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Biodiversity Assessment Of Medicinal Plants In Degraded Forest Ecosystems: Strategies For Conservation

Dr. Sudhamayee Behura[1]*, Lakshmikanth HM[2], Hyzil J B[3], Dr Rashmi Sumanth[4], Sakthivigneswari Ganesan[5]

[1]*HOD, Raghunathjew Degree College, Deulasahi, Cuttack, 08, Email: sudhamayee_behura@yahoo.co.in
[2]Research Scholar, Garden City University, Bangalore, Karnataka, India, Email Id: hmkanth76@gmail.com
[3]Assistant professor, Department of Zoology, Govt College for Women, Kerala university, Trivandrum, 0009-0001-2941-6566, Email Id: hyzilsyam@gmail.com
[4]CEO of Aerione Bharat, Bangalore, Karnataka, Email Id: rashmisumanth@gmail.com
[5]Assistant Professor, Department of Botany, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore 641 043, Email Id: sakthipaperwork@gmail.com
*Corresponding Author: Dr. Sudhamayee Behura
*HOD, Raghunathjew Degree College, Deulasahi, Cuttack, 08, Email: sudhamayee_behura@yahoo.co.in

Abstract
Traditional health systems rely heavily on medicinal plants to provide treatments for numerous conditions, especially among rural and indigenous people. Environmental degradation, specifically in tropical forests, represents a big threat to these precious assets. It seeks to evaluate the biodiversity of forest-degraded medicinal plants, specifically the effect of forest degradation on species diversity, ecological distribution, as well as ethnobotanical value. Stratified random sampling was applied at three levels of forest degradation (severe, moderate, and low) in the Nallamala forest range, Andhra Pradesh, India. Diversity and ecological parameters were measured using indices including Shannon-Wiener, Simpson's, and Informant Consensus Factor (ICF). Species richness, frequency, density, and Importance Value Index (IVI) were noted, and multivariate analysis (PCA and NMDS) was utilised to represent species-environment relations. 112 medicinal plant species were recorded in total, and species richness and diversity fell drastically in the more degraded sites. Dominant taxa like Andrographis paniculata and Tinospora cordifolia had high ecological plasticity and cultural significance. Ethnobotanical information revealed excellent informant consensus for digestive disorders. The study points to the necessity of conservation efforts that bring together ecological and cultural understanding, with a focus on the role of degraded forests as viable places for preservation and rehabilitation.

Keywords: *Medicinal Plants, Biodiversity, Forest Degradation, Conservation, Ethnobotany.*

