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# Population structure and regeneration status of tree species in Eastern Himalaya, Mahananda Wildlife Sanctuary, West Bengal

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## ABSTRACT

The study provides information on the tree diversity, stand structure, and regeneration pattern of the Mahananda Wildlife Sanctuary. Tree diversity and its relation to habitat have been explored using 88 plots with dimensions of 50 × 20 m. A survey of 8.8 ha of the study area was conducted during the fieldwork. Plants with a circumference of 30 cm and above were enumerated as trees, while plants with a circumference between 30–10 cm were considered juveniles (saplings and seedlings). A total of 1677 tree individuals belonging to 67 genera of 43 families were recorded. Five species - *Shorea robusta, Schima wallichii, Acer oblongum, Magnolia pterocarpa* and *Ficus benghalensis* contributed to the maximum stand density and species richness. The total stand density per hectare was recorded as 2160 individuals/ha, with a total basal area of 8.86 m²/ha. The regeneration status has been evaluated as 'Good', with 4336 regenerating individuals/ha recorded during the study. Diversity indices were calculated: Shannon-Weiner index was 3.607, Simpson dominance index was 0.937, Margalef index was 11.45, and evenness was 0.428.

**Key words:** Biodiversity, Conservation, Eastern Himalaya, Species Diversity, Regeneration, Stand density.

## INTRODUCTION

Biodiversity assessment is a crucial aspect of conservation biology, garnering significant attention for its role in shaping conservation strategies (Tarakeswara Naidu et al. 2018). Conservation organizations worldwide employ various biodiversity assessment methods to identify priority areas for conservation, especially when resources are limited. In contemporary times, forests face the impacts of climate change and various anthropogenic factors, necessitating more effective conservation strategies. Understanding the diversity of a region, structurally and at the community level, is vital. Forest management practices in India primarily focus on the structural diversity of woody species, as these species provide resources and habitat for other organisms, thereby influencing the diversity patterns of species (Kala 2015, Verma 2008). Several factors, including environmental, climatic, and anthropogenic influences, significantly affect the vegetation of a region. These factors lead to ecological transformations, altering species distribution and diversity patterns, land use changes, habitat loss and fragmentation, species invasions, and extinctions (Pandit et al. 2014, Saito et al. 2005). Anthropogenic and climatic factors are particularly pronounced in mountain ecosystems due to the heterogeneity of landforms and environments. A comprehensive understanding of forests, through the study of structural and community diversity, is crucial for devising appropriate conservation strategies for the region (Das et al. 2021). Additionally, studying forest regeneration is vital for assessing the stability of forest ecosystems (Lahiri and Dash 2021, Paul et al. 2019). Knowledge of the regeneration status of forest communities is considered a prerequisite for forest management, restoration, and sustainability (Pala et al. 2013). The Himalaya, spanning approximately 12.84% of the total geographic area, boast some of the richest and most diverse ecosystems globally, hosting a wide array of species and forest types. This diversity arises from significant variations in topography, climate, and altitude. The frequent changes in altitude and vegetation types across small geographical areas make the Himalayan Mountains an ideal site for research (Körner 2000). The Mahananda Wildlife Sanctuary, situated in the foothills of the Eastern Himalayas, is home to diverse and species-rich formations and is recognized as part of a Global Biodiversity Hotspot (Panda et al. 2013). The forests of the Eastern Himalayas are among the most diverse regions globally, characterized by high endemism (Barthlott et al. 2005, Tiwari et al. 2019). Vegetation in the foothills of the Eastern Himalaya is predominantly composed of species from tropical semi-deciduous forests (Pandit et al. 2014). Tropical dry deciduous forests, abundant in economically important species, represent one of the most exploited and endangered ecosystems worldwide (Mahapatra and Tewari 2005, Murphy and Lugo 1986). The vegetation in the study area provides numerous ecosystem services, yet faces risks of exploitation due to the growing population in the Himalayan region. Other factors contributing to biodiversity loss include timber collection, expansion of tea cultivation in areas adjacent to protected areas, and ecotourism practices that inadvertently harm the region's biodiversity. The study aims to identify and analyze forest communities, their regeneration patterns, and phyto-sociological parameters. The study recognizes the necessity for novel research approaches to reconcile economic interests in exploitation with ecological imperatives in conservation (Rana et al. 2021). The Government of India's development think tank, NITI Aayog (National Institution for Transforming India), highlights five key areas for achieving sustainable development in the Himalaya, one of which underscores the importance of data for decision-making (Anonymous 2018). This study aligns with this imperative by aiming to generate appropriate data through innovative research approaches. The selection of Mahananda Wildlife Sanctuary for this study is based on the absence of previous research in the region. Conducting this study will contribute significantly to framing effective conservation strategies aimed at preserving the biodiversity of the region in the most efficient manner possible.

