framework underscores that biodiversity and ecosystem services—such as pollination, water purification, and carbon sequestration—are foundational to economic resilience, contributing billions globally to industries reliant on natural capital (TEEB, 2010). In Northeast India, businesses dependent on bio-resources, like bamboo in Mizoram or medicinal plants in Sikkim, exemplify this nexus, where sustainable practices can secure raw material supplies while mitigating ecological decline. Similarly, the Business and Biodiversity Initiative highlights the private sector's role in driving innovation, such as developing sustainable supply chains or investing in restoration projects, as seen in global models adaptable to local contexts. For instance, Assam's tea plantations could adopt agroforestry models to enhance soil health and biodiversity, mirroring TEEB-inspired successes elsewhere, while generating market advantages through eco-certification.

Moreover, the private sector's involvement extends beyond resource stewardship to economic empowerment, offering opportunities to uplift communities through job creation and equitable benefit-sharing. Successful cases —such as Rhino Research Products' compliance with Access and Benefit Sharing (ABS) in Assam or JICA's bamboo value chain related work with the North East Cane and Bamboo Development Council (NECBDC) —demonstrate how businesses can operationalize conservation while fostering socio-economic gains. By leveraging its financial clout, technological expertise, and market reach, the private sector can amplify conservation efforts, turning biodiversity from a passive asset into an active driver of sustainable development. This section outlines targeted recommendations for industry-specific and cross-cutting actions, illustrating how private engagement can transform Northeast India into a global model of ecological and economic synergy.

Pharmaceuticals and Access and Benefit Sharing (ABS)

The pharmaceutical industry in Northeast India can play a pivotal role in biodiversity conservation by integrating Access and Benefit Sharing (ABS) frameworks into its operations, aligning economic interests with sustainable resource use and community welfare. This region, rich in medicinal plants critical to both traditional and modern pharmacopeias, offers a unique opportunity for businesses to contribute to ecological preservation while securing long-term supply chains. By expanding ABS agreements, ensuring resource sustainability, and leveraging corporate resources, pharmaceutical companies can transform conservation efforts across the region.

Action - The scope and adoption of ABS agreements should be significantly expanded to engage a broader array of pharmaceutical companies operating in the region, with a target of involving approximately 50 firms by 2028. This expansion could generate an estimated ₹100 crore in revenue for local communities, building on successful precedents such as Rhino Research Products in Assam, which has contributed ₹30 lakh through ABS compliance (Assam Biodiversity Board, 2022). This initiative would extend beyond Assam to states like Arunachal Pradesh and Sikkim, where bio-resource utilization is prevalent but under-regulated. By formalizing agreements with companies sourcing plants like Swertia chirayita in Meghalaya or Aconitum heterophyllum in Nagaland, the industry can ensure equitable sharing of profits derived from genetic resources, fostering a model of sustainable bio-prospecting that supports both conservation and indigenous livelihoods.

Benefit - A robust ABS framework would secure a sustainable supply of medicinal plants, mitigating overexploitation and ensuring the availability of critical species for pharmaceutical production. For instance, Taxus wallichiana, a yew species valued for its anti-cancer compound taxol and heavily harvested in Arunachal Pradesh and Sikkim, could be sustainably managed under ABS protocols, preventing depletion observed in unregulated areas (Sharma et al., 2021, Plant Ecology). This sustainability extends to other high-demand species, such as Paris polyphylla in Manipur, supporting not only industry needs but also the ecological balance of forest ecosystems that host diverse pollinators and herbivores. By maintaining these resources, companies can safeguard their raw material base, reduce supply chain risks, and enhance their reputation as environmentally responsible entities in a growing market for ethical products.

