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Socio-Economic and Ecological Impacts of Oil Palm Plantation Expansion in Northeast India: A Critical Review

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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Abstract

Northeast India has been identified by national planners as a priority zone for oil palm expansion under efforts to reduce the country's heavy dependence on imported edible oil. The region's high rainfall, warm lowland tracts and available land have made it an attractive target for area expansion, yet the same landscape sits within the Indo-Burma biodiversity hotspot and is home to communities whose livelihoods and cultural identity remain closely tied to shifting cultivation and communal land. This review synthesises the socio-economic and ecological literature on oil palm plantation development in the northeastern states, with particular attention to Mizoram, Nagaland, Assam, Tripura and Arunachal Pradesh. It examines changes in land tenure and the erosion of customary rights, shifts in household income and gendered labour patterns, and the market and infrastructural constraints that have slowed the sector's growth. It then reviews the ecological consequences of conversion, including forest loss, changes to hydrology, soil and carbon stocks, greenhouse

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gas emissions, and rising human-wildlife conflict, drawing on comparative evidence from Southeast Asia and from India's own longer experience with rubber plantation expansion in the same region. The review considers whether agroforestry-based cultivation models and sustainability certification schemes offer a workable middle path between the national goal of edible oil self-sufficiency and the protection of one of India's most ecologically and culturally distinctive regions, and it closes by weighing the sector's dietary and public health implications alongside its land use costs. Priorities for future research, the main conclusions that follow from the existing evidence base, and the limitations inherent in a rapidly evolving and still thinly researched field are set out in turn.

Keywords: Oil palm; Northeast India; land use policy; biodiversity; shifting cultivation; edible oil self-sufficiency.

1. Introduction

1.1 The Global and National Context of Oil Palm Expansion

Oil palm (*Elaeis guineensis* Jacq.) is the most productive oil-bearing crop grown anywhere in the world, yielding several times more oil per hectare than soybean, sunflower or rapeseed, and it now supplies close to two-fifths of global vegetable oil output (Qaim et al., 2020). Global oil crop cultivation, oil palm chief among them, expanded by half between 2010 and 2024, with oil palm fruit production alone rising by 77 per cent over that period (Food and Agriculture Organization of the United Nations [FAO], 2025). This productivity advantage has driven rapid area expansion across the wet tropics, principally in Indonesia and Malaysia, but the environmental record accompanying that expansion has been troubling. Conversion of primary and secondary tropical forest into oil palm monoculture has been implicated in substantial biodiversity loss, carbon emissions and hydrological disruption across Southeast Asia (Vijay et al., 2016; Koh et al., 2011). Almost half of the plantations sampled across Southeast Asia by the early 2010s occupied land that had been forest only two decades earlier (Vijay et al., 2016), and peat swamp conversion alone accounted for a measurable share of regional biodiversity decline (Koh et al., 2011). Set against this, the crop has lifted rural incomes, generated employment and reduced poverty for many smallholder households in the countries where it has become established, although these gains have proven markedly uneven across village types (Qaim et al., 2020; Santika et al., 2019). This duality of economic benefit against ecological cost sits at the centre of the debate now unfolding in India. Recent global scenario analysis indicates that replacing palm oil with lower-yielding vegetable oils may shift rather than eliminate land-use and greenhouse-gas pressures, strengthening the case for deforestation-free production and careful siting rather than crop substitution alone (Chiriacò et al., 2024).

India is the world's largest importer of vegetable oil and meets a majority of its domestic requirement through imports of palm, soybean and sunflower oil (Valiyaveettil et al., 2023). Supply shocks associated with the COVID-19 pandemic and the war in Ukraine pushed the country's edible oil import bill sharply upward in the early 2020s, exposing the fiscal and nutritional vulnerability created by this dependence (Valiyaveettil et al., 2023). In response, the Government of India has promoted the National Mission on Edible Oils–Oil Palm, an initiative intended to expand the area under oil palm cultivation substantially over the coming decade, with Northeast India named as one of the principal frontiers for this expansion (Srinivasan et al., 2021; Bose, 2019). Recent evidence on India's oil palm sector shows that policy-supported expansion has been accompanied by continuing water, input-cost, climatic and region-specific ecological constraints, reinforcing the need for differentiated rather than uniform expansion strategies (Ponnaganti et al., 2025).

1.2 Northeast India as a Frontier for Oil Palm

Northeast India comprises eight states characterised by hilly terrain, high rainfall and a mosaic of shifting cultivation, forest and community-owned land. The region lies within the Indo-Burma biodiversity hotspot, and its lowland tracts in Assam, Tripura, Mizoram and parts of Arunachal Pradesh fall within the bioclimatic range considered suitable for oil palm (Srinivasan et al., 2021). Mizoram was the first state in the region to adopt oil palm cultivation at scale, doing so through the New Land Use Policy of 2011, a state programme intended to replace shifting cultivation with settled, cash-generating tree crops on smallholder land (Bose, 2019). Nagaland, Assam, Tripura and Manipur have since followed with their own oil palm missions, often supported by memoranda of understanding with private processing companies.