## MATERIALS AND METHODS

### Study area

The Mahananda Wildlife Sanctuary is situated within the catchment area of the Mahananda River, located between latitudes 26°55'33"N and 26°47'54"N, and longitudes 88°33'31"E and 88°23'36"E, within the Darjeeling district of the northern part of West Bengal. Figure 1 shows the location of Mahananda Wildlife Sanctuary. The region seamlessly transitions into the lower reaches of the Eastern Himalayas. To the north, the area is bordered by tea and Cinchona plantations, characterized by hills with steep slopes and deep ridges. The terrain gradually slopes downwards to meet the flat alluvial plains in the south. In the southern part of the sanctuary, forested areas are predominantly limited by human settlements and tea plantations, except for a narrow strip of forestland serving as a connection between the Mahananda Wildlife Sanctuary and the Baikanthapur forest division. The sanctuary is bordered by the Teesta River to the east and the Mahananda River to the west. Covering an area of 127.22 $km^2$, the sanctuary ranges in elevation from 99 to 1176 m amsl. The region experiences three distinct seasons: summer, winter, and monsoon. The average temperature varies between 10.1 and 32.4°C. The wildlife sanctuary is divided into four ranges viz., North, South, East, and West, further subdivided into 33 blocks. Initially designated as a protected area in 1949, it was officially declared a Wildlife Sanctuary in 1976.

The Mahananda Wildlife Sanctuary falls within Zone 7 of the Indian vegetation classification, specifically categorized as Gangetic plains, province 7B (Lower Gangetic plains), further subdivided under the Bengal Dooars sub-division. The vegetation in this region can be classified into several types: Grasslands, Khair-Sissoo Forests, Simul, Siris Forests, Sal Forests, Dry Mixed Forests, Wet Mixed Forests, and Hill Forests. Sal Forests represent a dominant vegetation type within the Mahananda Wildlife Sanctuary, encompassing most of the sanctuary's blocks. Various types of Sal forests are present in the region, characterized by differences in associated species. Some of the plants growing in association with Sal include *Schima wallichii* Choisy, *Garuga pinnata* Roxburgh, *Tetrameles nudiflora* R.

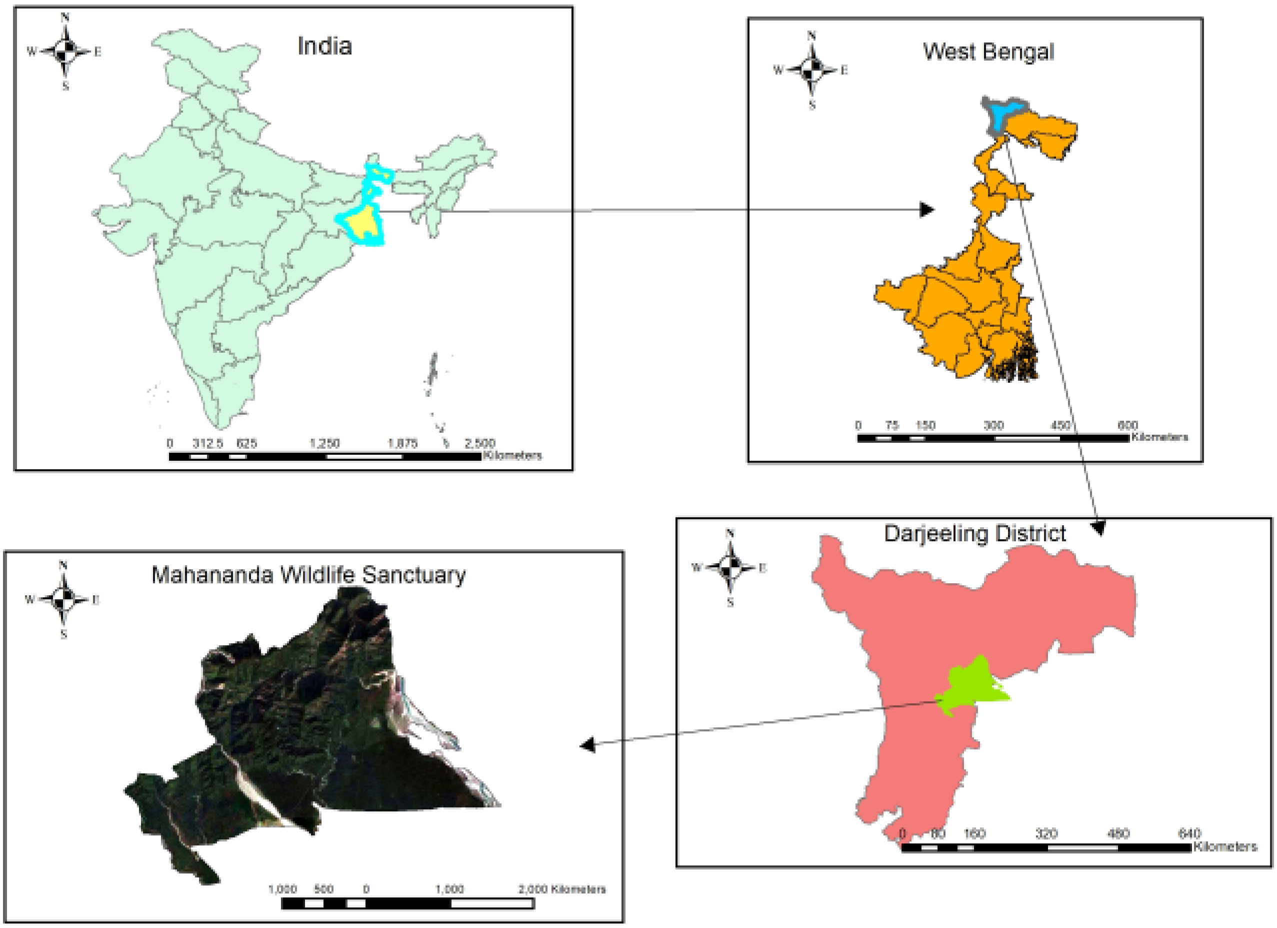


Figure 1. Study area map

Brown, *Terminalia crenulata* Roth, *Toona ciliata* M. Roemer, and *Chukrasiata bularis* A. Jussieau. The understory of these forests typically consists of species such as *Macaranga spp*., *Dillenia pentagyna* Roxburgh, *Careya arborea* Roxburgh, *Premna bengalensis* C.B. Clarke, and *Chromolaena odorata* (Linnaeus) R.M. King & H. Robinson (Paul and Kumar 2014).

