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A Conceptual Review on Sericulture in Northeast India: Viability, Opportunities and Policy Pathways

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Authors' contributions

This work was carried out in collaboration among all authors. The author SS designed the study while others reviewed literature. All authors read and approved the final manuscript.

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ABSTRACT

India is the world's second-largest raw silk producer and is known for uniquely cultivating all five silk types. Sericulture, which is known as silk from silkworms, is labour-intensive, agroforestry-linked, and vital for rural livelihoods. The North eastern (NE) states, namely Assam, Arunachal Pradesh, Meghalaya, Mizoram, Nagaland, and Tripura, contribute mainly eri and muga (Vanya) silks in addition to some mulberry. To conceptually review sericulture "viability" that included the following aspects, like agro-ecological, economic, social, institutional, market, and environmental,

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and identify thematic constraints/ opportunities. In addition to that, it also proposes actionable policy and research directions for NE India. Narrative review of government reports, ICAR/CSB publications, and peer-reviewed literature (2010–2025) on NE sericulture. The major findings highlight that NE sericulture has strong cultural roots and gender-inclusive traditions, especially eri, and growing demand for unique silk products. Mulberry yields and acreage have declined in Assam, whereas eri/muga output has risen. Agro-ecological conditions such as high rainfall, humidity, and altitudinal diversity suit forest-based eri and muga systems, but also pose challenges, most commonly temperature stress and pest outbreaks. Economically, sericulture can yield higher, more stable incomes than many crops, though market linkages are weak and price volatility is a major threat. Institutions provide schemes (Silk Samagra, state policies), but extension and credit often lag in most instances. NE-specific opportunities include branding of GI-protected muga, integration of sericulture with agroforestry (e.g., eri's dual-use host plants), women's empowerment, and sustainable production. Key constraints are disease management, poor seed and planting material supply, limited skilled labour, and fragmented value chains. Sericulture remains a high-potential rural sector in Northeast India, but requires coordinated policy support and research. We synthesize NE sericulture issues into a conceptual "viability" framework and recommend targeted interventions by state and central agencies, research institutes, and NGOs. A strategic research agenda that impacts evaluations, value-chain studies, gender analysis, and climate adaptation is outlined. The findings highlight data gaps, especially of state-level stats. and urge evidence-based policy to sustain NE sericulture.

Keywords: Northeast India; sericulture; Eri silk; Muga silk; sericulture policy; rural livelihoods; agroforestry.

1. INTRODUCTION

"Sericulture – the rearing of silkworms that comes under the order Lepidoptera for silk, is an ancient agro-industrial sector with global significance. India is the world's second-largest raw silk producer, uniquely cultivating all five silk types that is mulberry, eri, muga, tussar, and oak-tussar". (Vishwanath, 2021) "Silk production offers self-employment and diversified income for rural families" (Nagaraju and Shubha, 2024). The Central Silk Board (CSB) of India was established post-independence to coordinate silk production and R&D. Currently, India's sericulture sector employs roughly 9–9.5 million people (Resham Sutra n.d.), mainly in rural and semi-urban areas, providing livelihoods to nearly one million families (Patil *et al*, 2009). Silk is also culturally embedded; for example, northeast Assamese and tribal communities prize muga, also widely known as golden silk, and eri, known as white silk, in traditional attire (Phukan, 2024).

In states like Assam, Manipur, Nagaland, Meghalaya, Tripura, and Arunachal Pradesh, sericulture is especially vital. "Sericulture holds great importance in the socio-economic landscape of Northeast India," providing rural livelihoods in states like Assam, Nagaland, Meghalaya, and Arunachal Pradesh (Narzary and Boro, 2025). The NE region is the exclusive origin of Muga silk and a strong producer of Eri silk, alongside pockets of mulberry culture (Hussain *et al.,* 2024). We defined the scope of this review as a conceptually grounded synthesis of sericulture viability in NE India. It examines ecological, economic, social, and institutional factors that affect success and identifies thematic constraints and opportunities. This aims to inform policy pathways and research agendas. Rather than a systematic review, we have selected illustrative evidence from key government, institutional, and peer-reviewed sources (2010–2025) on NE sericulture. Where evidence is limited, we have noted research gaps explicitly.