INTRODUCTION

Medicinal plants have played a central role in traditional health care systems and cultures worldwide for centuries. For many rural and indigenous populations, they continue to be the first point of call for medicine, providing low-cost and readily accessible treatments for conditions from the common cold to cancer. Their importance transcends ethnomedicine into contemporary pharmacology, with many pharmaceuticals derived from or modelled on bioactive molecules from medicinal plants. This vital function in public health, especially in developing nations, is increasingly threatened by mounting environmental stresses [1], [2]. Tropical forests, which contain most medicinal plant diversity, are suffering acute degradation due to deforestation, habitat fragmentation, overexploitation, land conversion for agriculture, and urbanization without controls [3]. These human activities not only diminish the density of medicinal species but also compromise the ecological networks that maintain their regeneration, distribution, and chemical composition [4]. Across the world, loss of biodiversity and species decline have accelerated to alarming levels, with tropical forests experiencing some of the highest rates of habitat disturbance and species loss. This is particularly troublesome in regions of high diversity like the Indian subcontinent, which is home to thousands of medicinal plant species in its diverse forest ecosystems. Here, not only is degradation a cause of biodiversity simplification, but also a significant impediment to conserving biocultural heritage [5]. When forests are cut or disturbed, those medicinal plants that are ecologically stressed, sensitive, or habitat-specific are the first to vanish. The loss of traditional knowledge further aggravates the loss since the younger generations move away from ethnobotanical use, and oral transmission decreases [6]. The degradation of ecosystems thus leads to a double crisis: loss of biodiversity and erosion of cultural knowledge systems that have evolved in tandem with these landscapes over centuries [7]. In the face of an increasing literature on biodiversity loss and ecosystem degradation, the particular evaluation of medicinal plant diversity in degraded forests is under-researched. Numerous ecological studies have emphasized timber species or overall floristic make-up, usually neglecting the functional and cultural value of medicinal taxa [8], [9]. Similarly, conservation models have centered on protected areas and unaltered habitats, eclipsing degraded or secondary forests as much underappreciated and underutilized resources [10]. These transitional habitats are often rich reservoirs of medicinal plant diversity, particularly for those communities that rely on them for everyday health requirements [11]. The absence of specific research on medicinal plant ecology in such disturbed systems constrains the growth of sophisticated conservation strategies addressing ecological and sociocultural priorities [12]. Conservation actions that seek to maintain medicinal plant richness must be based on empirical evidence that accurately represents real-world ecological trends and cultural use [13]. Biodiversity measures of species richness, abundance, evenness, and similarity indices can offer valuable information on the effects of degradation on community composition and structure [14]. When combined with ethnobotanical information, use value, informant consensus, and therapeutic relevance, a greater integrated understanding of conservation priorities is obtained [15]. The use of a dual ecological-cultural approach is essential for developing strategies that are not only biologically sound but also socially just and sustainable. Regrettably, the use of such integrated approaches has been limited, especially in areas where medicinal plants constitute an integral part of traditional healthcare systems [16]. In this regard, a need exists for evaluations that measure medicinal plant diversity along degradation gradients, delimit species that are ecologically resilient and culturally important, and recommend conservation measures based on field evidence. A study that employs a stratified sample design at different levels of degradation, measures ecological indicators, and correlates them with ethnobotanical knowledge makes a new field [17]. It provides a means to appreciate degraded forests not as lost ecosystems but rather as dynamic landscapes capable of regeneration and ongoing cultural use [18]. These findings are particularly relevant to guiding participatory conservation practices engaging local people, incorporating traditional ecological knowledge, and aligning with wider biodiversity and health policy objectives.

This study aims to meet these shortcomings by investigating the composition, structure, and cultural significance of medicinal plant communities in degraded forest ecosystems. By methodically assessing diversity patterns, species dominance, and ethnobotanical consensus along a degradation gradient, this research advances the understanding of how ecological disturbance influences the availability and utilisation of medicinal plants. It emphasises the imperative for prioritising conservation efforts in degraded environments, not only for the protection of biodiversity, but for the maintenance of community health systems that rely on them. Also, it leads to the need for redefining degraded forests from ecological wastelands to conservation opportunities, wherein species recovery and cultural continuity may be supported actively through science-informed, locally framed interventions.

METHODOLOGY

STUDY AREA

The study was conducted in the Nallamala forest range, located in the south-eastern region of Andhra Pradesh, India, with elevations between 200 and 800 meters. This study area is typical of a tropical monsoon climate, with around 950 mm annual rainfall, which affects the seasonal vegetation dynamics of the area. The forest being studied has been heavily affected by human activities, mainly caused by logging, grazing, and shifting cultivation, which have resulted in its extensive degradation. The natural forest cover of the region is now in transition, with a dominance of open canopies, shrubs, and regrowth species of trees. These environmental conditions have resulted in an extreme change in the structure of the ecosystem. The land in the research site is primarily red sandy loam, a moderately fertile soil type that contributes to the re-growth of some plants, although it is not enough to restore the intensity of the original forest ecosystem.

SAMPLING DESIGN

The study used stratified random sampling, classified by three levels of forest degradation, i.e. severe, moderate, and low. This stratification was crucial in deciphering the effects of different levels of degradation on the

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biodiversity of the site. Within every degradation class, 10 m × 10 m plots were set up systematically, totalling 30 plots in the whole study site. The plots were strategically chosen to accurately represent every degradation gradient. Within plots, herbaceous plant richness was measured through nested 1 m × 1 m subplots. The technique gave a clear insight into the richness at finer spatial scales. To reduce edge effects and place the sample points correctly, plots were located with GPS coordinates. Such GPS-assisted placement helped in minimising edge effects, which might bias the data by affecting species composition. The sampling was undertaken in the post-monsoon period (October to December 2024), the time selected for optimising the visibility of plant species because it is at this time that they are most visible and easy to identify.

