



Review on Ecological implications of Monoculture Rubber Plantation on Soil Biodiversity: Tripura Perspective

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Abstract: Rubber (*Hevea brasiliensis*) monoculture has rapidly expanded across Tripura over the past few decades, emerging as a dominant land use practice due to its economic viability. However, this shift from diverse natural forests to single-species plantations has raised concerns about its ecological consequences, particularly on soil biodiversity. This review critically examines existing literature to assess the impact of monoculture rubber plantations on soil microbial diversity, diversity of fauna, nutrient cycling, and overall soil health and fertility status in Tripura. Studies indicate a decline in soil macrofauna (e.g., earthworms, termites), reduced microbial richness, and altered enzymatic activity under rubber monoculture when compared to natural or mixed forests. Factors such as canopy closure, litter quality, and use of synthetic inputs exacerbates these effects many folds. The review also highlights how long-term monoculture reduces organic matter input in native soil, affecting symbiotic relationships among detritivores and microbial functional redundancy in soil ecosystems. In contrast, agro forestry or polyculture systems show relatively better conservation of soil fertility and biodiversity. The findings underscore the urgent need to adopt sustainable land use management practices, such as intercropping, organic amendments, and conservation agriculture, to mitigate the ecological costs of rubber expansion in Tripura. This synthesis serves as a baseline for policymakers and researchers to promote sustainable rubber cultivation practices to conserve local biodiversity of the region.

Key words: soil biodiversity, monoculture rubber plantation, macrofauna, detritivore, sustainable land use

I. INTRODUCTION

Rubber (*Hevea brasiliensis*), a plant from the family of *Euphorbiaceae* and is native to the tropical rainforest in the Amazon River Basin of South America and preferably grows in high temperature and humid regions. Rubber cultivation has played a significant role in transforming the agricultural and economic landscape of Tripura as natural rubber is the most important cash crop in Tripura. Since its introduction in 1963 by the State Forest Department, Tripura has become 2nd largest producer of natural rubber in the country, after Kerala, which accounts for about 9% of the total production of India. Tripura also has the second largest rubber growing area in the country measuring about 110,649 hectares after Kerala. Over the past few decades Tripura has witnessed rapid expansion in rubber plantation among non-traditional areas of the north eastern regions of India and is emerging as one of the most important rubber growing zones (Sinha, 2007). The growth has provided economic benefits and employment opportunities; it has also made positive contributions by restoring the degraded ecological wastelands (Krishnakumar & Meenattoor, 2003). In spite of its positive role in restoring degraded land in Tripura, the negative consequences of large scale monoculture cannot be overlooked. On the other hand, there are unscientific arguments against such

plantations too. This literature review aims to synthesize existing research on how rubber monoculture influences soil biodiversity in Tripura, focusing on soil fauna, flora, microbial communities, and ecosystem functions.

II. REVIEW OF LITERATURE

In the recent past it has raised concerns about environmental implications of monoculture rubber cultivation and its impact on local biodiversity and proper ecological functioning of soil (Roy *et al.*, 2014). Rubber plantations in Tripura were introduced in 1963 as a soil conservation effort to reduce the slash and burn agricultural practice of local tribal community. Rubber plantation is mostly done in monocultures that exhaust the soil fertility and need a lot of fertilizers and pesticides in the form of inorganic inputs to maintain soil productivity and this can lead to soil and water pollution and causes negative consequences to the natural environment and ecological balance (Cohen, 2009). Loss of local biodiversity is probable important dangers associated with extensive rubber plantation (Li *et al.*, 2007). The root system and leaf coverage of rubber is treated as non nutrients for many herbivores, insectivores and frugivores and it has been found in Thailand that at least 60 percent local biodiversity was reduced due to extensive cultivation of rubber (Ravallion *et al.*, 2013). However to avoid such issues in immature rubber plantation sites intercropping of crops could be a nice option, as crops like spices, banana and pineapple can be grown and rubber planters can earn some extra income by keeping bee hives for collection of honey as honeybee attracts for extra floral nectaries in the rubber tree (Chaudhuri *et al.*, 2013).