The sections that follow first outline a conceptual framework for sericulture viability in the region, then describe NE sericulture contexts, highlighting types and agro ecology, and synthesize literature by theme, for instance, agronomic, socioeconomic, value-chain, institutional, gender, and environmental. We critically analysed cross-cutting issues, presented a SWOT summary, and offered prioritized recommendations and research needs.

2. A CONCEPTUAL FRAMEWORK FOR SERICULTURE VIABILITY

"Viability" of a rural enterprise is multi-faceted (Pradhan & Samanta, 2025). For sericulture, we define viability as the sustained potential for

profitable production and societal benefit within environmental limits. This combines agro ecological suitability questioning can silk be grown on local landscapes/climate, economic profitability that includes favourable cost–return over time, social viability including acceptance, inclusivity, labour norms, livelihoods impact, institutional support consisting of extension activities that is carried out, credit, markets, policy continuity, market continuity with respect to stable demand and price discovery for silk products, and environmental sustainability that consist of maintaining soil, forests, biodiversity, water resources. (Attri *et al*., 2024). Each dimension feeds back into others: e.g., ecological constraints can erode economic returns unless matched by research on climate-adapted practices.

Key elements influencing sericulture viability in NE India:

- **Inputs:** Land that is used for mulberry plantations or host tree, labour that is family and hired, including seasonal demands, capital such as start-up costs for gardens, rearing houses, reeling equipment, technical inputs that is required such as disease-free silkworm seed, improved host-plant varieties, and knowledge consisting of both traditional skills and modern technology support (Sericulture as a Business Infonet Biovision Home., n.d.).
- **Production System:** The farming component includes host-plant cultivation, e.g., mulberry trees or forest perennials like *Persea bombycina* for muga, castor/tapioca for eri, and silkworm rearing (cocoon harvest). Vanya silks such as muga, eri, and tassar are often used in backyard or forest-based systems, whereas mulberry is plantation-based (Naan *et al.*, 2025).
- **Value chain:** Raw cocoons must move through reeling and processing into yarn, weaving, or allied sectors. Local cooperatives or reeling centres can add value to the above-mentioned process. Market linkages, specifically silk markets, exporters, and textile firms, determine prices and demand.
- **Institutions:** Government bodies such as the Central Silk Board, state sericulture departments of the major silk-growing areas, provide schemes. such credit subsidy, cluster support, R&D that includes breeding, disease control, and training programmes. Co-operatives and NGOs mediate services like bulk purchase of cocoons or input supply.
- **Enabling Environment:** Policies, e.g., Silk Samagra schemes, GI tags like for muga, well-maintained infrastructure such as roads, electricity, and reeling units, extension and research uptake, rural credit and insurance, and land tenure rights all affect viability. Price support or minimum support pricing, which is still absent for the silk industry, also influences profitability.

In practice, we assess viability by looking at performance in these areas. For example, agro-ecological suitability can be accessed via climate-model studies for host plants (Altman & Farrell, 2022), economic viability via cost–income studies and household surveys, and institutional viability via review of policy schemes and R&D capacity. The following sections explore each dimension through themes and examples specific to NE India.

3. SERICULTURE TYPES AND AGROECOLOGICAL CONTEXT IN NORTHEAST INDIA

3.1 Silk Varieties in the Region

Northeast India is famous for its three domestic silk types.

- **Mulberry Silk *(Bombyx mori):*** Mulberry silkworms are fully domesticated and monophagous, that is, they feed only on mulberry leaves. In NE India, mulberry cultivation is concentrated mainly in Assam, Tripura, Meghalaya, and Manipur (NEDFi, 2020). The leaf and cocoon producers typically use plantation or garden systems, then harvest and rearing are done indoors to protect from the weather. Mulberry silk is prized for softness and strength, fetching higher market prices than some wild silks.
- **Muga Silk (*Antheraea assamensis*):** A semi domesticated silkworm native to Assam, also some parts of Meghalaya that feeds on forest trees like *Persea bombycina* “som” and *Litsea monopetala* “soalu”) (Tikader et al., 2013). Muga cocoons yield a natural golden-yellow silk unique to NE culture. Muga cocoon rearing traditionally occurs outdoors among home gardens/forest farms in the Brahmaputra

Valley. Muga sericulture has acquired a Geographical Indication (GI) tag due to its Assam exclusivity. Production is labour-intensive and mostly confined to a single season that is univoltine but culturally valued.

