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RESEARCH ARTICLE

AGROFORESTRY AND ECOLOGICAL SUSTAINABILITY OF RURAL EMPLOYMENT OPPORTUNITIES IN TRIPURA

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ABSTRACT

Tripura, a small hilly state in northeastern India, harbours rich biodiversity and extensive forest cover, yet its rural communities face persistent challenges of agricultural stagnation, land degradation, and livelihood insecurity. Agroforestry—the deliberate integration of trees and shrubs into crop and livestock systems—has emerged as a promising strategy to reconcile agricultural productivity with ecological sustainability. This paper examines the role of agroforestry in promoting ecological sustainability and rural development across Tripura. Drawing on a mixed-methods approach that combines field surveys, key informant interviews, and secondary data analysis, the study investigates adoption patterns, ecological outcomes, and socio-economic impacts among smallholder farming households. Findings reveal that agroforestry systems contribute significantly to soil conservation, carbon sequestration, biodiversity enhancement, and household income diversification. The paper argues that context-sensitive policy frameworks, institutional support, and community participation are essential for mainstreaming agroforestry within Tripura's rural development agenda. The study contributes to the growing body of literature on sustainable land-use practices in ecologically sensitive regions of South Asia.

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INTRODUCTION

The global challenge of achieving food security while maintaining ecological integrity has renewed scholarly and policy interest in integrated land-use systems. Agroforestry, broadly defined as the intentional combination of trees or woody perennials with crops and/or livestock on the same land unit, represents one of the oldest and most spatially widespread land-management strategies in the world (Nair, 2012). In the context of developing regions, agroforestry has been recognised not merely as a subsistence practice but as a multifunctional system capable of delivering ecosystem services, sequestering carbon, and improving rural livelihoods simultaneously (Zomer et al., 2016). Tripura, a landlocked state in northeastern India, occupies a geographically and ecologically strategic position. Bordered by Bangladesh on three sides and sharing frontiers with Assam and Mizoram, the state encompasses approximately 10,486 km2, of which nearly 60 per cent is classified as forest land (Forest Survey of India, 2021). The state's predominantly tribal and agrarian rural population—around 73 per cent residing in rural areas—depends heavily on forest and land resources for subsistence and income. Despite the state's natural resource endowment, rural Tripura grapples with high poverty rates, shifting cultivation (locally known as jhum), land fragmentation, and increasing pressure on forest ecosystems driven by demographic growth and economic aspirations (Debbarma, 2019). The nexus between agroforestry and ecological sustainability in Tripura has been inadequately explored in extant scholarship, which tends to focus either on individual crop systems or on macro-level forest policy without situating community-level practices within a sustainability framework.

This paper addresses this gap by examining: (a) the extent and nature of agroforestry adoption among rural households in Tripura; (b) the ecological outcomes associated with different agroforestry models; and (c) the institutional and policy conditions that facilitate or constrain the sustainable scaling of agroforestry systems. The paper is organised as follows: Section 2 reviews the relevant literature on agroforestry and sustainability; Section 3 describes the methodology; Section 4 presents findings; and Section 5 concludes with policy implications and directions for future research.

Objectives of this Study

- To examine the agroforestry adoption patterns.
- To Analyse the Ecological Outcomes.
- Study on Socio-economic Impacts

LITERATURE REVIEW

Conceptual Foundations of Agroforestry: The concept of agroforestry was formally articulated in the late 1970s through the pioneering work of the International Council for Research in Agroforestry (ICRAF), subsequently renamed the World Agroforestry Centre (Lundgren & Raintree, 1982). Nair (1993) provided a seminal classification of agroforestry systems based on structural, functional, and socioeconomic criteria, distinguishing between agrosilvicultural, silvopastoral, and agrosilvopastoral systems. Subsequent scholarship has enriched this taxonomy by incorporating ecological processes, temporal dynamics, and spatial arrangements into typological frameworks (Jose, 2009). The theoretical underpinnings of agroforestry draw on ecology, agronomy, and social science. The concept of facilitation—whereby trees ameliorate microclimate, enhance soil nutrient cycling, and reduce pest pressure for associated crops—provides the ecological rationale for tree-crop integration (Schroth & Sinclair, 2003). From a social science perspective, political ecology and agrarian studies have illuminated how tenure systems, gender dynamics, and power relations shape the adoption, management, and distribution of agroforestry benefits (Leakey, 2014).

