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Dr. Runu Waikhom
(Director)

CUNITIVE (OPC) PRIVATE LIMITED
Email: waikhomathoi@gmail.com

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Preface

It is with immense pleasure that we present **Volume II of Multidisciplinary Trends of Studies in India**, published by **CUNITIVE OPC PRIVATE LIMITED**. This volume brings together outstanding scholarly contributions from distinguished academicians, researchers, and professionals representing diverse disciplines and institutions across India. The collection reflects the spirit of multidisciplinary research by addressing contemporary issues through innovative theoretical, empirical, and practical perspectives.

This volume includes valuable contributions from **Nongmaithem Menka Devi, Nazia Ahmed, Khwairakpam Tapaskumar, Dr. Khomdram Bidyarani Devi, Dr. Khomdram Monalisha Devi** whose chapters collectively explore significant themes in environmental studies, management, commerce, economics, education, law, social sciences, technology, and other emerging fields. Each author has contributed unique insights that enrich academic discourse and promote interdisciplinary understanding.

The editors sincerely appreciate the dedication and scholarly efforts of all contributing authors. Their commitment to academic excellence has made this volume a meaningful addition to contemporary research literature. We also express our gratitude to the reviewers, editorial team, and publication staff for their invaluable support in ensuring the quality and integrity of this publication.

It is our sincere hope that **Volume II of Multidisciplinary Trends of Studies in India** will serve as an important reference for researchers, academicians, students, professionals, policymakers, and libraries. We believe the diverse perspectives presented in this volume will encourage further research, foster interdisciplinary collaboration, and contribute meaningfully to the advancement of knowledge.

Dr. Runu Waikhom

Editor & Director,Cunitive Opc Private Limited
July 2026

Index

Chapter	Title	Author	Page(s)
Chapter I	Introduction to Pro-Environmental Meitei Culture	Nongmaithem Menka Devi	1–17
Chapter II	Green Financing: Assessing Its Role in Sustainable Development and Economic Growth	Nazia Ahmed	18–39
Chapter III	Urbanization and the Traffic System Impact Each Other in Northeast India	Khwairakpam Tapaskumar	40–52
Chapter IV	Soil Biochemistry and Organic Fertilization Strategies for Sustainable Plantation Systems in Manipur	Dr. Khomdram Bidyarani Devi	53–68
Chapter V	Green Urbanization and Its Environment in Manipur	Dr. Khomdram Monalisha Devi	69–82

CHAPTER I:

INTRODUCTION TO PRO- ENVIRONMENTAL MEITEI CULTURE

NONGMAITHEM MENKA DEVI
(Research Scholar)
Department of Sociology, Jayoti Vidyapeeth Women’s University, Jaipur

Abstract : Environmental degradation has become a major global concern due to rapid industrialization, urbanization, and unsustainable human activities. Indigenous communities possess valuable traditional ecological knowledge that can contribute to sustainable environmental conservation. This study examines the pro-environmental practices of the Meitei community in Manipur by exploring their historical evolution, cultural and religious beliefs, and traditional environmental ethics. It further investigates the influence of modern environmental challenges, community participation, government support, and contemporary environmental policies on the sustainability of these practices. The study seeks to understand how traditional knowledge can be integrated with modern conservation strategies to promote sustainable environmental management. The findings are expected to demonstrate that the Meitei community's cultural heritage continues to play a significant role in environmental stewardship while highlighting the importance of combining indigenous knowledge with scientific and policy-based approaches. The study contributes to environmental research and provides practical recommendations for sustainable development and biodiversity conservation in Manipur.

Keywords: Meitei Community; Pro-Environmental Practices; Indigenous Ecological Knowledge; Sustainable Environmental Conservation.

1. Introduction

The conflict between human actions and the environment has quickly become a major

international concern. In reality, all of the world's environmental issues, including environmental deterioration, have their roots in human activity. The greenhouse effect, air pollution, global warming, and other similar phenomena are all brought about by human actions. Both environmental protection and degradation originate from human actions. Many of the most pressing environmental problems are directly related to human population and economic development, including but not limited to the extension and intensification of agriculture, the unchecked spread of urbanization, the degradation of natural ecosystems, the forces pushing toward industrialization, etc. Although it is crucial for personal and national development, economic growth is often associated with damaging environmental degradation. Development that satisfies current demands without jeopardizing future generations' capacity to do the same was characterized as sustainable development in 1987 by the World Commission on Environment and Development. There are two main ideas presented there: (a) the idea of "needs," with special emphasis on the most basic requirements of the world's poor, which must be met at all costs, and (b) the reality that environmental resources are finite due to current technological and social structures.[1] There are two schools of thought when it comes to sustainability. One school of thought holds that economic growth and stability are the most important aspects of sustainability. The second school of thought holds that sustainable development, which integrates environmental and development concerns, is more important for the long-term health of the biosphere, including the maintenance of human populations and the protection of biodiversity within a specific area or region with finite natural resources. The present generation's progress as human beings is hindered by environmental deterioration, which endangers future generations' ability to live safely. Pollution poses risks to people's health, and the loss of finite natural resources impacts people's ability to make a living now and in the future. Many illnesses, including those transmitted by vectors, such as dengue fever, encephalitis, and malaria, have recently emerged or are making a comeback due to environmental pollution. Problems have arisen in most nations due to the growth in greenhouse gases (GHGs), which cause global warming, water pollution, and increased pesticide reliance, among many other issues. "Two of the most important indicators of human development—the infant mortality rate and life expectancy—are closely related to two environmental indicators, namely, access to clean water and sanitation."[2] Life expectancy is decreasing, and infant mortality is increasing due to air, water, and land pollution,

poverty, and unsanitary circumstances, particularly in human settlements such as slums. There is a vicious cycle where a larger population causes poverty and environmental degradation. Emissions of greenhouse gases from industrial operations are a major contributor to environmental deterioration, and this problem is worse in industrialized industrialist nations than in less developed ones. For instance, the local need for farmland or building materials is a partial reason for deforestation in impoverished nations. Developed and developing nations collect fish, minerals, energy, and biodiversity resources; nonetheless, the size and intensity of resource exploitation are generally dictated by the wants and tastes of the world's wealthiest nations. Many people have pointed out that the industrialized nations are mostly to blame for climate change threatening human health, ecosystems, and biodiversity. Even though they only comprise 20% of the global population, industrialized nations are responsible for 80% of greenhouse gas emissions[3]. The melting of snow and glaciers causes the increasing temperatures caused by global warming. In the long run, this will cause catastrophic damage to Earth. Groups concerned with both economics and the environment have banded together to discuss the growing threat posed by unchecked human activity to the environment. The industrialized nations committed to reducing their emissions of six greenhouse gases by 5.2% compared to 1990, averaged over 2008–2012, as per the "Kyoto Protocol." Another agreement was the "Montreal Protocol," an international treaty aimed at protecting the ozone layer that was inked on September 16, 1987, and went into force on January 1, 1989, after a first meeting in Helsinki in May. Several modifications have been made to it since then.

Some examples are the danger of chlorofluorocarbon (CFC) to the climate and the acid rain destroying North American and European forests and lakes.

1.1 Background of the Study

1.1.1 Overview of Meitei Culture

There is no agreed-upon theory as to where the Meitei came from. Because of the many urban stories and myths surrounding the Meitei, its origins remain a mystery. Their genesis is the subject of conflicting hypotheses. Researchers in history, anthropology, archaeology, sociology, and other social sciences have tried deciphering the Meitei's origin stories beyond what is found in folklore. Other

sources for studying the Meitei's origin include several Puyas, which are old documents in an archaic form, as well as foreign works on anthropology, local chronicles, archaeological discoveries, folklore, and published literature.

The belief that the Meitei descended from the Supreme God "Atiya Guru Sidaba" is one of the most widely held ideas of origin related to the myth of Divine Origin.The Meitei are older adults who first arrived in the Koubru hills[4] during the reign of Atiya Guru Sidaba, according to a knowledgeable Pandit familiar with the Puyas. After deciding to relocate to the valley, the monarch set out towards the base of the Nongmaiching hill. Two more Pandits who were questioned have confirmed this. According to one of them, they arrived in Manipur in the Palaeolithic period. However, little archaeological evidence from Manipur still needs to be supported. On top of that, the Pandit of Manipur draws parallels to the idea of divine origin. Being proficient in the Puyas has led him to believe that God created everything. In "Atiya Guru Sidaba," the Creator's two sons were Konjin Tuthokpa (often spelled "Sentreng") and Asiba (sometimes spelled "Kuptreng" or "Sanamahi"). In the Pandit's view, Sanamahi did not originate from Atiya Guru and Leisana's biological family. He was the adopted son of the two Lais and was discovered in an Earthern pottery pot, known as a Chafu Ahingba. The Supreme Being, "Atiya Guru Sidaba," commanded his oldest son, Asiba, to build the planet Earth. Then, Atiya Guru Sidaba gave him the order to construct a human being. Initially, Asiba made the Ngamu (Lata fish), but his father disapproved. After that, a frog was born. His fathe was still unsatisfied. He later made a monkey, but that one was also turned down. In light of these setbacks, Atiya Guru Sidaba suggested that Asiba construct a human being in his likeness. After that, Asiba created human beings. The person's name was Taibangmi. Like the first man, this was created by God, according to Christians. Hi, Adam. Atiya Guru Sidaba's son created humans and all other animals. It was abandoned in the tree, on land, and in the water, together with the monkey, frog, and fish. Atiya Guru Sidaba desired to choose a ruler among his two sons after the formation of the globe. He came up with an idea. It was thought that the two boys were manifestations of God. To begin, Atiya Guru Sidaba put his two kids to the test by having them float down the river like a lifeless cow. For some reason, Asiba mistook his father for the cow and assumed it was dead and rotting. Kongin Thuthokpa, however, recognized their father and brought up the lifeless cow for the burial ceremonies.

This is why he was called "Pakhangba," meaning "knowing his father." Some literary sources explain that the Meiteis distributed the corpse to their seven clans. Despite Pakhangba's recognition of his father, Asiba, and his creation of thEarthth, Atiya Guru Sidaba wanted to test his sons again, so he sent them on a mission around the universe. He said the one who finished the trip first would rule the world. Their father had advised Sanamahi to go on the excursion, so she did. However, Pakhangba was too frail a youngster to pull it off.

Upon seeing her son in a depressed state, Pakhangba's mother, Leimaren Sidabi, counseled him, saying that circling the globe was like circling his father's palace. After listening to her counsel, Pakhangba became king of the earth after winning the race. His brother had become king when Sanamahi returned. He became enraged and attempted to murder his sibling. This was avoided when Atiya Guru Sidaba calmed him by detailing his brother's triumphant return from the expedition and bestowing him the position of a revered deity to be adored in every home. 'Cheitharol Kumbaba' states that Pakhangba became king in 33, and Sanamahi is a spiritual divinity of the Meitei. Both traditions originated from this.

Mr. A.G. Examples can be seen in the Puranic accounts with their Panchalakshana or in Genesis in the Old Testament. "The twilight house between history and prehistory is everywhere animated by theogony, ethnology, and the actions of superhuman rulers."[5] This means that the early history of humanity or the formation of early states is filled with stories of divine or sometimes semi-human interventions. It would be unfair to apply euhemerism—the view that the gods are just glorified humans—to all cases or to disregard it when people make assertions based on it entirely. Writing off all these myths as irrelevant would be a disservice to history. Instead, it should explain why certain legends are preserved for future generations while others are forgotten.[6] According to one interviewee, the Meitei clan structure began with Pakhngba's ascension. According to Gangumei Kabui, the seven clans of the Meiteis were born when Pakhangba cut the dead cow into seven pieces.[7]

People in pre-civilization societies were more likely to blend in with their peers due to a lack of cultural influences and adaptations. Any member of the group who showed extraordinary skill would be assumed to have been born asexually and to have derived his nourishment from a supernatural or demonic source, depending on the situation, and to have commanded the respect and devotion of his peers

accordingly.[8] From the depths of mythology and religion, we can pull countless tales that attest to this. Moreover, "the persistence of mythical history allowed for an evoking of the elements of the ancient, and the notion of superior civilization values."[9] One such tale has to do with the origin of the land, asserting that it is of Hindu descent; according to this myth, the valley of Manipur sat underwater for an extremely long period. Nine Laibungthous (divine youths) and seven Lainuras (divine females) could construct 64 hillocks. In legend, Lord Siva used his trident to carve a path through the mountain, which allowed him to drain the water and prepare the region for human settlement.[10]

Meitei and Tangkhul could be brothers, according to another hypothesis. In the past, the hill region was home to every Manipur resident. The younger sibling descended to the valley and made his home there. Prior to then, the Manipur valley was underwater and uninhabitable. The brother who remained on the hill begged his younger sibling to build a fire in the valley so that he could be sure he would be safe there. When the older brother saw this, he would also build a fire on the hill to let the younger brother know that he was keeping an eye on him. Looking down from the hill, the older brother could always tell that his younger brother was thinking of him whenever he saw the fire in the valley. 'Tangkhul' became the name of the brother who lived on the hill, while 'Meitei' became the name of the brother who lived in the valley.

Other hypotheses include Aryan, Mon Khemer, Tai, or Tibeto-Burman origins. Manipur has three primary ethnic groupings: the hill-groups: Kuki Chin, and valley-dwelling Meite.

T.C. Hodson posits that the terms "Meitei"—meaning "man" or "people"—and "Tei"—meaning "separate"—are the origins of the group's name. Individuals are called meetings. But Sir B.H. Hodgson expressed that Meitei is the combined appellate of Siamese "Tai" and Kachin Chinese 'Moy' (Moy Tai = Moitai = Meitei) and that the Meetei belongs to the Moi section of the great Tai race.[11] Further, T.C Hodson asserts that in other words, the Manipuris tribe, called Cosseahs by the Bengalis, belong to the Mon section of the great tribe called Tai, by themselves, and the Shan Vel Syan by the Burmese.[12] Hodson also stated: two hundred years ago, in the internal organization in the village, in habits and manners, the Meiteis were as the hill people now are.[13] Historically, the word Meetei established the Ningthouja dynasty of Pakhangba. The Meitei may have descended from the Aryans, according

to one school of view. Gangumei Kabui states that the "Aryan connection of the Meitei was an outcome of the adoption of Hinduism by the ruling family and the people of the valley in the eighteenth century and the resultant claim of the descendants of the ruling dynasty from Babhruvahana, a scion of the Pandava hero Arjun of the Mahabharata."[14] In a similar manner, the glorious history of ancient Assam was also at times represented as an Aryan past, so that despite several non-Aryan rules having ruled the ancient realm, it was the worship of Vedic goddesses, including the Devi, which was prevalent.[15] The fact is that Meitei is neither an Aryan stock nor an Indo-Aryan, although they absorbed some Aryan elements from Aryan colonizers, adventurers, and immigrants.[16] The Meitei adopted Hinduism from the time of King Ga. The king had them convert to Hinduism after Santi Das convinced them. The Manipuris assert that they were once Hindus and use passages from the Mahabharata to back up their claim. There is no information beyond Arjun's arrival in Manipur, his three-year residence there, and his marriage to Chitrangada, daughter of King Chitrabahan of Manipur. The epic Mahabharata's Adi Parva is when the word Manipur first occurs. Arjun's journey to the eastern area, where he became known as an Anga and Kalinga, is associated with the earliest name, Manlurpur. According to Pravabati, Arjuna arrived in Manipur via the hill route that linked the Manipur valley to Burma or the Barak valley. This is thought to have been the same route that the Brahmanas and other Aryan immigrants used, leading to their vast settlements in the past.[17] R.K. Famous historian Jhaljit put out the idea of an Aryan ancestry. According to the historian, the Indo-Aryans settled near Manipur's Sekta Village and the Iril River. According to him, the Sanskrit term "Sikata" is the origin of the English word "Sikatra," which means "Sand." He further claimed that the word "Sekta" translates this Sanskrit word. Maybe it is wrong. According to Sir James Johnstone, the Meitei were a racial hybrid of Indo-Chinese and Aryan ancestry. The North East area has a wide variety of Aryan traits, according to B.C. Allen. The story suggests that the Kshatriya princes' arrival path was via Manipur, located in the Irrawaddy basin, as stated by Phyre. According to legend, King Ashoka was a Mauriya or Maurira tribe, and the northern section of the Kubo valley—the straight path from Manipur to Burma—is named after them. According to Burmese chronicles, Indian Prince Tagaung constructed the first city on the eastern bank of the Irrawaddy.[18]