- **Eri Silk (*Samia ricini*):** A domesticated wild silkworm reared indoors. Eri larvae feed on castor leaves, botanically known as *Ricinus communis* or other broad-leaf plants such as tapioca. NE India, including Assam, Meghalaya, Nagaland, and Arunachal Pradesh, accounts for ~90% of India's eri cocoons (Chutia *et al.,* 2014). Eri cocoons are open-ended, allowing the moth to escape, hence more specifically called "Ahimsa" or non-violent silk. The yield is lower fineness, but it forms a staple-fibre spun yarn valued for thermal properties in fabrics. The dual-use castor and tapioca crops provide additional income from seeds and tubers.

A minor category is tussar/oak-tussar silks (genus *Antheraea*), usually not significant in NE. The state of Sikkim and Arunachal has small "oak-tussar" cultures such as *Antheraea proylei* on oaks, but the Northeast's silk economy is dominated by mulberry, muga and eri. So, considering these we have primarily focussed on Mulberry, Eri, and Muga.

3.2 Agro-ecological Suitability and Diversity

The NE states span a mosaic of climates and terrains, influencing sericulture. Generally, Assam's floodplain and valley areas receive high rainfall of about 1200–2000 mm and warm humid subtropical climate, which favors mulberry and eri host cultivation castor, tapioca. North eastern hills such as Arunachal, Nagaland, Mizoram, etc. have cooler climates and diverse soils. For example, the hilly regions require cold-tolerant mulberry varieties (e.g. TR-10, BC-2-59) and rearing techniques (Agriculture.Institute, 2023). Soil pH in the region (6.0–7.5) is generally good for mulberry. The varied topography means distinct sericulture zones: Assam plains focus on all three silks, Nagaland and Meghalaya emphasize eri due to its tribal traditions, and Arunachal/Tripura have more mulberry and eri. Climatic suitability studies more specifically species distribution models confirm that *Persea bombycina* forests in other word called as muga host overlap well with wild muga in Assam and parts of Arunachal, but both may shrink under mid-century climate scenarios (Sarma *et al*., 2025)

In summary, the NE's agroecology is in some ways ideal for sericulture that is ample rainfall and forests support eri/muga, and improved mulberry strains exist for rainfed or irrigated sites. However, challenges include annual flooding particularly in Assam valley, erratic monsoons, and winter leaf shortages especially for eri in high altitudes. Host-plant diversity that is existence of alternative feed for eri, or wild food-plants for eri provides resilience**.**

4. THEMATIC SYNTHESIS OF LITERATURE

We now synthesize knowledge by theme, noting evidence strengths and gaps for Northeast sericulture.

4.1 Agronomic and Biological Factors

Climate and Host Plants: Sericulture is climate-sensitive. Mulberry needs moderate temperatures (optimal ~24–28°C) and stable humidity, whereas muga and eri rely on forest ecosystems. Eri silkworms are notably robust: they tolerate varied conditions and have multiple ecotypes in NE (26 ecoraces known) (Gogoi *et al*., 2022). Muga cocoons require specific host trees; reforestation and host plantation of *Persea/Litsea* species is critical. *Litsea monopetala* (soalu) is an excellent substitute host for muga in wild conditions, and its habitat is projected to decline (2040–2060) without adaptation. Recommended agronomy advocates using drought-tolerant mulberry varieties such as BC-2-59 on slopes and improved spacing practices that are 60×60 cm spacing under irrigation or 90×90 cm in rainfed. Flood control and irrigation infrastructure, for instance, small check dams are needed to stabilize leaf production in Assam's plains.

Pests and Diseases: Silkworm health is a major constraint. Documented silkworm diseases, including pebrine, flacherie, and grasserie, regularly cause crop losses (Rabha *et al.,* 2025). NE farmers often lack timely detection and healthy seed stock. Leaf pests such as caterpillars, grasshoppers, and fungal diseases on mulberry also reduce yields. In Eri and Muga, fewer studies exist, but sporadic outbreaks are reported. NE sericulturists rely on traditional remedies (e.g., neem sprays) but often have limited access to modern pest management

(Elanchezhyan & Bojan, 2015). The Central Silk Board has developed disease-free layings (DFLs) of silkworm seed, but distribution and awareness in remote NE areas are uneven. Training on integrated pest/disease management is needed to enhance productivity.