**Sampling methods**

The study aims to assess the current status of floral diversity within the Mahananda Wildlife Sanctuary. To achieve this, random plots measuring 50 × 20 m were established across the protected area, totaling 88 plots. Sampling took place during the pre-monsoon season to ensure consistency. To minimize anthropogenic influences, the plots were randomly laid out, maintaining a minimum distance of 100 m from any means of communication within the Wildlife Sanctuary, such as major roads, minor secondary roads, and cart lanes. The precise locations of the sampling plots were determined on the ground using GPS technology. Within each plot, all tree species with a girth width at breast height (e”30 cm) were recorded and considered for analysis. Plant identification was conducted with the assistance of online resources such as www.theplantlist.org and www.ipni.org, following the APG III system of classification (Haston et al. 2009, Anonymous 2009). Furthermore, the current IUCN status of the enumerated tree species was determined by consulting www.redlist.org, providing valuable insight into the conservation status of the identified species.

**Data analysis**

The collected vegetation data from all sampled plots were subjected to quantitative analysis. Various parameters such as frequency, relative frequency, density, relative density, abundance, dominance, and relative dominance were calculated. Additionally, the importance value index, which is the summation of relative frequency, relative dominance, and relative density, was determined (Kala 2015, Verma 2008). The species diversity of each community was assessed using Shannon's Weiner index (Shannon and Wiener 1963), while the concentration of dominance was measured using Simpson's index (Simpson 1949). The Family Importance Value Index was also calculated (Mori et al. 1983, Panda et al. 2013). Furthermore, trees were grouped based on girth class-wise classification, and the A/F ratio was employed to determine the distribution pattern of plant species (Curtis and McIntosh 1950). All the mentioned parameters and diversity indices were computed using PAST software (version 4.03). To understand the distribution pattern of species, the dominance diversity curve was utilized. This comprehensive analysis provides valuable insights into the vegetation composition and diversity within the Mahananda Wildlife Sanctuary.

## RESULTS AND DISCUSSION

The study recorded a total of 1677 tree individuals belonging to 87 species across 43 families, along with 4 shrub species (*Cissus repanda, Helicteres plebeiea, Plectocomia himalayana, Premna benghalensis*), and 6 plant species classified as *Lianas* (*Clematis connata, Combretum decandrum, Mucuna macrocarpa, Caesalpinia cucullata, Clematis zeylanica, Stixis suaveolens*) (Table 1). The number of individuals per species ranged from 1 to 347. The family Dipterocarpaceae had the highest number of recorded individuals (347) for a single species.

Stand density varied from 3943.18 ± 773.01 individuals/ha to 11.36 ± 687.56, while basal area ranged from 0.44 m²/ha to 0.003 m²/ha. These values fell within the range observed in a previous study of tropical forests in the eastern Himalayas. The highest percentage of stem cover was observed in diameter class 10–20 cm (68.176) (Table 2). All tree species recorded exhibited a clumped pattern of distribution (A/F ratio > 0.05), indicating clustered vegetation. This pattern is commonly observed in natural plant occurrences and is accepted as a characteristic feature (Odum 1971). The rank abundance curve illustrated an even distribution of tree species throughout the surveyed area (Fig. 2). This analysis provides valuable insights into the composition, distribution, and diversity of vegetation within the Mahananda Wildlife Sanctuary.