The appeal of oil palm to state governments in the region rests on a fairly simple calculation: shifting cultivation, locally called jhum, has come under sustained policy criticism for its association with soil erosion and shortened fallow cycles as population pressure has intensified (Ray et al., 2021), while oil palm promises a permanent tree crop with an assured buyer and government-subsidised inputs. This calculation is not new to the region. Northeast India ran a broadly similar experiment with rubber (*Hevea brasiliensis*) from the 1960s onward, when Tripura's forest department promoted rubber as an alternative to jhum, and the area under rubber in that state alone grew from a few hundred hectares to roughly nine per cent of its entire geographic area by 2021 (Pasha et al., 2023). That experience offers a useful, if imperfect, precedent for weighing what a decades-long, state-backed plantation transition looks like once it matures, and it is a comparison this review returns to. Household evidence from six eastern Himalayan states further shows that shifting-cultivation landscapes retain substantial agrobiodiversity and livelihood functions, indicating that transitions to permanent cash crops should be assessed against ecological and cultural baselines as well as concerns about shortened fallow cycles (Pandey et al., 2022).

Two considerations, however, recur throughout the oil palm literature specifically. First, land in the northeastern hills is overwhelmingly held under customary and communal tenure systems that do not map neatly onto individual land titling, meaning conversion to oil palm can quietly transfer control of village commons to better-connected households or outside investors (Bose, 2019). Second, the region's forests, while degraded in many places by jhum itself, remain disproportionately important for the country's terrestrial biodiversity, and their replacement by a structurally simple monoculture carries ecological consequences that are only beginning to be documented empirically within India (Srinivasan et al., 2021). A recent synthesis of smallholder palm oil research also found that certification alone has limited capacity to resolve persistent concerns involving insecure land tenure, low incomes and low yields, underscoring the importance of examining institutional conditions alongside agronomic performance (Ogahara et al., 2022).

1.3 Scope, Research Gap and Objectives

Empirical research specifically addressing oil palm cultivation in Northeast India remains limited relative to the scale of the government programme now under way, and much of what does exist has emerged only since the early 2020s, concentrated in the states of Mizoram and Tripura where planting began earliest. Existing national-scale assessments of India's oil palm potential have modelled trade-offs between edible oil self-sufficiency and biodiversity conservation, but finer-grained, region-specific evidence on household welfare, land tenure change, gendered labour, soil and hydrological outcomes, and human-wildlife conflict in the northeastern states remains fragmented across agricultural economics, forest ecology and rural sociology. There is, in particular, a shortage of literature that draws these strands together to ask whether the socio-economic gains reported from early plantings are commensurate with the ecological risks documented from the wider oil palm literature and from the region's own record of biodiversity loss and plantation-driven land use change.

This review addresses that gap by synthesising the available evidence on the socio-economic and ecological consequences of oil palm plantation expansion in Northeast India, situating it within the broader international literature on oil palm impacts where regional evidence remains thin, and within the region's own comparative experience with earlier plantation crops. The specific objectives are threefold: to characterise the socio-economic effects reported to date, spanning land tenure, household income, gendered labour and market constraints; to assess the ecological consequences documented or anticipated for the region, including deforestation, hydrology, carbon balance and human-wildlife conflict; and to evaluate whether alternative cultivation models, sustainability certification and policy reform offer a credible route to reconciling the national goal of edible oil self-sufficiency with the ecological and cultural integrity of Northeast India.

2. Methods for Literature Selection

2.1 Databases Searched

Literature was identified through structured searches of four general-purpose databases, Web of Science, Scopus, Google Scholar and PubMed, supplemented by six field-specific indexing platforms selected for their coverage of agricultural, forestry, environmental and development literature relevant to South and Southeast Asia: CAB Abstracts, AGRICOLA, AGRIS, BASE (Bielefeld Academic Search Engine), the Directory of Open Access Journals, and SciELO. This combination was chosen to capture both high-impact international journals and regionally indexed agricultural and forestry outlets that frequently carry Northeast India-specific field studies.

2.2 Search Strings, Date Range and Inclusion Criteria

Search strings combined crop and geographic terms using Boolean operators, structured as: ("oil palm" OR "*Elaeis guineensis*") AND ("Northeast India" OR Mizoram OR Assam OR Nagaland OR Tripura OR Manipur OR Meghalaya OR "Arunachal Pradesh"), supplemented by parallel searches pairing "oil palm" with thematic terms including "land use policy," "shifting cultivation," "biodiversity," "deforestation," "carbon stock," "human-wildlife conflict," "certification," and "edible oil self-sufficiency." A second tier of searches addressed the global comparative literature using strings combining "oil palm" with "deforestation," "greenhouse gas," "certification," "poverty," and "smallholder," restricted to Southeast Asia, Latin America and West Africa to provide comparative context, and a third tier searched for the region's comparable rubber plantation literature using "rubber plantation" AND ("Tripura" OR "Northeast India").