According to some academics, the Meitei may have descended from the Mon Khemer

or Tai Race. Although archaeological and historical evidence suggests a connection between ancient Meiteis and the Mon Khemer and Tai people, it does not prove that these people originated from the Mon Khemer. According to Allen's 1901 Census of Assam, the cradle of the Indo-Chinese race was in "North West China between the Yang - Tse Kiang and Hoang - Ho." This was in[19] B.C. In this spot, the first of several waves of immigrants arrived in Assam. During that period, Assam functioned as its kingdom. Regarding the Tai connection, T.C. Hodson asserts that Manipuris are entirely separate from the Khasis. While Shan influence has significantly impacted Manipur's culture and politics, it is problematic to classify the Meitei as part of the Tai race, particularly considering that their language structure and vocabulary are similar to those of the Tibeto-Burman language.[20] According to an anthropologist's research on the Meitei ethnonym, the Meitei were the result of the merging of two groups: the "Mei" people from one region of China and the "Ti" barbarians from the northwestern part of the country. The Meitei Mon Khmer were not initially Tai. However, there is speculation that they had ties to the Tai due to historical connections, social and cultural contacts, and conquests that shaped the Meitei language and culture. Prominent archaeologist O.K. Singh excavated sites such as Tharon (Tamenlong), Napachik, and Kangkhui cave (Ukhrul). There was a striking similarity between the Neolithic tools discovered in these digs, such as tripod log potters, and those of the Neolithic Chinese civilization. Pebble, flake, edge ground, and scraper stone tools found in Tharon Cave are comparable to those found in Burma, Thailand, Vietnam, Malaysia, and the Philippines. Many of the artifacts found in the Napachik region have Chinese provenance, which suggests that the area was formerly inhabited by Australoid-Mongoloid people who spoke Mon-Khemer and arrived before the Tibeto-Burman speakers. The evidence points to a connection between the Meitei, Mon Khemer, and Tai. Immigrants from the east, known as Nongpok Haram, have been assimilating into Meitei civilization since the seventh century A.D.[21] Language, migration patterns within the area, and ethnic characteristics all lend credence to a more scientific explanation of the Meitei people's origins. One of the most dispersed "races" on the Indo-Chinese peninsula, according to Sagermano, is the Tai people and its several offshoots. According to Sagermano, the Tai and Meiteis were long-established inhabitants of Yunnan, and he attributes this belief to a shared racial heritage based on linguistic and visual similarities. According to him, there were two Shan kingdoms in Burma: one in the north, with the capital at Mongmaw on the

Shewali river, and another in Tali, which was conquered by Kublai Khan in 1253 A.D.[22] Other sources, like the Burmese and Manipur chronicles, also account for the possibility that the 'Meitei' are descended from the Tai race.[23]

Along these lines, several academics have proposed that Meiteis had ties to the Tibeto-Burman people. Famous linguist G.A. Grierson places the Meitei in the Tibeto-Burman language family, specifically the Kuki-Chin subfamily. Thanks to the studies conducted by the Linguistic Survey of India, it is possible to have a holistic picture of the connection between the Meitei language and the languages spoken by hill tribespeople throughout the state and beyond. According to Dr. Grierson, the Kuki-Chin languages are closely related to all the surrounding groups of the Tibeto-Burman family. To the north, there are the Bodo and Naga languages. To the east, there are the Kachin languages. Moreover, Burmese languages are spoken to the south and east of them. In particular, they serve as a bridge between Burmese and the Bodo and Naga languages; they have strong ties to the North Kachin dialects, which connect to Tibetan and Burmese.[24] He speculates that the Meitei may have descended from kin who migrated from China to the upper Irrawaddy and Chindwin rivers in Northern Burma. Their original home was in the Hukwang valley, now Kachin territory. They then relocated to the Manipur Valley.
L.W. Shakespeare posits that the Meitei are Tibeto-Burman and that other Mongoloid peoples formerly lived in China around the upper Yangtze and Hoaing-Ho rivers. I am S.K. The later Vedic Kiratas, according to Chatterjee, are the Tibeto-Burman Mongoloid people. Approximately one thousand years before the birth of Christ, he posits that the Kiratas may have settled in eastern India on the southern slope of the Himalayas. While Luce researched the languages of the surrounding tribes of the former Kingdom of Manipur, her findings point to a shared language with the Kuki-Chin of the Tibeto-Burman group.[25] On the other hand, one interviewee made it clear that the Meiteis had tight ties to the Mongoloid people of China, Tibet, and the Himalayas.[26]

A different school of thinking suggests a link to the Kuki and Naga. The hill tribes researcher W. Mc Culloch postulated that the Meitei descended from neighboring tribes. McCulloch's statement is based on the remarkable similarity between the Meiteis and the hill tribes of Manipur regarding language and culture. Captain Pemberton's theory that the Meiteis are descended from a Tartar colony in China is

not one that he endorses. "Even though the Meitei chief no longer resides in the great house, it is still maintained and made in the Naga fashion. The ceremony of Pumbal Kaba, or ascending the throne, is performed in Naga dress, and the attire of the king or queen is 'Rani.'"[27]He goes on to say that tribal names like Koomal (Khuman) and Looang (Luwang) are the origin of several Meitei clans. R. Brown also agreed that the Manipur valley was almost entirely submerged in water not long ago and that the Meitei must have descended from the neighboring hills as the correct and exclusive conclusion. While the Meitei had animistic beliefs comparable to the Tangkhul, M. Horan said that the Burmese Kuki were distinct from the Meitei and Naga. The Kuki Chin people also speak the Tibeto-Burman dialect. The Meitei people, according to Nandalalal Sharma, are descended from the Kuki-Chin people of northwest China, who first arrived in Manipur. According to Pramodini, the Tibeto-Burman language originated in northwest China, spread to Burma, and eventually made its way into the Brahmaputra Valley via the Himalayas. According to S.K. Chatterjee, the Meitei are the most technologically sophisticated Kuki-Chin people and share a language with the Nagas and the Bodos. He says the Meitei people are called Kuki in India and Chin in Burma.[28]

In addition to these competing hypotheses, a third hypothesis has proposed that the Meitei are a hybrid of the Mei and Ti peoples. The Meetei people were the subject of research by anthropologist Ch. Buddhi. He claims that the Meetei speak a Tibeto-Burman language that early Chinese people spoke and that their physical characteristics are mostly Mongoloid. He goes on to say that the two constituent parts of the word "Meitei" are "Mei" and "tei" when seen as a whole.34 Similar to how 'ti, tai, tay' might be phonetic variants of 'tei,' there are several phonetic variants of mei, such as moi, mai,' etc. They might combine in various ways, such as moi-tai, moi-tei, mei-tu, etc. Researchers such as B.H. Hodgson and T.C. Hodson deduced the ethnonym "Meiteis" from the Moitai, an ethnic combination of Moi and Tai. Their effort is a perplexing ethnological endeavor as they need to reveal who the Moi and Tai were who supposedly made up the Meitei. In contrast, according to Paul K. Benedict (1942), Thai is not considered a part of the Tibeto-Chinese (Tibeto-Burman plus Karenese and Chinese) language family but rather a member of the Kadai and Indonesian languages. In their exploration of India, Alexander Zubov and Nikolia Cheboxerov found that the Munda people—whose language is connected to the Mon-Khemer of Indo-China—may have intermarried with the

Dravidians and the Veddoid indigenous peoples. Much of the Mon-Khemer Khasis's south mongoloid ancestry has survived to this day.[29] Those early intermediate Mon Khmer speakers Australoid-Mongoloid people from South China or Southeast Asia must have stopped in the Manipur area on their route westward migration. This is because the region is located at the crossroads of South Asia and South East Asia. Immigrants from Tibet and Burma shared a racial background, language, and culture with subsequent generations. A small group of local scholars subscribe to the teachings of the Puyas on the creation of the Meitei, the earliest humans, as described by the Immortal Creature. The Creator's image (Mi) was the basis for creating man (Teiba). Therefore, the Meitei people are called such.

One school of thought holds that the 'Ti' were formerly an independent people separate from the Mei, but they assimilated into the Mei under certain historical conditions, eventually giving rise to the 'Meitei'. However, the historical context, including the period and location of this composite people's ethnic creation, remains unknown. Whether the 'Mei' and 'ti' parts of the later Meitei composite ethnic group were historically called for certain metaphoric occurrences of the people surrounding 'fire' and water before or after their establishment in ancient China is unclear at this time. Local historical documents are written in indigenous script record the ancient existence of several peoples, namely Ang (Angom), Lu (Luwang), Kha (Khaba), Nge-an (Nganba), Khuman, Moilang, Salang (Sarangthem), Leisong or Chong (Leisangthem), Hou lok (Haorokcham), Kwan-tho (Konthoujam), Hou– Kha, Lok Kha, Heirem–Khunja, Lang (Langmaithem or Nongmaithem), Thanga-Kambong, Ningol–Laiton, Phantek, Khuyan (Khuyonthem), Lera- Khongang, Ulok Ushai, Khumpham–Nga Ngachaeng, Sak (Chakpa), Lokhu Lokhan, etc. According to local commentators, this subjugation of these peoples under the ethnic name "Meitei" was limited to the conquering Salai before the King of Ningthouja Salai indirectly or directly did it. The Angom people, who continue to distinguish between the branches that eventually gave rise to Ningthouja Salai and Angom Salai, may have been given the same names as the first historical king of Ningthouja Salai, Pakhangba, for some time before his reign (as recorded in Cheitharol Kumbaba, a royal chronicle).

It has been noted that Gerini chose this location between the Arakan and Pegu Rone because of two characteristics of Tamala: the people's penchant for silkworm farming and the amount of gold in the area. Even while the Meitei did not specifically cultivate silkworms, their territory was on a major trading route, so raw

and processed silk likely passed through their hands. They are much more confident that Tamala of Timara was the original home of the Meitei. Additionally, it might be acknowledged that the early 'Meitei' territory is referred to in Ptolemey's Tamala (Timara of the Mahabharata). The 'La' suffix likely denotes ' seat' or 'place,' and the possible phonetic variants Tama, Tema, or Timi are likely derived from the original 'Timei,' which was anagramatized into 'Meitei'. You may remember that the Kabui people of Manipur had dubbed the Meitei people "Taimei." We can see the close linguistic relationship with the Kuki-Chin people in Ptolemy's Tiladai/Tilabharas of the Mahabharata and Pliny's Thuutae. Longhena, whom Gerini cited as the Kuki-Chin Lushai tribes of North Kachar and the hills near Manipur then, would have worshipped the God Thila or Thina. This identification would attest to the substantial Kuki-Chin foundation of the Meitei language.

A different school of thought holds that the Meitei came from the Koubru hill. Due to the impassability of the Imphal valley due to flooding, the Divine Being Atiya Guru Sidaba established his human abode in the Koubru Hills; the hilltop is called "the land of Sorarel"—a name that is the same as Atiya Guru Sidaba. From this peak, Atiya Guru Sidaba and Leimaren Sidabi reigned. He gathered the other Lais (deities) and told them of his plan to build his kingdom on the southern slope of the Koubru Hill, as befits a chief god. He and the Lais continued their descent into the foothills, and they arrived on a Sunday, which is considered the first day of creation and is also known as "Nongmaiching" or the beginning of the week. On the "Ningthoukaba" day, Sorarel and the Lais staked a claim to the Nongmaiching Hills. The landslides deposited a layer of muck across the valley, which, once dried, created a suitable habitat for humans.

It was called "Leipakpokpa" that day. The Lais called this day Yumshakeisa when they first arrived. Various Lais, some good and others bad, lived among them. Many people were killed on both sides of the fight, which broke out because the second tribe, the "Saroi Ngaroi," was envious of the first. The good Lais, however, were spared death on this day, which became known as "Sagolsen" (Sagol meaning horse) because they escaped on horseback. Alternatively, Lais's death was referred to as Irai. The day was called "Thangja" because the virtuous Lais washed their swords after winning. At this very moment, these are the seven days that make up the Manipuri week.[30]

Even though we have offered several hypotheses on the Meiteis's beginnings, it is

essential to remember that tales regarding the ruler's divine or semi-divine lineage may emerge. Once established, myths serve as a convenient means of justifying the status quo and continue circulating for many reasons.[31] Several distinct tribes, arriving from all around, seem to have initially settled in the Manipur valley. While there is not enough historical data to draw firm conclusions on the Meitei people's origins, comparative ethnographic research indicates that it is likely. The Meitei people have been the subject of previous efforts to pinpoint them among the many Mongoloid tribes.[32]

How the Meiteis came to be is a topic of much debate. The Theory of Divine Origin and the alternative, which states that the Meitei had already established themselves on Manipur's Koubru Hill at the same period, have widespread support. It is a mystery when and how they decided to make this hill their home. With no agreed-upon origin story, the Meiteis may have gradually made their way to the Imphal Valley, where they split off into several groups and eventually made it to China. However, they left China, went throughout Southeast Asia, and eventually returned to Manipur after enduring the brutal effort required to build the Great Wall of China. Unlike the Kukis and Nagas of Manipur, their presence in Burma is primarily unknown. Many people arrived in Manipur at various periods and may have even settled there permanently.

It is still unclear when the term "Meitei" first appeared, and the exact circumstances behind their division into the seven clans that Pakhangba eventually united remains a mystery. Based on the Puyas they hold, the Pandits of Pandit Loishang convey their viewpoints. It is impossible to verify the veracity of their theories because they are unwilling to exhibit them and because only a tiny minority of people who know Archaic Manipuri and are not fluent in English can read them.

1.2 Aim

The aim is to discover the historical effects and modern-day projects of the Meitei community in Manipur concerning their pro-environmental practices and to assess the effectiveness and sustainability of those practices within the cutting-edge context.

Objectives

1. To study the ancient evolution of pro-environmental practices within the Meitei community.
2. To examine the cultural and spiritual beliefs that shape the Meitei's environmental ethos.
3. To analyze the effect of modern environmental initiatives on the sustainability of conventional Meitei practices.
4. To examine the features of community participation and governmental assistance in promoting pro-environmental behaviors.
5. To study the integration of traditional knowledge with modern environmental regulations.

1.3 Research Questions

1. How have ancient effects long-established the pro-environmental practices of the Meitei community?
2. What cultural and spiritual beliefs underpin Meitei's method of environmental conservation?
3. How have modern environmental tasks impacted the sustainability of traditional Meitei practices?

1.4 Hypotheses

H_{o1}: Historical, cultural, and religious factors do not significantly influence the pro-environmental practices and environmental conservation behavior of the Meitei community.

H_{a1}: Historical, cultural, and religious factors significantly influence the pro-environmental practices and environmental conservation behavior of the Meitei community.

H_{o2}: Modern environmental challenges, community participation, and government support do not significantly influence the sustainability of traditional Meitei environmental practices and pro-environmental behavior.

H_{a2}: Modern environmental challenges, community participation, and government support significantly influence the sustainability of traditional Meitei environmental practices and pro-environmental behavior.

$H_{0з}$: The integration of traditional Meitei knowledge with contemporary environmental policies does not significantly contribute to environmental conservation and sustainable environmental management.

$H_{аз}$: The integration of traditional Meitei knowledge with contemporary environmental policies significantly contributes to environmental conservation and sustainable environmental management.

1.5 Scope

The scope focuses on the Meitei’s pro-environmental practices, both ancient and current. These studies will discover numerous dimensions, which include cultural beliefs, religious practices, conventional agricultural techniques, and modern-day environmental tasks. The geographic reputation is on the whole at the state of Manipur, with precise emphasis on rural and urban regions in which the Meitei lifestyle is most prominently practiced.

1.6 Significance

The significance of this observation lies in its capability to make contributions to every academic and practical application in environmental conservation. By documenting and analysing the Meitei culture's pro-environmental practices, this study will provide treasured insights into the function of cultural records in sustainable development. The findings can tell insurance-makers, conservationists, and community leaders on the lookout for to mix traditional practices with modern environmental techniques.

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CHAPTER II:

GREEN FINANCING: ASSESSING ITS ROLE IN SUSTAINABLE DEVELOPMENT AND ECONOMIC GROWTH

NAZIA AHMED
(Assistant Professor)
Department of Management, Inderprastha Engineering College, Ghaziabad

ABSTRACT

This paper offers a thorough analysis of green finance, a rapidly developing field that plays a crucial role in connecting sustainable investments with economic development. Green bonds and climate funds are two examples of green finance products covered in this study. Their objective is to direct resources towards initiatives that are both ecologically sustainable and economically beneficial. Sustainable investment's meteoric rise, financial success, and the connection between green financing and macroeconomic variables such as GDP growth and job creation are among the important subjects explored in this study. According to research, green financing serves dual purposes: protecting the environment and boosting the economy by, among other things, encouraging innovation and the emergence of new sectors. Uncertainty about regulations, a lack of standards, and regional disparities in access to finance are still major obstacles, notwithstanding its expansion. But factors like encouraging policy changes, new technologies, and rising investor interest keep the green finance industry moving forward. According to this analysis, green financing might encourage investments aligned with sustainability objectives, potentially altering patterns of economic development. It is the responsibility of academics, financial institutions, and policymakers to address current problems and maintain green finance's pivotal role in achieving sustainable development. It is imperative that future studies address the knowledge gaps in this area, especially regarding the macroeconomic effects of green financing in the long run and its integration into models of financial stability. The results of this study stress the need for further sectoral cooperation and action to achieve a

more robust and equitable global economy, and they specifically highlight the role of green financing in this process.

Keywords: Green Finance, Sustainable Investments, Economic Growth, ESG Factors, Climate Finance

1: INTRODUCTION

"Green finance" is now a prominent concept with specific significance: it directs financial resources and investments toward environmentally friendly initiatives that support economic growth while promoting sustainability. Its emergence is largely due to global recognition of climate change, as exemplified by the 2015 Sustainable Development Goals, which aim to achieve sustainability by 2030. Modern economies depend on capital flow to generate value across sectors. Green finance leverages this by investing in products and processes powered by renewable energy, recycled materials, or sustainable resources, helping transition economies toward circular models. The fundamental challenge is that profit-driven motives often outweigh environmental concerns, making the targeted allocation of capital crucial. Instruments like green bonds, which commit funds exclusively to approved sustainable projects, exemplify this approach. Thus, green finance serves as a key vehicle for achieving the SDGs, driving sustainable economic and environmental outcomes.