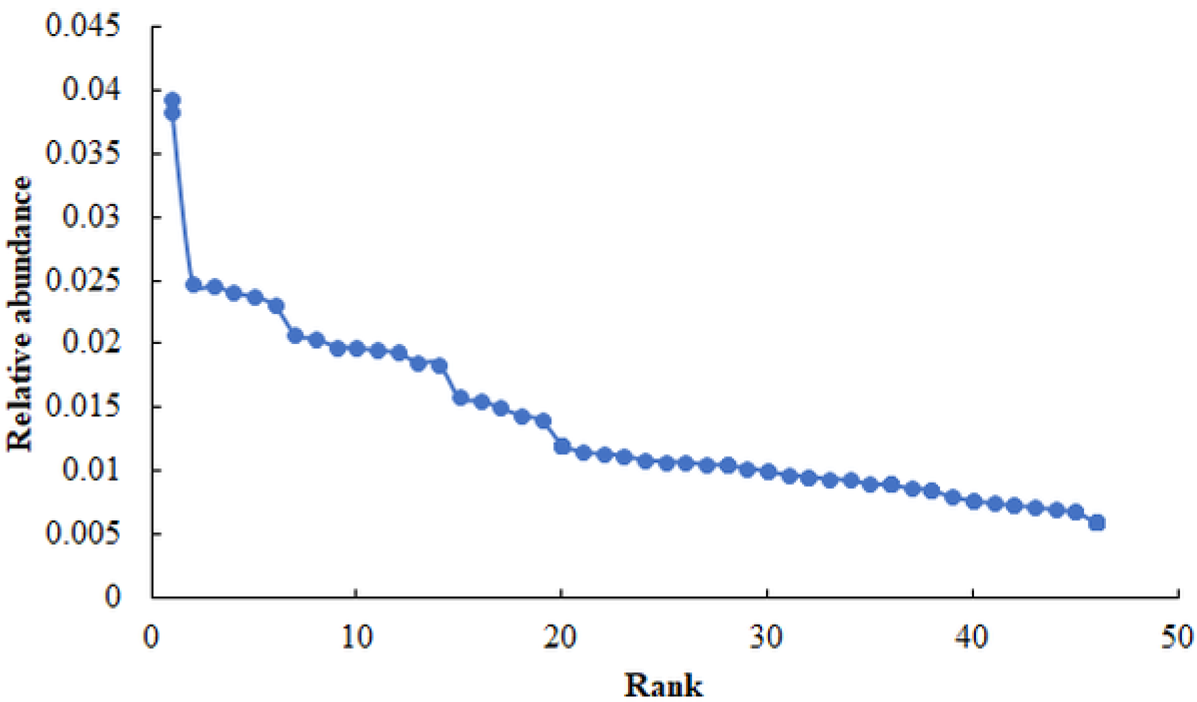


Figure 2. Rank abundance curve

Table 1. Phyto-sociological characteristics of tree species in Mahananda Wildlife Sanctuary

| Species | N | F% | BA/ ha | D± sd | IVI% | R |
|---|---|---|---|---|---|---|
| *Acer oblongum* | 103 | 28.4 | 0.283 | 1170.45± 455.84 | 13.3 | Good |
| *Acrocarpus fraxinifolius* | 13 | 9.09 | 0.113 | 147.72± 467.76 | 3.32 | Good |
| *Adina cordifolia* | 6 | 5.68 | 0.016 | 68.18± 452.94 | 1.32 | Poor |
| *Aglaia spectabilis* | 37 | 23.9 | 0.166 | 420.45± 455.37 | 7.39 | Good |
| *Ailanthus grandis* | 2 | 2.27 | 0.004 | 22.72± 457.51 | 0.47 | Good |
| *Alangium begoniifolium* | 3 | 3.41 | 0.014 | 34.09± 459.84 | 0.81 | Good |
| *Albizia lebbeck* | 7 | 4.55 | 0.023 | 79.54± 462.26 | 1.31 | Good |
| *Albizia procera* | 12 | 5.68 | 0.035 | 136.36± 464.90 | 1.9 | Good |
| *Amoora rohituka* | 33 | 11.4 | 0.076 | 375± 470.69 | 4.41 | Good |
| *Annona squamosa* | 8 | 7.95 | 0.018 | 90.90± 473.37 | 1.78 | Good |
| *Baccaurea sapida* | 3 | 2.27 | 0.009 | 34.09± 476.27 | 0.6 | Good |
| *Bauhinia purpurea* | 9 | 6.82 | 0.141 | 102.27± 478.98 | 3.1 | Good |
| *Bridelia retusa* | 12 | 7.95 | 0.032 | 136.36± 482.02 | 2.17 | Good |
| *Butea monosperma* | 10 | 7.95 | 0.089 | 113.63± 485.22 | 2.71 | Good |
| *Camellia drupifera* | 3 | 3.41 | 0.003 | 34.09± 488.42 | 0.68 | Good |
| *Casearia glomerata* | 10 | 7.95 | 0.034 | 113.63± 491.34 | 2.08 | Good |
| *Catunaregam longispina* | 20 | 12.5 | 0.082 | 227.27± 494.66 | 3.85 | Good |
| *Celtis tetrandra* | 3 | 3.41 | 0.013 | 34.09± 498.24 | 0.79 | Good |
| *Cephalanthus tetrandra* | 3 | 3.41 | 0.004 | 34.09± 501.35 | 0.69 | Good |
| *Chukrasia tabularis* | 40 | 14.8 | 0.177 | 454.54± 504.52 | 6.45 | Good |
| *Clematis connata* | 5 | 2.27 | 0.013 | 56.81± 32.14 | 0.76 | Good |
| *Clematis zeylanica* | 10 | 6.82 | 0.017 | 113.63± 45.92 | 1.73 | Fair |
| *Croton tiglium* | 11 | 10.2 | 0.161 | 125± 507.56 | 3.91 | Good |
| *Cryptocarya burkillii* | 16 | 9.09 | 0.054 | 181.81± 511.29 | 2.82 | Good |
| *Dalbergia latifolia* | 12 | 6.82 | 0.049 | 136.36± 515.24 | 2.22 | Good |
| *Daphniphyllum himalense* | 13 | 10.2 | 0.028 | 147.72± 519.18 | 2.5 | Good |
| *Dendrocnide sinuata* | 11 | 7.95 | 0.092 | 125± 523.24 | 2.8 | Good |
| *Dillenia indica* | 25 | 14.8 | 0.144 | 284.09± 527.33 | 5.18 | Good |
| *Diospyros malabarica* | 2 | 2.27 | 0.004 | 22.72± 531.67 | 0.48 | Good |
| *Duabanga grandiflora* | 70 | 12.5 | 0.316 | 795.45± 535.45 | 9.54 | Poor |
| *Dysoxylum excelsum* | 16 | 11.4 | 0.116 | 181.81± 707.30 | 3.85 | Good |
| *Elaeocarpus sikkimensis* | 18 | 11.4 | 0.044 | 204.54± 534.94 | 3.14 | Good |
| *Emblica officinalis* | 9 | 7.95 | 0.029 | 102.27± 539.60 | 1.96 | Good |
| *Erythrina arborescens* | 1 | 1.14 | 0.013 | 11.36± 43.56 | 0.37 | Nil |
| *Ficus benghalensis* | 23 | 7.95 | 0.797 | 261.36± 544.14 | 11.7 | Poor |
| *Ficus fenestrata* | 2 | 2.27 | 0.028 | 22.72± 549. 05 | 0.75 | Good |
| *Ficus hookeriana* | 19 | 11.4 | 0.105 | 215.90± 553.39 | 3.9 | Good |
| *Firmiana colorata* | 3 | 3.41 | 0.004 | 34.09± 558.58 | 0.69 | Fair |
| *Fraxinus paxiana* | 2 | 2.27 | 0.003 | 22.72± 563.24 | 0.47 | Fair |
| *Garcinia cowa* | 14 | 10.2 | 0.054 | 159.09± 567.93 | 2.86 | Good |
| *Garuga floribunda* | 16 | 11.4 | 0.103 | 181.81± 573.47 | 3.7 | Good |
| *Gmelina arborea* | 3 | 3.41 | 0.023 | 34.09± 579.22 | 0.91 | Nil |
| *Gynocardia odorata* | 9 | 7.95 | 0.18 | 102.27± 584.43 | 3.7 | Good |
| *Holarrhena pubescens* | 46 | 13.6 | 0.111 | 522.72± 590.23 | 5.89 | Good |
| *Knema erratica* | 6 | 3.41 | 0.031 | 68.18± 595.23 | 1.19 | Good |

