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ORIGINAL ARTICLE

Field deriving insights on the tree diversity of Kolli hills vegetation

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ABSTRACT
Studies on biodiversity and conservation require enumeration of available species and authentic documentation, which are essential for the conservation and sustainable renewal of resources. In Tamil Nadu, Kolli Hills is part of the Eastern Ghats, endowed with rich plant resources. Therefore, the present investigation focused on tree diversity based on altitudinal ranges from 200 to 1400 MSL, with new insights. An intensive field survey using line transects was conducted at 324 sites in the foothills of the Kolli Hills. GIS databases were also used to construct maps. This tree diversity survey recorded 183 species belonging to 62 angiosperm families. A total of 154 tree genera were identified in this study. A mixed pattern of species diversity was observed, with evergreen, semi-evergreen, deciduous, dry deciduous, and arid deciduous tree types, which are prominent and well adapted to local habitat characteristics. Species diversity analysis was conducted based on rare and dominant species. A maximum of 76 tree taxa was found predominantly on slopes and hilltops. Rare species were sporadically distributed across all the study sites. Tree distribution along the altitudinal gradient showed the dominance of certain family members from lower (200 MSL) to higher elevations. Angiosperm families such as Malvaceae, Sterculiaceae, and Rutaceae were prominent in rangeland and mid-elevation slopes, while in some arid terrain pockets, Euphorbiaceae was prevalent. Celastraceae and Lauraceae members were restricted to the top hill ranges. However, Leguminosae members were found at all sites. Phenological observations clearly demonstrated the synchronization of flowering and fruiting under local climatic conditions. This study documented tree diversity based on altitude, for which no other reports on the Kolli Hill trees are available. Therefore, this study strongly supports the vegetation analysis of trees on the Kolli Hills for conservation and utilization purposes.
KEYWORDS: Kolli hills, Population dynamics, Tree diversity, Altitudinal range, Ever-green, Deciduous, Phenology.

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INTRODUCTION

Biodiversity has primarily been studied at three levels: ecosystem, species, and genetics. However, the process of diversification across all life forms is controlled and triggered by numerous complex factors. To establish species, in particular ecological niches, evolved species undergo gradual changes in their traits, both in positive and negative terms, with pure organic homogeneity within the organism being beneficial for survival and reproduction. The last 200 years of human domination worldwide have exerted constant pressure on the natural environment, either directly or indirectly, affecting the normal hormonal phases of many plant and animal life forms. Furthermore, over the last 20 decades, erratic environmental conditions induced by human activities have directly affected natural plant populations among life forms [1]. The primary disturbance caused by man-made activities has created many ecological changes in plant communities within the environment. Consequently, changes within a species influenced by the environment can also alter the genetic composition of the species. Critical analyses and explorative research on forest vegetation have provided insights into the status of species diversity in specific ecosystems [2]. Forest ecosystems are complex and dynamic interactive networks among the species present in particular ecological regions. These interactions are caused by multiple factors such as climate, soil type, topography, and disturbances. The composition of forest vegetation in hilly regions, often considered pristine owing to their relatively untouched nature, is particularly rich in biodiversity and can support a wide variety of species, including many that are of ecological, economic, and medicinal value [3].

These regions, along with their diverse species associations, provide a critical opportunity to investigate the complex relationships that govern forest dynamics. Elucidating these interactions is essential for the conservation of forest ecosystems and for ensuring the sustainable utilization of their resources for human well-being. Numerous species in these forests are not only crucial for maintaining ecological equilibrium, but also contribute directly to the livelihood of local communities through timber, medicinal plants, and non-timber forest products (NTFPs) [4]. Tree species are permanent constituents of climax communities in the natural forest ecosystems. Several mechanisms have been proposed to explain the coexistence of tree populations. Spatial patterns and tree architecture play pivotal roles in accommodating neighboring variable species components in niche-based habitat heterogeneity and neutral-based dispersal limitations. Species interactions, such as growth, survival and reproduction have also been played a significant role in shaping the form and structure of forest communities [5].