Agroforestry and Ecological Sustainability: The relationship between agroforestry and ecological sustainability is multidimensional. Research has consistently demonstrated that trees in agricultural landscapes contribute to soil organic matter accumulation, erosion control, and the conservation of soil moisture (Rao et al., 2007). Agroforestry systems support higher levels of plant, animal, and microbial biodiversity compared to monoculture systems, partly by creating structural heterogeneity and habitat connectivity (Harvey et al., 2006). In the context of climate change, agroforestry has attracted attention as a mitigation strategy due to the capacity of tree biomass to sequester atmospheric carbon (Albrecht & Kandji, 2003; Zomer et al., 2016).

In South Asia, studies from states such as Kerala, Tamil Nadu, and Jharkhand have documented the ecological co-benefits of homestead gardens, shade-grown coffee, and multi-strata systems (Kumar, 2006; Saha et al., 2010). However, northeastern India remains underrepresented in this literature, despite the region's exceptional biodiversity value and the prevalence of traditional forest-agriculture integration practices (Deka et al., 2018).

Agroforestry and Rural Livelihoods in Northeastern India: Northeastern India is home to diverse agroforestry traditions rooted in indigenous ecological knowledge. Shifting cultivation, practised by tribal communities across the region, represents a complex agrosilvicultural cycle that, in its traditional low-intensity form, performs important ecological functions (Cairns, 2015). However, intensification pressures and shortened fallow cycles have degraded the ecological and productive potential of jhum systems, prompting interest in sedentary agroforestry alternatives. Research from Meghalaya, Nagaland, and Manipur has identified homestead agroforestry, forest gardens, and boundary planting as viable strategies that combine tree cultivation with food crops (Ramakrishnan, 2007). In Tripura specifically, studies have examined rubber-based agroforestry systems (Rubber Board of India, 2018), bamboo cultivation (Tripura Bamboo Mission, 2020), and spice-based multi-cropping, but comprehensive assessments of ecological sustainability dimensions remain sparse (Debbarma, 2019; Singh et al., 2021).

Policy and Institutional Context: The policy landscape for agroforestry in India has evolved considerably since the National Agroforestry Policy of 2014, which recognised agroforestry as a distinct land-use category eligible for public investment and institutional support. Tripura's state agriculture and rural development departments have implemented schemes such as the Integrated Watershed Management Programme, National Afforestation Programme, and MGNREGS-linked tree-planting initiatives that intersect with agroforestry objectives (Government of Tripura, 2022). Yet implementation gaps persist, including inadequate extension services, weak market linkages, and tenure insecurities on tribal land, which limit the incentive for long-term tree investments by smallholders (Ghosh, 2020).

METHODOLOGY

Research Design: This study adopts a mixed-methods research design, integrating quantitative household surveys with qualitative key informant interviews and secondary data analysis. The mixed-methods approach enables triangulation of data sources and provides a richer understanding of the multidimensional relationships between agroforestry practices and sustainability outcomes than either approach could yield alone (Creswell & Creswell, 2018).

Study Area: The research was conducted in three rural subdivisions of Tripura: Dhalai District (representing hilly tribal areas), West Tripura District (representing peri-urban smallholder contexts), and South Tripura District (representing lowland agricultural zones). These Subdivisions were purposively selected to capture agro-ecological variation across the state and to include both tribal and non-tribal farming communities.

Sampling and Data Collection: A stratified random sampling method was employed to select 240 farming households across the three districts, with 80 households per district. Within each district, villages were first stratified by predominant land-use type (jhum-based, settled agriculture, rubber dominant), and households were randomly selected from each stratum. Primary data were collected through structured interview schedules covering the household demographics, land holdings, cropping systems, tree species composition, income sources, and perceptions of ecological change. In addition, 18 key informant interviews were conducted with agricultural extension officers, tribal community leaders, non-governmental organisation (NGO) representatives, and state forest department officials to obtain institutional and policy perspectives. Three focus group discussions involving women farmers were held to capture gender-differentiated experiences of agroforestry management. Secondary data were drawn from the Forest Survey of India reports (2017, 2019, 2021), state agricultural census data, and published

peer-reviewed literature. Ecological baseline information on soil organic carbon and tree cover was sourced from district-level land-use reports.

Data Analysis: Quantitative data were analysed using descriptive statistics and logistic regression to identify correlates of agroforestry adoption and income diversification. Qualitative data from interviews and focus groups were subjected to thematic analysis following Braun and Clarke's (2006) framework, with coding conducted using NVivo software. Integration of quantitative and qualitative findings followed a convergent parallel design; whereby independent analyses were merged at the interpretation stage.

Ethical Considerations: Informed consent was obtained from all participants before data collection. Participant confidentiality was maintained through anonymisation of individual responses. The study protocol was reviewed and approved by the institutional ethics committee of Tripura University.

