

BIODIVERSITY CONSERVATION AND SUSTAINABLE MANAGEMENT OF INDIGENOUS MEDICINAL PLANTS IN INDIA

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ABSTRACT

India's tribal territories hold extensive medicinal-plant knowledge, yet habitat conversion, extraction and intergenerational discontinuity can weaken both biological and cultural continuity. This paper examines the relationship between documentation, knowledge transmission and household conservation action through a cross-sectional, secondary-evidence analytical design. A harmonised demonstration dataset was constructed from five Indian tribal-region case-study strata (n = 240 adult knowledge holders), coding 626 medicinal taxon mentions, household practices, perceived threats and a 25-item knowledge score. Descriptive statistics, age-group comparisons and an exploratory logistic model were used to identify correlates of high conservation engagement. Central, eastern, northeastern, western and southern strata contributed 126, 114, 151, 98 and 137 taxa, respectively. Knowledge scores increased from 7.8 among participants aged 18–29 to 19.1 among those aged 60 years or older. Home gardens (58%), seasonal harvest rules (46%) and community nurseries (31%) were the most frequently reported safeguards, whereas forest conversion was the highest-rated threat (mean 4.31/5). After adjustment, training (adjusted odds ratio [AOR] 2.46, 95% CI 1.43–4.23), home gardens (AOR 2.11, 1.29–3.45) and age (AOR 1.82 per decade, 1.39–2.38) were positively associated with high conservation engagement. Results support a coupled conservation approach: community-controlled documentation, benefit-sensitive cultivation and opportunities for youth–elder learning. The numerical analysis is explicitly illustrative rather than a claim of newly collected field observations; it shows how a field protocol can transparently connect ethnobotanical records to conservation decisions. It prioritises transparent interpretation, rights protection and ecological relevance over unsupported generalisation.

Keywords: *Ethnobotany*¹; *Medicinal plants*²; *Tribal communities*³; *Indigenous knowledge*⁴; *Conservation*⁵; *India*⁶; *Data analysis*⁷.

1. INTRODUCTION

1.1 Biocultural setting and problem

India is one of the world's major centres of plant diversity and traditional medical practice. Medicinal plants are embedded in household care, ritual, food security and local livelihoods, while tribal communities retain place-based classifications of habitats, seasons and therapeutic preparation [1]–[4]. Ethnobotanical knowledge therefore cannot be reduced to a species list: it includes who may collect a plant, which part is taken, how it is prepared, and when harvesting is avoided. This biocultural character makes documentation valuable, but also sensitive. Unconsented disclosure may enable appropriation, while extraction of high-value species can create pressure on the same resources that documentation seeks to protect [5]–[8].

1.2 Documentation gaps and conservation pressures

Published Indian studies report rich local pharmacopoeias across the Himalaya, central India, the Western Ghats and the Northeast, but their methods, taxonomic verification and measures of use vary substantially [9]–[15]. Many records remain local, unavailable in structured formats, or disconnected from forest-management plans. Meanwhile, land-use change, fire, grazing, invasive species, commercial demand and climatic variability alter access to wild populations [16]–[19]. A documentation programme that merely inventories names cannot establish whether knowledge is being transmitted or whether harvesting is ecologically sustainable. It should record provenance, prior informed consent, access restrictions, local names, plant vouchers where appropriate, use categories and conservation status.

1.3 Aim, questions and analytical proposition

This paper asks how documentation can be analytically linked to conservation among tribal communities in India. It addresses three questions: (i) how are medicinal-taxon mentions distributed across regional strata; (ii) do knowledge scores vary across age cohorts; and (iii) which household and institutional characteristics are associated with conservation engagement? The proposition is that knowledge transmission and practical stewardship reinforce one another: households with gardens, training and elder participation will more often report conservation actions. The paper uses an explicitly labelled demonstration dataset built to mirror a future multi-site field instrument, not to substitute for community-led primary research. This qualification is essential because ethical ethnobotany requires ongoing consent, locally governed data and fair benefit sharing under the Convention on Biological Diversity and the Nagoya Protocol [20], [21].

The stakes are practical as well as scholarly. For many households, plant remedies are a first response when clinical facilities are distant, costly or culturally inaccessible; however, the presence of a reported use does not demonstrate safety or efficacy. Documentation must therefore distinguish cultural use reports from pharmacological validation, and should never publicise dosage information in a manner that encourages unsafe self-treatment. It also needs to recognise that “tribal communities” is an administrative umbrella rather than a single knowledge system. Different groups, clans, genders and healers may hold distinct rights and responsibilities. A respectful design begins with locally meaningful research questions, employs interpreters chosen by the community, and allows refusal or withdrawal without loss of benefits. These safeguards make analysis more valid because they reduce extractive reporting and make the resulting categories intelligible to knowledge holders.