The Eastern Ghats, a discontinuous range of mountains spanning several Indian states, harbor rich biodiversity with diverse flora and fauna, including endemic species [6]. Studies have revealed significant plant diversity in this region, with over 3200 flowering plant species recorded [7]. A large-scale investigation in the southeastern Ghats identified 143 liana species across 55 hectares, with 20 species endemics to peninsular India and seven species categorized as rare and endangered [8]. Despite their recognized biodiversity, the Eastern Ghats remain comparatively understudied in relation to the Western Ghats biodiversity hotspots [9]. This paucity of research encompasses various aspects of plant ecology including species population dynamics, soil surveys, and geophysical studies [10]. Furthermore, there are discrepancies in the conservation status of different areas within the Eastern Ghats. Certain regions exhibit high plant diversity, whereas others experience declining plant diversity due to overexploitation, habitat destruction, and grazing pressures [11]. The Eastern Ghats constitute a significant biodiversity repository in India, characterized by high species richness and endemism. However, anthropogenic pressures threaten this diversity, underscoring the urgent need for conservation efforts [11]. To address these challenges, the implementation of modern scientific approaches such as remote sensing and GIS techniques is recommended for comprehensive ecological studies and effective conservation planning in this ecologically sensitive region [12]. Plant diversity sensing and GPS data are essential species and their population dynamics and provide clear-cut conservation strategies. Therefore, the present study deals with tree classification data on taxonomical and phenological aspects of altitude on the Kolli hills (Eastern Ghats, Tamil Nadu) by three district boundary zones I to III, from below 200 to a maximum of 1400 MSL.

MATERIAL AND METHODS

STUDY AREA

This study was conducted in the Kolli Hills, located in the Namakkal district of Tamil Nadu. This area comprises an isolated hill range of discontinuous Eastern Ghats and represents a prominent range in the southern region. It is situated between 110 10'54" - 110 30'00" N latitude and 780 15'00" - 780 30'00" E longitude, encompassing a total forest area of 490 square kilometers across three reserve pockets: Ariyur Solai, Kundur Nadu, and Pulianjolai [13]. The altitude varied from 200 to 1400 MSL, with slopes ranging from gentle to very steep. The average annual rainfall in the Kolli Hills is 1340 mm3, and the predominant soil type is loamy black soil. According to the Forest Survey of India (FSI) classification, the Kolli Hills encompass various vegetational zones, including dense forests, non-forests, open forests, scrublands, and water bodies [13].