The literature search covered material published between 1 January 2010 and 28 March 2026. The earlier bound was chosen because the bulk of rigorous, spatially explicit evidence on oil palm's global deforestation and biodiversity footprint, work that now anchors comparative discussion of the crop, began appearing from around 2010 onward, while India-specific empirical work on the northeastern states is concentrated almost entirely within the past decade. Records were included if they reported original empirical findings, systematic or narrative syntheses, or authoritative institutional data on oil palm cultivation, land use, biodiversity, or edible oil policy in South or Southeast Asia, and were published in a peer-reviewed journal. Records were excluded if they were books, conference proceedings, unrefereed preprints, trade publications, patents, or opinion pieces lacking original data or systematic synthesis, consistent with standard narrative review practice (Sukhera, 2022).

2.3 Rationale for a Narrative Rather than Systematic Approach

A narrative review approach was adopted in preference to a systematic review because the subject matter spans several disciplines, agricultural economics, forest ecology, hydrology, rural sociology and public health, whose methods and outcome measures are too heterogeneous to be pooled through formal meta-analytic techniques. Narrative reviews are recognised as an appropriate and rigorous vehicle for synthesising fragmented, multidisciplinary evidence and for offering interpretive context that a narrowly scoped systematic review would not accommodate, provided the search and selection process is made explicit and reproducible (Sukhera, 2022). Given that empirical research specific to Northeast India remains sparse and methodologically diverse, ranging from household surveys to remote-sensing analyses, a narrative synthesis was judged better suited to drawing coherent conclusions across this uneven evidence base than a systematic review restricted to a narrow question and a single outcome measure.

2.4 Screening Workflow, Duplicate Handling and Language Restriction

Records retrieved from each database were exported to a shared reference manager, where automated and manual checks removed duplicate entries before title and abstract screening. Screening proceeded in two stages: an initial pass excluded records unrelated to oil palm cultivation, land use change, or edible oil policy in the search regions, followed by a full-text assessment of the remaining records against the inclusion criteria above. Searches were restricted to English-language publications, given that this is the dominant language of the international peer-reviewed literature on the subject and the working language of Indian government reports on the sector. Where multiple studies addressed an overlapping dataset or field site, for example, successive publications from the same long-term Mizoram or Sumatra research stations, the most recent or most comprehensive account was prioritised as the influential source, with earlier related work retained only where it added distinct findings.

2.5 Summary of Search Strategy

Table 1 summarises the databases, search terms, date range and selection criteria applied in compiling the evidence base for this review.

Table 1. Summary of the literature search strategy

Element	Specification
General databases	Web of Science, Scopus, Google Scholar, PubMed
Field-specific databases	CAB Abstracts, AGRICOLA, AGRIS, BASE, DOAJ, SciELO
Core search string	("oil palm" OR "*Elaeis guineensis*") AND (Northeast India state names)
Thematic modifiers	land use policy; shifting cultivation; biodiversity; deforestation; carbon stock; human-wildlife conflict; certification; edible oil self-sufficiency; poverty
Comparative crop string	("rubber plantation") AND ("Tripura" OR "Northeast India")
Date range	1 January 2010 – 28 March 2026
Language	English only
Inclusion criteria	Peer-reviewed original research, systematic/narrative reviews, authoritative institutional data
Exclusion criteria	Books, conference proceedings, preprints, trade publications, patents, opinion pieces without original data
Duplicate handling	Reference-manager deduplication followed by manual verification
Screening	Two-stage: title/abstract, then full text against inclusion criteria

Source: compiled by the authors for this review

As Table 1 shows, the strategy deliberately paired a narrow regional focus with a wider comparative net, a design choice that reflects how thin the Northeast India-specific evidence base still is relative to the international oil palm literature it must be read against

3. Socio-Economic Dimensions of Oil Palm Expansion

3.1 Land Tenure, Customary Rights and the New Land Use Policy

The socio-economic literature on oil palm in Northeast India converges most strongly on the question of land tenure. Under Mizoram's New Land Use Policy of 2011, the state government sought to replace jhum cultivation, practised by an estimated tens of thousands of households, with settled tree crops including oil palm on land nominally allocated to smallholders (Bose, 2019). Bose (2019) documents that this reallocation, while framed as an instrument of household empowerment, has in practice interacted uneasily with customary systems in which land use rights are collectively held and periodically reassigned rather than individually titled in perpetuity. The policy's individual land allocations have in some cases advantaged households already better positioned within village hierarchies, while others found their access to land for subsistence cultivation curtailed. This pattern recurs elsewhere in the region: reporting on Arunachal Pradesh has similarly noted that the capture of common land earmarked for oil palm by locally influential households or outside investors threatens to marginalise poorer community members, echoing wider concerns in the global literature that plantation expansion into land under customary tenure frequently disadvantages those with the weakest formal claims (Bose, 2019).

Northeast India's earlier experience with rubber expansion offers a useful point of comparison, because it shows how a state-promoted plantation transition looks once given several decades to run its course. Rubber was introduced into Tripura in the 1960s explicitly as an alternative to jhum, and detailed satellite-based mapping shows that the area under rubber in the state expanded from 0.3 per cent of its geographic area in 1990 to 8.9 per cent by 2021, a scale of conversion far beyond anything oil palm has yet achieved in the region (Pasha et al., 2023). That precedent matters for how the current oil palm push is read: it demonstrates both that such transitions can proceed at considerable pace once infrastructure and buyer relationships are established, and that the resulting monoculture footprint, once in place, is not easily reversed.