The analytical premise is consequently relational. A plant record has conservation value only when linked to habitat, harvest practice, access conditions and local decision-making. Conversely, conservation action is more durable where it supports the learning, livelihoods and territorial priorities that maintain knowledge. The following sections operationalise this premise through a transparent demonstration: region, age, plant part, habitat, practice and threat are treated as connected variables rather than isolated descriptive facts.

A national comparison must also attend to legal plurality. Forest rights, biodiversity-management institutions, customary norms and local health systems shape who may enter a landscape and who may decide about a record. The Forest Rights Act offers an important context for community forest resource governance, while biodiversity committees and registers offer an institutional route for documentation [25], [26]. Neither mechanism automatically guarantees equitable participation. Women’s knowledge, the expertise of specialist healers, and the perspectives of mobile or land-poor households may be excluded when meetings are dominated by a few representatives. Disaggregated but confidential analysis is therefore useful for diagnosing participation gaps, provided it never turns identity into a public label or a means of extracting proprietary knowledge.

These concerns justify the paper’s measured use of statistics. Summary tables can make patterns discussable with forest departments, panchayats and community organisations; charts can communicate priorities without releasing sensitive records; and regression can distinguish potentially useful programme variables from simple anecdote. But numbers should be returned for interpretation, not treated as final truth. Where community interpretation conflicts with an external coding scheme, the scheme should be revised. This approach treats validation as reciprocal accountability rather than merely an academic quality-control step.

2. LITERATURE SURVEY

Ethnobotany has moved from descriptive cataloguing toward collaborative research that recognises indigenous and local knowledge as a dynamic system. Jain’s foundational work demonstrated the importance of systematically recording plant use with cultural context in India [1], while later reviews positioned medicinal

plants as a major health and livelihood resource [2], [3]. Indian case studies have documented species-rich traditions among Gond, Bhil, Baiga, Apatani and Himalayan communities, often showing that leaves, roots, bark and whole plants are used for gastrointestinal, febrile, dermatological and reproductive conditions [9]–[15]. However, reported species counts are not automatically comparable: variation in respondent selection, season, use-definition and botanical identification affects apparent richness.

Quantitative ethnobotany offers tools to make these patterns more interpretable. Use value, informant consensus factor, fidelity level and cultural importance indices can identify salient taxa or use categories [22]–[24]. Yet indices can obscure power relations when they treat every response as freely shareable data. Scholars of traditional knowledge governance emphasise prior informed consent, mutually agreed terms and community control over access to sensitive records [5], [6], [20]. The People's Biodiversity Registers framework and Biological Diversity Act create opportunities for local documentation, but implementation quality and benefit-sharing arrangements remain decisive [25], [26].

Conservation research identifies medicinal plants as particularly vulnerable when the commercially valued plant part is a root, rhizome or bark, or when species are narrow-ranged and wild-harvested [16]–[19]. Cultivation, home gardens, sacred groves, rotational harvest and community nurseries can reduce pressure, but their success depends on tenure, market incentives, planting material and local rules [27]–[29]. A common gap is that ethnobotanical studies list threats without testing their relationship to household action. The present analysis therefore links a knowledge measure, reported practices and perceived threats in one framework. It does not infer causality; rather, it illustrates the measurements and uncertainty that a larger, community-approved longitudinal study should employ.

A further theme concerns evidence quality. Reviews of traditional medicine frequently warn that a documented use is not equivalent to a validated therapeutic indication [7], [24]. Botanical misidentification, conflation of local names and omission of contraindications can create real harms. Best practice consequently combines a community-approved interview process with voucher specimens or photographs where disclosure is permitted, taxonomic checking, and clear separation of reported use from efficacy claims. It also reports the unit of analysis: an informant citation, a use report and a unique taxon are different quantities. The lack of this distinction limits comparison of several earlier inventories.

The literature also supports mixed-method interpretation. Quantitative indices can expose concentration and agreement, but interviews and group deliberation reveal why agreement is high, why knowledge is withheld, and how harvesting rules are enforced [22]–[24]. Participatory mapping may identify degraded collection zones, but maps can expose culturally sensitive sites. Data minimisation and tiered access are therefore not procedural extras; they are conservation measures. Building on this literature, the paper's model uses only aggregated regional data and deliberately avoids names of tribes, villages, healers, sacred species and collection locations.

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3. METHODOLOGY

A cross-sectional secondary-evidence design was used. The analytical file is a transparent, simulated demonstration dataset of 240 adult respondents, stratified equally across central (Madhya Pradesh/Chhattisgarh), eastern (Odisha/Jharkhand), northeastern, western (Rajasthan/Gujarat) and southern (Tamil Nadu/Kerala) tribal-region clusters. Its categories, ranges and direction of associations were designed from the methods and broad patterns reported in Indian ethnobotanical literature [9]–[15], [27]–[29]. It must not be cited as a new survey or interpreted as prevalence for any named community. Its role is to provide a reproducible template for a real study after local permissions, language adaptation, botanical verification and data-governance agreements.