III. RESEARCH METHODOLOGY

Secondary data was collected from relevant articles published before September 2025 to study the effects of rubber-based plantations on soil physiochemical properties and impact on local biodiversity. Different keyword combinations were used (“monoculture plantation” OR “rubber plantation and soil biodiversity” OR “natural rubber” OR “rubber and soil microbes”) to retrieve and collect relevant information and data from the established online resources like Google web (<https://www.google.com>), Web of Science (<https://www.webofknowledge.com>), Google Scholar, and academia (<https://www.academia.edu>), PMC, PubMed Central (<https://pmc.ncbi.nlm.nih.gov>). A total of 28 articles were analysed for preparing the manuscript.

IV. RESULT & DISCUSSION

The expansion of rubber plantations in Tripura has primarily come at the expense of natural forests and traditional agro forestry systems. According to the Tripura Forest Department and NER Data bank 2023-24, the total recorded forest area is 6,294.29 km² (6,29,429 ha) as of mid-2025 out of which the area under rubber cultivation is 1,10,649 ha (Figure-1) under rubber cultivation which comprises approximately ~17.6 % The ratio of natural forest to rubber stands at roughly 5.7:1. Tropical rainforests significantly influences biogeochemical cycling process and climate regulation and maintains global biodiversity by supporting the growth and distributions of at least 50% of all described species. They also play important role in carbon sequestration process and regulate the carbon pull in nature and are hot spots for biodiversity. Now-a-days these rain forests are being replaced by cultivation of rubber causing long term concern of reducing local biodiversity. Such changes in aboveground vegetation can also cause stronger impacts on belowground biodiversity. (Singh *et al.*, 2019).

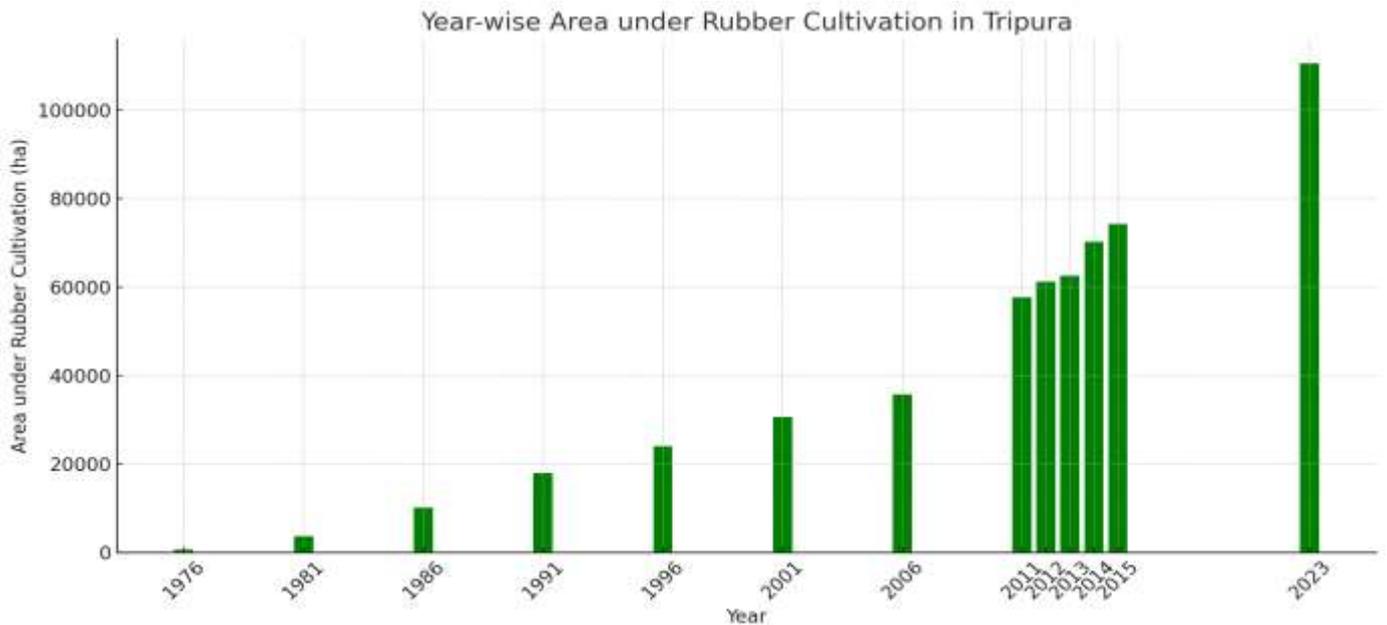


Figure-1: Area under rubber plantation (Year Wise)