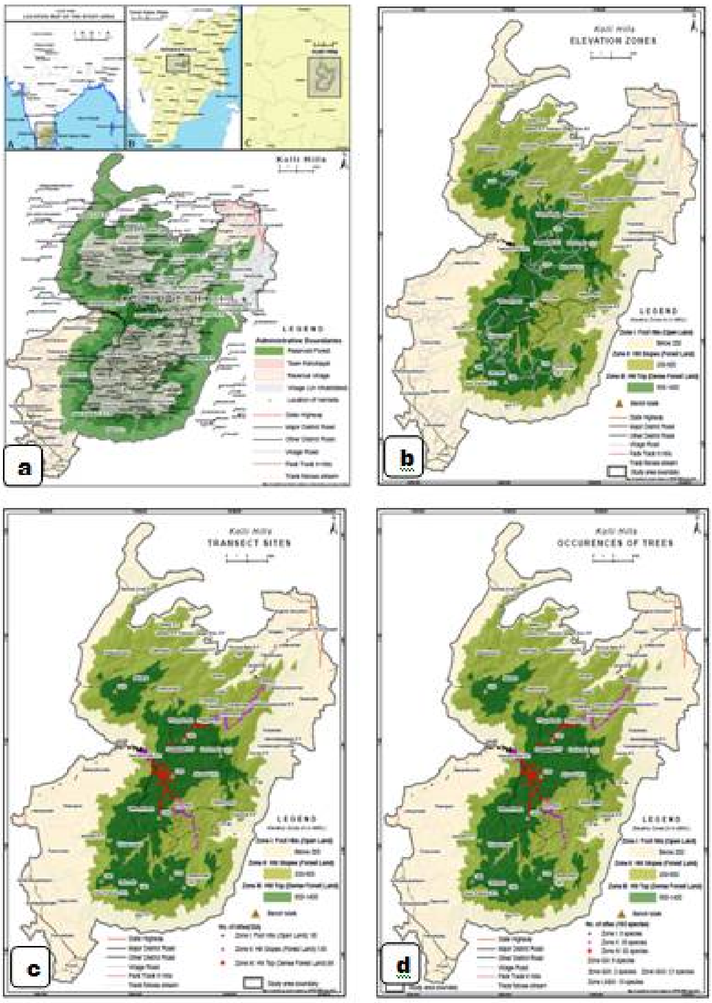

Figure 1: Map of Kolli hills a) Forest Boundary b) Eleveation zones c) Transect sites d) Occurrence of trees

MAPPING WORK

The primary and secondary data were collected from various sources and compiled using GIS software in digital format available for the Kolli Hills, obtained from reliable sources of Remote Sensing (RS) and geographical information systems (GIS). The GIS database of the structural boundaries of elevation ranges was superimposed with the primary data collected through a specific application on geotagged study sites. Spatial analyses were performed using spatial queries and overlay analysis conducted using the ArcGIS software platform to derive reliable insights into the study area [14].

FIELD SURVEY AND SAMPLING METHODS

The field survey was conducted over three years from 2017 to 2019. A periodical visit was performed every 2 months. Tree diversity was noticed without disturbing any vegetation to capture the necessary photographs using a canon DSLR camera. A line transect was made on the possible predetermined route randomly based on environmental criteria to support tree diversity. The transect can vary in length, other ranges 50 m to 500 m distance variation type which broadly included on 7 categories for the present above: 1. Individual species **(**Common):(IC);2. Individual species (Rare):(IR); 3. Individual species (Mixed population) :(IM);4. Population in (Dominant):(PD); 5. Population in (Rare):(PR);6. Population of (Cultivated):(PC);7. Population of (Planted):(PP).

RESULTS AND DISCUSSION

Biodiversity and conservation are crucial research areas that are essential for maintaining natural resources. Human activities and disasters significantly affect plant communities in altered environments, making plant conservation a critical scientific endeavor at the local, regional, and national levels [10]. Plant occurrence studies can be divided into two main categories: i) examining plants and their populations in urban biodiversity areas and ii) studying plants in natural forest ecosystems in hilly

regions, which are vital for sustainable human use. The structure and composition of natural vegetation are influenced by ecological and environmental factors that affect species diversity, dominance, and distribution. This study focused on tree diversity in the Kolli Hills, examining altitudinal variations from 200 to 1400 MSL [8].
Tree occurrence was recorded from the Karavalli comabi and Thammappatti range lands (200 MSL), designated as elevation zone I. Mid-elevation Zone II (200–800 MSL) features rocky, uneven terrain slopes. Zone III (800–1400 MSL) comprised dense forest vegetation with variable habitat richness. A detailed field survey identified 183 tree species from 62 angiosperm families and 154 genera (Table 1). This study focused on altitudinal diversification and distribution of tree species, contributing to biodiversity, conservation, and functional ecology. It provides information on forest formation, including evergreen, semi-evergreen, and deciduous tree types (Figure 2). Certain tree species were exclusive to specific zones, whereas others spanned multiple zones or all zones (Table-1). Zones II and III were characterized by This study reported the highest tree diversity (127/183) and examined tree distribution patterns at the individual (common, rare, mixed) and population (common, rare, planted, cultivated) levels, as well as flowering and fruiting phenology (Table) to understand biodiversity and conservation. Zone III predominantly consisted of evergreen, semi-evergreen, and deciduous trees. Species-specific distributions across zones showed that some species were unique to individual zones and others across combinations of two zones (I and II, I and III, or II and III), with some species common to all zones. Zone III had the highest tree diversity, while Zone II had 35 species. This study recorded 127 tree species within zone II & III.