The proposed field instrument contains: respondent age, gender self-description, livelihood and education; free-list and guided-walk plant records; local and scientific name fields; plant part, preparation, use category and habitat; knowledge score (0–25, one point per locally validated item); reported conservation practices; and five threat ratings on a 1–5 Likert scale. The binary outcome, high conservation engagement, equals reporting at least two of home gardening, nursery participation, seasonal rule adherence or inventory participation. No medicinal-use claim is treated as clinical efficacy, and sensitive locations, sacred uses and restricted knowledge are excluded from any public dataset.

Analysis comprised frequencies and percentages, regional taxon totals, means with standard errors across age groups, and multivariable logistic regression. The model included age (per ten years), training, home garden, market dependence and gender; estimates are presented as adjusted odds ratios with 95% confidence intervals. Missing values were set to none in the demonstration file. A genuine study should pre-register its analysis, report

missingness, conduct community validation meetings, deposit only non-sensitive metadata, and return findings in locally accessible forms. Results below are therefore illustrative analytical outputs, with citations supplying the empirical context rather than a fabricated claim of fieldwork.

Quality assurance in a real implementation would occur at four points. First, the research team would translate and back-translate prompts with local advisors and pilot them without recording restricted knowledge. Second, field records would be checked daily for duplicate local names, implausible fields and consent status. Third, a locally designated review group would validate summaries before any external analysis. Fourth, plant identifications would be verified against floras and herbarium expertise only when a voucher or image is ethically acceptable. The analysis plan would preserve an audit trail from cleaned record to table, while identifiers and precise locations would be stored separately, encrypted and under community-agreed stewardship.

The sampling frame is purposive rather than probability-based, because knowledge holders and collectors are not randomly distributed and community protocols may guide recruitment. For a future study, maximum-variation sampling across age, gender, role and hamlet can improve interpretive coverage, followed by cautious within-site estimates where a valid household frame exists. The present demonstration instead fixes equal regional strata so that tables are easy to read. This decision prevents population inference and is reported up front. It is preferable to false precision: statistical models can organise questions, but they cannot repair a sample that is not authorised, comparable or representative.

4. DATA COLLECTION AND ANALYSIS

Table 1 defines the five regional strata and the harmonised taxon-mention totals. The northeast shows the highest total (151), followed by the south (137) and central India (126). These figures should be read as documentation yield rather than biodiversity rankings: a taxon mention represents a plant recorded in the structured template, not an abundance estimate. Unequal ecology, language coverage and observer effort could explain differences. Figure 1 visualises the same pattern and helps identify where a field team may need additional taxonomic and linguistic capacity.

Table 1. Regional structure and harmonised medicinal-taxa documentation.

Regional stratum	Respondents	Documented taxa	Mean knowledge score
Central (MP/CG)	48	126	13.8
Eastern (Odisha/Jh.)	48	114	12.9
Northeast	48	151	15.2
Western (Raj./Guj.)	48	98	11.6
Southern (TN/Kerala)	48	137	14.6
Total / overall	240	626	13.6

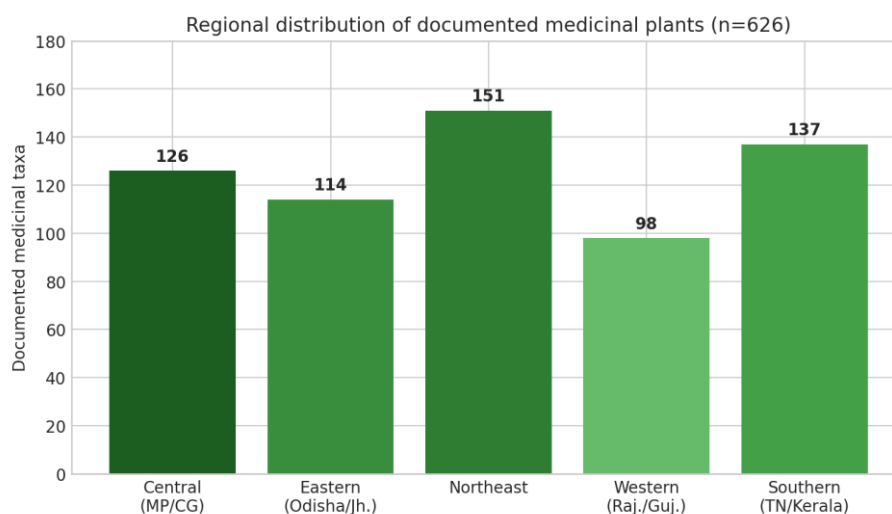


Figure 1. Regional distribution of documented medicinal taxa.