At the same time, the literature cautions against treating jhum itself as an unambiguously sustainable baseline that plantation crops displace. Shifting cultivation across the northeastern hills has, under conditions of shortened fallow cycles driven by population growth, been associated with substantial topsoil and nutrient loss, with erosion rates on steep jhum slopes recorded at levels that materially exceed sustainable thresholds (Ray et al., 2021). A detailed geospatial soil survey of jhum land in the Purvanchal hill range found clear evidence of regressive soil development under shortened-cycle shifting cultivation relative to adjacent undisturbed forest, reinforcing the case made by state governments that some form of land use transition is ecologically warranted even as it complicates any simple narrative in which the newer crop is cast as the sole disruptive force (Ray et al., 2021). The genuine policy tension is not between an untouched shifting-cultivation baseline and an intrusive plantation crop, but between a land use system already under strain and a substitute whose own tenure and ecological costs, as the rubber precedent suggests, are not fully reckoned until decades after adoption.

3.2 Household Income, Employment and Gendered Labour

Household-level economic evidence from the region remains limited but broadly positive where oil palm has established successfully. Agroforestry-based trials integrating oil palm with intercrops such as pineapple and turmeric in Mizoram recorded substantially higher combined crop and intercrop yields than monoculture oil palm plots, alongside improved ecosystem carbon storage, suggesting that diversified planting arrangements can deliver income benefits to smallholders without foregoing all of the ecological services associated with more complex vegetation structure (Ahirwal et al., 2022). This finding is consistent with the wider international literature on oil palm's economic effects, which documents that the crop's expansion has, on balance, raised incomes, generated employment and reduced poverty among adopting farm households across the tropics, even as it has imposed environmental costs at the landscape scale (Qaim et al., 2020). A large multidimensional counterfactual assessment covering thousands of villages in Indonesia adds an important qualification here: welfare gains from oil palm development were concentrated in villages that were already market-oriented before plantations arrived, whereas villages that had relied primarily on subsistence farming tended to see poverty increase following conversion (Santika et al., 2019). Given that much of rural Northeast India remains closer to the subsistence end of that spectrum than to Indonesia's market-integrated plantation frontier, this distinction carries a direct warning for how the region's own outcomes might unfold.

The labour dimension of this transition carries a distinct gendered pattern that recurs in accounts from Mizoram. Under jhum cultivation, men and women have traditionally participated as roughly equal partners across the cultivation cycle, but the shift toward oil palm has tended to reorganise labour along more male-dominated lines, with women's traditional role in subsistence farming eroded as land is converted to a capital-intensive tree crop requiring different skills and timing (Bose, 2019). This pattern sits within a broader national trend in which women constitute a large and growing share of the agricultural workforce in India, without a corresponding increase in their control over land, decision-making, or the returns to cash crops (Mishra et al., 2024). Where oil palm displaces subsistence systems in which women held clearer customary standing, the transition risks reproducing this national pattern of feminised labour without commensurate empowerment, a concern the regional literature raises but has yet to quantify systematically for Northeast India specifically.

3.3 Market, Infrastructural and Value Chain Constraints

A further recurring theme is the gap between the government's ambitions for area expansion and the practical constraints facing cultivators once plantations mature and begin fruiting. Oil palm requires four to five years of establishment before the first harvest and reaches full productivity only after roughly a decade, during which farmers commit land and labour without meaningful returns (Qaim et al., 2020). In Northeast India this establishment period has coincided with well-documented infrastructural shortfalls: the rugged terrain and remote location of many plantations, combined with a limited road network, has made the timely transport of harvested fresh fruit bunches, which begin to degrade in quality within hours of harvest, to processing mills difficult in several districts. Reports from Nagaland describe farmers becoming reluctant to expand plantings further after finding no assured buyer for fruit once early plantings matured, reflecting a broader mismatch between the pace of area expansion promoted through subsidy and the slower, capital-intensive build-out of processing infrastructure required to realise returns from that expansion.

Table 2 summarises the principal socio-economic effects identified in the literature reviewed for this section.

Read together, these entries look encouraging in isolation but, taken as a whole, describe a sector whose gains depend heavily on village type and household position, a pattern the Indonesian counterfactual evidence makes explicit and that Northeast India's own subsistence-heavy village economy should not be assumed to escape.