Best Practices: Scientific rearing, including sterile trays, controlled temperature/humidity chambers, and disinfection protocols, is less widespread in NE villages. Traditional "forest" rearing for muga/eri is simple, but yields remain low compared to potential. There is evidence that even modest adoption of improved rearing, such as net houses for the main crop season, use of 2–3 rearings per year for muga indoors, can boost yields by 20–30%. Extension trials suggest, for example, introducing hybrid eri breeds like the high-yield "C2" hybrid of Assam could increase output significantly (Bhattacharyya, 2018). Overall, agro-ecological and breed improvement research is critical to develop mulberry/muga strains adapted to NE microclimates, or eri races that feed on local fodder shrubs.

4.2 Socioeconomic Viability

Costs and Income*:* Sericulture generally demands low capital. Once a mulberry garden or castor patch is established, maintenance costs are modest. In many cases, sericulture incomes rival or exceed those from staple crops. For example, in diverse contexts sericulture incomes often surpass traditional agricultural wages, leading to improved rural standards especially where farmers' share of value chain is strengthened. However, start-up costs for small rearing houses, procurement of DFLs, buying spinning equipment can be barriers for marginal farmers. Credit linkages that is bank loans under state schemes are in place but reaching remote NE hamlets requires effort.

Labour and Seasonality: Sericulture is labour-intensive but provides more steady work than most rainfed crops. Mulberry cropping indoors can be year-round, eri is a multi-crop that is the moth's way to survive in colder months. Muga, however, typically yields one main crop per year, more specifically in the spring season in Assam, creating seasonality gaps. Families often alternate muga with eri or other income, e.g., agriculture, NTFP collection in the off-season. Notably, sericulture is largely a household (family) enterprise; women typically do the rearing and spinning chores, while men may engage in market sales or weaving. Recent data from Assam shows a dramatic shift, over 2013–2023, family involvement in eri sericulture grew (191,566 to 240,350 families) (Hussain *et al.,* 2024). This reflects eri's greater stability due to multi-voltine, indoor, and possibly more efficient labour use.

Livelihood Impact: Beyond direct income, sericulture can lift household resilience. Local case studies highlight improved nutrition, here eri pupae is considered a high-protein food, savings from silk revenue, and community development. In tribal Bodo areas of Assam, for instance, eri culture is a traditional female activity that bolsters both income and women's status. However, the evidence base on poverty alleviation is thin. Quantitative data on how many NE families rise above poverty through silk is largely lacking. More broadly, NE sericulture incomes are currently lower on average than those in major southern mulberry states, due to smaller scales and lower technologies. Historical data suggest Assam's total raw silk production rose from ~2,766 MT in 2013 to ~5,720 MT by 2022 (Hussain, 2024), implying a healthy sector, but this growth is mainly confined to eri/muga segments.

4.3 Value-chain and Market Factors

The sericulture value chain in NE has many small actors and intermediaries. Farmers often sell green cocoons to local chawki rearers or traders; these, in turn, supply cocoons to reeling units or Silk Board facilities. NE silk faces challenges in price transparency and aggregation. Many farmers sell at village levels via informal traders called "agents", receiving low prices due to a lack of market information. Organised co-operatives such as Assam Silk Farmers' Cooperative societies exist but have limited coverage. There are occasional small cocoon markets, yet these don't ensure competitive bids. For muga and eri, the raw silk market is a niche; often, raw cocoons or even reeles are collected by merchants for weaving centres in Guwahati and Kolkata. Silk "gurus," or more specifically called as middlemen dominate pricing, which discourages many farmers. There is an urgent need for strengthened cooperative marketing and e-market platforms.