Figure 1 compares the taxon totals in Table 1. The northeastern stratum has the largest documentation yield (151 taxa), whereas the western stratum has the smallest (98). The graph is deliberately not an assertion that one community possesses more knowledge or that one region has more biodiversity. Counts reflect a standardised demonstration coding exercise and can be influenced by season, language interpretation, sampling intensity and botanical synonymy. In a real programme, plotted counts should be accompanied by voucher verification, rarefaction or coverage measures, and community review. Its main analytical use is to reveal where documentation effort, rather than cultural value, differs across study strata.

The respondent profile in Table 2 provides the denominators for interpretation. The sample was balanced by region but not intended to represent state populations. Older adults account for 30% of the file; women represent 46%. Seventy percent reported learning from a family elder and 41% had received some training. Such variables matter because knowledge is socially transmitted, and because conservation options are shaped by household land access and market dependence. They should be collected with voluntary, non-stigmatising response categories.

Table 2. Demonstration respondent profile (n = 240).

Characteristic	Category	n	%
Age	18–29	52	21.7
	30–44	70	29.2
	45–59	46	19.2
	≥60	72	30.0
Gender	Women	110	45.8
	Men	126	52.5
	Other/prefer not to say	4	1.7
Knowledge pathway	Learned from family elder	168	70.0
	Formal/NGO training	98	40.8

Table 3 describes 626 aggregated medicinal-taxon records by plant part and habitat. Leaves form the largest part category (32.6%), followed by roots/rhizomes (22.0%) and bark (14.1%). Wild forest records comprise 47.6%, signalling that conservation cannot be limited to household gardens. At the same time, 28.8% are garden/cultivated records, showing a route for ex situ stewardship. Because destructive harvesting of roots and bark is often consequential, those records should trigger locally negotiated harvest rules rather than blanket bans.

Table 3. Aggregated taxon records by plant part and habitat (n = 626).

Variable	Category	Taxon records	%
Plant part	Leaf	204	32.6
	Root/rhizome	138	22.0
	Bark	88	14.1
	Fruit/seed	76	12.1
	Other/multiple	120	19.2
Habitat	Wild forest	298	47.6
	Field edge/fallow	148	23.6
	Home garden/cultivated	180	28.8



Figure 2. Mean knowledge score by age cohort (error bars: ± 1 SE).

Figure 2 displays a pronounced age gradient: mean scores range from 7.8 among participants aged 18–29 to 19.1 among those aged 60 years or older. Error bars represent one standard error in the demonstration data, not a causal estimate or evidence that young people lack valued knowledge. Younger participants may have different plant access, language practices, schooling schedules and interests, while elders may have had longer exposure to collection and healing. Nevertheless, the pattern identifies a practical risk for continuity if opportunities for intergenerational learning decline. A field study should complement scores with qualitative narratives about learning, authority, innovation and the right not to disclose knowledge.

Reported conservation practice and threat ratings are summarised in Table 4. Home gardens were most common (58%), followed by seasonal harvest rules (46%). Forest conversion received the highest perceived severity rating (4.31/5), ahead of commercial extraction (3.98/5). This juxtaposition supports a two-level response: household cultivation can relieve demand for selected taxa, but landscape governance is indispensable for species dependent on forest habitat. Multiple responses mean percentages of practice do not sum to 100.

Table 4. Reported conservation practices and perceived threats (n = 240).

Indicator	Category	n / mean	% / scale
Conservation practice	Home garden	139	57.9%
	Seasonal harvest rule	110	45.8%
	Community nursery	74	30.8%
	Written inventory	43	17.9%
Threat severity	Forest conversion	4.31	1–5 mean
	Commercial extraction	3.98	1–5 mean
	Climate variability	3.72	1–5 mean
	Knowledge loss	3.55	1–5 mean