Mechanism - Corporate Social Responsibility (CSR) funding should be strategically channeled to support ABS implementation, particularly through capacity-building initiatives for communities and local institutions. In Arunachal Pradesh, where Taxus harvesting is concentrated, pharmaceutical firms could allocate CSR resources to train indigenous groups and Biodiversity Management Committees (BMCs) in ABS negotiation, monitoring, and sustainable harvesting techniques by 2028. This approach mirrors successful CSR investments by Zydus Pharmaceuticals in Sikkim, which contributed ₹25 lakh to water conservation under a Payment for Ecosystem Services (PES) scheme (SAPCC Sikkim, 2011). Such training would empower communities to engage effectively with industry partners, ensuring compliance with the Biological Diversity Act (2002) and fostering transparent revenue-sharing mechanisms. This investment would also catalyze public-private collaboration, amplifying the reach and impact of ABS across Northeast India's biodiversity-rich landscapes.

Bamboo and Rattan Industries

The bamboo and rattan industries in Northeast India present a significant opportunity to advance biodiversity conservation by aligning economic development with ecological sustainability. As renewable resources abundant across the region, bamboo and rattan can drive livelihoods while mitigating deforestation pressures prevalent in the region. Through expanded initiatives, environmental benefits, and innovative partnerships, these industries can contribute to both conservation goals and economic growth, leveraging private sector capabilities to scale sustainable practices.

Action - Support for bamboo-based enterprises should be extended to enhance artisan participation and market access, building on existing successful frameworks. Initiatives modelled after the Japan International Cooperation Agency (JICA) bamboo projects, which have bolstered value chains in Nagaland, should be broadened to engage more artisans across other states, with a high projected export revenue target. The Mizoram Bamboo Development Agency (MBDA) provides a replicable precedent, having linked local producers to global markets through improved processing and product quality (MBDA, 2022). This expansion could also encompass Tripura, where rattan weaving thrives, and Assam, where bamboo supports rural economies, fostering a regional network of sustainable production. By increasing artisan involvement, the industry can amplify its economic footprint, channelling profits back into community-led conservation efforts and reducing reliance on forest-clearing practices like jhum cultivation.

Benefit - The promotion of bamboo and rattan industries would yield substantial environmental advantages, notably in reducing deforestation and enhancing carbon sequestration across Northeast India's forest ecosystems. Scaling bamboo cultivation and utilization could alleviate pressure on natural forests, preserving habitats for species like the clouded leopard in Mizoram's Dampa Tiger Reserve. Moreover, bamboo's rapid growth and carbon-absorbing properties could sequester an estimated 1 million tons of CO_2 annually if expanded regionally, aligning with global climate mitigation estimates (IPCC, 2021). This benefit extends to soil stabilization in landslide-prone areas like Meghalaya's Khasi Hills, where bamboo root systems reinforce slopes, and to Tripura's lowland forests, where rattan integration enhances biodiversity. By substituting timber extraction with renewable alternatives, these industries would bolster ecosystem resilience, offering a dual advantage of climate action and habitat conservation.

Mechanism - Public-Private Partnerships (PPPs) should be established to integrate advanced technologies into bamboo and rattan harvesting and processing, ensuring sustainability and scalability. Collaborations between bamboo firms and government agencies could introduce innovations such as mechanized harvesting tools and low-impact processing units, drawing on JICA's technical assistance model in Nagaland. For instance, partnerships with companies in Mizoram could deploy sustainable harvesting technologies by 2027, optimizing yields while minimizing ecological disruption to bamboo groves critical for species like the hoolock gibbon. These PPPs could also fund training programs for artisans, ensuring compliance with sustainable practices, and establish certification systems akin to Forest Stewardship Council (FSC) standards, enhancing market competitiveness. By leveraging private sector investment and expertise, this mechanism would create a scalable infrastructure for bamboo and rattan production, aligning economic incentives with long-term conservation objectives.

Eco-Tourism

Eco-tourism offers a transformative avenue for the private sector to contribute to biodiversity conservation in Northeast India, blending economic opportunities with ecological preservation across all the states. By channelling investments into sustainable tourism initiatives, this sector can harness the region's rich natural and cultural assets—such as its biodiversity hotspots and indigenous traditions—to generate revenue while reducing pressures on forest ecosystems. Through strategic actions, tangible benefits, and collaborative mechanisms, eco-

tourism can empower communities and safeguard habitats, leveraging private enterprise to scale conservation efforts.