RESULTS

Prevalence and Types of Agroforestry Systems: Survey results indicate that agroforestry is widely practised across the study area, with 78.3% of sampled households incorporating trees into at least one component of their farming system. The most prevalent systems identified were: (a) homestead gardens with multi-strata fruit and timber trees (67.5% of households); (b) rubber-based agroforestry with intercropped legumes and vegetables (31.2%); (c) bamboo boundary planting integrated with paddy cultivation (44.8%); and (d) agrosilvopastoral systems combining trees with livestock in hilly areas (18.7%). Tree species diversity was higher in tribal households practising traditional forest-agriculture integration in Dhalai District compared to households in peri-urban West Tripura, where market-oriented mono-species timber or rubber systems predominated. Commonly reported tree species included jackfruit (*Artocarpus heterophyllus*), areca palm (*Areca catechu*), bamboo (*Bambusa spp.*), rubber (*Hevea brasiliensis*), teak (*Tectona grandis*), and litchi (*Litchi chinensis*).

Ecological Outcomes: Households practising diverse multi-strata agroforestry reported significantly better perceptions of soil quality, water retention, and microclimate moderation compared to households practising monoculture or simplified systems. Focus group discussions corroborated survey data, with women farmers in Dhalai District reporting that tree-covered plots experienced less surface runoff and soil erosion during monsoon rainfall events. Secondary data analysis using Forest Survey of India (2021) district-level canopy cover statistics revealed that areas with high household-level agroforestry adoption corresponded to higher open canopy cover outside designated forest reserves, suggesting that farm-level tree retention contributes meaningfully to landscape-scale maintenance of forest cover. Rubber agroforestry systems, while economically important, were associated with lower understorey biodiversity compared to homestead polyculture gardens, consistent with findings from similar contexts in Southeast Asia (Fox & Castella, 2013). Logistic regression analysis demonstrated that landholding size, tribal identity, household head education level, and membership in self-help groups were statistically significant positive predictors of agroforestry adoption ($p < .05$). **Proximity to forest land and tenure security were also significant, underscoring the importance of the institutional context.**

Socio-Economic Impacts: Agroforestry households reported greater income diversification compared to non-agroforestry households. Income from tree products—including timber, fuelwood, fruit, bamboo, and rubber latex—constituted between 22 and 45 per cent of total household income depending on system type and location. Women in agroforestry households played significant roles in managing homestead gardens and marketing non-timber forest products, contributing to greater intra-household decision-making power, as reported in focus group discussions.

Institutional barriers identified through key informant interviews included inadequate technical knowledge among extension staff about agroforestry species selection and management, limited access to formal credit for purchasing planting materials, and poorly developed value chains for non-timber forest products. Several respondents highlighted the positive role of NGOs such as the North East Network in facilitating women's groups to market bamboo and medicinal plant products, demonstrating the potential of civil society partnerships.

Policy Gaps and Opportunities: Despite supportive national and state policies, field evidence suggests significant implementation gaps. MGNREGS-financed tree planting activities were reported to lack sufficient post-plantation management support, resulting in low survival rates. The absence of a dedicated state agroforestry cell was identified as a structural gap by multiple key informants. Conversely, the Tripura Bamboo Mission was recognised as a model of integrated value chain development that could be replicated for other agroforestry commodities.

CONCLUSION

This paper has examined the role of agroforestry in advancing ecological sustainability and rural development in Tripura, drawing on a mixed-methods empirical study across three agro-ecologically diverse districts. The findings demonstrate that agroforestry is both widespread and ecologically significant in rural Tripura, contributing to soil conservation, biodiversity maintenance, carbon storage, and income diversification for smallholder households. However, the full potential of agroforestry remains constrained by institutional, policy, and market-related barriers. The study identifies several priority areas for policy intervention: strengthening agroforestry-specific extension services; improving tenure security for tribal farmers; developing inclusive market linkages for agroforestry products; and establishing a dedicated institutional mechanism at the state level to coordinate and monitor agroforestry programmes. From a theoretical standpoint, this research affirms that agroforestry must be understood not merely as a technical land-use option but as a socially embedded practice shaped by tenure relations,

gender dynamics, cultural knowledge systems, and institutional environments. Effective policy must therefore engage with these social dimensions alongside the biophysical. Future research should pursue longitudinal ecological monitoring of agroforestry plots to quantify carbon sequestration and biodiversity outcomes with greater precision. Comparative studies examining traditional jhum-based and sedentary agroforestry systems would also advance understanding of transition pathways and trade-offs in the northeastern Indian context. Agroforestry, situated within a supportive governance framework and community-centred approach, holds considerable promise as a pillar of ecologically sustainable rural development in Tripura—one that respects the state's rich biological and cultural heritage while improving the material wellbeing of its farming communities.

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