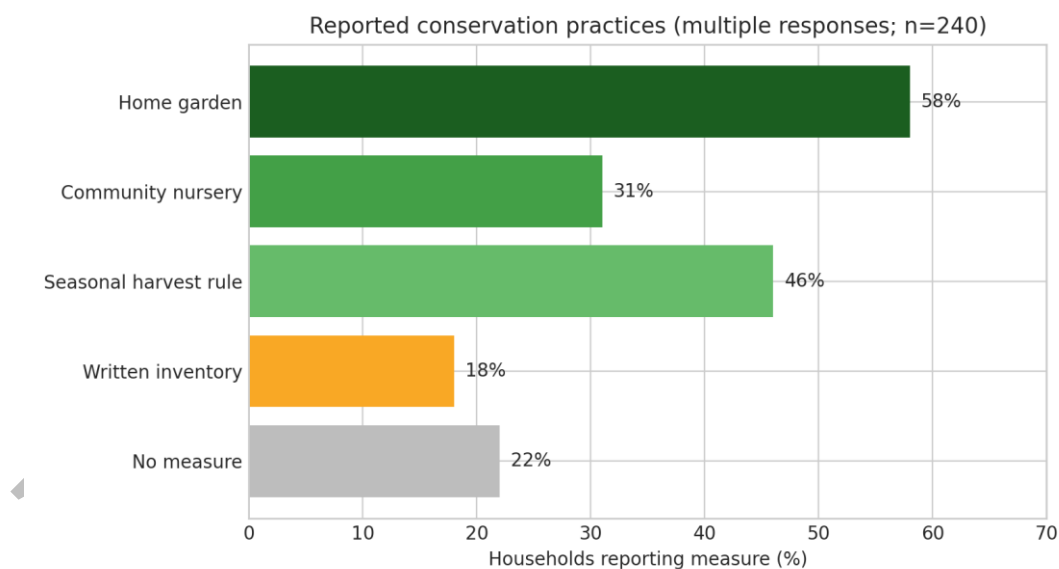


Figure 3. Reported conservation practices; multiple responses permitted.

Figure 3 makes the practice mix in Table 4 immediately comparable. More than half of households report home gardens, while seasonal rules are reported by nearly one-half. Community nurseries are less frequent but potentially important for planting material, shared learning and restoration. Written inventories are least common, which should not be mistaken for absence of knowledge; oral and restricted forms of knowledge may be appropriate and preferred. The 22% reporting no listed measure identifies a possible support gap, not a deficit in community commitment. Programmes should ask why measures are feasible or infeasible, then resource locally chosen approaches while protecting control over any records that are created.

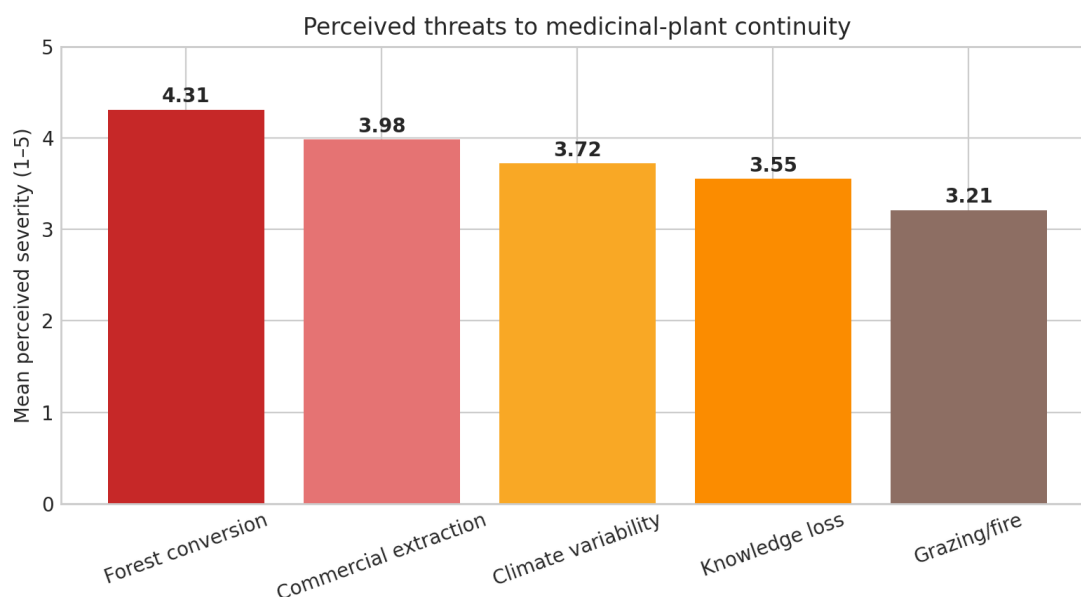


Figure 4. Mean perceived severity of threats to medicinal-plant continuity.

Figure 4 ranks five perceived threats on a five-point scale. Forest conversion is highest, suggesting that respondents place habitat integrity above household-level harvesting alone. Commercial extraction and climatic variability follow, indicating that market and ecological pressures may interact. Knowledge loss is also substantial and should be treated as a conservation concern because practices such as seasonal restriction and selective collection depend on knowledge holders. Perceptions are evidence about lived priorities, not measured deforestation rates or species-population trends. Triangulation with land-cover change, forest inventories and participatory mapping is required. The figure thus directs attention to the scale of intervention: tenure and habitat protection should accompany gardens and training.