| Species | N | F% | BA/ ha | D± sd | IVI% | R |
|---|---|---|---|---|---|---|
| *Lagerstroemia speciosa* | 25 | 15.9 | 0.227 | 284.09± 601.22 | 6.29 | Good |
| *Lithocarpus pachyphyllus* | 10 | 9.09 | 0.035 | 113.63± 608 | 2.25 | Good |
| *Litsea monopetala* | 11 | 10.2 | 0.028 | 125± 614.67 | 2.38 | Good |
| *Lyonia ovalifolia* | 4 | 2.27 | 0.019 | 45.45± 621.63 | 0.77 | Fair |
| *Magnolia cathcartii* | 29 | 10.2 | 0.105 | 329.54± 628.31 | 4.35 | Fair |
| *Magnolia champaca* | 1 | 1.14 | 0.008 | 11.36 | 0.31 | Fair |
| *Magnolia pterocarpa* | 79 | 22.7 | 0.335 | 897.72± 636.01 | 11.7 | Good |
| *Mallotus nudiflorus* | 14 | 9.09 | 0.072 | 159.09± 635.68 | 2.91 | Good |
| *Mallotus philippensis* | 1 | 1.14 | 0.002 | 11.36± 643.85 | 0.23 | Good |
| *Mangifera indica* | 2 | 1.14 | 0.005 | 22.72± 651.35 | 0.33 | Nil |
| *Mimusops elengi* | 12 | 9.09 | 0.231 | 136.36± 659.23 | 4.63 | Fair |
| *Monoon simiarum* | 8 | 7.95 | 0.045 | 90.90± 668.27 | 2.09 | Fair |
| *Pandanus furcatus* | 20 | 13.6 | 0.062 | 227.27± 677.40 | 3.78 | Good |
| *Phanera vahlii* | 1 | 1.14 | 0.024 | 11.36± 687.56 | 0.49 | Good |
| *Phoebe bootanica* | 10 | 5.68 | 0.022 | 113.63± 696.74 | 1.63 | Good |
| *Punica granatum* | 7 | 6.82 | 0.013 | 79.54± 729.15 | 1.5 | Good |
| *Sabia paniculata* | 1 | 1.14 | 0.003 | 11.36± 740.96 | 0.25 | Good |
| *Saurauia napaulensis* | 14 | 9.09 | 0.051 | 159.09± 752.48 | 2.67 | Good |
| *Schima wallichii* | 110 | 37.5 | 0.731 | 1250± 766.25 | 20.1 | Good |
| *Senegalia catechu* | 15 | 9.09 | 0.049 | 170.45± 757.70 | 2.71 | Good |
| *Shorea robusta* | 347 | 60.2 | 1.306 | 3943.18± 773.01 | 44 | Good |
| *Spathodea campanulata* | 8 | 2.27 | 0.011 | 90.90± 126.24 | 0.92 | Good |
| *Sterculia villosa* | 1 | 1.14 | 0.007 | 11.36± 128.82 | 0.29 | Nil |
| *Stereospermum colais* | 5 | 5.68 | 0.016 | 56.81± 129.19 | 1.27 | Fair |
| *Stixis suaveolens* | 2 | 1.14 | 0.028 | 22.72± 23.65 | 0.6 | Fair |
| *Styrax serrulatus* | 8 | 4.55 | 0.012 | 90.90± 131.18 | 1.23 | Good |
| *Syzygium kurzii* | 17 | 5.68 | 0.046 | 193.18± 134.12 | 2.33 | Good |
| *Syzygium ramosissimum* | 8 | 6.82 | 0.023 | 90.90± 137.21 | 1.67 | Good |
| *Tectona grandis* | 41 | 11.4 | 0.402 | 465.90± 140.70 | 8.64 | Good |
| *Terminalia bellirica* | 29 | 12.5 | 0.089 | 329.54± 118.48 | 4.47 | Good |
| *Terminalia chebula* | 28 | 13.6 | 0.112 | 318.18± 109.15 | 4.84 | Good |
| *Terminalia elliptica* | 13 | 4.55 | 0.038 | 147.72± 97.05 | 1.84 | Nil |
| *Terminalia myriocarpa* | 3 | 2.27 | 0.007 | 34.09± 99.56 | 0.57 | Good |
| *Tetrameles nudiflora* | 34 | 12.5 | 0.251 | 386.36± 102.22 | 6.64 | Good |
| *Tinospora cordifolia* | 13 | 5.68 | 0.049 | 147.72± 55.27 | 2.12 | Good |
| *Toona ciliata* | 12 | 9.09 | 0.181 | 136.36± 52.14 | 4.05 | Good |
| *Trewia nudiflora* | 2 | 2.27 | 0.002 | 22.72± 48.08 | 0.46 | Good |
| *Viburnum colebrookeanum* | 6 | 4.55 | 0.051 | 68.18± 50.18 | 1.57 | Nil |
| *Walsura tubulata* | 12 | 6.82 | 0.036 | 136.36± 53.55 | 2.07 | Good |
| *Woodfordia fruticosa* | 1 | 1.14 | 0.007 | 11.36± 47.18 | 0.29 | Good |
| *Wrightia arborea* | 10 | 7.95 | 0.078 | 113.63± 48.43 | 2.59 | Fair |