Processing and Value Addition: The NE has several small raw silk reeling mills, and the Central Muga Eri Research and Training Institute (CMER&TI) in Jorhat provides testing and some

finishing. However, high-end weaving and garment units are rare in the NE that is the textiles often go to Kerala/Karnataka handloom units or export houses. Conversely, there is growing demand both for the domestic and export market for unique NE silks – for example, luxury sari designers prize muga's "luster" and eri's thermal comfort. Brand-building efforts like Silk Mark certification could capture higher margins, but these require scale and quality control.

Price Trends: Silk prices are volatile globally. Farmers in NE have little price risk mitigation. According to a sustainability study, such price swings can deter production investment. Ensuring better price discovery through auctions or cooperative bargaining and perhaps a minimum support price would greatly enhance viability.

4.4 Institutional and Policy Environment

The Central Silk Board (CSB) under the Ministry of Textiles is the apex body for sericulture policy. In recent years, CSB launched Silk Samagra (Phase I & II) with multi-thousand-crore budgets (e.g., ~₹4,679.85 Cr for 2021–26) for integrated sector development (The Magic of Indian Silk, n.d.). Silk Samagra focuses on "backward and forward linkages" and covers R&D, seed production, planting material, infrastructure, reeling machines, and market infrastructure.

At the state level, Assam has been most proactive. It promulgated a Sericulture Policy (2013) explicitly targeting vanya silks and rural jobs. This policy seeks to make Assam a global leader in vanya silk by encouraging scientific practices, quality upgrades, farmer clustering, and marketing infrastructure. Notably, it emphasizes raising women's incomes and clustering reeling/weaving for efficiency. Other states, such as Meghalaya, Nagaland, etc., have smaller schemes but often lack formal policy articulation. In Assam, CSB and state extension agencies run host-plant nurseries of som, *litsea*, castor, mulberry, and silkworm seed multiplication farms. Insurance schemes such as cocoon/parasite insurance have been piloted to protect farmers from crop failure, and that can also help the farmer to receive a better price.

Extension and R&D are mostly through ICAR–Central Muga Eri Research Institute (CMERI, Jorhat) and CSB's institutes. CMERI and CMER&TI develop and disseminate eri/muga technology. For instance, they have identified 26 eri ecotypes and launched high-yield hybrids; and conduct breeder seed supply for muga. Still, technology transfer to far-flung villages is slow. Programs like "Seri-marketing expos" and skill training camps have helped thousands. CSB also conducts area expansion campaigns under schemes such as the cluster approach, village adoption. Quality silkworm seed (DFLs) and planting material, that is, saplings, are central to viability. In NE, these are provided free/subsidized under state and national programs, but many farmers still use old garden stock with declining yields.

Finance and credit support include: (a) crop loans for mulberry/host plantation (some priority sector lending), (b) microcredit via NABARD schemes, and (c) central subsidies (e.g., 50% subsidy on reeling machines). Nonetheless, high transaction costs limit bank penetration in NE villages. Many farmers rely on informal credit or self-help groups.

4.5 Gender, Social Inclusion and Livelihoods

Sericulture in NE is notably inclusive of women and marginalized communities. In Assam's rural communities (Bodo, Mishing, Kachari, etc.), eri and handloom weaving are traditionally women's domains. Across the Brahmaputra valley tribes, girls learn spinning and weaving from childhood. Such female labour intensity means sericulture directly empowers women economically. However, women often lack market or land ownership. They rear cocoons at home, but men handle sales or weaving profits. Ensuring women's cooperatives or joint land titles would improve equity.

Marginalized groups: Tribal and caste minorities predominate in NE sericulture. For instance, the Muga culture was historically confined to tribal households in the upper Assam hills. The industry's GI status (for Muga) helps protect local communities from outside exploitation. Several initiatives (e.g., BC-I beneficiaries, NGO SHG groups) target SC/ST families for host-plant enrichment. Eri's flexible host crop requirement also means land-poor farmers, even women-headed households, can rear it in homestead gardens.

Social impact: Sericulture provides supplementary nutrition that as eri pupae are protein-rich and consumed locally. Cooperative

spinning/weaving groups often become women's self-help groups, fostering literacy and social networks. However, there are equity issues that is witnessed. Middlemen and agents capture a large margin of cocoon value. Also, younger generations increasingly migrate for urban jobs, leaving few youth in sericulture unless livelihood quality improves.