Direct effect of plant species on soil ecosystem specially on soil organisms are caused by the plant’s inputs to soil in the form of organic matter and allelopathic chemicals released from litters and root exudates in various forms in above and below the ground, while indirect effect of plants on biota include shading, soil protection and uptake of water and nutrients by the root (Neher., 1999). This transformation results in habitat simplification, where a diverse ecosystem is replaced by a monoculture system with reduced structural and species diversity. Tripura’s rubber plantations are predominantly concentrated in the southern and western districts notably in South Tripura, Sepahijala, Gomati, and West Tripura with scattered pockets in the north. This distribution corresponds to areas of favourable terrain and climate (Figure-2)

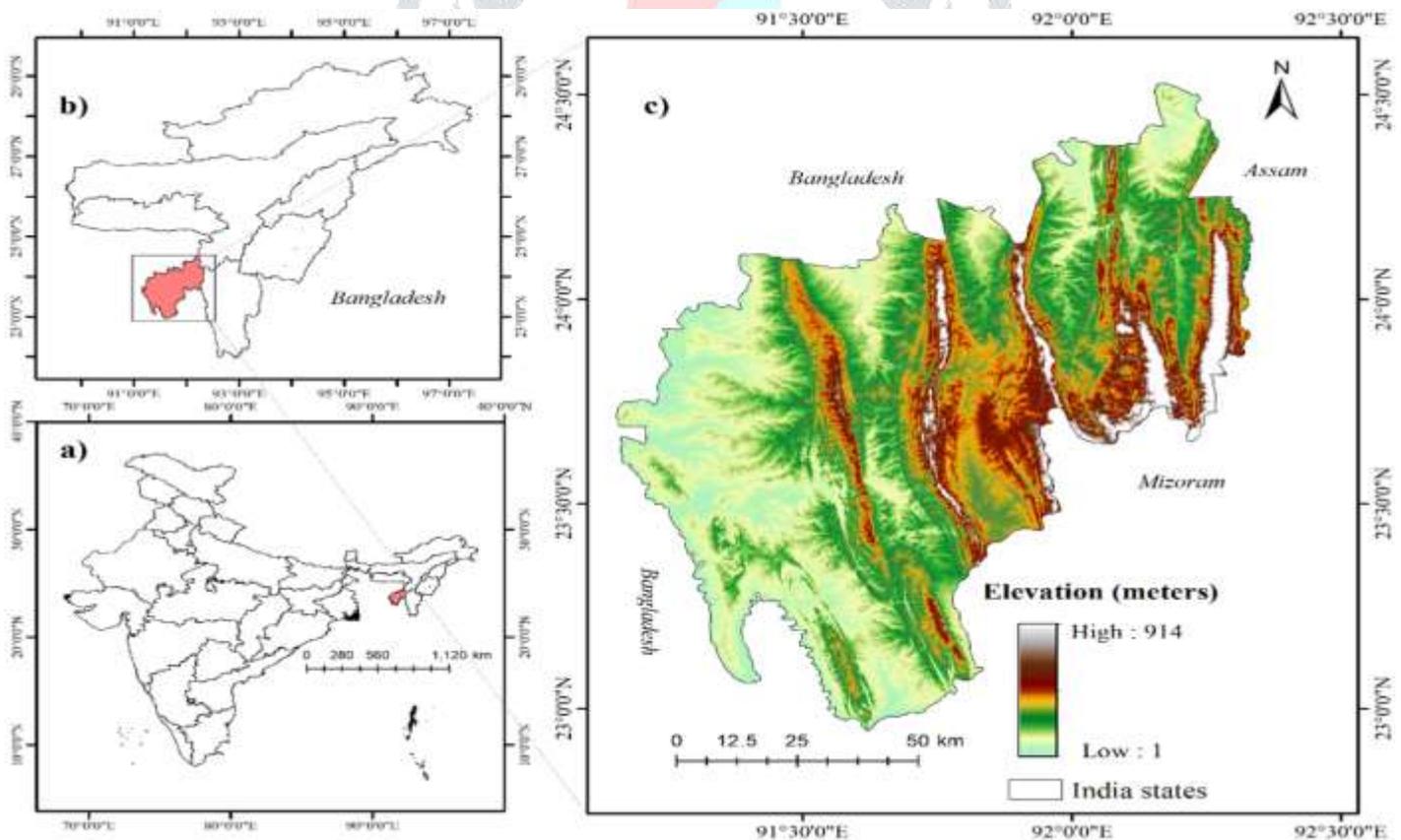


Figure-2: Distribution favourable terrain of rubber cultivation in Tripura

According to Mandal and Raman (2014), extensive rubber plantations lead to a significant loss of native vegetation and associated fauna, altering the ecological balance of the region. Under the dense canopy of rubber trees, the understory becomes dominated by shade-tolerant species, leading to a homogenization of plant communities and a decline in habitat heterogeneity.

4.1. Impact on Biodiversity & Soil Fauna

Major concern about monoculture rubber cultivation is loss of local biodiversity and there are reports that, its plantation causes shortage of water resource (Roy *et al.*, 2014). Soil fauna, including earthworms and arthropods, play a critical role in maintaining soil health and fertility. In a study by Chaudhuri *et al.*, 2013 the impact of rubber plantations on earthworm communities in West Tripura was examined. The study found that rubber plantations, especially as they mature, support a limited diversity of earthworm species, predominantly *Pontoscolex corethrurus*. While the biomass and density of earthworms increased with the age of the plantations, species richness and evenness showed a declining trend. This indicates a shift towards species that are more tolerant of disturbed and simplified habitats. The reduction in diversity of soil arthropods has also been reported in areas under long-term rubber cultivation. These organisms are sensitive to changes in soil moisture, temperature, pH, and organic matter content—factors that are significantly altered in monoculture systems. Li *et al.*, (2019) reported that tropical forest conversion to rubber plantations resulted in a decrease in both the abundance and diversity of soil micro and mesofauna, with implications for nutrient cycling and soil structure. Microarthropods plays vital role in nutrient transformation and decomposition of organic matter and provides considerable ecosystem services. In this study when relative abundance (% RA) of major microarthropod groups like insecta, acari and other arthropods were analysed from rubber plantation sites and compared with soils of natural forest except acari all other microarthropod community showed higher relative abundance which is an indication of grater biodiversity in natural forest. Higher relative abundance of acari in rubber plantation suggests species dominance in monoculture. So from the observations it clear that monoculture plantations may increase species dominance but reduces diversity of flora and fauna (Roy *et al.*, 2019).