*N= number of individuals, F%= frequency percentage, Ba/ha= Basal area per hectare, D ± SD= Density ±Standard deviation, IVI%= Importance Value Index percentage, R= regeneration status.

Table 2. Diameter class-wise proportion of stem density and basal area of different tree species

| DBH class | Species | Number of individuals | % of stems | Basal area | % of basal area |
|---|---|---|---|---|---|
| 0- 10 | 8 | 16 | 0.979192166 | 0.121922933 | 0.160347625 |
| 10- 20 | 77.00 | 1114 | 68.17625459 | 18.64267965 | 24.51802404 |
| 20- 30 | 86 | 360 | 22.03182375 | 16.00509158 | 21.04918539 |
| 30- 40 | 35 | 84 | 5.140758874 | 7.768249457 | 10.21645657 |
| 40- 50 | 15 | 32 | 1.958384333 | 4.933517035 | 6.488342423 |
| 50- 60 | 25 | 31 | 1.897184823 | 7.305602593 | 9.608003964 |
| 60- 70 | 11 | 13 | 0.795593635 | 4.177779459 | 5.494429938 |
| 70- 80 | 7 | 9 | 0.550795594 | 4.071052321 | 5.354067148 |
| 80- 90 | 2 | 3 | 0.183598531 | 1.191153842 | 1.566552613 |
| 90- 100 | 7 | 8 | 0.489596083 | 5.098695939 | 6.70557838 |
| >100 | 7 | 7 | 0.428396573 | 6.720886943 | 8.839011918 |

Based on density, the species were classified into five classes: Predominant (>50 individuals), Dominant (25 to <50 individuals), Common (10 to <25 individuals), Rare (2 to <10 individuals), and Very Rare (<2 individuals) (Majumdar et al. 2014). Overall, five species were classified as Very Rare, 32 as Rare, 34 as Common, 10 as Dominant, and 4 as Predominant in nature. The total basal area occupied by tree species was 8.66 $m^2$/ha, with Dipterocarpaceae identified as the dominant family based on basal area. The highest Importance Value Index (IVI) was exhibited by *Shorea robusta* (0.4395), followed by *Schima wallichii* (0.2009), *Acer oblongum* (0.1327), *Magnolia pterocarpa* (0.1166), and *Ficus benghalensis* (0.1166) (Table 1). IVI is a crucial metric used in ecological studies to assess the importance of species in a particular ecosystem. It indicates the significance of species for conservation efforts within that ecosystem. Species with lower IVI values demand more attention regarding conservation status than species with higher IVI values. Based on the Family Importance Value Index (FIV), Dipterocarpaceae was identified as the dominant family (22.018), with 347 individuals and 1 species. This was followed by Magnoloneaceae (14.671) with 168 recorded tree individuals belonging to 4 species, Meliaceae (14.152) with 178 individuals belonging to 3 species, Theaceae (9.674) with 124 tree individuals belonging to 2 species, and Fabaceae (8.72) with 68 individuals belonging to 4 species.

The distribution of tree individuals across different diameter classes is depicted in Figure 3, showing a reverse J-shaped distribution pattern for all species. Higher densities of trees in lower girth classess suggests that the forest is still evolving.

This distribution pattern is commonly observed in previous studies conducted in the Himalayan region. Examining the density and basal area cover of dominant species across ascending diameter classes reveals that individuals belonging to higher girth classes have lower density but contribute to a larger basal area cover. The presence of such old stands with large girth sizes indicates that these species belong to the primary forest of the region. Species such as *Shorea robusta, Schima wallichii, Tetrameles nudiflora*, and *Aglaia spectabilis* exhibit the highest density in the lower diameter class (10 – 20 cm), still, their basal area contribution is comparatively low compared to other species with similar distribution patterns. The increased numbers of lower diameters at breast height (DBH) indicate closely spaced individuals, suggesting an increase in secondary forest structure. This could result from both natural and anthropogenic disturbances the forest faces, which may have altered the course of succession. Secondary species, which are fast-growing and present in open forest areas, are abundant and monopolize a significant portion of dominance. *Shorea robusta* emerges as the most dominant species in the forest, with the highest number of individuals belonging to the lower