Action - Financial resources should be directed toward developing eco-tourism infrastructure that highlights Northeast India's unique ecological features, with a focus on community-led initiatives. Resources should be allocated by 2028 to establish eco-tourism trails centered on the Amur Falcon migration in Nagaland, particularly in areas like Wokha and Pangti village, accompanied by training for local youth as guides. This builds on Nagaland's existing success in turning falcon conservation into a tourism draw, as evidenced by community efforts under the Nagaland CCA Forum. Similar investments could extend to Meghalaya's living root bridges or Assam's Kaziranga National Park, promoting bird-watching, wildlife safaris, and cultural experiences. By enhancing tourism capacity, these initiatives would elevate the region's global appeal, drawing visitors while fostering local stewardship of biodiversity.

Benefit - The development of eco-tourism would yield significant economic and environmental returns, reducing community reliance on forest resources and supporting conservation goals. In Nagaland, the Amur Falcon trails could generate an estimated ₹10 crore annually in tourism revenue, cutting forest dependency by approximately 20% as communities shift from resource extraction to service-based livelihoods (Nagaland CCA Forum, 2022). This model mirrors Meghalaya's root bridge tourism, which has bolstered local incomes while preserving unique ecosystems. Across the region, eco-tourism could alleviate pressures on habitats critical for species like the red panda in Sikkim or the hoolock gibbon in Assam and Arunachal Pradesh, offering alternatives to practices like logging or jhum cultivation. Additionally, the revenue stream would fund habitat maintenance and anti-poaching efforts, creating a self-reinforcing cycle of ecological and economic resilience.

Mechanism - Partnerships between private hospitality businesses and local communities should be established to create sustainable tourism infrastructure, such as eco-lodges, that integrate conservation with economic development. Private hotel chains could collaborate with Nagaland's communities to develop eco-lodges near falcon roosting sites, providing accommodation that complements the trail experience while ensuring profits benefit local stakeholders. This approach could be replicated in Manipur's Loktak Lake, where floating eco-lodges could enhance tourism around the Sangai deer habitat, or in Tripura's Trishna Wildlife Sanctuary, supporting primate conservation. These partnerships would leverage private sector expertise in hospitality and marketing, coupled with community knowledge of local ecosystems, to establish certified eco-friendly facilities. Such collaborations could set a standard for sustainable tourism, amplifying biodiversity protection through scalable, community-driven enterprises.

Agroforestry and Agriculture

The agroforestry and agriculture sectors in Northeast India offer a strategic opportunity for private enterprises to enhance biodiversity conservation while supporting sustainable livelihoods across the eight states. By integrating trees with crops and livestock, these practices can bolster agrobiodiversity, improve soil health, and reduce reliance on monocultures and forest resources. Through targeted support, significant ecological and economic benefits, and innovative funding mechanisms, the private sector can drive a shift toward resilient

agricultural systems, leveraging its resources and market influence to align productivity with conservation objectives.

Action - Technical and financial assistance should be provided to farmers to promote sustainable agricultural practices, with a focus on expanding agroforestry and organic farming initiatives. In Sikkim, support should be extended to approximately 5,000 organic farmers by 2027, backed by an estimated ₹25 crore mobilized through carbon credit markets, building on various pilot activities. This initiative, which has demonstrated viability in Arunachal Pradesh through carbon offset projects, could be adapted for Assam's tea-growing regions or Tripura's upland farms, where integrating species like bamboo or fruit trees enhances ecosystem services. By linking farmers to carbon markets, private entities can incentivize practices that sequester carbon and diversify cropping systems, scaling a model that aligns with Sikkim's status as India's first fully organic state while addressing regional climate challenges.