4.2. Effects on Soil Microbial Communities

It is well known that microorganisms play vital role in maintaining the nutrient dynamics in rhizospheric soil so when the soil of rubber and tea plantation ware analysed and compared with natural forest where there is considerably diverse group of flora and fauna it is found that, in natural forest soil, there is more microbial biomass in the form of bacteria, fungi and actinomycetes. Another important observation by Roy *et al.*, 2019 while studding and comparing microbial diversity in Natural forest and rubber plantation sites suggests that there was diverse group of bacteria fungi and actinomycetes in natural forest soil as compared to the rubber plantation soil abundance of microorganisms like nitrogen fixers and phosphate solublisers (NFB and PSB) was also very poor in rubber garden soil in comparison to natural forest. The natural forest soils are reported to harbour higher number of microbial populations and their activity. Being one of the most important components of soil environment, microorganisms exert considerable influence on soil fertility and plant growth (Tiwari *et al.*, 1989). Soil microorganisms, including bacteria and fungi, are crucial for nutrient cycling, organic matter decomposition, and maintaining soil structure. Rubber plantations, particularly those using chemical inputs such as herbicides and fertilizers, can negatively affect microbial diversity and activity. The use of like Glyphosate, a common herbicide in rubber plantations, has been linked to the suppression of non-target soil microbes. Research indicates that microbial biomass carbon and microbial respiration rates are lower in rubber plantations compared to natural forests or diversified cropping systems (Liu *et al.*, 2023). This suggests a decline in microbial functional diversity, which can affect soil resilience and productivity. Additionally, reduced litter diversity and changes in soil organic matter input under rubber monocultures contribute to a less favourable environment for microbial colonization and diversity. It is well known that microorganisms play vital role in maintaining the nutrient dynamics in rhizospheric soil so when the soil of rubber and tea plantation ware analysed and compared with natural forest where there is considerably diverse group of flora and fauna it is found that, in natural forest soil, there is more microbial biomass in the form of bacteria, fungi and actinomycetes. Another important observation reported by Tiwari *et al.*, 1989 has shown diverse group of bacteria, fungi and actinomycetes in natural forest soil as compared to the rubber and tea garden soil. Even the populations of nutrient mobilising microorganisms like nitrogen fixers and phosphate solublisers (NFB and PSB respectively) was also very poor in rubber garden soil in comparison to natural forest and to further confirm the observation and to reassess the biomass soil dehydrogenase activity was compared and it also suggests higher microbial load in natural forest soil and very poor activity in rubber plantation soils. The natural forest soils are reported to harbour higher number of microbial populations