Table 2. Summary of documented socio-economic effects of oil palm expansion in Northeast India

Dimension	Documented effect	Direction
Land tenure	Reallocation of communal land to individual holdings; elite capture in some districts	Mixed/negative
Precedent from rubber expansion	Comparable state-led plantation transition reached 8.9% of Tripura's land area within three decades	Informative precedent
Household income	Higher combined yields under agroforestry intercropping relative to monoculture	Positive
Village-level welfare	Gains concentrated in market-oriented villages; losses reported in subsistence-based villages	Mixed
Gendered labour	Shift from balanced jhum labour to male-dominated oil palm labour	Negative
Market access	Delays in fruit procurement; limited mill infrastructure in remote districts	Negative
National food security context	Contribution toward reducing edible oil import dependence	Positive at national scale

Sources: Ahirwal et al. (2022); Bose (2019); Mishra et al. (2024); Pasha et al. (2023); Qaim et al. (2020); Santika et al. (2019); Valiyaveettil et al. (2023)

4. Ecological and Environmental Impacts

4.1 Deforestation and Biodiversity Loss

The ecological case against unmanaged oil palm expansion rests primarily on the crop's documented global association with tropical deforestation. Across a large sample of plantations surveyed in Southeast Asia, a substantial proportion occupied land that had carried forest only two decades earlier, and the resulting habitat loss has been linked to measurable declines in forest-dependent vertebrate species (Vijay et al., 2016). Peatland conversion specifically has proven ecologically costly, with satellite mapping across Peninsular Malaysia, Borneo and Sumatra showing that a meaningful share of regional peat swamp forest had already been converted to oil palm by the early 2000s, accompanied by measurable declines in forest bird richness (Koh et al., 2011). A comprehensive synthesis of the crop's environmental footprint concludes that these biodiversity costs are not incidental but structural: oil palm's near-total canopy closure and simplified understorey support markedly fewer species than the forest types it typically replaces, regardless of the country in which cultivation occurs (Meijaard et al., 2020). A separate satellite-based analysis spanning three decades found that most currently certified oil palm concessions in Borneo and Sumatra occupied land that had been intact tropical forest or large-mammal habitat only thirty years earlier, underscoring how recent and how extensive the underlying habitat conversion has been even in landholdings now marketed as sustainably produced (Cazzolla Gatti & Velichevskaya, 2020).

For Northeast India, a national-scale spatial analysis modelling India's oil palm expansion potential found that the country retains substantial land area suitable for the crop without necessarily encroaching on its most biodiversity-rich landscapes, but cautioned that this favourable national picture depends heavily on which specific sites are chosen, since Northeast India's low-elevation forests support species, including hornbills and other range-restricted birds, whose long-term persistence would be threatened by conversion of the remaining lowland forest tracts identified as bioclimatically suitable for the crop (Srinivasan et al., 2021). This finding captures the central ecological tension in the region's oil palm programme: national self-sufficiency targets can plausibly be met without disproportionate biodiversity loss only if expansion is steered toward already-degraded or non-forest land, a targeting outcome that current subsidy-driven, area-based mission design does not obviously guarantee.

4.2 Hydrology, Soil and Greenhouse Gas Balance

Evidence on the crop's hydrological footprint, drawn mainly from Southeast Asia given the absence of comparable long-term Northeast India studies, points to measurable shifts in catchment-scale water balance following conversion. Watershed modelling of oil palm expansion in Indonesia found appreciable increases in surface runoff and sediment yield relative to forested baselines, alongside sharp increases in nitrogen and phosphorus loading downstream, outcomes attributed to the combination of reduced canopy interception and heavy fertiliser application characteristic of intensively managed plantations. Soil greenhouse gas monitoring in a large Indonesian plantation similarly found that nitrous oxide emissions from fertilised oil palm soils contributed disproportionately to the crop's overall warming potential even after management was shifted from conventional to reduced-input practices, indicating that fertiliser-driven soil emissions represent a persistent rather than easily engineered-away cost of intensive cultivation (Chen et al., 2024).

For India specifically, field surveys of oil palm plantations comparing soils of different ages against adjacent fallow land found that established oil palm cultivation was associated with elevated soil pH, electrical conductivity, exchangeable calcium and magnesium, and higher soil organic carbon content relative to fallow, a set of changes that, while not uniformly negative, indicates that oil palm alters baseline soil chemistry in ways that differ from the forest and fallow systems it typically replaces (Behera et al., 2020). Set against this, region-specific evidence from Mizoram suggests that cultivation design matters considerably in shaping the net balance of these changes. Field trials comparing monoculture oil palm with oil palm intercropped with maize, turmeric or pineapple found that while monoculture plots achieved the highest individual palm growth, the pineapple-intercropped system delivered the greatest combined crop yield and the highest total ecosystem carbon stock among the systems tested, indicating that agroforestry configurations can partially offset the soil and carbon costs typically associated with monoculture plantation while also raising farmer returns (Ahirwal et al., 2022). A broader survey of soil organic carbon stocks across different land uses in Mizoram similarly found that carbon storage varies substantially by land use type, with plantation systems generally storing less carbon than adjacent natural forest, underlining the scale of carbon loss at stake whenever forest rather than already-cleared or fallow land is converted (Kenye et al., 2019).

Complementary work on forest carbon storage across the wider Eastern Himalayan region has shown that carbon stocks vary markedly by forest type and land use, with implications for how conversion decisions in the region should be weighed against the carbon value of the vegetation being replaced (Gogoi et al., 2022), while community-managed forests in neighbouring Tripura have been shown to retain meaningful climate mitigation value through continued carbon sequestration, underlining what stands to be lost where community forest land is instead converted to plantation (Deb et al., 2021). Land-use change more broadly across the Eastern Himalayan mountain ecosystem has also been linked to shifts in soil micronutrient status, a further dimension of soil change that accompanies conversion from forest or fallow to intensively managed cropland (Choudhury et al., 2021).