DATA COLLECTION

Data collection was centered on the identification and recording of medicinal plant species in the demarcated plots. Regional floras and taxonomic literature were used to identify all medicinal plants found in the plots. Identification of species was further confirmed with the help of specialists at the Botanical Survey of India, with maximum precision in plant identification. Voucher specimens were kept and preserved for any taxa that were not identified instantly, thus helping in the ongoing documentation of flora in the region. Ethnobotanical information was collected during semi-structured interviews with 45 local informants to gain an understanding of the indigenous use of plants and their cultural importance. Frequency, density, and the Importance Value Index (IVI) were noted as principal ethnobotanical parameters. The Use Value (UV) and Informant Consensus Factor (ICF) were also calculated to evaluate the cultural importance and degree of consensus on the uses of various plant species in the local community.

DATA ANALYSIS

For measuring plant diversity, various indices were employed, such as Shannon-Wiener, Simpson's, and Pielou's indices, which are all frequently used in ecological research to measure species diversity. They give varying measures of the diversity of species, with Shannon-Wiener measuring both richness and evenness of species, Simpson's index measuring dominance, and Pielou's index determining evenness of species distribution. To analyse the compositional variations among the different levels of degradation, Jaccard's index was used, which measures the similarity of species composition between the degradation gradients. Statistical diversity differences were tested through Analysis of Variance (ANOVA) to see whether the degradation levels had any significant impact on the biodiversity. Multivariate analytical methods, namely Principal Component Analysis (PCA) and Non-metric Multidimensional Scaling (NMDS), were employed to graphically represent species-environment relationships and examine the pattern and aggregation of plant species along the degradation gradients. R version 4.3.1 and dedicated packages like 'vegan' and 'biodiversityR,' which are widely recognized tools for ecological and biodiversity studies, were employed to perform all statistical analyses. These analyses gave a complete picture of the determinants of species diversity and the interrelation between plant species and environmental factors.

RESULT

SPECIES DIVERSITY AT VARIOUS DEGRADATION GRADES

112 medicinal plant species were documented in the study area, with 72 species in the least degraded, 55 in moderately degraded, and a mere 33 species in the most degraded areas. Diversity measures showed a trend of deterioration in ecological condition. The Shannon-Wiener Index (H') fell from 3.12 for the least degraded areas to 1.94 for the most degraded plots. Concurrently, Simpson's Index (1-D) and Evenness (J') fell, both signalling reduced richness and uneven distribution of species under increased stress.

Table 1: Diversity Indices Across Degradation Levels

Degradation Level	No. of Species	Shannon Index (H')	Simpson Index (1-D)	Evenness (J')
Minimally Degraded	72	3.12	0.92	0.82
Moderately Degraded	55	2.67	0.85	0.76
Severely Degraded	33	1.94	0.68	0.61

The biodiversity indices in Table 1 show clearly reduced species diversity and distribution evenness along a degradation sequence. The least degraded forests had the highest species richness (72) and diversity (Shannon Index = 3.12), showing a homogeneous and stable plant community. Conversely, highly degraded plots exhibited significant declines in diversity (H′ = 1.94) and ecological evenness (J′ = 0.61), indicating dominance by a small number of hardy species and loss of ecological balance. These trends highlight the extensive impact of human-induced disturbances on forest composition and the necessity for focused conservation and restoration in highly degraded ecosystems.

DOMINANT MEDICINAL SPECIES AND ECOLOGICAL IMPORTANCE

Among the species documented, 10 medicinal plants were present in all degradation gradients, indicating high ecological plasticity (Table 2). *Andrographis paniculata* had the highest (IVI = 31.2), followed by *Tinospora cordifolia* and *Ocimum tenuiflorum*. They also exhibited high frequency and density, indicating they dominate disturbed environments.