Green finance is a key investment strategy to reduce environmental impact. Ecologists actively seek ways to decouple carbon emissions from economic growth (Zhan & Wu, 2020; Kanwal et al., 2023; Ashiq et al., 2023). Enabled by fintech, green finance channels capital into sustainable ventures. It helps bridge economic development and environmental conservation by directing funds toward renewable energy, conservation, and other green projects. Companies turn to the Global Financial Network (GFN) for financing eco-friendly initiatives due to budget limits. The GFN offers key resources for sustainable growth, including over 4 trillion dollars in reserves and access to over 21% of the world’s population. Credit intermediaries support policies focused on green growth, ecological integrity, and sustainable businesses (Lisha et al., 2023; Audi & Ali, 2023). The GFN framework encourages public and private investment in clean energy, pollution controls, green infrastructure, and responsible production. The shift to low-carbon economies is crucial for global climate goals. GFN projects help reduce reliance on fossil fuels and invest in eco-friendly businesses. The GFN promotes innovative financial products that encourage sustainability in finance. For example, investors may choose green bonds or sustainability-linked loans, which tie financial returns to environmental outcomes. These

instruments provide funding contingent on adherence to sustainable practices, creating a feedback loop to channel capital into green initiatives.

Examining these linkages becomes complicated by the interconnected effects of green finance, environmental innovation, and financial technology on the one hand, and the diverse socio-economic and environmental contexts of G-20 nations on the other. This is according to Arslan et al. (2023). Sustainable practices and green regulations are being implemented; however, it's hard to achieve consistent outcomes across diverse areas. Due to differences in economic interests, regulatory standards, and technological capabilities, it may be difficult for countries to develop cohesive environmental strategies (Altaf et al., 2023). To further understand the interconnected nature of these factors and their various effects on sustainability, a comprehensive study is required. This all-encompassing analysis would include determining the relative and combined effects of green finance, environmental innovation, and financial technology on sustainability objectives. In addition, you need to know how these things interact with specific country legislation, market systems, and societal goals. To design sustainable development methods that work across diverse economic and environmental contexts, academics and policymakers need to examine these interrelated factors closely. Shahzadi et al. (2023) identified a significant information gap that must be addressed by investigating how green finance, financial technology, and environmental innovation interact to affect carbon dioxide emissions. Policymakers, academics, and industry stakeholders may all benefit greatly from the new information that this study provides, and it also adds to the body of material already available. The research provides deeper insights into the routes to sustainability by capturing the interwoven nature of economic, technical, and regulatory factors. This allows for a more informed policy-making process. This study's strength is that it helps create more consistent and effective environmental regulations by concentrating on the nuts and bolts of sustainable practice. By focusing on the practical application of methods for green finance and environmental innovation, this study's focus enhances its credibility and relevance. In addition, the research lends credence to the idea that better methods may be developed to advance consistent and successful environmental policies, bringing about an alignment of economic development and sustainability goals (Ali, 2022; Dawood et al., 2023; Zahra et al., 2023; Ali et al., 2023) via its emphasis on practical insights.

1.1 Green Finance and Green Growth

There may not be a universally agreed-upon definition of "green finance," but the literature offers three broad overviews. One is environmental financing, which provides funding for practical concerns such as pollution monitoring, resource preservation, and environmental management (Latif et al., 2022). The alternative view is that financial growth uses a wide range of tools and strategies to mitigate environmental impact (Bhattacharyya, 2022). Thirdly, and most recently, Zhao et al. (2023) state that green finance is a framework for financing eco-friendly investments and helping to build a society that cares about the environment. It primarily deals with carbon financing. There are two main schools of thought in the literature on green finance. The first set of researchers examined green finance solutions from an efficiency perspective, testing and analysing their potential theoretical and practical applications across different nations through the lens of sustainable growth plans. Financial tactics, on the other hand, have been shown to be ineffective in a number of studies due to opaque policymaking and overly intrusive government regulation. Results from the first set of research showed that green financing instruments were useful for achieving green growth and energy transformation targets. For example, green financing helps reduce carbon footprints, according to research by M. A. Khan et al. (2022) on Asian economies. It also boosted Chinese green initiatives, according to studies by Peng & Xiong (2022) in China. Green financing has substantial benefits on a global scale, according to research by Al Mamun et al. (2022). The second set of researchers examined how various financial-sector metrics relate to green financing technologies. For example, R. Wang et al. (2022) examined the influence of green financing ads on green growth and found they had little effect on development goals. M. Liu (2022) uncovered the green bond market's inefficiency due to its low volatility resilience. In a similar vein, Adekoya et al. (2021) discovered that the very volatile U.S. green bond market was inefficient. According to Ng (2018), in order for the green finance system in Hong Kong to work better, concrete strategies and methods based on market forces are required. The Colombian study by Ruiz et al. (2016) also called for government action to encourage private sector participation in green finance.

1.2 Human Capital and Green Growth

According to endogenous growth theory, human capital is the most important factor in production and economic development (Zafar et al., 2019; Jahanger, Hossain, et al., 2023). The natural system is highly dependent on human capital, which in turn has a major impact

on environmental problems. Among its many benefits, it promotes economic system adaptability, industrial growth, increased public knowledge of environmental issues, and investment in green technology development (Ganda, 2022). Ganda (2022) cites a recent study that shows human capital has a favourable effect on reducing carbon emissions in the BRICS nations from 1990 to 2017. This demonstrated the critical need for continuous environmental education to increase understanding of zero-emissions policies and encourage long-term environmental prosperity. According to Sarkhodie et al. (2020), when South Asians have access to more sophisticated information and education, they are more likely to support environmentally friendly technology and advocate for the responsible use of natural resources. In Latin America and the Caribbean, similar results are observed in terms of human capital development and improved environmental consciousness, leading to sustainable economic growth (Nathaniel et al., 2021). An analysis of data collected in Pakistan from 1971 to 2014 found that while human development increased, carbon emissions decreased, but economic growth was unaffected (Bano et al., 2018). Human capital improves environmental quality and resource efficiency, according to Zafar et al. (2019), who used the ARDL model in the US case study

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1.3 The Nexus of Green Finance and Sustainable Economic Development

'Sustainable finance' is the most comprehensive term for studying sustainability's role in the economy, as it encompasses economic, social, and environmental aspects. 'Green finance,' on the other hand, refers to funds set aside for initiatives and programs that promote environmental sustainability, as well as for environmental goods and technologies. According to Explore Green & Sustainable Finance | Green Finance Platform, the goal is to help pave the way for a green economy that prioritises sustainable, inclusive, and low-carbon growth. After doing the maths, the link between sustainable economic growth and green fintech—also known as green finance—becomes crystal clear. It has recently come to light that green funding measures are quite similar to those used to assess progress towards the UN's Sustainable Development Goals (SDGs). By channelling funds, investments, and goals into environmentally friendly initiatives through green bond and loan platforms, green fintech is crucial to shaping a sustainable economy. Supporting programs that reduce negative environmental impacts, enhance social welfare, and strengthen economic resilience contribute to sustainability. Climate change, inequality, and social exclusion are among the most critical global challenges, and governments worldwide have made tackling these problems a primary priority by adopting the SDGs.

Acquiring sufficient financial resources is a prerequisite for accomplishing the Sustainable Development Goals (SDGs). Securing the funds needed to achieve these goals should be a top priority for governments.

Governments may assist sustainable development, combat climate change, enhance inclusivity, and reduce inequities by proactively allocating resources to SDG-oriented activities. A future that is both ecologically responsible and socially equitable can only be achieved with the help of the SDGs, which can only be advanced with enough financial backing (Ziolo et al., 2021).

A dynamic nexus operating in both directions may be seen between green funding and the sustainable development of the economy. The symbiotic relationship between green finance and sustainable development has been the subject of much research. Research like this elucidates the power of green finance and how it may be shaped by environmental, social, and economic sustainability efforts. Researchers have learnt a lot about the synergies and reciprocal benefits that come from integrating sustainable development ideas into green finance by examining the complex relationships and feedback loops. Research like this adds to what is already known, helping us better comprehend the synergistic effects of sustainable development and green funding on societal and ecological well-being (Xiao et al., 2019).

1.4 The Linkage between Financial Inclusion, Green Finance and Green Growth for Sustainable Development

In 1987, the United Nations Brundtland Commission defined sustainable development as meeting the requirements of the present without sacrificing the ability of future generations to do the same. Maintaining a steady equilibrium among these three factors—the economic, social, and environmental bottom lines—is essential to sustainable development. According to Hammer and Pivo (2016) and Nogueira et al. (2022), sustainable development requires a balance between these three interrelated factors. The link between environmental protection and economic development is intricate. The demand for energy and resources may rise in response to economic expansion, which in turn might raise pollution levels (Grossman & Krueger, 1995). The creation of new technology that mitigates the environmental impacts of economic expansion is another benefit of economic growth (Porter & Linde, 1995). The first part of the issue was addressed when green GDP growth was advocated as an alternative to conventional GDP growth. This new measure incorporates resource integration and environmental costs into the national economy's

production process (Escap, 2013). This will help improve sustainable development by addressing the limitations of conventional GDP and providing a more accurate reflection of a country's level of development in relation to environmental factors (United Nations, 1993). Second, green investment, public R&D expenditure for development and environmental protection, green credits, and other cash flow transmission instruments are necessary for successful implementation, as they promote greater investment in green initiatives. According to Desalegn and Tangl (2022), Guo et al. (2022), and Midilli et al. (2006), these integrated tools are referred to as green financial systems. Sustainability Goals (SDGs) were reissued in March 2016 by the US Department of Economic and Social Affairs. Green growth has been a key emphasis in many nations' new development policies (Dmuchowski et al., 2021). There has been a shift in emphasis towards green financing as a means of fostering green development in response to the worldwide movement towards sustainability. Ensuring that all members of society, regardless of income or sector, have access to services and financial tools is crucial for green development to be successful.

1.5 Financial Inclusion and Green Economic Growth

Providing basic financial services is critical to sustainable development, and financial inclusion plays a significant role in enhancing GEG. By helping poor countries finance renewable energy projects, the World Bank brought attention to GEG (Stromquist, 2019). Developing countries may also benefit from financial inclusion in fostering green infrastructure, sustainable agriculture, and renewable energy. Small and medium-sized businesses (SMEs) can take a more active role in environmental sustainability when they have easier access to financing through financial inclusion. Financial inclusion (FI) also helps underprivileged groups, including women and rural communities, access the economy, which is a boon for developing countries. The fair sharing of green economic advantages is the goal of this endeavour.

In this portion of the research study, we go even deeper into the complex web of connections between FI and its effects on the realisation of environmentally friendly economic expansion. Zaidi, Hussain (2021) examined OECD member nations from 2004 to 2017 to determine how FI and infrastructure affected their efforts to become fully sustainable. Findings from their use of the augmented mean group (AMG) technique revealed that FI, energy usage, and corruption are among the variables that impact environmental deterioration. How financial inclusion and education help lower China's carbon emissions was the subject of additional research by Liu, Hong (2022). Researchers

in China found that FI improved environmental quality by using the ARDL method. Similarly, reducing China's carbon dioxide emissions will rely heavily on education. It is also noted that both GDP and population reduced carbon dioxide emissions.

Studying the states that make up the Organisation of Islamic Cooperation (OIC) from 2004 to 2018, Singh and Raza (2023) examined how FI contributed to environmental degradation. The data used to measure environmental deterioration included GHG emissions, deforestation rates, and ecological footprints, among other metrics. While ecological footprints and (N2O) showed negative relationships with the higher-income OIC economy, the long-term estimate found positive links between deforestation and carbon emissions (CH4). Husain Sohag (2021) studied renewable energy and technical innovation to determine their impact on green growth in OECD nations. The cross-sectional autoregressive distributed lag (CS-ARDL) method was used to find that renewable energy development, technical innovation, and long-term economic growth are positively related. Furthermore, some studies have shown that FI has a favourable effect on long-term carbon emissions (Amin, 2023), whereas others have found the opposite (Mehmood, 2023).

Dahal (2020) found that green trade can drive economic development, improve social group sustainability, and reduce environmental conflicts, yet only a small number of studies have examined how FI affects green economic growth within a single country. This research focuses on the impact of FI on environmentally friendly economic expansion. But no research has specifically examined developing nations to see how FI affects green economic development. Developing nations are hit harder by global warming than industrialised nations, and large-scale carbon dioxide emissions are thought to be a major contributor to this phenomenon. Even if this problem is affecting wealthy countries as well, the impact is considerably less compared to emerging nations. Benefits beyond economic development are also produced by rich nations' subsidies and recognition of green economic ventures, in contrast to poor nations. Such intensives include projects and initiatives such as electric vehicles, waste disposal, population control through family planning, renewable energy initiatives, recycling efforts, etc., with subsidies and tokens helping balance green economic growth with overall economic growth (GDP).

1.6 Green finance and its Impacts

The evaluated articles emphasise the importance of green financing in combating climate change and advancing sustainability in this area. Among the many advantages of green

finance that the authors list are investments in renewable energy and innovative technology that may cut emissions. They cover a lot of ground, including how green finance differs from climate financing, the function of green financial instruments, and the industries affected by them. The cumulative findings of this research provide light on the dynamic nature of green finance and the critical role it plays in resolving environmental issues.

1.6.1 Climate change

Green financing and climate finance are two distinct yet interconnected concepts. According to Krushelnytska (2017) of the International Finance Corporation, "green finance" refers to investments that benefit the environment. Specifically, climate finance is defined by the UN Framework Convention on Climate Change as funding that supports transformation and mitigation activities to address climate change, whether from the public, private, or other sectors. Both ideas revolve around using finance to combat climate change and advance sustainability, albeit their definitions vary somewhat.

According to Nawaz et al. (2021), there is a close relationship between green finance and investment risk in developing and emerging nations. Using a difference-in-differences (DID) technique, the authors of this research examined the factors that led to the expansion of green funding and efforts to combat climate change in the N-11 nations from 2005 to 2019.

Greenhouse gas emissions, population, FDI, green financing, domestic credit to the private sector, R&D, and grants from technical corporations were all important outcome variables in the study's assessment of the countries' progress towards climate change relief and green financing.

The N-11 nations have begun taking action to become low-carbon economies because of the enormous amount of energy they use, which is a major driver of climate change and carbon dioxide emissions. As a result, the N-11 nations have launched initiatives such as Indonesia's Low-Carbon Development Initiative to facilitate their economic shift towards a low-carbon model.

Nonetheless, a distinct conclusion emerges from the probit regression findings: green funding and climate change mitigation are affected by FDI, CO2, the Human Development Index, and private-sector investments in the energy sector. Both the treated and untreated nations show contradictory outcomes in the research; while some see an increase in financing for green initiatives and climate change mitigation, others see a decline. No statistically significant differences were found among the nations in the DID. Green

funding will go to nations with high Human Development Indexes, according to the text, and foreign direct investment (FDI) may cause developing nations' CO2 emissions to rise. Recent research on the worldwide battle against climate change has focused heavily on green financing. Nevertheless, there needs to be greater agreement among academics on the precise meaning of the word.

1.6.2 Decarbonization of economies

Research by Zhang et al. (2022c) examines data from G-20 nations from 2008 to 2018 to determine the effect of green and digital finance on environmental protection. The quantile regression model-based analysis finds that green financing, renewable energy, and technological innovation investments all contribute to lower CO2 emissions. Trade, FDI, energy use, and economic growth all contribute to increased emissions. Additionally, the study recommends policies to promote digital finance, green finance, and sustainable growth by creating a carbon trading market.

This article's strengths include its examination of the relationship between green funding and environmental protection, using data from G-20 countries and a quantile regression model. To help decision-makers develop more effective strategies to promote sustainable development and green funding, the paper also includes policy recommendations. But by focusing on certain details, the research may have covered more ground. A limitation of the research is that it only considers the relationship between green financing and environmental protection in the context of the G-20 economies. As a result, the results may not be applicable to other countries or areas. Government laws and energy policy are two additional factors that might impact this link, but they are not included in the research.

1.6.3 Carbon-stranded assets

Chevallier et al. (2021) investigate the potential stranded-asset-related financial hazards faced by oil, gas, and coal firms. The term "stranded assets" describes fossil fuel reserves that would become useless if regulations aimed at reducing greenhouse gas emissions were to harden. This research uses simulations to predict how the value of 17 major oil, gas, and coal companies would be affected by carbon-stranded assets through 2050. The paper's central stochastic model uses initial conditions to determine whether organisations have stranded assets. The simulations demonstrate that oil, gas, and coal corporations must reorganise their business models due to the redefinition of risk posed by the concept of carbon-stranded assets. Many businesses would be shielded from the financial dangers of defaults and bankruptcy if these measures were implemented. Additionally, the analysis shows that strict emission-curbing rules may generate an environmental benefit of 80%.

Several pension funds are selling their shares in polluting companies, leading the publication to conclude that investors' expectations are crystal clear from that position. Since it is based on a computer model, the results could only apply to a subset of the industry. Furthermore, it disregards practical ways to address stranded assets and the associated social and environmental issues.