4.6 Environmental and Sustainability Aspects

Sericulture is, in many respects, an environmentally friendly enterprise. It relies on renewable biomass, that is, leaf plants, and can use underutilized land.

Mulberry: Pruned mulberry branches can be composted or fed to cattle, noted in Northeast extension bulletins. Eri: Castor and tapioca, the main eri hosts, are mostly dual-purpose. Castor seeds yield oil, tubers yield food, so crop residues are fully used. Planting these shrubs in fallow or eroded lands can restore soil and prevent degradation. Muga: its hosts are native forest trees, so production inherently conserves forest cover. Indeed, indigenous practice often integrates muga plots in conserved groves.

Sustainability Concerns Exist: Deforestation for expanding mulberry monocultures, common in some NE valleys, can remove other native vegetation. Water use – Mulberry irrigation competes with other crops during dry months. Overuse of chemical fertilizers/pesticides in mulberry plantations could harm local ecosystems. Disease/pesticide trade-off: To combat silkworm disease, some farmers use chemicals that may affect biodiversity. Therefore, organic or low-input approaches are preferable. The literature recommends promoting integrated pest management and organic silkworm rearing to "protect local ecosystems and ensure long-term viability."

Climate Change is an Emerging Threat: Projections for 2040–2060 in NE India indicate shrinking suitable habitat for *Litsea* and wild muga. This could reduce muga silkworm availability, risking the industry. Adaptive strategies such as identifying new host clones, building irrigation for eri, or selecting mulberry clones for heat tolerance are much needed. On the positive side, sericulture sequesters carbon: a study notes that expanding eco-friendly mulberry plantations (e.g., by Resham Sutra NGO) can capture 450+ tons CO_2/yr per 75 acres. Many NE silks are still produced with manual, low-energy processes, giving them a relatively low carbon footprint compared to synthetic fibers.

5. CRITICAL SYNTHESIS AND CROSS-CUTTING ISSUES

Bringing together the above themes, we identify the main constraints and enabling factors across NE sericulture:

- **Strengths/Enablers:** Deep cultural tradition and knowledge, especially in the case of muga/eri, give sericulture a social license and skilled labour base. Ecologically, NE forests and farms are well-suited to eri/muga polyphagous silkworms (multipurpose hosts). Government commitment, like Silk Samagra, state schemes provide substantial funding and infrastructure support. Gender inclusion is a strength: women-led sericulture maximizes labour availability. Furthermore, changing markets have created niche demand like sustainable natural silk, GI-branded products that NE sericulturists can capitalize on.
- **Weaknesses/Constraints:** Productivity remains low. Traditional methods prevail, and modern infrastructure, including hatcheries and reeling units, is sparse outside Assam. Diseases/pests and climate, including floods and droughts, frequently disrupt yields. Poor seed/planting material quality is a common complaint – for instance, lack of high-yielding mulberry varieties for NE conditions, or limited supply of disease-free silkworm stock. Market barriers are severe: farmers have little bargaining power and many are cut off from urban silk markets. Lack of reliable extension education leaves knowledge gaps: e.g. many farmers overuse chemicals or do not practice sanitation. Finally, socio-economic issues for example outmigration, ageing farmer populations threaten the future workforce.
- **Heterogeneity:** Not all NE states or silk types face identical issues. Assam is the powerhouse both in output and schemes, and differs from smaller states. For example, Meghalaya's hill tracts focus on eri and a bit of oak-tussar, but have virtually no mulberry; Arunachal's cold-

climate areas grow some mulberry varieties particularly in Tezpur, Namsai. Mizoram and Nagaland have very small sericulture industries and struggle with connectivity. Even within Assam, districts with a tradition, for example, Barpeta muga gardens, outperform newer areas. Each context has unique institutional support and community profiles.

- **Knowledge Gaps:** Empirical evidence is uneven. Reliable statistics on NE silk on acreage, farmers, and incomes are outdated; the latest CSB publications often lump NE with "rest of country". Few rigorous impact evaluations exist of NE sericulture interventions. Gender analyses beyond basic participation, for instance, decision-making roles, benefit sharing, are scarce. Market studies like consumer segments for NE silk and, value of GI branding are limited. Finally, long-term ecological studies such as water use and, biodiversity impacts of mulberry in NE are thin.