Table 2: Top 10 Medicinal Plant Species by Importance Value Index (IVI)

Species	IVI	Frequency (%)	Density (ind./m²)
Andrographis paniculata	31.2	82	4.2
Tinospora cordifolia	29.7	76	3.8
Ocimum tenuiflorum	28.4	74	3.5
Terminalia chebula	27.6	70	3.3
Azadirachta indica	25.3	68	2.9
Gymnema sylvestre	24.9	65	2.7
Phyllanthus emblica	23.7	64	2.5
Withania somnifera	22.5	60	2.3
Adhatoda vasica	21.4	58	2
Centella asiatica	20.6	55	1.9

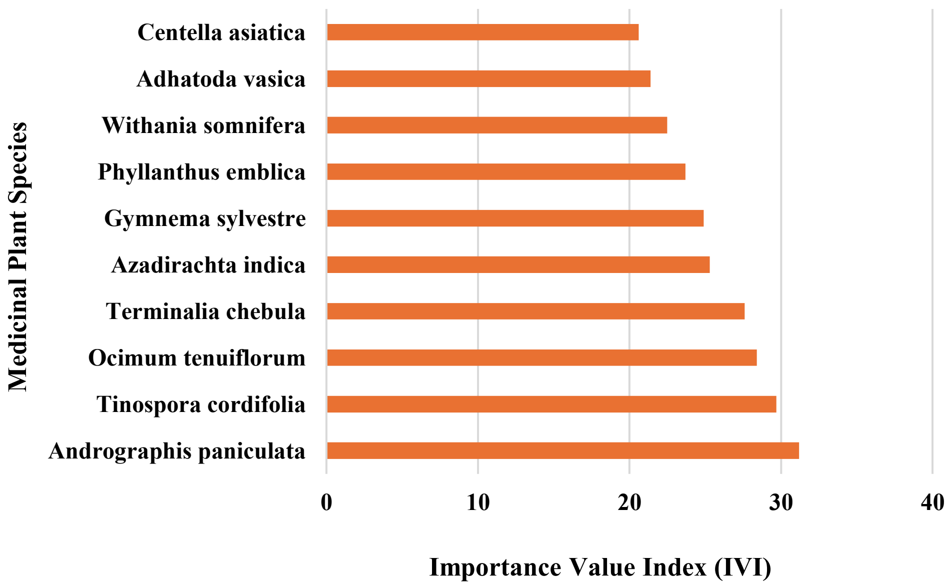

Figure 1: Importance Value Index (IVI) of the top 10 dominant medicinal plant species recorded in degraded forest zones

Figure 1 shows the ecological dominance of top medicinal plant species as indexed by their IVI. The highest IVI (~31) was recorded by *Andrographis paniculata*, reflecting its widespread prevalence and ecological resilience along degradation gradients. Other top species were *Tinospora cordifolia*, *Ocimum tenuiflorum*, and *Terminalia chebula*, which sustained robust field presence and ethnomedicinal significance. The chart emphasises the prevalence of a limited number of species among degraded ecosystems, critical to targeting in situ conservation efforts and planning for sustainable utilisation.