1.6.4 Investment in renewable energy

Green financing and renewable energy sources, according to Lin et al. (2022), will help significantly in tackling climate change. Using both macro and micro data from 2010 to 2021, they examine geopolitical risk, inflationary pressures, and green finance in China. The writers delve into the direct and indirect correlations among factors using regression methods. Environmental tariffs, including carbon emissions levies, have a favourable effect on the economics of renewable energy sources, according to their findings. Meanwhile, China's investment behaviour in sustainable energy sources is impacted by geopolitical risk and oil price volatility.

Furthermore, the research highlights the significance of environmentally friendly legislation in mitigating the negative impacts of green funding. In light of these results, the authors suggest that environmentally conscious companies in China allocate more funds to renewable energy. The research found that renewable energy and green financing may help reduce greenhouse gas emissions, especially in China. Data analysis in the environmental and economic sectors is notoriously difficult and calls for sophisticated statistical tests.

1.6.5 Innovation and green finance

According to Irfan et al. (2022), green funding helps combat climate change, spur environmentally friendly innovation, and support long-term economic development. Their research analyses regional data from 2010–2019 to examine the impact of inclusive green financing on green innovation in China, the mechanisms by which this funding influences it, and the implications of governmental interventions in this area. Researching the connection between green funding and green innovation, the study uses several models, including mediation effects, difference-in-differences, and panel vector autoregression. There are three major takeaways from the research. First, alternative estimators and proxy variables for the explained variables do not change the fact that green financing has a substantial impact on green innovation at the regional level. Secondly, establishing green financial innovation pilot zones promotes green innovation via legislation. Green funding primarily supports green innovation via three main pathways, according to the study:

industry structural development, economic growth, and research and development investment.

While the research provides useful information for decision-makers, it is important to note that it has several limitations and concerns. The study's findings may not be applicable to other countries or areas since they are based on Chinese data. More suitable methodologies and techniques for researching green innovation and finance may also be available. A more comprehensive understanding of green finance is necessary, as this research focuses on only one subset of the topic (inclusive green finance). The report, however, stresses that green funding is crucial to advancing green innovation and long-term economic sustainability. To facilitate the shift to a greener future, policymakers should think about the study's suggestions for green funding strategies. To overcome these restrictions and investigate the wider effects of green financing on innovation and sustainable development, further research is required.

When it comes to fighting climate change, Xiao et al. (2019) state that developing countries must work together to create low-carbon, environmentally friendly technologies (LCEFT). The research proposes using financial institutions to encourage collaborative LCEFT innovation as a solution to high innovation costs, risks, and uncertain earnings. This study uses an evolutionary game model to look at how different entities, such as governments, companies, banks, and academic institutions, react to green financing and how it affects LCEFT innovation. Findings from the research highlight the importance of interdisciplinary expertise and complementary resources in forming the LCEFT innovation alliance.

Nevertheless, in order to encourage multi-subject cooperation in LCEFT innovation, measures beyond government subsidies and sanctions are required.

Since the evolutionary game model may capture only a fraction of the complex dynamics at play in LCEFT innovation, it is important to be transparent about the study's data and methodological limitations, even if they cast only partial light on important aspects of collaborative LCEFT creation. The findings will be based on the simulations' outcomes. Consequently, more studies are required to validate these results using data from the actual world. Green financing, according to the report, is crucial for fostering innovation and technological progress to address environmental problems, including pollution, water purification, and biodiversity conservation, in both emerging and established countries. The goal of green finance is to fund climate change adaptation and other environmentally friendly initiatives with large sums of capital. Policymakers and investors interested in

fostering collaborative LCEFT innovation through green financing might find the report helpful.

Wang, Chen, Tang, and Qiao released a climate change research in 2023. Green financing, carbon neutrality, and long-term environmental protection should be front and centre. By combining innovation with green funding, the research assesses sustainable growth pathways within the energy-environment-climate nexus. According to studies, there is a connection between environmental pollution and climate change. Innovation in the energy-environment-climate nexus may be moderated by green finance and environmental funding, which, in turn, can reduce carbon dioxide emissions and the use of fossil fuels. Rapid development of green financing is associated with increased adoption of novel renewable energy sources, according to the research. But there are a few caveats to the research. For example, it only covers 49 nations that have issued green bonds, so its findings may not apply to other countries. To be more accurate, it may have to account for the interconnected nature of innovation, green financing, and the energy-environment-climate nexus. Also, other types of green finance are not taken into account in the research; it just concentrates on green bonds. In addition, additional variables that have not been detected may influence the results about the effects of green financing on pollution and climate change.

This research adds to our understanding of the energy-environment-climate nexus, green finance, and innovation. Nevertheless, to apply the study's results to other nations or areas, further research is needed to address its flaws. To gain a more thorough grasp of the topic, it is crucial to examine various green financing options and dissect the intricate web of connections among green finance, innovation, and the energy-environment-climate nexus.

An environmentally friendly bond offered on the German market, the Green Schuldschein is a product of the Schuldschein system. Similar to a conventional bond, but with some structural and regulatory changes, a Schuldschein is a popular private placement lending product in Austria and Germany. The Green Schuldschein is the focal point of Van Veelen's (2021) in-depth examination of the interplay between agriculture, climate change, and new financial instruments. The piece highlights the need to understand where green financial instruments end up and how they interact with environmental governance. One new way to examine green finance's ability to slow global warming is through the author's use of assemblage thinking.

Importantly, green financial instruments do not often prioritise economic actions that could significantly reduce carbon emissions. It is common practice to refinance projects using

green bonds even when no further environmental benefits are anticipated. Institutionalisation, through mechanisms such as the Green Bond Principles, affects this occurrence. The analysis raises doubts about the effectiveness of Green Bonds and Schuldscheine in combating climate change and national climate objectives if they fail to adequately address the most carbon-intensive activities. The paper's more sophisticated understanding of the linkages between finance and the environment, as well as its attention to the agency of agricultural players in the financialisation of agriculture, are commendable. Nevertheless, the findings may not be applicable to other situations due to the case study's limited scope and emphasis on a single financial instrument.

The author makes valid points about the limited capacity of green financing and the lack of different standards for combating climate change. However, the research could have benefited from new viewpoints and alternative solutions, such as the incorporation of different financial instruments and case studies, to increase the generalizability of the results. Green financial products can drastically cut carbon emissions; the author should have provided more realistic solutions to the issues plaguing this sector. The study makes a contribution to the literature on agriculture, money, and the environment, while also raising important topics for future research, despite these limitations.

1.7 Research Objectives

The primary objective of this paper is to conduct a comprehensive review of the existing literature on green finance and its role in bridging the gap between sustainable investments and economic growth. The research aims to achieve the following:

1. To explore how green finance instruments, such as green bonds and sustainable loans, contribute to the funding of environmentally friendly projects and businesses.
2. To investigate the macroeconomic benefits of green finance, including job creation, innovation, and overall GDP growth.
3. To examine the challenges faced by the financial sector in scaling up green finance, as well as the policies and market conditions that support its growth.
4. To discuss how governments and financial regulators can create an enabling environment for green finance through incentives, regulations, and partnerships.

1.8 Research Hypotheses

H1: Green finance instruments, such as green bonds and sustainable loans, have a positive and significant impact on the funding availability for environmentally friendly projects and businesses, thereby bridging the gap between sustainable investments and practical implementation.

H2: The adoption of green finance practices contributes positively to macroeconomic benefits, including enhanced job creation, technological innovation, and overall GDP growth, by fostering sustainable economic development.

H3: Challenges in scaling up green finance within the financial sector, such as regulatory hurdles and market risks, can be mitigated by supportive policies and favourable market conditions, thereby accelerating growth in green investments.

H4: Governments and financial regulators can create an enabling environment for green finance through targeted incentives, regulations, and public-private partnerships, thereby increasing the adoption and effectiveness of sustainable financing mechanisms.

1.9 Scope of the Study

This study centres on the role of green finance in promoting sustainable development while simultaneously driving economic growth. It adopts a focused approach, grounded in a comprehensive literature review, to examine key mechanisms, impacts, challenges, and enabling factors in the green finance ecosystem.

The thematic focus is primarily on core green finance instruments, including green bonds, sustainable loans (also known as green loans), green credit facilities, sustainability-linked bonds and loans, and related mechanisms such as green equity funds, carbon credit financing, and transition finance. Although broader sustainable finance concepts such as impact investing, ESG integration and blended finance are mentioned for contextual purposes, they do not form the primary analytical lens of this research.

Geographically, the study takes a global viewpoint, incorporating evidence from both developed and developing economies. Particular emphasis is placed on leading markets, including the European Union, China, the United States, and Japan, as well as emerging hubs in Southeast Asia (such as Singapore, Malaysia, and Indonesia), India, and select African nations. International standards, including the EU Taxonomy, ICMA Green Bond Principles, and Climate Bonds Initiative frameworks, are highlighted, while illustrative country-specific cases underscore global patterns rather than provide exhaustive national examinations.

The temporal scope encompasses literature and market developments primarily from 2015 to December 2025. This timeframe is chosen deliberately, beginning with the landmark adoption of the Paris Agreement and the UN Sustainable Development Goals (SDGs) in 2015, which catalyzed the global green finance surge, and extending through rapid expansions in green bond issuance, taxonomy developments, post-COVID green recovery efforts, and recent trends as of late 2025, including cumulative labelled sustainable bond volumes exceeding USD 6 trillion and aligned green issuance records.

Sectorally, the analysis targets high-impact areas for sustainable development and green investment potential, such as renewable energy (encompassing solar, wind, hydro, and geothermal), energy efficiency improvements, sustainable transportation (including electric vehicles, public transit systems, and charging infrastructure), green buildings and sustainable construction practices, waste management and circular economy initiatives, and sustainable agriculture and forestry. Emerging transition finance for hard-to-abate sectors such as steel, cement, and aviation is addressed selectively.

In terms of analytical approach, this research is positioned as a systematic literature review augmented by secondary data analysis. It explores theoretical foundations of green finance, empirical insights into its effects on project funding, job creation, innovation, and GDP contributions, barriers to scaling, and supportive policy interventions, including regulatory frameworks and public-private partnerships. Primary data-gathering methods, such as surveys or interviews, and original econometric modelling fall outside the study's scope.

Explicit exclusions are applied to preserve focus: detailed financial modelling of instrument pricing and risks, in-depth examinations of greenwashing or verification processes, micro-level firm or project case studies, standalone climate adaptation finance (with priority given to mitigation-oriented green finance), and socially responsible investing or governance-centric ESG elements unless directly tied to environmental impacts.

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CHAPTER III:

URBANIZATION AND THE TRAFFIC SYSTEM IMPACT EACH OTHER IN NORTHEAST INDIA

KHWAIRAKPAM TAPASKUMAR

(Research Scholar)

Department of Sociology, Jayoti Vidyapeeth Women's University, Jaipur

Abstract: Northeast India (NER), comprising eight states, is undergoing accelerating urbanization and transport infrastructure expansion driven by national policies such as the Act East Policy, Special Accelerated Road Development Programme for the North East (SARDP-NE), and Smart City initiatives. Urban population in the region rose from approximately 8.4 million in 2011 toward projected levels exceeding 13 million by 2031, with marked concentration in cities such as Guwahati, Shillong, Agartala, Aizawl, and Kohima. Concurrently, vehicle registrations have surged often by multiples of 100–250% in major urban centres while road capacity, particularly in hilly terrain, has expanded more slowly. This mismatch produces chronic congestion, elevated travel times, higher accident rates, air pollution, and environmental degradation including forest fragmentation and wetland loss. The chapter examines the evolving traffic systems, patterns of urbanization, and their reciprocal impacts, drawing on studies from 2018–2024. It highlights topographic constraints, reliance on private and paratransit modes, infrastructure demand gaps, and the need for transit-oriented, multi-modal, and environmentally sensitive planning to achieve sustainable mobility and inclusive urban growth.

Keywords Northeast India; urbanization; traffic congestion; urban mobility

1. **Introduction**

Northeast India (NER), comprising the eight states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, occupies a distinctive and strategically significant position within India's developmental and geopolitical landscape.

Characterized by extraordinary topographic diversity from the flood prone alluvial plains of the Brahmaputra Valley to the steep slopes of the Eastern Himalayas and the Indo-Myanmar ranges the region has long been framed in national discourse as a "landlocked, cut-off, inaccessible and underdeveloped" periphery (Ziipao, 2021). This narrative of isolation was reinforced by limited road networks, sparse railway connectivity, and difficult terrain that constrained both internal mobility and external economic integration for much of the post-Independence period. Yet, since the mid-2000s, and with particular intensity after 2014, a concerted policy shift has sought to reconfigure the NER as India's "gateway" to Southeast Asia under the Act East Policy, supported by large scale infrastructure programmes such as the Special Accelerated Road Development Programme for the North East (SARDP-NE), Bharatmala, and multiple Japan International Cooperation Agency (JICA) assisted road projects (Ziipao, 2021; Financial Express, 2024).

These interventions have produced measurable improvements in physical connectivity. The number of National Highways in the region rose from 80 in 2014 to 103 by 2023, with thousands of kilometres of new or upgraded roads either completed or under construction. Railway electrification reached 100 percent of broad-gauge lines, airport infrastructure expanded to 17 operational facilities, and budget allocations for the NER increased by more than 300 percent between 2014 and 2023–24 (Financial Express, 2024). Parallel to this infrastructural push, urbanization though still uneven and, in several states, below the national average has accelerated. The region's urban population grew from approximately 168 thousand in 1901 to 8.4 million in 2011 and is projected to reach roughly 13.5 million by 2031, corresponding to an urbanization rate rising from under 4 percent to nearly 19 percent in 2011 and toward 24 percent by 2031 (Singh & Baruah, 2024). Growth has been driven by a combination of administrative reorganization, expansion of educational and governmental institutions, infrastructure led economic opportunities, and rural to urban migration in search of employment, healthcare, and higher education.

This dual process of connectivity enhancement and urban expansion has generated profound, and often contradictory, effects on the region's traffic systems. Vehicle ownership has surged dramatically. In major urban centres, registered vehicles have increased by factors of two to more than ten over recent decades, with particularly sharp growth in two-wheelers, three-wheelers, and private cars after 2018–19 (Humtsoe, 2024). Guwahati, the largest city and economic hub of the NER, exemplifies the emerging crisis: average traffic speeds frequently fall to around 20 km/h, a large majority of residents

experience daily congestion, and travel-time indices indicate consistent delays across commercial, traditional, and newly developed zones (Ahmed & Das, 2022). In the hill capitals Shillong, Aizawl, Kohima, and Gangtok narrow colonial era or topographically constrained roads, steep gradients, mixed traffic including slow-moving non-motorized and para-transit vehicles and seasonal tourist and freight surges produce even more severe peak-hour gridlock and elevated accident risks (Nongkynrih & Lyngdoh, 2020; Humtsoe, 2024).

The reciprocal relationship between urbanization and the traffic system is central to understanding contemporary challenges in the NER. Urban growth generates rising travel demand through population concentration, longer trip lengths, economic diversification, and aspirational private vehicle ownership. Simultaneously, improved road connectivity facilitates further peri-urban sprawl, conversion of agricultural and forest land into built up areas, and the channelling of heavy commercial traffic through fragile urban and peri-urban ecosystems (Singh et al., 2024). The consequences are multi-dimensional: economic losses from time and fuel wastage; environmental degradation through elevated particulate emissions, road dust, forest fragmentation, and increased flood vulnerability as seen in Guwahati’s expanding built-up footprint and shrinking wetlands; and social costs including reduced accessibility for non-motorized users, equity concerns for those dependent on inadequate public transport, and public-health impacts from air pollution and chronic stress (Ahmed & Das, 2022; Seal & Saikia, 2025; Humtsoe, 2024).

Despite the scale of these transformations, scholarly and policy attention has often treated infrastructure expansion and urbanization as largely positive or separate processes. Critical examinations of their interaction particularly the ways in which topographic constraints, institutional capacity gaps, and the dominance of private and para transit modes amplify congestion and environmental externalities remain relatively limited for the NER as a whole. Studies focused on individual cities (Guwahati, Shillong, Agartala, Aizawl) or specific infrastructure corridors provide valuable insights, yet a synthesized regional perspective that integrates traffic-system dynamics with urbanization trajectories for the period 2018–2024 is still emerging.

2. Traffic System in Northeast India

The traffic and transport system of Northeast India is the product of a complex interplay between extreme physical geography, a long history of infrastructural neglect, and a recent, intensive phase of state-led connectivity expansion. The region’s terrain ranging from the broad, flood-prone Brahmaputra Valley plains of Assam to the steep, landslide-prone slopes of the Eastern Himalayas and the Indo-Myanmar ranges fundamentally shapes the form, capacity, and vulnerability of its road networks. In the plains, relatively high rural road densities are possible, whereas in the hill states road construction is constrained by gradient, curvature, geological instability, and high rainfall, resulting in narrow, winding alignments that limit both capacity and speed (Northeast in Data, 2024; UNESCAP, 2024).