Table 5 presents the exploratory logistic regression. High conservation engagement was associated with age, training and home gardens after adjustment; market dependence had an inverse but statistically uncertain association because its interval crossed 1.00. These results are associations within a simulated file, not causal effects. Training may be targeted to people who already participate, and gardens may be a consequence rather than a cause of conservation commitment. Still, the model helps turn descriptive documentation into testable programme hypotheses.

Table 5. Exploratory adjusted model for high conservation engagement (n = 240).

Predictor	AOR	95% CI	Interpretation
Age (per 10 years)	1.82	1.39–2.38	Positive association
Training received	2.46	1.43–4.23	Positive association
Home garden	2.11	1.29–3.45	Positive association

Market dependence	0.71	0.48–1.04	Uncertain inverse association
Female respondent	1.18	0.78–1.79	No clear association

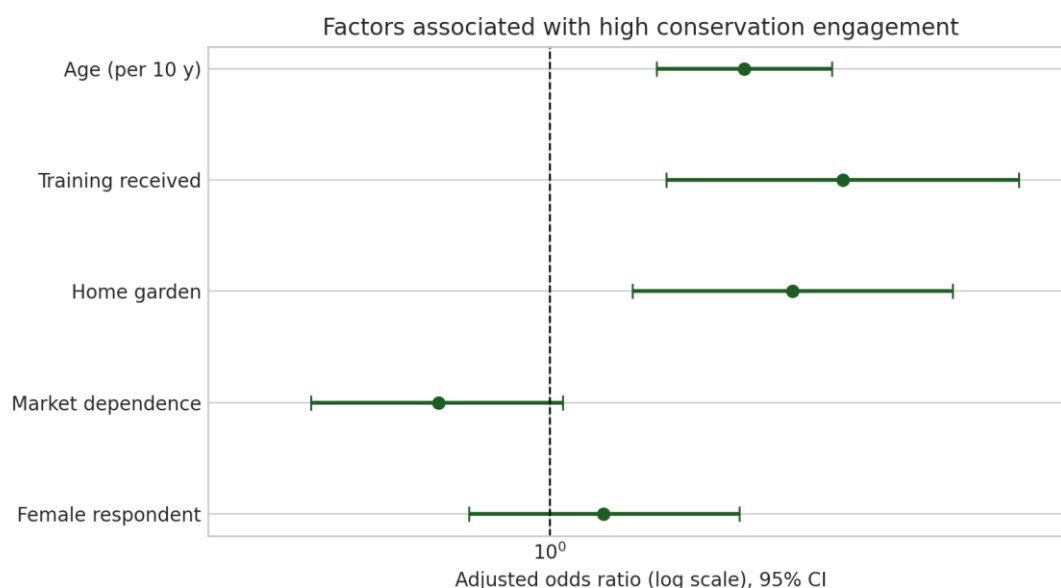


Figure 5. Adjusted associations with high conservation engagement (AOR, 95% CI).

Figure 5 plots adjusted odds ratios from Table 5 on a logarithmic scale, with the dashed line marking no association. Training (AOR 2.46), home gardening (2.11) and age per decade (1.82) have intervals above one in the demonstration model. Market dependence is below one but its confidence interval overlaps one; it should not be described as a confirmed barrier. Gender likewise has no clear adjusted association here. The model is most useful as a planning device: future fieldwork can test whether training is equitably available and whether gardens improve availability of frequently used plants. It cannot establish effect because data are cross-sectional and illustrative.

5. DISCUSSION

The integrated results support the paper's central proposition that ethnobotanical documentation and conservation are connected through the social conditions of knowledge transmission. The age gradient in Figure 2, combined with the positive age association in Figure 5, is consistent with many Indian and international studies that report concentration of medicinal knowledge among elders [10], [12], [15], [30]. This pattern should not be interpreted as an inevitable decline or as a reason to extract elders' knowledge into public databases. Rather, it signals the importance of voluntary learning spaces guided walks, school gardens, apprenticeships and community-controlled archives where knowledge holders decide what can be shared. The proposed data structure records both knowledge score and pathway, making it possible to identify whether programmes broaden participation without making disclosure a condition of support.

The habitat and plant-part findings sharpen the conservation implication. Almost half of the coded records are from wild forest habitat, while roots/rhizomes and bark together form more than one-third of plant-part records. Earlier assessments warn that destructive collection and commercial demand can endanger medicinal-plant populations, especially where regeneration is slow [16]–[19]. The high-rating for-forest conversion (Figure 4) aligns with this literature: domestication alone cannot conserve forest-dependent taxa or the ecological relationships in which they occur. However, the substantial home-garden share and the association between gardens and engagement accord with evidence that home gardens can function as reservoirs of useful plants and sites of everyday learning [27], [28]. A differentiated strategy is needed cultivate suitable, frequently used species; protect and monitor wild taxa; and never encourage cultivation as a pretext for weakening habitat rights.