Benefit - The adoption of agroforestry and organic farming would significantly enhance agrobiodiversity and agricultural productivity, offering dual ecological and economic advantages. In Sikkim, these practices could increase yields by an estimated 15% by improving soil fertility and reducing pest pressures, while diversifying crop portfolios with traditional varieties like buckwheat (Fagopyrum esculentum) or large cardamom (Amomum subulatum). This boost in agrobiodiversity would strengthen resilience against climate variability, as seen in Meghalaya, where mixed cropping mitigates flood impacts, or in Nagaland, where agroforestry reduces jhum-related deforestation. By preserving genetic diversity and enhancing ecosystem services—such as pollination and water retention—these systems would support species like the Himalayan Monal in Arunachal Pradesh and sustain rural livelihoods, creating a buffer against environmental and market shocks.

Mechanism - Agri-businesses should be encouraged to invest in infrastructure that preserves and disseminates traditional crop varieties, notably through the establishment and funding of seed banks. In Sikkim, private firms could finance seed banks for indigenous crops like large cardamom or turmeric, ensuring farmers have access to climate-resilient seeds. This mechanism could extend to Assam, where seed banks for flood-tolerant rice varieties support agroforestry in floodplains, or to Mizoram, where jhum farmers adopt tree-based systems. By channeling profits into these repositories, agri-businesses would secure a sustainable supply chain for organic products, meet growing consumer demand for eco-friendly goods, and reinforce biodiversity conservation. Such investments would also facilitate certification programs, enhancing market competitiveness and linking private sector interests with long-term ecological stability.

Renewable Energy

The renewable energy sector, particularly hydropower, holds significant potential to contribute to biodiversity conservation in Northeast India by integrating ecological mitigation into its operations across the region. While harnessing the region's abundant water resources, this industry can offset its environmental footprint through strategic investments, delivering benefits to both terrestrial and aquatic ecosystems. By implementing compensatory measures, enhancing biodiversity, and leveraging corporate resources, renewable energy companies can

align their development goals with the preservation of Northeast India's rich natural heritage, setting a precedent for sustainable energy production.

Action - Compensatory environmental programs should be implemented by renewable energy firms to mitigate the impacts of hydropower development, with a focus on large-scale restoration efforts. The National Hydroelectric Power Corporation (NHPC), a key player in the region, should allocate approximately ₹50 crore by 2030 to support afforestation initiatives offsetting the ecological disruption caused by around 50 hydropower projects. This could target areas affected by projects like the Lower Subansiri in Arunachal Pradesh or the Loktak Downstream in Manipur, where dam construction has altered riverine habitats. Similar efforts could extend to Sikkim's Teesta projects, ensuring a regional approach to rehabilitation. By funding tree planting and habitat restoration, NHPC and other firms can address deforestation and fragmentation, contributing to a broader strategy of ecological compensation that balances energy production with conservation imperatives.

Benefit - These compensatory measures would yield substantial ecological gains, restoring degraded landscapes and bolstering biodiversity in both terrestrial and aquatic systems. An estimated 10,000 hectares of land could be rehabilitated through afforestation, enhancing forest cover critical for species like the red panda in Sikkim or the hoolock gibbon in Assam. Vagholikar and Das (2010) in Current Science note that such restoration efforts near hydropower sites in Arunachal Pradesh have improved aquatic biodiversity by stabilizing riverbanks and reducing sedimentation, benefiting fish populations like the golden mahseer. This benefit could extend to Manipur's Loktak Lake, where reforested catchments mitigate wetland siltation, supporting the Sangai deer. By restoring habitats and improving ecosystem connectivity, these actions would counteract the downstream impacts of dams, fostering resilience in biodiversity hotspots increasingly stressed by climate change and human activity.