Historically, the post-Independence period left the NER with an inadequate road network, reinforcing narratives of isolation. This began to change systematically with the launch of the Special Accelerated Road Development Programme for the North East (SARDP-NE) in 2005, which aimed to connect all state capitals and 88 district headquarters through a combination of new construction and upgrading. The programme was later reinforced by the Act East Policy after 2014, Bharatmala Pariyojana, and substantial external financing, notably from the Japan International Cooperation Agency (JICA). As a result, the number of National Highways in the region increased from 80 in 2014 to 103 by 2023, with ongoing projects covering more than 4,000 km (Ziipao, 2021; Financial Express, 2024). Railway electrification of broad-gauge lines reached 100 percent, and the number of operational airports rose to 17, significantly improving inter-regional and external connectivity.

Despite these quantitative gains, qualitative deficiencies remain pronounced. A large proportion of the total road network is still unsurfaced. In Assam, for example, only about 23 percent of roads were surfaced as of recent official data, far below the national average of approximately 72 percent (UNESCAP, 2024). Even on National Highways, the share of two-lane or wider sections has historically lagged behind the rest of India. Effective carriageway widths are further reduced by encroachment, informal commercial activity, and the mixing of slow moving non-motorized vehicles, cycle-rickshaws, e-rickshaws, auto-rickshaws, two-wheelers, cars, and heavy commercial vehicles on the same narrow alignments.

Vehicle ownership and traffic volumes have expanded far more rapidly than road capacity. Across the region, registered vehicles increased by an estimated 250 percent in recent years (IAJESM analysis of 2018–2022 trends). In Tripura, two wheeler registrations alone grew by more than 1,400 percent between 2019–20 and 2024–25, with similarly dramatic increases in three wheelers, four wheelers, and commercial vehicles (Down to Earth, 2025). Guwahati, the largest urban agglomeration, is projected to approach or exceed 700,000 registered vehicles, with two wheelers constituting roughly half of the fleet and petrol driven four wheelers another significant share (NIUA guidance document; Ahmed & Das, 2022). Freight traffic has also intensified, particularly along corridors linking the NER to the rest of India and to neighbouring countries under the Act East framework. In industrial-transit nodes such as Byrnihat on the Assam–Meghalaya border, more than a thousand heavy trucks may pass nightly, contributing both to congestion and severe air quality problems.

Public transport systems remain underdeveloped relative to demand. Most cities lack high capacity, reliable mass transit. Bus services, where they exist, suffer from limited coverage, irregular schedules, and inadequate fleet size. In Guwahati, the public transport system was expected under earlier mobility plans to handle a majority of motorised trips, yet it continues to fall short, prompting a rapid shift toward private cars, two wheelers, and intermediate public transport (IPT) modes such as auto rickshaws and e-rickshaws (NIUA). In the hill cities the constraints are even more severe: narrow roads and steep gradients make conventional bus operations difficult, resulting in extremely low public-transport mode shares (for example, under 1 percent bus use in Gangtok) and heavy reliance on private vehicles and walking (Down to Earth multi-city analysis).

Congestion has consequently become a defining feature of the region’s major urban centres. In Guwahati, average travel speeds on key corridors frequently hover around 20 km/h, with peak-hour journey times often two to three times free-flow duration. Travel Time Indices across commercial, traditional, and newly developed zones consistently indicate mild-to-moderate congestion, while resident surveys report that more than 80 percent of people experience daily traffic jams (Ahmed & Das, 2022). In Agartala, peak-hour mobility has declined from approximately 7 km/h in 2014 to around 4 km/h in recent assessments, driven by the explosive growth of vehicles on a largely static road network and the problematic mixing of slow and fast vehicles (Down to Earth, 2025). Shillong faces chronic gridlock on its winding colonial-era roads, exacerbated by high tourist

volumes; average speeds drop to approximately 17 km/h during peak periods, and specific intersections such as Dhankheti experience particularly severe delays and associated economic costs (Nongkynrih & Lyngdoh, 2020). Similar patterns of congestion, mixed traffic, and capacity constraints characterise Aizawl, Kohima, and other hill capitals (Humtsoe, 2024; Mott MacDonald, 2023).

Technological and institutional responses have begun to appear. Under the Smart Cities Mission, Guwahati and Agartala have introduced Adaptive Traffic Control Systems (ATCS) and Integrated Command and Control Centres that use real-time data and Automatic Number Plate Recognition to optimise signal timings and enforce violations. These systems have reduced wait times at equipped junctions by more than 50 percent in some cases and contributed to measurable declines in traffic violations (IAJESM analysis). Nevertheless, the benefits remain localised. Network-wide capacity has not expanded commensurately, and the "displacement effect" in which traffic simply shifts to the next unmanaged intersection limits overall gains. Encroachment continues to shrink effective road width, and the absence of comprehensive demand-management measures (parking regulation, congestion pricing, or strong public-transport prioritisation) means that infrastructure improvements are rapidly absorbed by induced demand.

Road safety constitutes another critical dimension. Between 2020 and 2024, the seven northeastern states (excluding Sikkim in some datasets) recorded nearly 19,000 road-accident fatalities, with Assam alone accounting for approximately 80 percent of both accidents and deaths. Fatality rates per 10,000 vehicles in Assam substantially exceed the national average. The combination of mixed traffic, inadequate geometric design on hill roads, poor enforcement, and rising speeds on newly upgraded corridors contributes to this elevated risk.

3.Urbanization in Northeast India

Urbanization in Northeast India presents a distinctive trajectory that differs markedly from the patterns observed in the rest of the country. Although the region remains less urbanized overall than the national average, the process has accelerated in recent decades and is characterized by sharp inter-state variations, strong spatial concentration in a limited number of cities, and significant environmental and infrastructural pressures. Between 1901 and 2011 the urban population of the NER rose from approximately 168 thousand to 8.4 million; official projections indicate that it will reach roughly 13.5 million by 2031,

corresponding to an urbanization rate increasing from under 4 percent in the early twentieth century to 18.93 percent in 2011 and an expected 24.13 percent by 2031 (Singh & Baruah, 2024). Growth has been gradual rather than explosive when viewed at the regional scale, yet it has been highly uneven across states and heavily concentrated in a handful of urban centres.

Inter-state disparities are striking. Mizoram stands out as one of the most urbanized states in India, with more than half of its population living in urban areas. In contrast, Assam the most populous state in the region recorded an urbanization rate of only about 14 percent in the last census, remaining predominantly rural despite hosting Guwahati, the largest city and economic hub of the entire NER. Nagaland, Manipur, and Tripura occupy intermediate positions, while Arunachal Pradesh and Meghalaya continue to exhibit relatively low overall urbanization levels, albeit with rapid growth in their respective capital regions (Singh & Baruah, 2024; ISPP, 2024). These differences reflect variations in topography, historical administrative development, educational infrastructure, and the strength of rural livelihood systems.

The drivers of urbanization in the NER are multi-faceted. Administrative reorganization and the expansion of state capitals and district headquarters have played a major role, as have investments in higher education, healthcare, and government employment. Improved connectivity under the Act East Policy and related infrastructure programmes has reduced historical isolation, making urban centres more attractive for trade, tourism, and private investment. Rural-to-urban migration is fuelled by the search for better education, employment opportunities outside agriculture, and access to modern services. Tourism has emerged as an additional catalyst, particularly in hill stations such as Shillong, Gangtok, and parts of Mizoram and Arunachal Pradesh, where visitor numbers have risen sharply in the post-2018 period (ISPP, 2024). Natural resource-based economic activities and the gradual diversification into services and small-scale manufacturing further reinforce urban concentration.

Spatially, urbanization in the NER tends to follow linear or radial patterns dictated by topography and transport corridors. Cities expand along major highways and rivers rather than in compact, concentric forms. Guwahati illustrates this process most clearly. Its metropolitan area has expanded dramatically: built-up land increased from approximately 9.8 percent of the study area in 2013 to 36.8 percent by 2023, while barren land declined sharply and water bodies and vegetation also contracted (Seal & Saikia, 2025). Similar

road-linked conversion of forest and agricultural land into built-up and peri-urban uses has been documented in the foothills of Manipur between 2012 and 2022, where rising road density correlates with forest fragmentation and the outward expansion of urban and peri-urban zones (Singh et al., 2024). In the hill capitals—Shillong, Aizawl, Kohima, and Itanagar—urban growth is constrained by steep slopes, resulting in dense, multi-storeyed construction along ridges and valleys and the progressive occupation of ecologically sensitive slopes.

A notable feature of NER urbanization is the phenomenon of "urban congestion" at the district level even where overall urbanization rates remain moderate. Analysis of Census 2011 data identified 16 districts showing clear signs of urban congestion, with particularly high concentrations in Mizoram and Nagaland (academia study on urban congestion). This suggests that population and activity are concentrating intensely within limited urbanizable land, producing high densities and pressure on services long before the states as a whole reach high urbanization threshold. Guwahati, Agartala, Shillong, and Aizawl function as primate cities within their respective states, absorbing a disproportionate share of urban growth and economic activity.

The environmental and infrastructural consequences of this urbanization pattern are already visible. Rapid conversion of wetlands, forests, and agricultural land has reduced natural drainage capacity and increased flood vulnerability, most dramatically in Guwahati. Forest loss linked to infrastructure and urban expansion across the broader NER between 2013 and 2023 has been substantial. At the same time, the provision of basic urban services—water supply, solid-waste management, drainage, and public transport has struggled to keep pace with the physical expansion of cities. Many urban centres continue to exhibit significant deficits in these services, a condition noted by the Asian Development Bank more than two decades ago and still largely valid (Humtsoe, 2024).

4.How Urbanization and the Traffic System Impact Each Other in Northeast India

The relationship between urbanization and the traffic system in Northeast India is deeply reciprocal and mutually reinforcing. Urban growth generates rising travel demand, while improvements in connectivity and road infrastructure simultaneously enable and accelerate further urban expansion. This interaction, shaped by the region's unique topography, institutional capacities, and rapid motorization, produces a complex set of economic,

environmental, social, and spatial consequences that have intensified between 2018 and 2024.

Urbanization drives traffic demand through several interrelated mechanisms. Population concentration in primate cities such as Guwahati, Shillong, Agartala, Aizawl, and Kohima increases the absolute volume of daily trips. Economic diversification—into services, trade, education, administration, and tourism lengthens average trip distances and multiplies journey purposes. Rising household incomes and aspirational consumption patterns fuel private vehicle ownership. In Guwahati, registered vehicles are projected to approach or exceed 700,000, with two-wheelers constituting roughly half the fleet; across the broader NER, vehicle numbers have risen by an estimated 250 percent in recent years (NIUA guidance document; IAJESM analysis of 2018–2022 trends; Humtsoe, 2024). In Tripura, two-wheeler registrations alone grew by more than 1,400 percent between 2019–20 and 2024–25, while three-wheelers, four-wheelers, and commercial vehicles recorded similarly dramatic increases (Down to Earth, 2025). Because public transport systems have expanded far more slowly than private and intermediate public transport (IPT) fleets, the modal share of cars, two-wheelers, and auto-rickshaws has risen sharply, placing intense pressure on limited road space.

The physical form of NER cities amplifies these pressures. Linear and corridor-based urban expansion dictated by rivers, ridges, and highways concentrates traffic onto a small number of arterial roads. In Guwahati, major corridors such as GS Road, Zoo Road, and the approaches to Khanapara and Jorabat routinely experience Travel Time Indices of 1.5 or higher, with average speeds often falling to around 20 km/h and peak-hour journeys taking two to three times free-flow duration (Ahmed & Das, 2022). In the hill capitals, narrow, winding roads with steep gradients and limited scope for widening mean that even modest increases in vehicle numbers produce severe congestion. Shillong’s average speeds drop to approximately 17 km/h during peak periods; specific intersections such as Dhankheti impose substantial time and fuel costs on commuters (Nongkynrih & Lyngdoh, 2020). Agartala has seen peak-hour mobility decline from about 7 km/h in 2014 to roughly 4 km/h in recent assessments, driven by the mixing of slow-moving cycle-rickshaws and e-rickshaws with faster cars and two-wheelers on a largely static road network (Down to Earth, 2025).

Conversely, the expansion and upgrading of the traffic system actively shape urbanization patterns. New and improved National Highways, bridges, and urban roads reduce travel

times and lower the friction of distance, making peri-urban and previously marginal locations more accessible and attractive for residential, commercial, and industrial development. Satellite-based studies of Manipur's Himalayan foothills between 2012 and 2022 demonstrate a clear correlation between rising road density and the conversion of forest and agricultural land into built-up and peri-urban uses (Singh et al., 2024). In Guwahati, built-up area expanded from 9.8 percent to 36.8 percent of the analysed landscape between 2013 and 2023, largely at the expense of barren land, vegetation, and water bodies, with the most intensive change occurring along major transport corridors (Seal & Saikia, 2025). Improved connectivity under the Act East Policy and SARDP-NE has also facilitated the growth of secondary urban nodes and industrial-transit corridors, such as Byrnihat on the Assam–Meghalaya border, where heavy freight traffic and industrial activity have transformed a once-rural landscape.

These reciprocal processes generate significant negative externalities. Economically, congestion imposes direct costs through excess fuel consumption and vehicle operating expenses, and indirect costs through lost productive time. Studies in Shillong quantify substantial daily losses varying by occupation and intersection (Nongkynrih & Lyngdoh, 2020); similar patterns are reported across Guwahati's zones (Ahmed & Das, 2022). Environmentally, the combination of rapid motorization, mixed traffic, road dust, and land-use change elevates particulate matter concentrations. In Guwahati, two-wheelers alone contribute a large share of PM2.5 emissions, while road dust is a dominant source of PM10; the same city has experienced progressive loss of wetlands and vegetation that once moderated flooding and air quality (Seal & Saikia, 2025; related IIT Guwahati findings). Across the wider NER, infrastructure and urban expansion contributed to the loss of more than 3,000 km² of natural forest between 2013 and 2023. In hill cities, construction on steep slopes increases landslide risk, while the funneling of traffic through narrow valleys traps pollutants.

Social and equity impacts are equally pronounced. Inadequate public transport disproportionately affects lower-income groups, students, and women who rely on buses or walking. The dominance of private vehicles and unregulated IPT modes reduces road space available for pedestrians and non-motorized transport, compromising safety and accessibility. Road accident data underscore the human cost: between 2020 and 2024 the region recorded nearly 19,000 fatalities, with Assam accounting for the overwhelming majority and fatality rates per 10,000 vehicles exceeding the national average (Times of

India reporting of official statistics). Chronic congestion also generates psychological stress and reduces quality of life, particularly for daily commuters.

Positive feedbacks exist but remain underdeveloped. Quality road infrastructure can support economic growth, facilitate the movement of goods under the Act East framework, and, when paired with effective demand management, enable more efficient urban forms. Smart City interventions in Guwahati and Agartala Adaptive Traffic Control Systems and Automated Number Plate Recognition have reduced junction delays by over 50 percent in equipped locations and lowered certain violation rates (IAJESM analysis). The introduction of electric buses in Guwahati represents an initial step toward cleaner public transport. Yet these gains are often localized; without complementary measures such as parking regulation, transit-oriented development, protection of road space from encroachment, and significant expansion of reliable public and non-motorized transport, infrastructure capacity is rapidly absorbed by induced demand. Experience with flyovers in Guwahati illustrates the classic pattern: short-term relief followed by the return of congestion as vehicle volumes continue to rise (Question of Cities, 2024).

In essence, urbanization and the traffic system in Northeast India form a tightly coupled system. Urban growth multiplies travel demand on a constrained and topographically challenging network, while transport improvements open new land for urban expansion and further motorization. The result, visible across both plains and hill cities between 2018 and 2024, is a cycle of congestion, environmental degradation, safety risks, and equity challenges. Breaking this cycle requires moving beyond supply-side road expansion toward integrated land-use and transport planning, prioritization of sustainable modes suited to local topography, strong institutional coordination, and explicit ecological safeguards. Only through such a comprehensive approach can the NER harness the developmental benefits of connectivity and urbanization without locking its cities into unsustainable mobility trajectories.

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CHAPTER IV:

SOIL BIOCHEMISTRY AND ORGANIC FERTILIZATION STRATEGIES FOR SUSTAINABLE PLANTATION SYSTEMS IN MANIPUR

DR.KHOMDRAM BIDYARANI DEVI

(Assistant Professor)

Department of Chemistry, Jadonang Memorial College, Noney

Abstract: Manipur’s diverse topography produces a mosaic of soils primarily Inceptisols, Ultisols, and Entisols characterized by strong acidity, variable organic carbon, low cation exchange capacity (CEC), and contrasting fertility between valley alluvial plains and hill slopes. This chapter examines the biochemical processes governing nutrient cycling, microbial activity, and organic-matter dynamics in these soils and compares the performance of organic fertilization strategies (farmyard manure, vermicompost, green manures, and locally derived composts such as phumdi compost). Key soil parameters (pH, soil organic carbon [SOC], available NPK, bulk density, water-holding capacity) differ markedly between land uses and altitudes, necessitating site-specific organic amendments. Organic inputs consistently elevate SOC, microbial biomass, enzyme activities, and nutrient availability while improving physical structure, offering a sustainable pathway for organic plantation systems in both jhum/terrace hill lands and intensive valley agriculture. Findings underscore the value of integrating indigenous knowledge with modern organic practices to maintain long-term soil health under Manipur’s humid subtropical climate.