6. SWOT ANALYSIS

Strengths: Traditional expertise in eri/muga, unique GI status of Muga, high rural employment potential, eco-friendly agroforestry alignment, (Gangopadhyay, 2024) especially eri's polyphagy, government schemes (Silk Samagra II, state policies), and R&D infrastructure, women's inclusive labour base, niche market appeal of NE silks, including luxury textiles.

Weaknesses: Low productivity under traditional methods, inadequate quality planting material/seed, disease vulnerability, fragmented value chains with weak market linkages, poor access to credit/insurance, seasonal shortages, particularly in the muga cycle, lack of scale, like smallholder fragmentation limits processing investment; outdated rural infrastructure (Likhila et al., 2025.

Opportunities: Growing domestic and export demand for sustainable, artisanal silk products, potential for integrated farming such as vanya silks on degraded land, host agroforestry, technology adoption for example solar reeling machines, women's empowerment programs, PPP in fashion branding and tourism, value-addition e.g. sericulture by products, pupae oil, climate-adaptive R&D in drought-tolerant varieties, expansion of cooperatives/digital markets (Likhila et al., 2025).

Threats: Climate change, like floods, droughts, altering host plant growth and silkworm life-cycles, market volatility and competition from synthetics, land use change, deforestation, commercial forestry, youth migration reducing labour supply, under-investment if policy focus shifts, disease outbreaks, and policy delays, like funds for schemes may not reach remote areas timely manner (Likhila et al., 2025).

7. RECOMMENDATIONS FOR POLICY AND PRACTICE

Based on the above analysis, we propose the following prioritized actions. Each recommendation notes feasibility (H/M/L) and main actors:

- **State Governments in Assam, NE states:** Develop state sericulture action plans that build on Assam's 2013 framework, with region-specific targets for eri/muga/mulberry area expansion and infrastructure (Feasibility: Medium; Actors: State Sericulture Departments, Agriculture Depts). For example, identify waste/degraded lands for silk host plantations. Invest in rural silk-collection centres and cold storage for cocoons. Strengthen cooperatives and SHGs, especially women's groups, with seed grants and training (Feasibility: High). Provide market support: facilitate state-level silk melas and fairs, link producers to designers. Implement transparent pricing, e.g., e-auction portals. Continue land/forest rights for tribal farmers to expand host-plant gardens.
- **Central Silk Board & Ministry of Textiles:** Expand NE-focused R&D: fund ICAR/CSB projects on eri/muga breeding for climate tolerance, yield, multipurpose host improvement, integrated pest management (Feasibility: High). Enhance CSB extension in NE: more field centres or mobile units, in local languages. Scale up Silk Samagra in NE by earmarking funds for cold storage, mobile demonstration reeling units, and new DFL centres in NE states (Feasibility: High). Coordinate with the Ministry of Rural Development (MGNREGA) to plant silkworm host species on rural works projects, offering dual NRM-income benefits. Facilitate GI certification and branding for NE silks beyond current muga recognition, e.g., "Assam Eri Silk" label.

- **ICAR / Agricultural Universities:** Conduct participatory trials of best-bet practices, e.g., tray rearing for eri, shade net for muga in different NE zones. Study agro-climatic optimization of mulberry varieties. Evaluate business models like cooperatives, contract farming via action research. Support NE-centric sericulture MOOCs and training material in Assamese, Nepali. Collaborate with social scientists to assess the poverty impacts of silk interventions. Establish geo-tagged databases of sericulture farms, host plantations to monitor trends leveraging climate mapping techniques. (Feasibility: Medium.)
- **NGOs and Cooperatives:** Facilitate skill development and micro-enterprise training for sericulture families, like weaving, entrepreneurship. Encourage women's groups to start silk processing or fabric groups, with linkage to fair-trade networks. Pilot novel financial instruments like group lending or microinsurance tailored to sericulture. Partner with technology providers, e.g., Resham Sutra model, to introduce energy-efficient reeling and cleaning machines in villages. (Feasibility: Medium.)
- **Private Sector and Industry:** Invest in joint ventures in NE like silk reeling hubs in Assam or Tripura, possibly through CSR funds. Build partnerships with designer garment brands to create NE silk lines. Provide market intelligence to farmers, like price indices, via mobile apps. Support agro-forestry extension for host plants supplying seedlings, and credit for expansion. Develop import-substitution ventures: e.g., silk-recycling or blends using NE silk, to broaden demand. (Feasibility: Low-Medium; Actors: Textile firms, CSR, social enterprises.)
- **Donors and International Agencies:** Fund cross-cutting initiatives: e.g., climate adaptation grants for muga-eri systems, comprehensive value-chain studies, market/processing bottlenecks, impact evaluations of sericulture interventions. Support participatory research with indigenous communities on traditional sericulture knowledge. Given the gender angle, allocate some aid to "women in sericulture" empowerment projects. (Feasibility: Low; Actors: World Bank, FAO, UNDP, bilateral development agencies, foundations.)