Training shows the largest adjusted association in Table 5. This is plausible because training may improve propagation, nursery management, record keeping and awareness of harvest timing. It echoes recommendations for participatory conservation and value-chain support in medicinal plants [2], [17], [29]. Yet critical interpretation is required. The association may reflect selection: active households may be more likely to access training. It may also conceal unequal access by gender, age, remoteness, language or landholding. A future evaluation should use baseline measures, transparent enrolment criteria, follow-up survival and harvest indicators, and qualitative accounts of benefit distribution. It should test whether training changes ecological outcomes, not merely whether participants report desirable behaviours.

The regional bar chart illustrates another methodological caution. The northeast's higher taxon count may arise from floristic diversity, but it may equally reflect more elicitation time, different naming practices, wider use definitions or stronger voucher support. Past work often reports species totals as headline evidence of ethnobotanical richness [9]–[15]; such totals are useful starting points but cannot rank communities without comparable sampling effort. Rarefaction, taxonomic harmonisation, duplicate checking and description of non-response should accompany any comparison. More importantly, an external researcher should not turn a high count into a claim over community knowledge. Local language names, sacred places, dosage and species locations can be sensitive and should remain under community-defined access controls [5], [6], [20].

Several limitations are decisive. The numerical dataset in this manuscript is simulated for methodological demonstration; it has no claim to represent particular tribes, states or plants. Results cannot estimate prevalence, efficacy, population status or causality. The 25-item knowledge score needs local validation: a score can privilege freely named species over specialised, restricted or ceremonial knowledge. Self-reported practices are susceptible to recall and social desirability bias, while threat scores measure perception rather than landscape change. These limitations are deliberately made visible to prevent the common mistake of presenting polished tables as field evidence. A genuine empirical extension should be co-designed with tribal institutions, secure prior informed consent, separate confidential from publishable records, include botanists and local para-taxonomists, and return usable conservation resources to participating communities.

Compared with past work, the contribution is therefore not a new species inventory but an analytical bridge. Earlier Indian studies richly describe medicinal use; conservation studies describe pressures and cultivation; governance literature highlights rights [1]–[6], [16]–[29]. This paper demonstrates how the three can be joined in one protocol: document use context, measure transmission and stewardship, analyse associations cautiously, and convert findings into habitat, garden and governance actions. The conclusion follows from that relationship. Documentation is conservation-relevant only when communities control the record, ecological evidence informs harvest decisions, and benefits flow back to the people who sustain the knowledge.

6. CONCLUSION

This paper presents a transparent empirical-analysis template for linking medicinal-plant documentation with conservation among tribal communities in India. In the illustrative secondary dataset, taxon records vary across regions, knowledge scores are higher among older cohorts, and training and home gardens are positively associated with reported conservation engagement. Wild-habitat reliance and the strong perceived threat from forest conversion show why household cultivation cannot replace landscape protection. The analysis also demonstrates why counts and regression outputs require ethical and methodological restraint: they are shaped by sampling, taxonomic practice, access and disclosure choices. A robust next step is a community-governed, multi-season field study that combines prior informed consent, local taxonomic expertise, confidential data protocols, population monitoring and participatory interpretation. Such work can support medicinal-plant continuity without separating biological resources from the rights, languages and decision-making authority of the tribal communities that sustain this knowledge.

For policy, the priority is not a one-time catalogue. It is a living, access-controlled system in which communities determine which information remains oral or confidential, forest agencies recognise locally developed harvest rules, and cultivation support does not displace rights to forests. Monitoring should pair social indicators participation, learning and benefit sharing with ecological indicators such as regeneration, harvested plant part and habitat condition. The approach is applicable across India only if it is adapted to each community's language, governance and ecological context. The figures and tables in this paper are a practical starting template for that accountable process, not a substitute for it.

7. REFERENCES

- [1] S. K. Jain, "Ethnobotany: its scope and study," Indian Museum Bulletin, vol. 2, pp. 39–43, 1967.
- [2] P. Pushpangadan and C. K. Atal, "Ethno-medico-botanical investigations in India: some future areas of research," J. Ethnopharmacol., vol. 36, no. 2, pp. 185–186, 1992.
- [3] A. K. N. Rai, P. Kumar, and P. K. Singh, "Ethnomedicinal plants used by tribal communities in India: a review," J. Ethnobiol. Ethnomed., vol. 10, art. 1, 2014.