Keywords: Manipur soils, soil biochemistry, organic fertilization, soil organic carbon,

1) INTRODUCTION

Manipur, one of the eight sister states of India’s North-Eastern Region (NER), occupies a distinctive geographical and ecological niche between latitudes 23°50′ N and 25°42′ N and

longitudes 92°58′ E and 94°45′ E. Covering approximately 22,327 km², the state is characterised by a central oval-shaped valley (Imphal Valley) surrounded by steep, densely forested hills that constitute nearly 91 % of its total geographical area. This dramatic physiographic contrast flat alluvial plains versus dissected mountain slopes has produced one of the most diverse soil landscapes in the Indian subcontinent. The soils of Manipur have developed primarily from Tertiary sedimentary rocks of the Disang and Barail Groups (sandstones, shales, and siltstones), under a warm, humid subtropical to tropical climate with mean annual rainfall ranging from 1,400 mm in the valley to over 3,000 mm on the windward slopes and a hyperthermic soil temperature regime (Sen et al., 1997; Sahoo et al., 2020). The interplay of parent material, high rainfall, intense leaching, steep topography, and centuries of human land-use has created soils that are overwhelmingly acidic, low in base saturation and cation-exchange capacity, yet often surprisingly rich in organic carbon under natural or long-fallow conditions.

According to the soil resource inventory of the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), the dominant soil orders in Manipur are Inceptisols (approximately 38.4 % of the total geographical area), Ultisols (36.4 %), Entisols (23.1 %), and a minor proportion of Alfisols (0.2 %) (Sen et al., 1997; Nayak et al., 1996; Sen et al., 1996). These soils are further differentiated into red ferruginous soils of the hills, brown forest soils, alluvial soils of the valley, lateritic patches, and various residual and colluvial soils on slopes. Surface soil pH commonly ranges between 4.0 and 5.5 in the hills and 5.2 to 6.5 in the valley; organic carbon content varies widely from less than 0.7 % in intensively cultivated valley fields to more than 3–5 % under dense forest or recent jhum fallows; available phosphorus is generally low because of fixation by iron and aluminium oxides; and cation-exchange capacity remains modest owing to the predominance of low-activity clay minerals (kaolin interstratified with hydroxy-interlayered vermiculite) (Sahoo et al., 2020; Monsang et al., 2023; Haobijam, 2020). Bulk density, water-holding capacity, and nutrient-supplying power likewise differ markedly between the deep, finer-textured alluvial soils of the valley and the shallower, coarser, erosion-prone soils of the hills.

Agriculture in Manipur reflects this soil diversity. The Imphal Valley supports intensive, largely irrigated rice-based systems that form the state's food bowl, while the surrounding hills are characterised by a mosaic of shifting cultivation (jhum), settled terrace farming, and emerging horticultural and plantation crops (pineapple, orange, banana, passion fruit, ginger, turmeric, and various spices). Traditional jhum cycles once allowed long fallow periods that restored soil fertility through natural litter accumulation and biological

nitrogen fixation; progressive shortening of fallow periods under population pressure has, however, led to accelerated soil erosion, nutrient depletion, and declining yields (Meetei et al., 2017; Lungleng & Shimrah, 2023). Chemical fertiliser consumption in the NER as a whole remains among the lowest in India (often below 12–20 kg ha^{-1} in the hill districts), partly because of logistical constraints and partly because of a cultural preference for organic and indigenous nutrient sources (Das et al., 2011). This low external-input baseline, combined with growing consumer demand for chemical-free produce and the state's policy emphasis on organic agriculture, creates both an opportunity and an urgent scientific necessity to develop site-specific organic nutrient-management strategies.

Soil biochemistry lies at the heart of any such strategy. In Manipur's acid soils the classical processes of organic-matter decomposition, nutrient mineralisation, and microbial transformation operate under the strong influence of low pH, aluminium toxicity, phosphorus fixation, and fluctuating moisture regimes (Nayak et al., 1996; Sahoo et al., 2020). Soil organic matter is not merely a reservoir of nitrogen, phosphorus and sulphur; it is the principal source of cation-exchange capacity, the chief agent of soil aggregation, and the substrate that sustains a diverse microbial community whose enzymes (dehydrogenase, acid and alkaline phosphatases, β-glucosidase, arylsulphatase) mediate nutrient release (Ansari et al., 2022; Ezung et al., 2018). The quantity, quality and turnover rate of soil organic carbon therefore determine, to a large extent, the fertility and resilience of both valley and hill soils. Organic amendments farmyard manure, vermicompost, green manures, phumdi compost derived from Loktak Lake biomass, and various indigenous preparations interact with these biochemical pathways in ways that differ markedly according to soil type, altitude, land-use history and climate. Understanding these interactions is essential if organic plantation systems are to be both productive and sustainable.

The present chapter therefore undertakes a detailed examination of the biochemistry of Manipur's major soil groups and of the differential responses of these soils to organic fertilisation. It begins by characterising the physical, chemical and biological attributes of valley alluvial soils, hill red and lateritic soils, and intermediate residual soils. It then explores the key biochemical processes carbon and nutrient cycling, enzyme activities, microbial biomass dynamics, and acidity-related chemistry that govern fertility. Against this background it compares the performance of major organic inputs across soil types, presenting available data on changes in soil organic carbon, available NPK, microbial parameters, physical structure and crop response. Finally, it evaluates the agronomic,

ecological and socio-economic value of organic fertilisation for plantation agriculture in Manipur and identifies research and policy priorities for the future. By integrating pedological, biochemical and agronomic knowledge, the chapter seeks to provide a scientific foundation for the rational design of organic nutrient-management systems suited to the unique soil landscape of Manipur.

1.1 Biochemistry Scope

The biochemical functioning of Manipur’s soils is governed by the interaction of climate, parent material, topography, and land-use history. High annual rainfall (1 400–3 500 mm), warm temperatures (hyperthermic regime), and intensely weathered sedimentary parent rocks create an environment in which organic-matter dynamics, acidity chemistry, and microbial processes dominate fertility (Sen et al., 1997; Sahoo et al., 2020). Understanding these processes is essential for designing effective organic fertilisation regimes for plantation systems.

1. Soil Organic Matter Dynamics and Carbon Cycling : Soil organic carbon (SOC) is the central currency of fertility in Manipur’s low-activity-clay soils. Under natural forest and long-fallow jhum systems, surface SOC frequently exceeds 2.5–4.5 %, while intensively cultivated valley soils may contain less than 0.8–1.2 % (Devi & Yadava, 2015; Meetei et al., 2017; Lungleng & Shimrah, 2023; Monsang et al., 2023). The vertical distribution is typically steep: the majority of organic carbon is concentrated in the upper 0–15 cm and declines sharply with depth, except in permanently wet rice soils where anaerobic conditions slow decomposition.

Organic matter inputs arrive mainly as leaf litter, root turnover, and, under managed systems, crop residues and applied manures. Decomposition proceeds through a cascade of microbial enzymes. Labile fractions (very labile and labile carbon) turn over within months to a few years and supply the bulk of mineralisable nitrogen and phosphorus. Less-labile and recalcitrant fractions, stabilised by association with iron and aluminium oxides or protected within aggregates, constitute longer-term carbon stores. In Manipur’s acid soils the presence of amorphous iron and aluminium hydroxides enhances physical protection of organic matter, contributing to relatively high SOC stocks even when cation-exchange capacity remains low (Sahoo et al., 2020; Bhattacharyya et al., 2008).

Land-use change exerts a strong influence. Conversion of forest or long-fallow land to continuous cultivation accelerates mineralisation and erosion losses, reducing SOC by 30–60 % within a decade (Guo & Gifford, 2002; Meetei et al., 2017). Conversely, organic

amendments and green manuring rebuild both labile and intermediate pools, improving aggregate stability and water-holding capacity (Ansari et al., 2022; Ezung et al., 2018).

2. Nutrient Transformation Processes: Nitrogen cycling is mediated by ammonification, nitrification, and denitrification. In acid soils (pH < 5.5) nitrification is often restricted, so ammonium tends to predominate. Organic manures and vermicompost release nitrogen gradually through microbial mineralisation, reducing leaching losses that are otherwise severe under high rainfall. Biological nitrogen fixation by free-living bacteria and by symbiotic associations (especially with green-manure legumes such as *Sesbania* and *Crotalaria*) assumes particular importance in low-fertiliser systems (Ansari et al., 2022; Athokpam et al., 2017).

Phosphorus chemistry is dominated by fixation. At low pH, soluble phosphate reacts rapidly with iron and aluminium oxides to form insoluble Fe-P and Al-P compounds (Nayak et al., 1996; Sahoo et al., 2020). Organic anions released during decomposition of manures and green manures compete for sorption sites and form soluble organo-metallic complexes, thereby increasing phosphorus availability. Organic phosphorus fractions themselves constitute a substantial portion of total P; their mineralisation by acid phosphatases becomes a critical supply pathway under organic management (Ansari et al., 2022).

Potassium and secondary nutrients are less strongly fixed, yet their retention depends heavily on organic matter because the mineral clay fraction contributes limited exchange sites. Calcium and magnesium levels are generally low; organic amendments and occasional liming materials help replenish these bases while moderating aluminium toxicity (Sen et al., 1996).

3. Acidity Chemistry and Aluminium Toxicity: Soil acidity is the single most pervasive chemical constraint. Exchangeable aluminium frequently occupies a significant proportion of the exchange complex, especially in Ultisols and highly weathered Inceptisols (Nayak et al., 1996; Sahoo et al., 2020). Aluminium toxicity impairs root elongation, reduces water and nutrient uptake, and inhibits beneficial microbial activity. Organic matter mitigates these effects through several mechanisms: (i) complexation of Al^{3+} by carboxyl and phenolic groups of humic substances, (ii) elevation of soil pH during ammonification and subsequent base release, and (iii) stimulation of microbial populations that further

immobilise aluminium. The magnitude of these benefits varies with the quality of the organic input and the initial severity of acidity (Athokpam et al., 2017; Ezung et al., 2018).

4. Microbial Biomass and Enzyme Activities: Microbial biomass carbon, nitrogen and phosphorus serve as both a reservoir of nutrients and an indicator of biological fertility. In Manipur soils, microbial biomass responds rapidly to organic amendments. Vermicompost, farmyard manure and green-manure residues consistently elevate microbial biomass and dehydrogenase activity (a general indicator of oxidative metabolism) more effectively than equivalent mineral fertiliser rates. Specific enzyme activities—acid phosphatase, alkaline phosphatase, β-glucosidase and arylsulphatase—also increase, reflecting enhanced capacity for organic phosphorus, carbon and sulphur mineralisation (Ansari et al., 2022; Ezung et al., 2018).

The microbial community composition itself shifts under organic management. Populations of nitrogen-fixing bacteria, phosphate-solubilising microorganisms and arbuscular mycorrhizal fungi tend to increase, further improving nutrient acquisition by plantation crops. These biological enhancements are particularly valuable in low-CEC soils where chemical retention of nutrients is inherently limited.

5. Physical–Biochemical Interactions: Organic matter improves soil physical structure by promoting aggregation. Stable aggregates enhance porosity, reduce bulk density, increase water-holding capacity and improve resistance to erosion critical attributes on Manipur's steep hill slopes (Monsang et al., 2023; Haobijam, 2020). Better aeration and moisture regimes in turn stimulate aerobic microbial activity, closing a positive feedback loop between physical and biochemical fertility.

6. Implications for Organic Plantation Systems: The biochemical characteristics outlined above dictate that organic fertilisation strategies must simultaneously:

i. supply readily mineralisable carbon and nutrients,
ii. buffer acidity and reduce aluminium activity,
iii. stimulate microbial populations and enzyme systems, and
iv. rebuild soil structure and water-retention capacity.

Because these processes operate differently across the valley and hill continuum and across land-use histories, a uniform recommendation is inappropriate. The following section

therefore examines the differential responses of Manipur's major soil groups to the principal organic amendments used or potentially available in the state.

1.2 Fertilization and Differences Across Different Soils of Manipur: Parameters, Values, and Comparative Responses

The effectiveness of organic fertilisation in Manipur is strongly conditioned by the inherent differences among its major soil groups. Valley alluvial soils, hill red and lateritic soils, and intermediate residual soils differ in texture, acidity, organic-carbon status, nutrient-supplying capacity, and physical constraints. Consequently, the same organic amendment produces quantitatively and qualitatively different responses across these soils. This section synthesises available data on key soil parameters and the differential effects of major organic inputs.

Table 1. Baseline Soil Parameters Across Major Soil Groups

Parameter	**Valley Alluvial Soils (Inceptisols/Entisols)**	**Hill Red & Lateritic Soils (Ultisols/Inceptisols)**	**Intermediate / Residual Soils**
pH (H_2O)	5.2 – 6.5	4.0 – 5.5	4.5 – 5.8
Soil Organic Carbon (%)	0.6 – 2.0 (often <1.2 under continuous rice)	1.5 – 4.5 (higher under forest/jhum fallow)	1.0 – 2.8
Available N (kg ha^{-1})	220 – 380	280 – 620	250 – 450
Available P (kg ha^{-1})	12 – 28	8 – 22	10 – 25
Available K (kg ha^{-1})	180 – 320	150 – 280	160 – 300
CEC (cmol(+) kg^{-1})	8 – 18	6 – 14	7 – 16
Bulk Density (g cm^{-3})	1.15 – 1.35	0.90 – 1.30	1.05 – 1.30
Texture	Loam to clay loam	Sandy loam to gravelly loam	Sandy clay loam to loam
Dominant	Declining SOC, moderate	Strong acidity, Al toxicity,	Moderate acidity

Parameter	Valley Alluvial Soils (Inceptisols/Entisols)	Hill Red & Lateritic Soils (Ultisols/Inceptisols)	Intermediate / Residual Soils
constraint	N & P	low P, erosion	& fertility

These values are compiled from multiple district-level studies across Imphal Valley, Senapati, Churachandpur, Ukhrul, Chandel and Tamenglong (Sen et al., 1996; Sahoo et al., 2020; Monsang et al., 2023; Devi & Yadava, 2009, 2015; Haobijam, 2020; Meetei et al., 2017).

2) DIFFERENTIAL RESPONSES TO MAJOR ORGANIC AMENDMENTS

2.1 Vermicompost

Vermicompost (typically 1.8–3.0 % N, 1.5–2.5 % P_2O_5, 1.5–2.5 % K_2O plus humic substances) is the most widely adopted organic input in Manipur.

- ✓ Valley soils: Application of 5 t ha^{-1} significantly raises SOC (0.3–0.6 percentage points), available N and P, and microbial biomass. Yield responses in rice and vegetables are substantial because baseline SOC is often low. Combined use with 50 % recommended mineral fertiliser frequently outperforms 100 % mineral fertiliser alone (Athokpam et al., 2017; Scientific Reports, 2025).
- ✓ Hill soils: Benefits are equally strong but expressed differently. Vermicompost improves P availability by complexing aluminium and iron, reduces exchangeable Al, and markedly increases water-holding capacity and aggregate stability critical on erosion-prone slopes. Higher-altitude soils (>1 000 m) with already elevated SOC show smaller relative increases in carbon but large gains in biological activity and nutrient-use efficiency (Ezung et al., 2018; Monsang et al., 2023).

2.2 Farmyard Manure (FYM) and Animal Manures

Traditional FYM (0.5–1.0 % N) remains important, especially in mixed farming systems.

- ✓ Valley soils respond well to 5–10 t ha^{-1} FYM through gradual N release and improved soil structure.

- ✓ Hill soils benefit more from the physical mulching effect and the modest liming action of well-decomposed manure, which helps counteract aluminium toxicity. Response is slower than with vermicompost because of lower nutrient concentration and wider C:N ratio (Das et al., 2011; Athokpam et al., 2017).

2.3 Green Manures

Sesbania, *Crotalaria*, *Indigofera* and local legumes are particularly effective.

- ✓ In valley rice systems, incorporation of *Sesbania* increases SOC stock, available N, P and micronutrients, and elevates dehydrogenase, phosphatase and β-glucosidase activities in both surface and subsurface layers (Ansari et al., 2022).
- ✓ On hill slopes, nitrogen-fixing hedgerow species used in sloping agricultural land technology (SALT) simultaneously control erosion and enrich soil nitrogen. The residual effect on subsequent plantation crops (pineapple, ginger, turmeric) is pronounced (Ezung et al., 2018).

2.4 Phumdi Compost and Local Biomass Composts

Compost prepared from Loktak Lake phumdi (floating biomass) and other locally available organic wastes has shown excellent results in valley soils. When 50 % of recommended mineral fertiliser is substituted by phumdi compost, rice grain yield has increased by more than 30 % relative to 100 % mineral fertiliser, accompanied by higher soil organic carbon and improved nutrient status (Scientific Reports, 2025). In hill soils the same material improves moisture retention and supplies a balanced suite of nutrients, although transport logistics can limit large-scale use.

3) KEY PARAMETER CHANGES UNDER ORGANIC MANAGEMENT

Across studies, consistent trends emerge:

1) Soil organic carbon: Increases of 0.2–0.8 percentage points after 2–3 years of regular organic amendment; largest relative gains occur in low-SOC valley soils (Ansari et al., 2022; Ezung et al., 2018; Meetei et al., 2017).
2) Available nitrogen: Gains of 40–120 kg ha^{-1}, with vermicompost and green manures outperforming FYM.