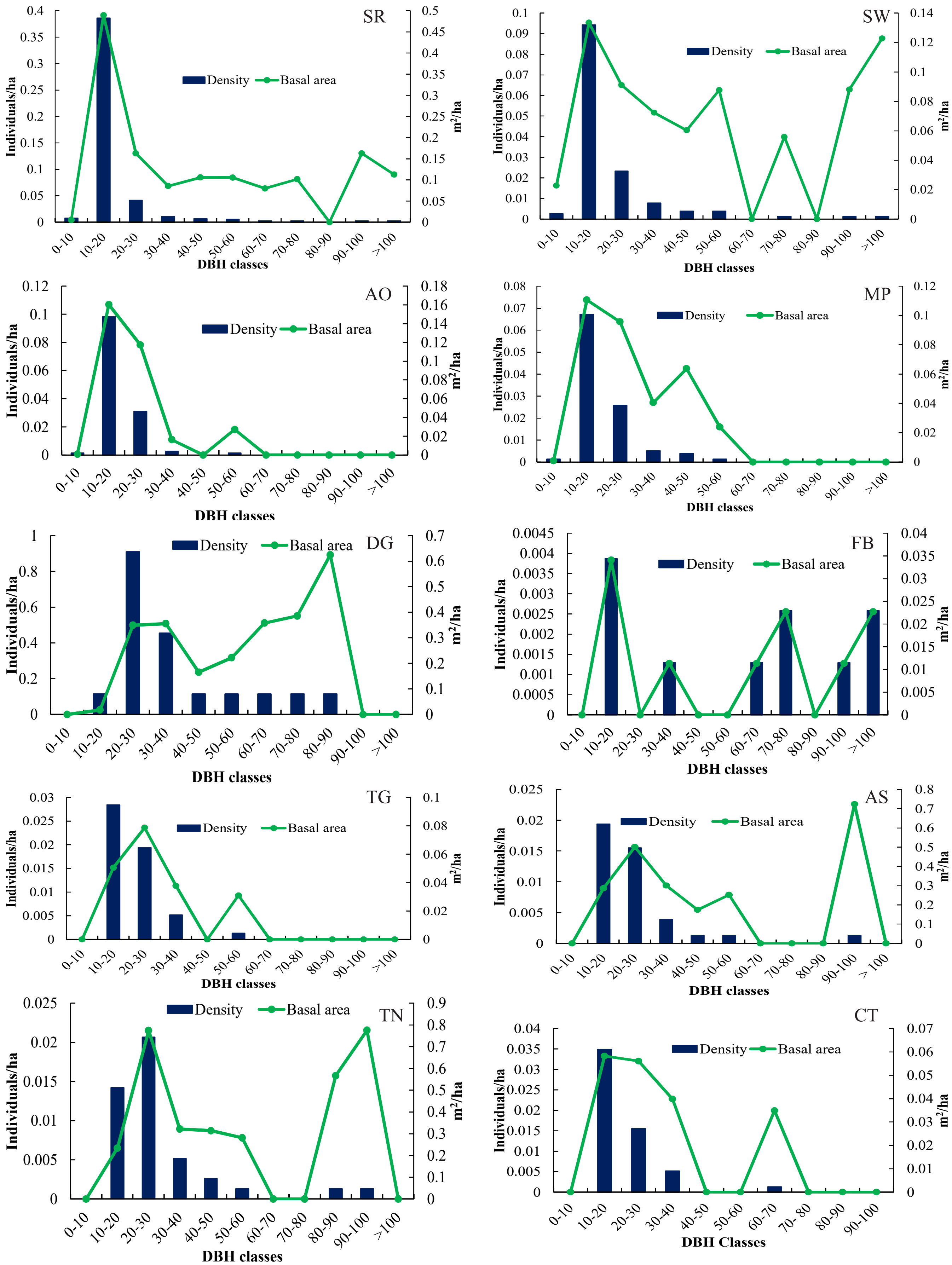


Figure 3. Diameter class distribution of tree species based on density (N/ha) and basal area ($m^2$/ha) of top ten dominant species. Species names are as in Figure 4.

diameter class (10-20 cm). This dominance can be attributed to its aggressive regeneration through suckers following disturbances. Similarly, other co-dominant species exhibit a similar distribution pattern due to their ability to tolerate competition for space and resources from other dominant species, as well as their ability to colonize open spaces and gaps in forest cover (Riyanto 2006, Sapkota et al. 2010, Tripathi et al. 2020, Yassir 2014).

The regeneration status of the recorded juveniles was assessed based on the population size of seedlings and saplings (Sharma et al. 2018). In the Himalayas, the regeneration of tree species is influenced by varied microclimate conditions, resulting in different regeneration patterns across the region (Lahiri and Dash 2021). Forests with dense canopy may affect the survival of seedlings by reducing the amount of sunlight reaching the forest floor (Pokhriyal et al. 2010). A total of 4336 regenerating individuals per hectare were recorded. Figure 4 illustrates the regenerating individual count for the 10 dominant tree species. Out of the 87 tree species recorded, 'Good regeneration' was observed in 67 species, 'Fair regeneration' in 11 species, 'Poor regeneration' in 3 species, and 'Nil regeneration' in 6 species. 'Good regeneration' implies a pattern where seedlings> saplings> mature trees (Khan and Tripathi 1987, Paul et al. 2019). The complete absence of regeneration for species such as *Erythrina arborescens, Mangifera indica, Sterculia villosa, Trewia nudiflora, and Terminlia elliptica* raises concerns, as these species may be on the threshold of extinction from the forest. Community diversity indices including the Shannon-Weiner index, Simpson dominance index, Evenness index, and Margalef index were calculated (Swamy et al. 2000). The calculated indices were within range compared to values reported in previous studies from the Eastern Himalaya (Rawat et al. 2018, Haq et al. 2022, Saito et al. 2005), indicating relatively stable community diversity within the Mahananda Wildlife Sanctuary.