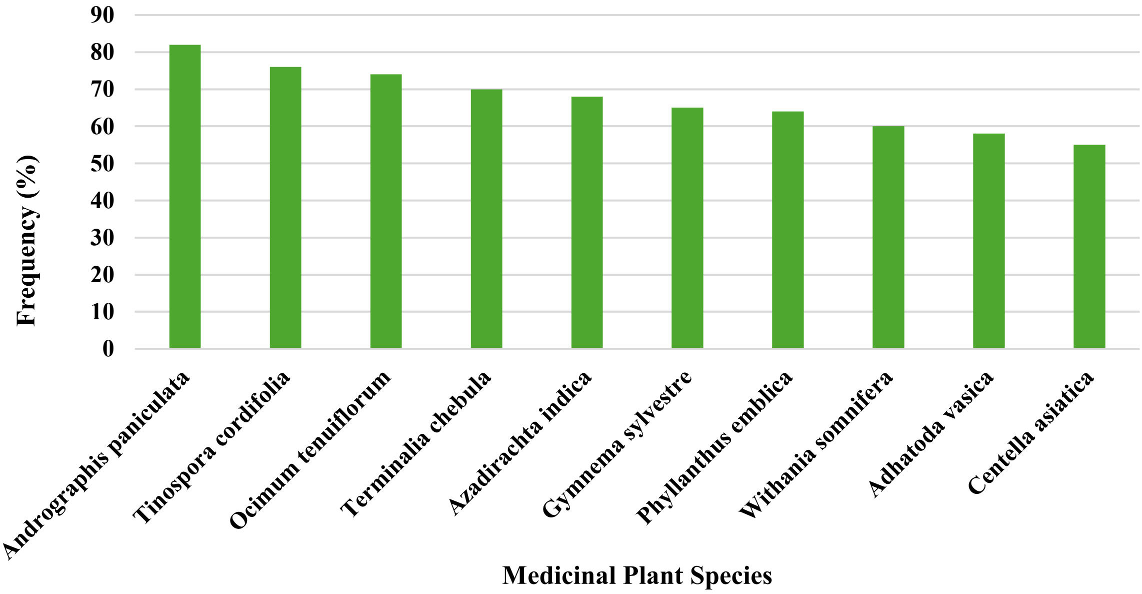

Figure 2: Frequency (%) of occurrence of dominant medicinal plant species across all sampled plots

Figure 2 shows the frequency (%) of the top 10 most frequently encountered medicinal plant species among the sampled plots. *Andrographis paniculata* recorded the highest frequency (82%), followed by *Tinospora cordifolia* and *Ocimum tenuiflorum*, reflecting their extensive distribution and adaptability in degraded forest areas. Species such as *Centella asiatica* and *Adhatoda vasica*, which have smaller frequency values, are likely to have more localised niches or be more sensitive to disturbance. Such frequency trends are key to ranking species within restoration and conservation planning owing to their dominance and ecological recovery potential.

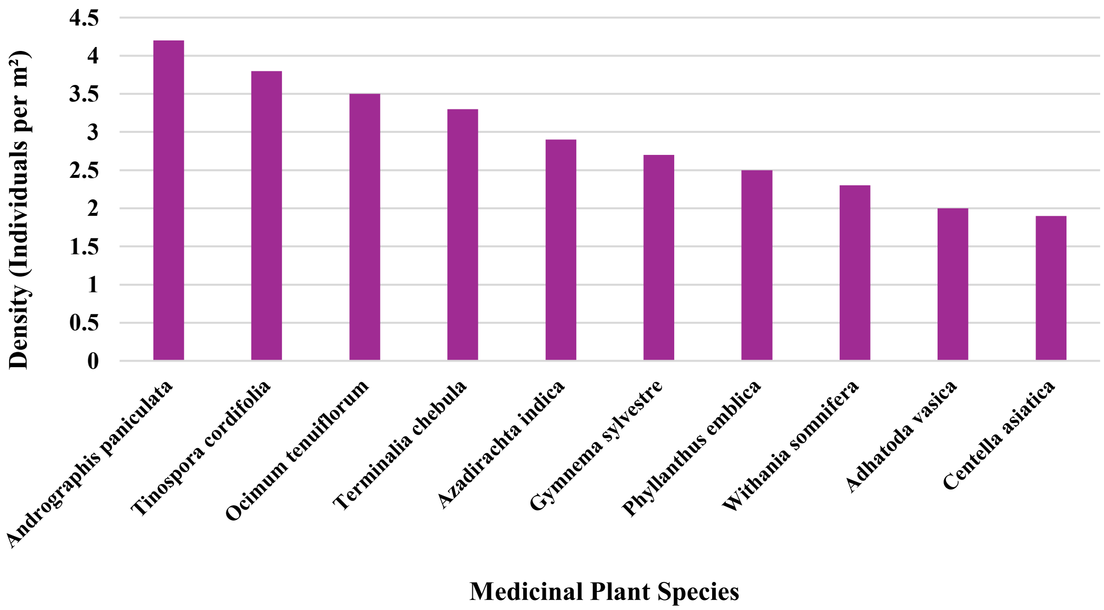

Figure 3: Density (individuals per m²) of dominant medicinal plant species recorded across the study area

Figure 3 shows the population density of the leading 10 medicinal plant species as documented in the study plots. *Andrographis paniculata* featured the highest density (~4.2 individuals/m²), indicating its strong regenerative capacity and dominance of degraded habitats. *Tinospora cordifolia* and *Ocimum tenuiflorum* had high densities, while *Centella asiatica* and *Adhatoda vasica* had the lowest. These density patterns indicate ecological competitiveness and adaptation potential that are needed when selecting species in forest restoration and ethnobotanical conservation programs.