3) Available phosphorus: Increases of 4–15 kg ha^{-1}; more pronounced in acid hill soils where organic acids enhance P solubility.
4) pH and exchangeable aluminium: Modest rise in pH (0.2–0.6 units) and reduction in exchangeable Al, especially when vermicompost or well-decomposed manures are used (Athokpam et al., 2017; Sahoo et al., 2020).
5) Physical properties: Bulk density declines by 0.05–0.15 g cm^{-3}; water-holding capacity and aggregate stability improve significantly, reducing erosion risk on slopes (Monsang et al., 2023; Haobijam, 2020).
6) Biological indicators: Microbial biomass carbon and dehydrogenase activity commonly double or more under organic versus sole mineral fertilisation (Ansari et al., 2022; Ezung et al., 2018).

4) INTERACTION WITH ALTITUDE AND LAND-USE HISTORY

Higher-elevation soils (>1 000 m) generally possess higher baseline SOC, moisture and available N and K. Organic amendments here function more as maintenance and biological stimulants than as primary nutrient sources. Mid-altitude jhum soils, often the most degraded, show the strongest absolute responses to organic inputs. Continuously cultivated valley soils respond primarily through restoration of depleted carbon and nitrogen pools (Lungleng & Shimrah, 2023; Meetei et al., 2017; Monsang et al., 2023).

5) PRACTICAL IMPLICATIONS FOR ORGANIC PLANTATION

- ✓ Valley plantations (citrus, banana, vegetables): Emphasise vermicompost + green manure to rebuild SOC and supply balanced nutrients.
- ✓ Hill plantations (pineapple, ginger, turmeric, passion fruit): Combine vermicompost or FYM with nitrogen-fixing hedgerows and surface mulching to address acidity, P fixation and erosion simultaneously.
- ✓ Rates should be adjusted according to baseline soil test values; 4–6 t ha^{-1} vermicompost or 8–10 t ha^{-1} FYM annually, supplemented by green manuring, provides a robust starting framework for most soils.

The comparative evidence demonstrates that organic fertilisation is not a uniform prescription but a set of flexible, soil-specific interventions that exploit the biochemical strengths and correct the inherent weaknesses of each soil group in Manipur.

6) VALUE OF ORGANIC FERTILISATION FOR PLANTATION SYSTEMS IN MANIPUR

Organic fertilisation offers a multi-dimensional set of benefits that are particularly well-suited to the ecological, agronomic and socio-economic conditions of Manipur. In a state characterised by acid, low-CEC soils, steep slopes, high rainfall, low chemical-fertiliser use and a growing emphasis on sustainable and market-oriented agriculture, organic nutrient management is not merely an alternative but a strategic necessity. This section evaluates the value of organic fertilisation across four interrelated domains: soil health and productivity, environmental sustainability, economic viability, and social and institutional relevance.

1. Restoration and Sustained Improvement of Soil Health : The most immediate and enduring value of organic fertilisation lies in its capacity to rebuild the biological and physical foundation of fertility. Regular application of vermicompost, farmyard manure, green manures and locally derived composts consistently elevates soil organic carbon, the single most important determinant of fertility in Manipur's low-activity-clay soils. Increases of 0.3–0.8 percentage points in SOC over two to three years translate into measurable improvements in aggregate stability, porosity, water-holding capacity and resistance to erosion—attributes of critical importance on hill slopes where soil loss under conventional jhum or poorly managed terraces remains severe (Ansari et al., 2022; Ezung et al., 2018; Monsang et al., 2023).

Biochemically, organic inputs stimulate microbial biomass and enzyme activities (dehydrogenase, phosphatases, β-glucosidase), accelerate nutrient mineralisation, and enhance the solubilisation of fixed phosphorus through the release of organic acids and chelating compounds. In strongly acidic hill soils, these processes simultaneously reduce exchangeable aluminium toxicity and improve root exploration. In valley soils depleted by continuous rice cultivation, organic amendments reverse the progressive decline in organic matter and nitrogen-supplying capacity. The net result is a more resilient soil system capable of buffering climatic variability and supporting sustained plantation productivity (Lal, 2004; Bhattacharyya et al., 2008).

2. Agronomic Performance and Crop Quality in Plantation Systems: Organic nutrient management has demonstrated clear agronomic advantages for the high-value crops that form the backbone of Manipur's emerging plantation economy includes pineapple, citrus, banana, passion fruit, ginger, turmeric and various spices. Yield responses are often

comparable to, and in integrated systems superior to, sole mineral fertilisation, particularly when organic sources are combined with biofertilisers or modest quantities of mineral nutrients (Athokpam et al., 2017; Scientific Reports, 2025). More importantly, produce quality frequently improves: higher secondary-metabolite content, better flavour profiles, longer shelf life and reduced chemical residues enhance marketability in both domestic organic and export channels.

Because nutrient release from organic sources is gradual, the risk of luxury consumption or nutrient imbalances is lower than with soluble mineral fertilisers. This steady supply is especially advantageous for perennial and semi-perennial plantation crops whose nutrient demand extends over long periods. Residual effects further increase the cumulative value of organic fertilisation; benefits commonly persist into subsequent seasons, reducing the need for annual high-rate applications.

3. Environmental and Ecological Benefits: Organic fertilisation aligns closely with the environmental priorities of the North-Eastern Region. By increasing soil organic carbon stocks, it contributes to climate-change mitigation through enhanced carbon sequestration (Lal, 2004; Guo & Gifford, 2002). Improved soil structure and surface cover (especially when combined with mulching or nitrogen-fixing hedgerows) substantially reduce runoff and soil erosion, major problems on Manipur's steep terrain. Reduced reliance on synthetic fertilisers lowers the risk of nutrient leaching into water bodies, an important consideration given the presence of Loktak Lake, a Ramsar site of international significance, and the dense network of streams that drain the hills.

Biodiversity benefits are equally notable. Organic systems support higher populations of earthworms, beneficial insects, mycorrhizal fungi and free-living nitrogen-fixers, reinforcing the biological nutrient cycles that have traditionally sustained agriculture in the region. The use of locally available biomass (crop residues, animal manures, phumdi, forest litter) closes nutrient loops within the landscape and reduces the environmental footprint associated with long-distance transport of mineral fertilisers (Das et al., 2011; Sinha et al., 2020).

4. Economic and Livelihood Value: From an economic perspective, organic fertilisation offers several advantages under Manipur's conditions. Chemical fertiliser use in the hill districts remains low; therefore the opportunity cost of switching to organic sources is modest. Local production of vermicompost and other organic inputs generates rural employment and entrepreneurial opportunities, as evidenced by the growth of community-

level and private vermicompost enterprises across the state. Farmers who produce their own compost reduce cash outflows and gain greater control over input quality and timing. Market premiums for certified organic produce provide an additional incentive. Manipur's reputation for low chemical use and its rich agro-biodiversity position it favourably in organic and specialty markets for spices, fruits and medicinal plants. Even without formal certification, many consumers within the region already prefer "chemical-free" local produce, creating a ready domestic demand. Over the medium term, the cumulative improvements in soil productivity and resilience reduce the risk of yield decline and the need for costly rehabilitation of degraded lands.

5. Social, Cultural and Institutional Relevance: Organic fertilisation resonates strongly with indigenous agricultural knowledge systems. Traditional practices which includes application of animal manure, incorporation of forest litter, use of green-manure species, and fallow management share a common philosophical foundation with modern organic approaches (Sinha et al., 2020). Building upon these traditions rather than replacing them facilitates farmer adoption and strengthens cultural continuity. Government programmes promoting organic farming, vermicomposting and integrated nutrient management find a receptive audience precisely because they align with existing practices and values. Institutionally, organic systems reduce dependence on external input supply chains that are often unreliable in remote hill districts. They also complement soil and water conservation programmes, watershed development initiatives and climate-resilient agriculture strategies currently prioritised by state and central agencies.

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CHAPTER V:

GREEN URBANIZATION AND ITS ENVIRONMENT IN MANIPUR

DR. KHOMDRAM MONALISHA DEVI
(Assistant Professor)
Department of Botany, Jadonang Memorial College, Noney

Abstract Manipur, nestled at the junction of the Himalayan and Indo-Burma biodiversity hotspots, faces accelerating urbanization, particularly in the Imphal Valley, that threatens its rich forest cover, wetlands, and traditional agroforestry systems. This chapter examines green urban initiatives and tree plantation efforts grounded exclusively in Manipur-based studies. It highlights the diversity of native and commonly planted tree species, the ecological roles of Trees Outside Forests (TOF), urban campuses, home gardens, and recent high-density restoration projects such as Miyawaki plantations. Evidence from Imphal campuses, Imphal-West district assessments, institutional and roadside plantings, and community-led restoration shows that strategic tree plantation supports carbon sequestration, temperature regulation, biodiversity retention, and soil fertility while enabling urbanization that minimizes environmental disruption. Policy emphasis on native species, institutional greening, and community participation emerges as essential for sustaining Manipur's ecological integrity.

Keywords Green urbanization; Tree plantation; Manipur; Trees Outside Forests

1. Introduction

Manipur occupies a unique biogeographic position at the confluence of the Himalayan and Indo-Burma biodiversity hotspots, two of the thirty-four global hotspots recognized for exceptional species richness and high endemism. The state's physiography a central alluvial valley (the Imphal Valley) ringed by ranges of the Patkai and Naga hills creates a mosaic of tropical moist deciduous forests, subtropical broadleaf forests, wetlands, and

traditional agroforestry systems. This ecological complexity has long sustained diverse plant communities, including numerous multipurpose tree species that form the backbone of local livelihoods, cultural practices, and environmental stability. Yet the same landscape is now undergoing rapid socio-economic transformation. Population growth, expansion of road networks, conversion of agricultural and forest land for housing and commercial purposes, and the progressive urbanisation of Imphal and secondary towns have begun to reshape land-cover patterns at an accelerating pace.

Recent Manipur-based assessments document these shifts with clarity. In the Imphal-West district, satellite-derived land-use and land-cover analyses spanning 2011–2021 reveal a measurable increase in built-up area (approximately 2.9 per cent over the decade) accompanied by contraction of barren land and, in places, of productive vegetation (Momo & Devi, 2022. Parallel observations from the wider Imphal Valley indicate progressive fragmentation of green cover, rising land-surface temperatures in densely built zones, and growing pressure on residual forest patches and wetlands. These changes are not merely statistical; they translate into tangible ecological consequences reduced carbon sequestration capacity, altered microclimates, diminished habitat connectivity for native flora and fauna, and heightened vulnerability of communities that depend on trees for food, fuel, medicine, and cultural identity.

Against this backdrop, the concept of green urbanisation assumes particular urgency. Green urbanisation does not reject urban growth; rather, it seeks to embed vegetation deliberately within the expanding urban matrix so that ecosystem services continue to function even as settlements densify. In the Manipur context this means treating Trees Outside Forests (TOF) those occurring on institutional campuses, roadsides, home gardens, agricultural boundaries, and residual commons as critical green infrastructure rather than incidental greenery. It means recognising that university campuses, government compounds, and peri-urban degraded sites can function as carbon sinks, thermal buffers, and biodiversity refugia when planted and managed with ecological intent. It also means drawing upon Manipur’s own scientific and community knowledge rather than importing generic solutions.

A growing body of research conducted entirely within the state supplies the empirical foundation for such an approach. Inventories of campus vegetation at Dhanamanjuri University in Imphal have quantified the carbon-sequestration and oxygen-production potential of more than one hundred tree species, demonstrating that institutional green spaces can make measurable contributions to atmospheric carbon balance (Singh et al.,

2025). Systematic surveys of TOF across multiple land-use categories have mapped the distribution, density, and functional roles of trees outside formal forest boundaries, revealing that institutional lands already support the highest proportions of such trees and that urban residential areas, though lower in density, still harbour culturally and ecologically significant species (Devi et al., 2025). Village-level floristic studies, such as the documentation of eighty-one tree species in Utlou, Bishnupur district, illustrate both the residual richness of local tree diversity and the losses already incurred through urban expansion (Laishram & Imotomba Singh, 2024). Complementary work on home gardens in the Imphal-West district has shown that even small homestead plots store meaningful quantities of carbon while conserving useful germplasm and buffering households against climatic and economic stress (Nicholas et al., 2026). At the landscape scale, high-density restoration experiments employing the Miyawaki method in the Langol Reserve Forest and community-led nursery and plantation programmes in the Phalee commons of Ukhrul district demonstrate that rapid ecological recovery is feasible when native species and local stewardship are prioritised (Central Forest Division, Manipur, 2026; Shatsang, 2026).

Collectively these studies establish three interrelated propositions that frame the present chapter. First, Manipur retains a rich and functionally diverse tree flora that can be mobilised for urban and peri-urban greening. Second, existing institutional, roadside, and household plantings already deliver measurable ecosystem services and can be systematically expanded. Third, urbanisation need not entail irreversible ecological degradation provided that native species, multi-layered planting designs, continuous monitoring, and community participation are integrated into planning and practice.

The remainder of the chapter elaborates these propositions. It begins by situating green urbanisation within the specific ecological and socio-cultural conditions of Manipur. It then surveys the principal tree species recorded in urban, institutional, and village settings. Subsequent sections examine the contributions of current plantation and restoration initiatives to carbon balance, micro-climate regulation, and biodiversity retention, and finally outline practical pathways through which urban expansion can proceed while safeguarding, and even enhancing, the state’s environmental integrity. Throughout, the analysis remains grounded exclusively in research and documentation generated within Manipur, thereby ensuring that recommendations are both scientifically robust and contextually appropriate.

2. Green Urbanization

Green urbanization represents a deliberate planning paradigm that seeks to reconcile the physical expansion of human settlements with the continued delivery of essential ecosystem services. Rather than treating vegetation as an afterthought or as residual open space, it positions trees, multi-layered plantings, and connected green infrastructure as integral components of the urban fabric capable of moderating microclimates, sequestering carbon, supporting biodiversity, enhancing human well-being, and buffering the impacts of land-use change. In the specific context of Manipur, this paradigm acquires heightened relevance because of the state's dual character: a biodiversity-rich landscape of global significance that is simultaneously experiencing concentrated urban growth within a geographically constrained valley system.

The Imphal Valley, the demographic and administrative heart of Manipur, occupies a relatively narrow alluvial plain surrounded by hills. This physiographic confinement means that urban expansion cannot simply spill outward indefinitely; instead, it intensifies within existing settlement boundaries and along transport corridors, placing direct pressure on agricultural land, residual forests, wetlands, and traditional home-garden systems. Manipur-based remote-sensing studies have quantified these pressures. Analyses of land-use and land-cover change in Imphal-West district between 2011 and 2021 documented a progressive increase in built-up area of approximately 2.9 per cent over the decade, accompanied by a corresponding decline in barren land and, in certain zones, a reduction in vegetative cover (Momo & Devi, 2022). Parallel observations across the wider Imphal Valley reveal fragmentation of green patches, localized elevations in land-surface temperature, and incremental loss of habitat connectivity. These biophysical shifts are not abstract; they translate into reduced capacity for carbon storage, altered hydrological regimes, diminished shade and evaporative cooling, and erosion of the cultural and utilitarian values that local communities have long derived from trees.

Against this backdrop, green urbanization in Manipur cannot be reduced to ornamental planting or isolated park creation. It must address the functional roles that trees and vegetated spaces perform within a rapidly densifying landscape. Research conducted within the state demonstrates that such functional roles are already being fulfilled, albeit unevenly, by existing green elements. Institutional campuses, government compounds, roadside plantations, home gardens, and residual commons collectively constitute a dispersed but significant green infrastructure. The systematic inventory of Trees Outside Forests (TOF) across Manipur has shown that institutional lands currently support the

highest proportion of these trees (approximately 30 per cent of recorded TOF), followed by agricultural land (25 per cent) and urban residential areas (22 per cent) (Devi et al., 2025). These trees continue to sequester carbon, enhance soil fertility, regulate local climate, and provide aesthetic and cultural benefits even as urban encroachment proceeds. Their presence indicates that the foundational elements of green urbanization already exist; the challenge is to protect, expand, and deliberately design them as coherent systems rather than incidental remnants.

Campus-scale studies supply further empirical grounding. At Dhanamanjuri University in Imphal, an exhaustive enumeration of 124 tree species quantified substantial carbon sequestration and oxygen production, establishing the campus as a measurable atmospheric carbon sink within the urban matrix (Singh et al., 2025). Such findings illustrate a core principle of green urbanization: even relatively modest institutional landholdings, when planted and managed with ecological intent, can deliver quantifiable environmental services that offset a portion of the carbon and thermal burdens generated by surrounding built-up areas. Similar potential exists in other institutional and public spaces throughout Imphal and secondary towns, provided that species selection, planting density, and longterm maintenance are guided by local ecological knowledge rather than purely aesthetic or exotic preferences.

The temporal dimension is equally important. Urbanization in Manipur is not a sudden event but a cumulative process unfolding over decades. Longitudinal remote-sensing and modeling work in Imphal-West district has shown that carbon stocks and land-surface temperatures have not exhibited abrupt, catastrophic shifts despite measurable growth in built-up area (Momo & Devi, 2022). This relative stability suggests a residual buffering capacity within the existing vegetation mosaic—capacity that can be strengthened through targeted interventions. High-density restoration techniques, such as the Miyawaki method applied in the Langol Reserve Forest, demonstrate that degraded peri-urban sites can be rapidly converted into multi-layered native forests capable of accelerating canopy closure, enhancing biodiversity, and improving microclimatic conditions (Central Forest Division, Manipur, 2026). Community-led nursery and plantation programmes in hill districts further illustrate that ecological recovery can be achieved at meaningful scale when local stewardship is combined with scientific support (Shatsang, 2026).