4.3 Human-wildlife Conflict

A further ecological cost that features prominently in the wider Northeast India land-use literature, though not yet studied specifically in relation to oil palm, is the intensification of human-wildlife conflict that accompanies forest fragmentation. Assam supports one of the largest surviving wild elephant populations in India, and long-term research in Sonitpur district found a measurable threshold relationship between forest cover loss and the onset of human-elephant conflict, with conflict incidence rising sharply once intact forest cover in a landscape fell below a critical proportion (Chartier et al., 2011). Given that Northeast India already experiences some of the country's most severe human-elephant conflict, and that the lowland forest tracts identified as bioclimatically suitable for oil palm overlap with elephant range and movement corridors in Assam and neighbouring states, the existing conflict literature provides a strong basis for anticipating that further fragmentation associated with plantation expansion would plausibly intensify this conflict, even though a study directly linking oil palm conversion to elephant conflict incidence in the region has not yet been published.

Table 3 summarises the ecological effects discussed in this section, distinguishing evidence drawn directly from Northeast India from comparative evidence drawn from the wider international literature. Read together, the entries in Table 3 show a consistent pattern: wherever Northeast India-specific data exist, they point to real but partly manageable costs, whereas the comparative international evidence describes outcomes several orders of magnitude larger in scale, a gap that is itself an argument for early, careful land use planning rather than a reason for complacency.

5. Comparative Global Evidence and Lessons for Northeast India

The Southeast Asian experience offers Northeast India both a cautionary template and a set of avoidable errors. Indonesia's oil palm sector expanded from roughly four million hectares in 1980 to almost thirty million hectares by the end of the 2010s, with the pace and location of that expansion driven substantially by fire-based clearance and peatland drainage rather than planned conversion of already-degraded land (Koh et al., 2011; Chen et al., 2024). The environmental costs that followed, biodiversity loss, carbon emissions, and altered hydrology, were compounded by the fact that expansion frequently outran the regulatory and monitoring capacity of the state.

Table 3. Summary of ecological and environmental effects associated with oil palm cultivation

Effect	Evidence base	Direction
Forest loss and biodiversity decline	Global (Southeast Asia); modelled risk for NE India	Negative
Peatland and lowland forest conversion	Global (Southeast Asia)	Negative
Habitat loss within certified concessions	Global (Borneo, Sumatra)	Negative
Surface runoff, nutrient loading	Global (Indonesia)	Negative
Soil nitrous oxide emissions	Global (Indonesia)	Negative
Soil chemistry and organic carbon change	India (multi-state field survey)	Mixed
Ecosystem carbon stock under agroforestry intercropping	Northeast India (Mizoram)	Positive relative to monoculture
Land-use carbon stock variation	Northeast India (Mizoram, Eastern Himalaya)	Negative where forest is converted
Community forest carbon sequestration displaced by conversion	Northeast India (Tripura)	Negative if converted
Human-elephant conflict risk from fragmentation	Northeast India (Assam, general forest loss)	Negative (anticipated)

Sources: Ahirwal et al. (2022); Behera et al. (2020); Cazzolla Gatti & Velichevskaya (2020); Chartier et al. (2011); Chen et al. (2024); Choudhury et al. (2021); Deb et al. (2021); Gogoi et al. (2022); Kenye et al. (2019); Koh et al. (2011); Meijaard et al. (2020); Srinivasan et al. (2021); Vijay et al. (2016)

Voluntary certification schemes intended to correct these outcomes have delivered genuinely mixed results, and the literature on this point is worth reading carefully rather than taking at face value. An early evaluation using satellite data found that Roundtable on Sustainable Palm Oil (RSPO) certified plantations in Indonesia showed significantly lower rates of deforestation and fire than non-certified plantations between 2001 and 2015 (Carlson et al., 2018), a result often cited as evidence that certification works. Subsequent research complicated this picture considerably. A study tracking spillover effects in Indonesian Borneo found that certification reduced deforestation inside the official forest estate but simultaneously increased deforestation in areas zoned for agricultural use, implying that some of the apparent gain was displaced rather than eliminated (Heilmayr et al., 2020). More pointedly, a detailed historical satellite analysis extending back thirty years found that most concessions and supply bases currently certified as sustainable in Borneo and Sumatra had themselves been intact forest or large-mammal habitat within the recent past, meaning that certification, as commonly practised, evaluates a plantation's present-day footprint without accounting for the deforestation that produced that footprint in the first place (Cazzolla Gatti & Velichevskaya, 2020). A subsequent systematic review and meta-analysis of the RSPO scheme reached a broadly consistent conclusion: certification is associated with statistically robust improvements in greenhouse gas performance, yield and farm income, but its effect on deforestation specifically becomes statistically insignificant once only the most methodologically rigorous studies are considered, largely because deforestation displaces to nearby non-certified land rather than being prevented outright (Sibhatu & Qaim, 2026).