Each recommendation's feasibility reflects existing political will and resources. High-impact actions leverage ongoing schemes or low-cost measures like training. Lower feasibility items require new investment or behaviour change. By assigning actors, we emphasize coordinated action: CSB should lead technical upgrades, while state governments enact enabling policy, and NGOs/private actors plug implementation gaps.

8. CONCEPTUAL RESEARCH AGENDA

To fill knowledge gaps and test interventions, we outline priority research topics and methods by time horizon:

- **Short-term (1–2 years):** Baseline surveys to accurately map current NE sericulture, considering acreage, output, and incomes by state/silk type. Market assessment of NE silk products, like price chains, and consumer preferences. Gender studies, such as participatory rural appraisal in tribal villages, are used to understand decision-making in silk households. Impact evaluations like quasi-experimental of recent interventions: e.g., measure how provision of DFLs or reeling machines changed yields/incomes using survey or administrative data. Such work can use mixed methods, including household surveys, focus groups.
- **Medium-term (3–5 years):** Value-chain analyses like cost-benefit for eri/muga vs alternatives. Agronomic trials on improved varieties and agroforestry linkages like castor + pulses + eri vs monoculture. Operational research on institutional models like cooperatives and contract farming, including the cost-effectiveness of cooperative marketing. Participatory breeding programs with traditional communities. GIS-based studies on host-plant distribution changes. Cross-state comparisons with the help of econometrics to identify success factors in some states vs others. Use technology for real-time data collection in remote areas.
- **Long-term (5–10 years):** Climate-impact modelling on sericulture, which is a scenario of 2050 muga and eri production zones. Genetic research, including genomic tools to develop superior silkworm and mulberry strains for NE ecosystems. Systems-level poverty impact studies (longitudinal) to measure how sericulture

affects rural livelihoods over generations. Development of digital/AI decision-support tools for disease early-warning for silkworm farms. Interdisciplinary studies on sericulture's role in landscape sustainability.

Methodologies should blend quantitative methods such as surveys, RCTs where feasible, GIS/remote sensing, modeling, qualitative methods, value-of-culture, and ethnography. The agenda emphasizes innovation adapted to NE realities and close collaboration with local farmers, co-design research to ensure relevance.

9. CONCLUSION

Northeast Indian sericulture – anchored in eri and muga traditions and supported by some mulberry culture – remains a viable livelihood strategy but faces distinct challenges. Its viability hinges on multiple factors: favourable agro-ecology and strong cultural value on one hand, but on the other, technological gaps and market constraints. This review synthesizes that sericulture in the NE can provide year-round rural income, empower women, and utilize agroforestry landscapes sustainably. To harness these opportunities, coordinated actions are needed: scaling up scientific rearing methods and planting of host plants, strengthening farmer market linkages, and addressing socio-economic needs like credit, training, and inclusion. Policy frameworks like Silk Samagra and state sericulture plans provide a foundation, but must be tailored to NE's heterogeneity. Critical research is needed to generate evidence on what works in these contexts. Evidence indicates that targeted interventions, e.g., disease control programs, improved planting material, and market cooperatives, can significantly boost NE silk outputs. Many claims rely on older data and pilot studies, so updated surveys are essential. In sum, policy and research must advance hand-in-hand to make Northeast sericulture ecologically sustainable, economically profitable, and socially inclusive.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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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