ETHNOBOTANICAL USE PATTERNS AND CONSENSUS

Local informants documented varied applications of medicinal plants, with the majority of species used to treat digestive, respiratory, and dermatological conditions. The ICF was highest for digestive diseases (0.86), with high levels of agreement among respondents. High ICF values in categories imply sustained and verified traditional knowledge.

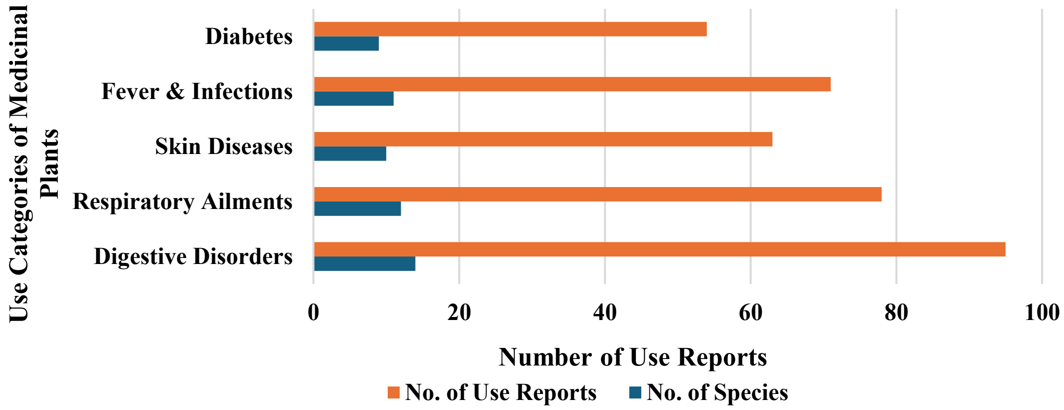

Figure 4: Number of medicinal plant species and use reports across major therapeutic categories based on ethnobotanical data

Figure 4 shows the comparison between medicinal plant species and use reports by therapeutic categories, with the highest values for digestive disorders. The high ratio of use reports to species suggests that there is strong informant consensus and cultural significance. The highest ethnobotanical significance was observed for digestive disorders, with close to 95 use reports and 14 species, followed by respiratory disease and fever & infections. The comparatively lower counts for diabetes indicate more specialised or less commonly known remedies. The elevated proportion of use reports to species per category indicates a high informant consensus and cultural significance of some plant-based treatments within traditional healthcare systems.

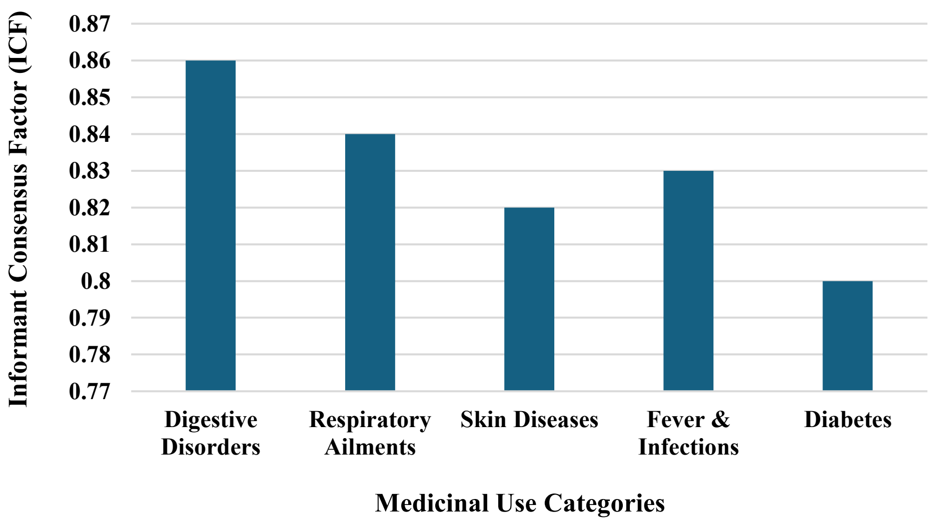

Figure 5: Informant Consensus Factor (ICF) values across different medicinal use categories reported by local communities