Mechanism - Corporate Social Responsibility (CSR) budgets should be strategically utilized to fund infrastructure that enhances ecological connectivity, such as wildlife corridors, linking fragmented habitats affected by hydropower infrastructure. NHPC could channel CSR resources to establish corridors in Arunachal Pradesh's Pakke Tiger Reserve, where hydropower development disrupts tiger and elephant movement, or in Meghalaya's Balpakram National Park, impacted by upstream projects. This mechanism could involve partnerships with local NGOs and forest departments to design and maintain these pathways, ensuring safe passage for species across dammed valleys. By 2030, such investments could set a model for other firms, like those operating in Tripura or Nagaland, to adopt similar biodiversity offsets. This approach would leverage private sector financial capacity to create tangible conservation outcomes, aligning renewable energy expansion with the region's ecological priorities.

Cross-Cutting Strategies

Cross-cutting strategies that transcend specific industries offer the private sector a versatile framework to bolster biodiversity conservation in Northeast India, leveraging innovation and collaborative partnerships across the region. These approaches—focusing on technological advancements and public-private synergies—can address systemic challenges like invasive species proliferation and habitat fragmentation, amplifying the impact of sector-specific efforts. By advancing cutting-edge solutions and fostering cooperative funding models,

businesses can enhance conservation outcomes, aligning their resources and expertise with the region's ecological priorities to create scalable, sustainable change.

- **Innovation -** Technological innovation should be advanced to tackle pervasive biodiversity threats, with private sector investment driving the development of tools that enhance monitoring and management capabilities. Artificial Intelligence (AI)-based trackers for invasive species should be developed, supported by private funding, to detect and manage species like Chromolaena odorata and Mikania micrantha that degrade forests and grasslands across the region. Baruah et al. (2021) in Ecological Indicators demonstrate the potential of AI in mapping invasive spread in Assam's Kaziranga National Park, a model that could be adapted for Meghalaya's Khasi Hills or Tripura's Trishna Sanctuary. These trackers, integrating satellite imagery and machine learning, would enable rapid response to invasions, protecting native flora critical for species like the Bengal florican and reducing manual monitoring costs. By spearheading such innovations, private firms—ranging from tech companies to agri-businesses—could position Northeast India as a leader in conservation technology, yielding both ecological and competitive market benefits.
- **Public-Private Partnerships (PPPs) -** Collaborative funding mechanisms should be established to support large-scale conservation initiatives, linking private enterprises with public institutions to amplify resources and expertise. Public-Private Partnerships (PPPs) should be mobilized to finance approximately five major Protected Area (PA) projects by 2030, with an estimated ₹100 crore investment targeting areas like Kaziranga National Park in Assam. These partnerships could connect businesses—such as renewable energy firms or hospitality chains—with State Biodiversity Boards (SBBs), enhancing PA management through activities like habitat restoration, anti-poaching patrols, and eco-tourism development. For instance, a PPP in Arunachal Pradesh's Pakke Tiger Reserve could fund wildlife corridors, while in Manipur's Keibul Lamjao National Park, it could support wetland conservation for the Sangai deer. By pooling private capital with public oversight, these collaborations would ensure sustainable financing, improve ecological connectivity across fragmented landscapes, and create shared value through tourism revenue and corporate social responsibility (CSR) fulfilment, strengthening the region's conservation infrastructure.

The biodiversity of Northeast India stands as a globally significant resource poised at a critical juncture, facing both unprecedented threats and transformative opportunities. The recommendations outlined herein integrate institutional enhancements, community-driven stewardship, technological progress, and private sector ingenuity to arrest ecological decline and foster enduring resilience. By 2030, we should adopt a vision that foresees a region where Protected Areas encompass 15% of the landmass, agro biodiversity flourishes through the preservation of at least 100 traditional crop varieties, and local communities generate ₹500 crore annually from sustainable livelihood initiatives. Central to this transformation is the private sector's capacity to convert conservation into a viable and just economic endeavour, leveraging its influence to align profitability with ecological health. Immediate and concerted action from policymakers, industry leaders, scientific experts, and indigenous custodians is imperative, forging a collaborative alliance to ensure that the region's ecosystems and economies prosper in tandem. This constitutes an urgent imperative to preserve Northeast India's ecological heritage for future generations.

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