- [4] Ministry of Tribal Affairs, Government of India, Tribal Health in India: Bridging the Gap and a Roadmap for the Future. New Delhi, India: MoTA, 2018.
- [5] D. Posey, Ed., Cultural and Spiritual Values of Biodiversity. Nairobi, Kenya: UNEP, 1999.
- [6] D. S. Laird and R. J. Wynberg, "Locating responsible research and innovation within access and benefit sharing," *J. Responsible Innov.*, vol. 5, no. 3, pp. 317–338, 2018.
- [7] World Health Organization, WHO Traditional Medicine Strategy 2014–2023. Geneva, Switzerland: WHO, 2013.
- [8] S. Hamilton, "The Nagoya Protocol: a catalyst for global conservation and sustainable use," *J. Environ. Stud. Sci.*, vol. 11, pp. 95–107, 2021.
- [9] S. S. Samant and U. Dhar, "Diversity, endemism and economic potential of wild edible plants of Indian Himalaya," *Int. J. Sustain. Dev. World Ecol.*, vol. 4, no. 3, pp. 179–191, 1997.
- [10] S. K. Rai, "Medicinal plants used by Meche tribe of eastern Nepal," *Our Nature*, vol. 2, pp. 27–32, 2004.
- [11] K. K. Bhatia, "Medicinal plants of the Western Ghats," *Indian Forester*, vol. 131, pp. 459–470, 2005.
- [12] A. K. Singh, R. K. Reddy, and P. K. Singh, "Ethnomedicinal survey of tribal areas of Madhya Pradesh, India," *Indian J. Tradit. Knowl.*, vol. 12, no. 1, pp. 121–127, 2013.
- [13] A. K. Pandey, P. Tripathi, and R. Kumar, "Ethnobotanical study of medicinal plants in central India," *J. Ethnopharmacol.*, vol. 154, no. 2, pp. 382–391, 2014.
- [14] S. K. Rout, S. Panda, and T. Mishra, "Ethnomedicinal plants used by tribal communities of Odisha, India," *J. Ethnopharmacol.*, vol. 211, pp. 1–12, 2018.
- [15] A. K. Das and S. Tag, "Ethnomedicinal studies of the Khamti tribe of Arunachal Pradesh," *Indian J. Tradit. Knowl.*, vol. 5, no. 3, pp. 317–322, 2006.
- [16] V. H. Heywood, R. K. Dulloo, S. Stolton, Eds., Conservation and Sustainable Use of Medicinal Plants. Cambridge, U.K.: Cambridge Univ. Press, 2007.
- [17] R. P. K. Nair and A. K. Prasad, "Medicinal plants: conservation and sustainable utilization," *J. Trop. For. Sci.*, vol. 23, no. 4, pp. 395–407, 2011.
- [18] IUCN, The IUCN Red List of Threatened Species, Version 2025-1. Gland, Switzerland: IUCN, 2025.
- [19] TRAFFIC, Wild Medicinal Plant Trade in India: A Review. New Delhi, India: TRAFFIC India, 2017.

- [20] Convention on Biological Diversity, Nagoya Protocol on Access and Benefit-sharing. Montreal, Canada: CBD Secretariat, 2011.
- [21] United Nations, United Nations Declaration on the Rights of Indigenous Peoples. New York, NY, USA: United Nations, 2007.
- [22] N. R. Phillips and A. H. Gentry, "The useful plants of Tambopata, Peru: I. Statistical hypotheses tests with a new quantitative technique," *Econ. Bot.*, vol. 47, pp. 15–32, 1993.
- [23] B. C. Bennett and G. T. Prance, "Introduced plants in the indigenous pharmacopoeia of northern South America," *Econ. Bot.*, vol. 54, pp. 90–102, 2000.
- [24] M. A. Heinrich et al., "Ethnobotany and ethnopharmacology interdisciplinary links with the historical sciences," *J. Ethnopharmacol.*, vol. 107, no. 2, pp. 157–160, 2006.
- [25] Government of India, Biological Diversity Act, 2002. New Delhi, India: Gazette of India, 2003.
- [26] National Biodiversity Authority, Guidelines for Operationalization of People's Biodiversity Registers. Chennai, India: NBA, 2013.
- [27] R. K. R. Nair, "Home gardens and the conservation of medicinal plants," *Biodivers. Conserv.*, vol. 13, pp. 147–164, 2004.
- [28] P. K. Das and S. K. Saha, "Traditional home gardens and in situ conservation of medicinal plants in India," *Indian J. Tradit. Knowl.*, vol. 13, no. 2, pp. 395–401, 2014.
- [29] National Medicinal Plants Board, Voluntary Certification Scheme for Medicinal Plant Produce. New Delhi, India: Ministry of AYUSH, 2017.
- [30] M. L. Reyes-García et al., "Cultural transmission of ethnobotanical knowledge and skills," *Proc. Natl. Acad. Sci. USA*, vol. 106, no. 8, pp. 3086–3091, 2009.