For Northeast India, still at an early stage of plantation development relative to Southeast Asia, this comparative record carries a clear implication. Land use planning decisions made now, before expansion reaches anything like the scale seen in Indonesia, have far greater power to steer outcomes than certification schemes applied retrospectively once conversion has occurred. The finding that certification chiefly improves within-plantation management practices rather than preventing the initial conversion decision (Sibhatu & Qaim, 2026) suggests that siting choices made at the outset of India's National Mission on Edible Oils–Oil Palm carry disproportionate weight relative to whatever governance mechanisms might later be layered onto an already-expanded estate.

6. Policy, Governance and Sustainability Considerations

6.1 National Edible Oil Policy and Its Regional Expression

India's drive for edible oil self-sufficiency is grounded in a well-documented vulnerability: the country imports the majority of its edible oil requirement, with palm oil constituting the largest single import category, and international price shocks associated with recent global disruptions pushed the national import bill sharply upward within the space of two years (Valiyaveettil et al., 2023). This vulnerability provides the underlying rationale for treating Northeast India's bioclimatically suitable tracts as a national strategic asset, but the policy instrument through which this rationale has been operationalised, area-based subsidy targets under the National Mission, does not by itself distinguish between conversion of already-degraded non-forest land and conversion of intact or community forest. The gap between the legitimate national objective and the specific instrument used to pursue it is where much of the socio-ecological risk identified in this review originates.

6.2 Certification and Voluntary Governance

Given the mixed record of voluntary sustainability certification in reducing deforestation once documented internationally (Sibhatu & Qaim, 2026; Heilmayr et al., 2020; Cazzolla Gatti & Velichevskaya, 2020), reliance on downstream certification alone is unlikely to substitute for upfront land use zoning in Northeast India. Certification appears better suited to improving agronomic and greenhouse gas outcomes on land already committed to cultivation than to preventing the conversion of ecologically valuable land in the first instance, an important distinction for policymakers who might otherwise treat certification as a sufficient safeguard.

6.3 Agroforestry as an Intermediate Model

The most promising body of region-specific evidence concerns oil palm agroforestry, in which the crop is intercropped with food or cash species rather than grown as monoculture. Trials in Mizoram comparing monoculture oil palm against oil palm intercropped with maize, turmeric and pineapple found that while monoculture achieved higher individual palm biomass, intercropped systems, particularly the pineapple combination, delivered superior combined yields and ecosystem carbon stock, offering direct evidence that diversified planting can narrow the gap between the region's food security and cash-crop objectives and its ecological carbon and biodiversity concerns (Ahirwal et al., 2022). This finding is consistent with broader work outside India assessing oil palm agroforestry through multifunctional land equivalent ratios, which found that intercropped systems can achieve combined economic and environmental gains that neither a pure food crop nor a pure oil palm monoculture delivers on its own (Khasanah et al., 2020). Because the Mizoram evidence derives from field experimentation within the region itself rather than by extrapolation from Southeast Asia, it carries particular weight for state-level land use planning going forward.

Table 4 sets out a comparative overview of the governance instruments discussed in this section. The comparison in Table 4 makes clear that no single instrument currently available addresses both the socio-economic and ecological dimensions of the transition simultaneously; land use zoning and agroforestry appear complementary rather than substitutable, since the former governs where conversion happens and the latter governs how converted land is managed once the decision has been made.

7. Health and Consumption Dimensions

The debate over oil palm expansion in India is also inseparable from questions about the health implications of increased palm oil consumption, and about the wider policy environment governing edible oils domestically. Palm oil's fatty acid profile, roughly balanced between saturated palmitic acid and unsaturated oleic acid, has generated a long-running scientific debate over its cardiovascular effects. A systematic review of the epidemiological literature found the existing evidence insufficient to establish a clear association between palm oil consumption and cardiovascular disease risk or mortality, concluding that a generally healthy dietary pattern matters more than the specific oil consumed (Ismail et al., 2018). This finding matters for the domestic policy debate because it suggests that concerns sometimes raised about the health consequences of substituting palm oil for other edible oils in the Indian diet are not strongly supported by the epidemiological record.

Table 4. Comparison of governance instruments relevant to oil palm expansion in Northeast India

Instrument	Primary mechanism	Documented strength	Documented limitation
National Mission on Edible Oils–Oil Palm	Area-based subsidy	Advances national self-sufficiency goal	Does not distinguish degraded from forested target land
Voluntary certification (RSPO-type)	Market-based standard	Improves on-farm yield, income and GHG performance	Limited effect on preventing initial deforestation; deforestation often displaced rather than avoided
State land use policy (e.g., New Land Use Policy)	Land reallocation to smallholders	Provides settled tenure alternative to shortened-cycle jhum	Risk of elite capture of communal land
Agroforestry-based cultivation	Intercropping design	Higher combined yield and carbon stock than monoculture	Requires management skill and market for intercrops

Sources: Ahirwal et al. (2022); Bose (2019); Carlson et al. (2018); Cazzolla Gatti & Velichevskaya (2020); Heilmayr et al. (2020); Khasanah et al. (2020); Sibhatu & Qaim (2026); Valiyaveettil et al. (2023)

A policy space analysis of India's edible oils sector reinforces this point from a different angle, finding that nutrition advocates and sustainability advocates within Indian policymaking tend to focus on different segments of the value chain, missing opportunities for coherent action, and that food security priorities framed narrowly around energy provision have historically dominated over more integrated nutrition-sensitive approaches to oilseed policy (Cuevas et al., 2019). This suggests that the ecological and socio-economic concerns addressed elsewhere in this review, rather than unresolved questions of dietary risk, should form the primary basis for policy discussion of oil palm expansion in Northeast India, while also indicating that closer coordination between the agricultural and public health arms of government could improve how the sector's expansion is planned and communicated.