Figure 5 shows the ICF values for the five main therapeutic use categories. Digestive disorders recorded the highest ICF (0.86), followed by respiratory conditions (0.84) and fever & infections (0.83), suggesting the presence of high informant consensus regarding species usage in these categories. Lower ICF for diabetes (0.80) indicates higher variation in species choice or knowledge fragmentation. Higher ICF values indicate culturally endorsed and widely shared ethnomedicinal knowledge, thereby rendering these categories prime targets for pharmacological validation and conservation.

FLORISTIC SIMILARITY BETWEEN DEGRADATION ZONES

Species overlap reduced with greater degradation, as measured by the Jaccard Similarity Index. The most similar (0.61) was between moderately and minimally degraded zones, and the least (0.38) was between severely and minimally degraded zones. This indicates obvious turnover in community composition along the disturbance gradient.

Table 3: Jaccard Similarity Index Between Degradation Levels

Comparison	Common Species	Total Species (Combined)	Jaccard Index
Minimally vs. Moderately	48	79	0.61
Minimally vs. Severely	29	76	0.38
Moderately vs. Severely	33	65	0.51

Table 3 shows the Jaccard Similarity Index also shows a decreasing trend in species overlap with rising intensity of degradation. The greatest similarity (0.61) existed between weakly and moderately degraded areas, which mirrored common ecological composition. Conversely, weakly vs. severely degraded areas had the lowest similarity (0.38), which is an indication of high species turnover and loss of common taxa as a result of habitat degradation. These findings highlight that degradation not only lowers total diversity but also breaks up species continuity over the landscape, further supporting the necessity to conserve less disturbed habitats as biodiversity reservoirs.