and greater biological activity. Being one of the most important components of soil environment, microorganisms exert considerable influence on soil fertility and plant growth.

4.3. Soil Physical and Chemical Properties

The physical and chemical characteristics of soil are also altered under rubber cultivation. Rubber trees produce large quantities of leaf litter, which decomposes rapidly and affects the nutrient dynamics of the soil. While this litter can initially enrich the topsoil with nutrients, long-term accumulation without adequate management can lead to nutrient leaching and soil acidification. Mandal & Raman., 2014 observed that rubber plantations in Tripura exhibited changes in soil pH, bulk density, and water retention capacity. These changes, in turn, affect the distribution and activity of soil organisms. Soils under older plantations were found to be more compacted, with reduced porosity and water infiltration rates, conditions unfavourable for many soil-dwelling organisms.

4.4. Reduction in Agro biodiversity and Ecological Services

The conversion of diverse ecosystems into rubber monocultures has broader implications for agro-biodiversity. India Water Portal, 2015 notes that traditional mixed cropping systems, which supported a variety of plant and animal species, have been replaced by rubber monoculture, leading to a decline in genetic diversity and ecosystem services. This loss of diversity affects pollination, pest control, and nutrient cycling, which are essential for sustainable agriculture. Rubber plantations also affect the surrounding landscape by altering microclimates and hydrological patterns. These changes can extend beyond plantation boundaries, affecting adjacent agricultural lands and forest patches. The cumulative impact is a reduction in the ecological resilience of the landscape, making it more vulnerable to pests, diseases, and climate variability (Ma *et al.*, 2019).

4.5. Conservation and Sustainable Management Strategies to be used for rubber cultivation

To mitigate the negative impacts of rubber cultivation on soil biodiversity, several conservation and management strategies have been proposed. These include:

1. **Agro-forestry Integration:** Incorporating diverse tree species and intercrops within rubber plantations can help maintain biodiversity and ecological functions.
2. **Reduced Chemical Use:** Promoting organic farming practices and minimizing the use of herbicides and synthetic fertilizers can protect soil microbial and faunal communities.
3. **Soil Conservation Techniques:** Using mulching, cover cropping, and contour planting can improve soil structure and reduce erosion.
4. **Monitoring and Research:** Regular monitoring of soil health indicators and biodiversity assessments can guide adaptive management.

More over government may diversify the agro-forestry system in such a way that cash crops cannot be cultivated as a part of monoculture. Policy makers and government should encourage more research on the ecological and economical effects of rubber plantation on different social communities specially the rural and tribal communities (Panda BK & Sarkar S., 2020).

V. CONCLUSION

In general it appears that forest replacement by rubber plantation results in an overall loss and extensive replacement of soil micro- and mesofaunal biodiversity, which should be regarded as an additional aspect of the impact of forest conversion Rubber cultivation in Tripura, while economically beneficial, presents significant ecological challenges, particularly concerning soil biodiversity. The replacement of diverse natural forest ecosystems with monoculture plantations leads to a decline in soil fauna, microbial diversity, and essential ecosystem functions. Sustainable management practices, judiciously conducted by scientific research, are essential to balance economic development with ecological integrity. Future policies should encourage agroecological approaches and biodiversity friendly land use planning to ensure the long term sustainability of rubber cultivation in the region.

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