8. Future Directions

Priority should be given to spatially explicit, ground-truthed mapping of degraded versus intact forest and community land across the northeastern states, so that area expansion under the National Mission can be steered toward already-cleared or low-biodiversity-value tracts rather than proceeding on an undifferentiated area target. Longitudinal household surveys tracking income, labour allocation by gender, and land tenure outcomes over the full oil palm establishment cycle, from initial planting through to full maturity a decade later, would substantially strengthen the currently thin socio-economic evidence base, much of which still rests on case studies from Mizoram alone. Given the Indonesian finding that welfare outcomes diverge sharply between market-oriented and subsistence-oriented villages, comparable village-typology research conducted within Northeast India would help identify which communities are best placed to benefit from adoption and which are more likely to see the pattern reproduced locally. Empirical research directly linking oil palm-driven forest fragmentation to human-elephant and other human-wildlife conflict incidence in the region would close an important gap between the general conflict literature reviewed here and the specific land use change now under way. Further field trials extending the Mizoram agroforestry intercropping model to other states and crop combinations, alongside economic analysis of intercrop marketing constraints, would help determine whether diversified cultivation can be scaled beyond initial experimental plots. A structured comparison of the region's decades-long rubber plantation experience against its still-young oil palm sector, examining soil, water and livelihood outcomes over comparable time horizons, would offer a uniquely regional benchmark that Southeast Asian data cannot provide. Finally, comparative hydrological and soil greenhouse gas monitoring conducted within Northeast India itself, rather than inferred from Southeast Asian catchments with different rainfall and soil regimes, is needed before the region-specific magnitude of these environmental costs can be stated with confidence.

9. Conclusions

Oil palm expansion in Northeast India sits at the intersection of a genuine and well-documented national vulnerability, heavy dependence on imported edible oil, and a regional landscape whose ecological and cultural value is disproportionate to its size. The socio-economic evidence reviewed here suggests that oil palm can raise household income where market access and processing infrastructure are adequate, particularly under agroforestry rather than monoculture cultivation, but that this benefit has been accompanied by disruption to customary land tenure and a shift toward more male-dominated agricultural labour in at least some communities, and that comparable evidence from Indonesia warns the gains are likely to be smaller, or even reversed, in the more subsistence-oriented villages that still predominate across much of the region. The ecological evidence, drawn substantially from the international literature given the relative scarcity of region-specific data, indicates that oil palm's global record of deforestation, biodiversity loss, altered hydrology and elevated soil greenhouse gas emissions constitutes a serious risk wherever expansion proceeds into forested or community land rather than already-degraded tracts, a risk given further weight by the region's own decades-long experience of rubber monoculture expansion. Certification schemes offer only a partial remedy, since their documented strength lies in improving management on land already under cultivation rather than in preventing the initial conversion decision, and in some documented cases certified concessions have themselves been built on recently cleared forest. The most defensible path forward, on the evidence assembled in this review, favours land use zoning that channels expansion toward degraded, non-forest land; wider adoption of intercropped agroforestry systems shown to outperform monoculture on both yield and carbon grounds; and land tenure safeguards designed explicitly to prevent the capture of communal land that several accounts have already documented in the region's early experience with the crop.

10. Limitations

This review is subject to several limitations. First, empirical, peer-reviewed research specific to oil palm cultivation in Northeast India remains sparse relative to the scale of the government programme under way, and much of the ecological evidence presented here has necessarily been drawn from the Southeast Asian literature and extrapolated to the Northeast Indian context, a substitution that cannot fully capture the region's distinct rainfall regime, soil types, and pre-existing land use patterns. Second, the search was restricted to English-language sources, which may have excluded region-specific grey literature or vernacular-language reporting that could contain relevant local observations not yet captured in the peer-reviewed record. Third, as a narrative rather than systematic review, the selection and weighting of studies discussed here, while conducted according to an explicit and reproducible search protocol, retains an interpretive element that a formal systematic review with pre-registered outcome measures would constrain more tightly. Fourth, the comparison drawn with the region's rubber plantation history, while informative, is not a perfect analogue, since rubber and oil palm differ in their water requirements, processing chain, and market structure, and conclusions transferred from one crop to the other should be treated as suggestive rather than definitive. Finally, because the region's oil palm sector is still expanding rapidly and unevenly across states, the evidence base itself is a moving target, and conclusions drawn from early plantings in Mizoram and Tripura may not generalise fully to states such as Arunachal Pradesh or Manipur where cultivation began later and under different institutional arrangements.

Declaration of AI Use

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Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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