DISCUSSION

The findings show a drastic degradation-induced reduction in the diversity, composition, and functional representation of forest medicinal plants. The ecological parameters demonstrated that species richness, diversity indices, and evenness were maximum in the least degraded areas with 72 species and a Shannon Index of 3.12, whereas only 33 species and an index of 1.94 were observed in highly degraded areas. This trend is indicative of the negative effect of anthropogenic disturbances on the ecological integrity of medicinal plant communities. Decline in Simpson's diversity and evenness with degradation indicates a disruption in community balance, with just a few disturbance-tolerant taxa dominating, while more sensitive taxa are eliminated or relegated to ecological peripheries. Species like *Andrographis paniculata*, *Tinospora cordifolia*, and *Ocimum tenuiflorum* had consistently high Importance Value Index, frequency, and density along all degradation gradients. This resilience reflects ecological plasticity that allows adaptation to changing light, soil, and competition in disturbed sites. Species like *Centella asiatica* and *Adhatoda vasica* had lower values of abundance and distribution, reflecting environmental sensitivity. These stronger species not only possess ecological strength but also cultural value, as seen through the reports of high usage and high informant consensus values. Ethnobotanical knowledge reveals that medicinal plants are highly important in the treatment of common diseases, mainly digestive and respiratory afflictions. The ICF was highest at 0.86 for digestive illness, indicating common traditional knowledge and repetitive use of some plant species for this ailment category. This strong agreement is consistent with previous research in the Western Ghats and central Indian forests, where gastrointestinal health is the most commonly treated condition using ethnomedicine. The recurrence of certain species usage also implies long-term cultural validation and proposes fruitful leads for drug development. The floristic similarity data, presented using the Jaccard Similarity Index, indicate significant turnover of species composition along degradation gradients. The minimum similarity (0.38) between highly and least degraded areas highlights the structural and compositional disintegration of plant communities as habitat conditions diminish. This turnover is symptomatic of the crossing of ecological thresholds, where the capacity of ecosystems to host rich medicinal flora is compromised. These results affirm the general ecological hypothesis that, beyond a certain threshold, disturbances produce regime shifts with the possibility that recovery will no longer be along traditional successional pathways. Comparison of these results with previous biodiversity measurements in degraded tropical forest suggests analogous trends in loss of species diversity, especially of functional groups like understorey herbs and shrubs. Such observations have been made before in the Nilgiris and Satpura hills as well, where sharp reductions in richness and evenness scores were noted in overgrazed, fire-scarred, and unregulated extraction-impacted sites. A general trend for dominance by a select group of resilient species is a common finding in tropical forest literature, corroborating the current observations [19]. The uniform occurrence of culturally important and ecologically superior species in all zones implies that the degraded ecosystems also harbour enclaves of resistance, which may be strategically exploited for restoration. Although the present research offers useful information on forest degradation and species responses and their ethnobotanical value, it is not without its limitations. The foremost is the seasonality of sampling that may have overlooked ephemeral or seasonally fluctuating species. Morphological identification, though diligent, might fail to capture cryptic diversity or distinguish among closely related taxa in the absence of molecular data. The use of self-reported ethnobotanical material introduces the possibility of recall bias and limits pharmacological verification to reported use rather than documented bioactivity. The spatial extent of sampling, although statistically powerful, reduces the generalizability of results over broader biogeographic gradients. Despite these limitations, the information gathered has immediate applications in conservation planning and sustainable resource use. The occurrence of species with high ecological and cultural value as medicinal species in degraded areas presents opportunities for assisted natural regeneration, enrichment planting, and community conservation programs [20]. Such species with high ICF and IVI values must be given high priority in restoration plans, not just from the ecological resilience standpoint but also for their contribution to the traditional health care system. Strategies like creating ethnobotanical gardens, facilitating habitat corridors, and incorporating local knowledge into forest management policy will maximise both biodiversity and livelihood returns [21]. Future evaluations should incorporate multi-seasonal monitoring, combine soil and microclimatic factors, and employ molecular methods to improve species identification and measure genetic diversity. Combining ethnobotanical surveys with phytochemical screening and pharmacological validation can yield more robust evidence of the therapeutic effectiveness of culturally significant species. Long-term studies that follow the recovery of medicinal plant populations after restoration or under different protection regimes would provide greater insights into ecosystem resilience and guide adaptive management [22]. By synergising ecological information with native knowledge, a more integrated and sustainable method of forest health and cultural preservation can be realised.

CONCLUSION

The results of this study reinforce the dramatic role of forest degradation in influencing medicinal plant diversity, with evident trends of loss in species richness, diversity, and evenness with enhanced levels of degradation. The loss of the Shannon-Wiener Index and Simpson's Index, as well as the diminished ecological evenness in highly degraded sites, points to the adverse effects of human-altered disturbances on forest communities. In spite of these losses, there is a stable core of strong and culturally significant medicinal species like *Andrographis paniculata* and *Tinospora cordifolia* with ecological plasticity and regenerative ability in disturbed habitats. These plants, with their high Use Value and Informant Consensus Factor, highlight the ongoing significance of traditional knowledge of plants and their important contribution to community health systems. The findings also indicate high turnover in species assemblage along degradation gradients, with high overlap between minimally and moderately degraded sites but extreme contrasts between severely degraded and less disturbed zones. This change in species composition also shows how sensitive medicinal plant communities are to habitat degradation and how irreversible changes could become if such trends persist. The paper highlights the need for the incorporation of both ecological and ethnobotanical information to develop conservation strategies that favour both biodiversity and indigenous knowledge. Though the paper gives a commendable overview of the status of medicinal plant diversity in degraded forests, the limitations based on seasonality of sampling and morphological identification indicate possibilities for future work. Future research should emphasise multi-seasonal data collection, molecular identification, and pharmacological validation to consolidate the knowledge of medicinal plant resilience. In summary, the study emphasises the imperative to re-evaluate degraded forests as likely locations for active conservation, supporting species recovery and the sustainability of traditional health practices.

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