## CONCLUSIONS

Assessing the floral diversity pattern under prevailing

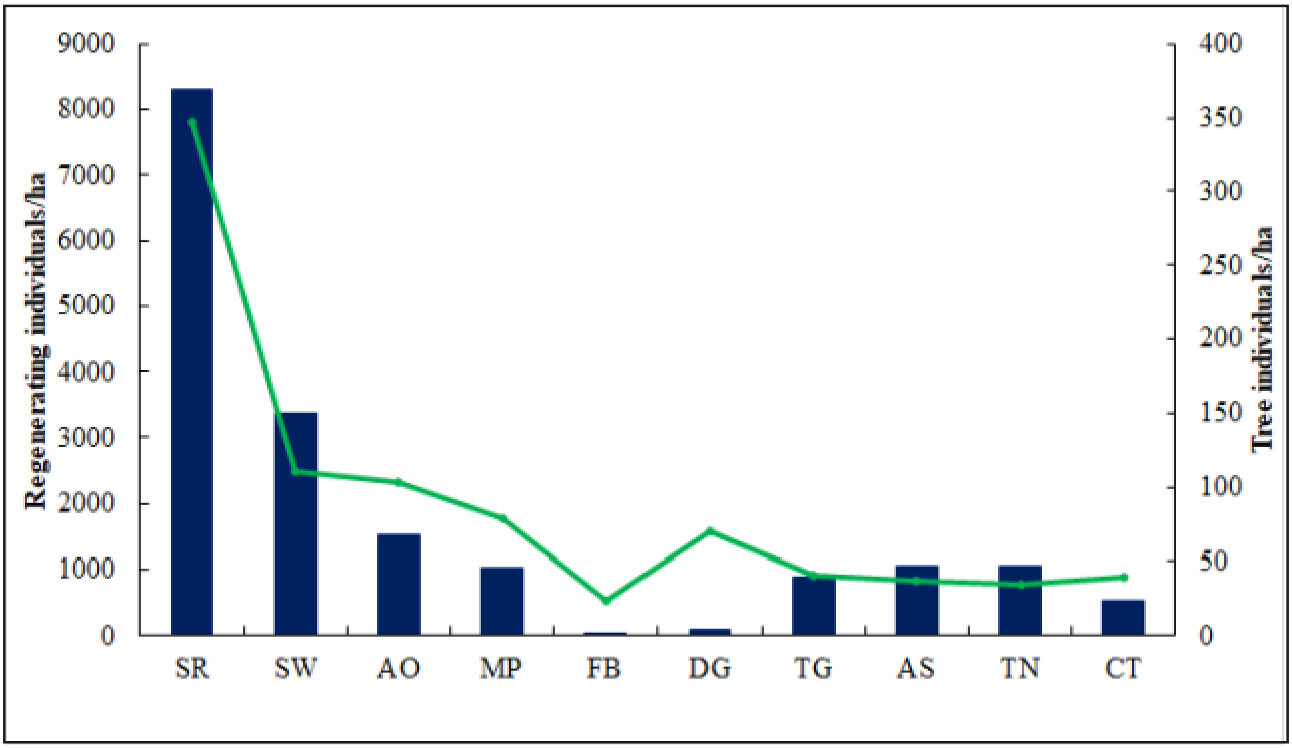


Figure 4. Regeneration status of dominant tree species; SR - *Shorea robusta*, SW - *Schima wallichii*, AO - *Acer oblongum*, MP - *Magnolia pterocarpa*, FB - *Ficus benghalensis*, DG - *Duabanga grandiflora*, TG - *Tectona grandis*, AS - *Aglaia spectabilis*, TN - *Tetrameles nudiflora*, CT - *Chukrasia tabularis*

environmental conditions is crucial for establishing baseline information on ecosystem health and understanding the complexities of ecosystem functions. This aids in accurately estimating species threat levels and prioritizing conservation efforts for threatened ecosystems in a timely manner. The changing climate in the Himalayas significantly impacts the species composition, survival, and regeneration of native flora in the region. Additionally, anthropogenic disturbances exert a considerable influence on the Himalayan environment. Rural communities residing around forests often face socio-economic challenges, resulting in adverse effects on the ecosystem services provided by the region. This study aims not only to comprehend the present status of vegetation in the region to develop appropriate management strategies for preserving native flora but also to formulate management policies that accommodate the traditional rights of local communities for sustainable livelihoods. This can be achieved by identifying and quantifying forest types, biodiversity distribution, and natural resources. Promoting agro-forestry among plantations in adjoining forest areas and encouraging the use of native tree species for providing shade in tea plantations are important conservation strategies. Efforts such as plantation drives with native plant species in degraded forest areas should be implemented. Moreover, cross-breeding of native plant species in research forest areas and promoting their plantation in forest gaps can enhance the diversity of native species in the wild, thus maintaining natural biodiversity. These measures are crucial for the long-term conservation and sustainability of Himalayan ecosystems

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