Green urbanization in Manipur therefore rests on three interrelated foundations. First, it recognizes the continuing ecological and cultural value of existing TOF, home gardens, and institutional green spaces, and seeks to protect and densify them. Second, it prioritizes

native and locally adapted species in both conventional and high-density planting designs so that new green infrastructure is resilient, functionally diverse, and culturally resonant. Third, it integrates continuous monitoring through satellite-derived indices, ground inventories, and community observation so that the performance of green spaces can be assessed and adaptive management applied as urbanization proceeds.

In practical terms, this means embedding tree cover requirements into urban planning regulations, treating roadside and median plantations as climate-regulation infrastructure rather than mere beautification, expanding campus and institutional greening as public carbon sinks, supporting the persistence and expansion of home gardens as distributed conservation nodes, and deploying scientifically informed restoration on degraded peri-urban lands. When these measures are pursued coherently, urbanization ceases to be a zero-sum contest between development and environment. Instead, it becomes a process through which the ecological functions that have long sustained Manipur's landscapes are deliberately carried forward into its emerging urban future.

The sections that follow examine the specific tree species available for this purpose, the measurable contributions of current plantation and restoration initiatives to ecological balance, and the concrete pathways by which urban growth can be guided so that environmental integrity is not merely preserved but actively enhanced.

3. Variety of Trees Found in Manipur

Manipur's tree flora reflects its position at the biogeographic crossroads of the Eastern Himalaya and Indo-Burma regions. The state's elevational range from the alluvial plains of the Imphal Valley to the higher ridges of the surrounding hills supports a continuum of tropical moist deciduous, subtropical broadleaf, and lower montane forest communities. Within this continuum, a substantial number of tree species occur not only in formal forest reserves but also as Trees Outside Forests (TOF) on institutional campuses, roadsides, home gardens, agricultural boundaries, and residual commons. Systematic inventories conducted within the state provide a detailed picture of this diversity and its relevance to green urbanisation.

One of the most comprehensive urban inventories was undertaken at Dhanamanjuri University in Imphal. Researchers recorded 124 tree species across the campus and quantified their structural and functional attributes. The most abundant species by stem count were *Enterolobium cyclocarpum* (236 individuals), *Lagerstroemia speciosa* (223), *Mangifera indica* (175), *Delonix regia* (160), and *Ficus benghalensis* (140). Other frequently encountered taxa included *Eucalyptus globulus*, *Eucalyptus mannifera*,

Artocarpus heterophyllus, *Ficus religiosa*, *Acacia auriculiformis*, *Tamarindus indica*, *Bambusa* spp., *Magnolia* spp., *Spathodea campanulata*, *Roystonea regia*, *Bischofia javanica*, and *Kigelia africana* (Singh et al., 2025). Carbon-sequestration analysis of the same dataset revealed that while *Enterolobium cyclocarpum* contributed the largest absolute carbon stock because of its high abundance and large stature, *Eucalyptus mannifera* exhibited the highest sequestration potential on a per-tree basis. These findings demonstrate that both native and long-naturalised species already function as significant carbon sinks within the urban matrix of Imphal.

A parallel statewide assessment of Trees Outside Forests further expands the documented palette. Across urban residential areas, institutional lands, roadside plantations, agricultural fields, and home gardens, researchers recorded a diverse assemblage that included *Ficus religiosa* (Peepal / Sanakhongnang), *Ziziphus mauritiana* (Boroi), *Mangifera indica* (Heinou), *Magnolia champaca* (Leihao), *Artocarpus heterophyllus* (Theibong), *Citrus grandis* (Nobab), *Psidium guajava*, and various members of the Fabaceae, Myrtaceae, and Lythraceae (Devi et al., 2025). Institutional lands supported the highest densities (approximately 130–170 trees ha^{-1}), followed by roadside and agricultural settings, while urban residential areas showed lower but still functionally important densities (80–120 trees ha^{-1}). The study emphasised that many of these species continue to deliver shade, fruit, medicinal products, and cultural value even under conditions of progressive urban encroachment.

Village-level floristic work supplies additional resolution. In Utlou village of Bishnupur district, an exhaustive survey documented 81 tree species belonging to 40 families and 72 genera. The recorded taxa served at least ten distinct utilitarian categories timber, fuelwood, food, medicine, fodder, fibre, dye, ornamental, religious, and soil improvement illustrating the deep integration of trees into local livelihoods (Laishram & Imotomba Singh, 2024). The same study noted that urbanisation and infrastructure development had already resulted in the loss of several previously common species, underscoring both the residual richness of the local flora and the urgency of deliberate conservation planting.

Restoration and plantation projects have further refined the list of species considered suitable for ecological recovery and urban greening. The Miyawaki-style plantation established in Compartment No. 2 of the Langol Reserve Forest deliberately combined canopy, mid-storey, and understorey layers. Canopy species included *Terminalia myriocarpa*, *Gmelina arborea*, and *Parkia* spp.; mid-storey components comprised *Syzygium cumini* and *Citrus limon*; and a diverse suite of native shrubs, herbs, and climbers

completed the vertical structure (Central Forest Division, Manipur, 2026). Community-managed nurseries in the Phalee commons of Ukhrul district have raised more than 10,000 saplings of approximately 65 native species, with particular emphasis on fruiting trees that support both human use and wildlife (Shatsang, 2026). Carbon-stock assessments conducted in natural and plantation forests of Imphal East and West districts additionally evaluated *Tectona grandis*, *Gmelina arborea*, *Paulownia fortunei*, and *Populus deltoides*, confirming their high biomass accumulation potential under Manipur's climatic conditions (Wungshap et al., 2023).

Taken together, these Manipur-based inventories reveal a practical and functionally diverse suite of trees available for green urbanisation. The assemblage includes large canopy species capable of substantial carbon sequestration and shade provision (*Enterolobium cyclocarpum*, *Terminalia myriocarpa*, *Gmelina arborea*), culturally significant and pollution-tolerant species suited to roadside and institutional settings (*Ficus religiosa*, *Lagerstroemia speciosa*, *Magnolia champaca*), multipurpose fruit and agroforestry trees that integrate easily into home gardens and peri-urban farms (*Mangifera indica*, *Artocarpus heterophyllus*, *Citrus* spp., *Parkia* spp.), and fast-growing or high-density candidates appropriate for rapid restoration (*Eucalyptus* spp. in limited contexts, *Syzygium cumini*, various native pioneers).

Importantly, the data also highlight a tension that any green-urbanisation strategy must address: the presence of exotic or naturalised species that perform well in carbon terms but may offer limited support for native biodiversity. The preference emerging from community nurseries and recent restoration projects is therefore clear—prioritise indigenous and long-naturalised multipurpose species that simultaneously deliver ecological services, cultural continuity, and livelihood benefits. This species palette, grounded entirely in research conducted within Manipur, forms the biological foundation upon which the subsequent sections on ecological initiatives and sustainable urban pathways are constructed.

4. Initiatives in Ecological Balance

Tree-plantation and urban-greening initiatives in Manipur have begun to demonstrate measurable contributions to ecological balance across multiple spatial scales—from individual institutional campuses to district-level landscapes and community-managed commons. These efforts operate through four primary mechanisms: enhancement of carbon sequestration and oxygen production, moderation of local microclimates and land-surface temperatures, support for biodiversity and habitat connectivity, and improvement of soil

stability and hydrological function. Evidence drawn exclusively from Manipur-based studies illustrates both the current performance of these initiatives and their potential for further expansion.

At the institutional scale, the most detailed quantification of carbon-related services comes from Dhanamanjuri University in Imphal. An inventory of 124 tree species revealed that the campus functions as a significant atmospheric carbon sink. *Enterolobium cyclocarpum* alone accounted for 385.38 Mg of carbon sequestration, followed by *Mangifera indica* (271.48 Mg), *Delonix regia* (207.57 Mg), *Lagerstroemia speciosa* (185.45 Mg), and *Ficus benghalensis* (179.93 Mg). Corresponding CO_2 fixation and oxygen production values were highest for *Enterolobium cyclocarpum* (1,156.14 Mg CO_2 fixed and 1,027.68 Mg O_2 produced). On a per-tree basis, *Eucalyptus mannifera* exhibited the highest sequestration potential (3.18 Mg), followed by *Eucalyptus globulus* (2.25 Mg) (Singh et al., 2025). These figures demonstrate that even a single urban campus, when supporting a diverse and structurally mature tree population, can offset a meaningful portion of the carbon emissions generated by surrounding built-up areas.

Trees Outside Forests (TOF) extend these services beyond institutional boundaries. A statewide assessment found that institutional lands, roadside plantations, agricultural margins, and home gardens collectively maintain important carbon stocks, enhance soil fertility, and contribute to local climate regulation (Devi et al., 2025). Institutional sites supported the highest tree densities (approximately 130–170 trees ha^{-1}) and therefore the greatest immediate contribution to ecosystem services. Urban residential areas, although lower in density (80–120 trees ha^{-1}), still harbour culturally significant species such as *Ficus religiosa* and *Citrus grandis* that provide shade, reduce ambient temperatures, and support urban biodiversity. The same study identified ongoing pressures from urban encroachment and land-use change, underscoring that the ecological value of TOF is real but vulnerable without deliberate protection and expansion.

Home gardens constitute another distributed but functionally important component of Manipur's green infrastructure. Research in Imphal-West district showed that an average home garden of approximately 0.069 ha produces economic yields while simultaneously storing carbon. Extrapolated values indicate that a 0.1 ha home garden can store around 10.6 tonnes of carbon in trees and soil (Nicholas et al., 2026). Beyond carbon, these gardens conserve genetic resources of multipurpose species, provide habitat for pollinators and birds, and maintain traditional ecological knowledge. Their persistence within

densifying urban and peri-urban neighbourhoods represents a form of fine-grained ecological resilience that formal forest reserves alone cannot supply.

At the landscape scale, high-density restoration projects have begun to reverse degradation on peri-urban and common lands. The Miyawaki plantation established by the Central Forest Division in Compartment No. 2 of the Langol Reserve Forest planted 10,000 native saplings at densities of three to four individuals per square metre. Canopy species such as *Terminalia myriocarpa*, *Gmelina arborea*, and *Parkia* spp. were combined with mid-storey *Syzygium cumini* and *Citrus limon* and a diverse understorey of herbs, shrubs, and climbers. Early monitoring indicated vigorous growth and high survival rates within the first year, with the developing multi-layered structure expected to accelerate canopy closure, enhance biodiversity, improve soil moisture retention, and contribute to the broader “Greening Imphal” vision (Central Forest Division, Manipur, 2026). Because the Miyawaki method mimics natural forest stratification, it offers a rapid pathway to functional ecosystem recovery on degraded sites that conventional single-species plantations cannot match.

Community-led initiatives provide complementary evidence of ecological recovery at local scales. In the Phalee commons of Ukhrul district, residents have planted approximately 6,000 native trees over recent years and established nurseries that have produced more than 10,000 saplings of roughly 65 native species. These efforts, supported by a UNDP-North-East India Biocultural Initiative grant, focus on regenerating degraded hill slopes and restoring rainforest structure. Participants emphasise the dual value of fruiting trees for both human use and wildlife, illustrating how ecological restoration can be aligned with livelihood and cultural priorities (Shatsang, 2026).

District-level modelling reinforces the cumulative significance of these initiatives. In Imphal-West district, InVEST-based assessments of carbon stock for 2011, 2021, and projected 2030 conditions showed that, despite measurable urban expansion, overall carbon storage did not collapse. Spatial redistribution of carbon stocks accompanied land-use change, yet the residual and restored vegetation continued to buffer the landscape against abrupt losses (Momo & Devi, 2022). Parallel carbon-stock studies in natural and plantation forests of Imphal East and West districts further confirmed that well-managed plantations of *Tectona grandis*, *Gmelina arborea*, and other species can achieve high aboveground and belowground carbon densities, in some cases exceeding those of adjacent natural stands (Wungshap et al., 2023).

Collectively, these Manipur-based initiatives demonstrate that tree plantation and urban greening are already contributing to ecological balance through quantifiable carbon sequestration, microclimatic moderation, biodiversity support, and soil protection. The evidence also reveals clear opportunities for scaling: institutional campuses and public lands can be densified with high-performing native species; TOF can be systematically expanded along roadsides and within residential zones; home gardens can be supported as distributed conservation nodes; and scientifically informed, community-anchored restoration can reclaim degraded peri-urban and common lands. When these strands are pursued coherently, the net result is a landscape in which urban growth is accompanied by a measurable strengthening, rather than a progressive erosion, of ecological function.

5. Role of Urbanization Without Disturbing Its Environment in Manipur

Urbanization in Manipur is an irreversible demographic and economic process, yet it need not produce irreversible ecological loss. The central challenge is to guide the physical expansion of settlements particularly within the spatially constrained Imphal Valley so that the ecosystem services historically provided by trees, home gardens, residual forests, and wetlands continue to function, and in some cases are deliberately enhanced. Manipur-based research supplies both diagnostic evidence of current pressures and practical pathways for reconciling urban growth with environmental integrity.

The biophysical constraints are clear. Remote-sensing analyses of Imphal-West district show that built-up area increased by approximately 2.9 per cent between 2011 and 2021, while barren land declined and vegetative cover experienced localized contraction (Momo & Devi, 2022). Similar patterns of forest and agricultural land conversion have been documented across the wider valley and along expanding road networks. These changes elevate land-surface temperatures in densely built zones, reduce carbon storage potential, fragment habitat, and erode the traditional tree-based livelihood systems that remain important to many households. The same studies, however, also reveal residual buffering capacity: carbon stocks and temperature regimes have not collapsed abruptly, indicating that existing vegetation—TOF, institutional plantings, home gardens, and residual commons continues to perform critical regulatory functions even under moderate urban pressure.

This residual capacity provides the foundation for a non-destructive urbanization strategy. Five interlocking principles, each grounded in Manipur-specific evidence, emerge as essential.

First, institutional and public lands must be treated as priority carbon sinks and thermal buffers. The Dhanamanjuri University inventory demonstrated that a single well-vegetated campus can sequester hundreds of megagrams of carbon and generate substantial oxygen (Singh et al., 2025). Extending similar standards of species diversity, structural complexity, and long-term maintenance to other government compounds, educational institutions, hospitals, and public parks would multiply these services across the urban matrix without requiring large new land acquisitions.

Second, Trees Outside Forests must be systematically protected and expanded. The statewide TOF assessment showed that institutional sites already support the highest densities (130–170 trees ha^{-1}), while urban residential areas lag behind (80–120 trees ha^{-1}) (Devi et al., 2025). Policy instruments that mandate minimum tree cover on private plots, protect mature roadside and boundary trees during road-widening projects, and incentivize planting of native multipurpose species in residential colonies can raise urban tree densities and thereby strengthen shade, carbon, and biodiversity functions within the densifying city.

Third, high-density native restoration should be deployed on degraded peri-urban and common lands. The Miyawaki plantation of 10,000 saplings in the Langol Reserve Forest has shown that multi-layered native plantings can achieve rapid canopy closure and high survival rates on sites that conventional afforestation has struggled to rehabilitate (Central Forest Division, Manipur, 2026). Scaling this approach to other degraded slopes and residual commons around Imphal would convert ecological liabilities into functional green infrastructure that simultaneously cools the urban fringe, sequesters carbon, and restores habitat connectivity.

Fourth, home gardens and traditional agroforestry systems must be recognized as distributed conservation infrastructure. Research in Imphal-West district established that even small homestead plots (average 0.069 ha) store measurable carbon (approximately 10.6 t per 0.1 ha) while conserving useful germplasm and buffering households against climatic and economic stress (Nicholas et al., 2026). Urban planning regulations that protect existing home gardens from conversion and support their expansion through extension services and seedling supply would maintain fine-grained ecological resilience inside the growing city.

Fifth, continuous monitoring and adaptive management are indispensable. The combination of satellite-derived land-surface temperature and vegetation indices with ground-based carbon and floristic inventories has already provided early-warning capacity in Imphal-West (Momo & Devi, 2022). Institutionalizing such monitoring linked to clear

thresholds for intervention would allow planners to detect emerging hotspots of vegetation loss or temperature rise and to adjust planting programmes, building regulations, or land-use zoning before irreversible damage occurs.

Community participation supplies the social foundation for all five principles. Village-level restoration in Phalee, where residents have planted approximately 6,000 native trees and established nurseries producing tens of thousands of saplings, demonstrates that local stewardship can deliver both ecological recovery and livelihood co-benefits (Shatsang, 2026). Similar participatory models, extended to urban wards and peri-urban settlements, increase the likelihood that newly planted trees will be protected and maintained over the long term.

When these elements operate together institutional densification, TOF expansion, high-density native restoration, home-garden protection, continuous monitoring, and community stewardship urbanization ceases to be a zero-sum contest between development and environment. Instead, it becomes a process through which the ecological functions that have long sustained Manipur’s landscapes are deliberately carried forward into its emerging urban future. The result is not an absence of change, but a form of change that strengthens, rather than erodes, the state’s environmental integrity.

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