Table 1: The trees species of Kolli hills with botanical name, Family, Species Occurrence at altitudinal Zones, diversity Pattern, Types and Phenology

S. No	Botanical name	Family	Species occurrence on zones*	Species diversity pattern**	Tree types	Phenology
1.	*Magnolia champaca* L.	Magnoliaceae	III	PR	Evergreen	Fl P: March –July
2.	*Annona reticulata* L.	Annonaceae	I & II	IM	Evergreen / Deciduous	Fl P: March – April
3.	*Capparis grandis* L.f.	Capparaceae	I & II	PR	Deciduous	Fl P: October-November.
4.	*Crateva religiosa* G.Forst.	Capparaceae	III	PR	Deciduous	Fl P: March – April
5.	*Cochlospermum religiosum* (L.) Alston	Cochlospermaceae	III	IM	Deciduous	Fl P: February to April
6.	*Flacourtia ramontchi* L. Her	Flacourtiaceae	III	PD	Deciduous	Fl P: May-August
7.	*Scolopia crenata* (Wight & Arn.) D.Clos	Flacourtiaceae	I & II	PD	Evergreen	Fl P: October-April
8.	*Pittosperum floribundum* Wight & Arn.	Pittisporaceae	III	PR	Dry deciduous	Fl P : May-August
9.	*Eurya japonica* Thumb	Theaceae	III	IM	Evergreen	Fl P: March-December
10.	*Shorea roxburghii* G.Don	Dipterocarpaceae	III	PR	Deciduous / semi evergreen	Fl P: January - March
11.	*Grewia asiatica* L.	Malvaceae	I, II & III	PD	Deciduous	Fl P: November-August
12.	*Grewia hexamita* Burret	Malvaceae	III	PR	Evergreen	FlP: November-March
13.	*Grewia obtusa* Wallich ex Gamble	Malvaceae	II & III	IM	Evergreen	Fl P and Fr P: April-July
14.	*Grewia orbiculata* Rottl.	Malvaceae	II & III	IM	Deciduous / semi evergreen	Fl P: February – September
15.	*Guazuma ulmifolia* Lam.	Sterculiaceae	I & III	PD	Deciduous	Fl P: February – September
16.	*Sterculia guttata* Roxb.	Sterculiaceae	III	PR	Deciduous / semi-evergreen	Fl P: August – September
17.	*Firmiana colorata* (Roxb.) R. Br	Sterculiaceae	I, II & III	PR	Deciduous	Fl P: March–June
18.	*Eriolaena hookeriana* Wight & Arn.	Sterculiaceae	I, II & III	PR	Deciduous	Fl P: February–March.
19.	*Helicteres isora* L.	Sterculiaceae	III	PR	Deciduous	Fl P: April –December
20.	*Hildegerdia populifolia* (Roxb.)Schott & Endl.	Sterculiaceae	III	PR	Deciduous	Not known
21.	*Kleinhovia hospital* L.	Sterculiaceae	III	PR	Evergreen	Fl P: February–April

22.	*Pterospermum xylocarpum* (Gaertn.) Santapau & Wagh	Sterculiaceae	III	PR	Deciduous	Fl P: November – January
23.	*Sterculia urens* Roxb.	Sterculiaceae	I & II	IM	Deciduous	Fl P: April – May
24.	*Elaeocarpus serratus* L	Elaeocarpaceae	III	PD	Evergreen	Fl P: November to February
25.	*Muntingia calabura* L.	Elaeocarpaceae	I & III	PD	Evergreen	Fl P: December – January
26.	*Melpighia sps*	Malpighiaceae	III	PR	Evergreen	Not known
27.	*Melicope lunu-ankenda* (Gaertn.) Merr.	Rutaceae	III	PR	Ever green	Fl P: July –August
28.	*Limonia acidissima* L.	Rutaceae	III	PP	Deciduous	Fl P: January - March
29.	*Clausena dentata* (Willd.) Roemer	Rutaceae	I & II	PD	Evergreen	Fl P: February-May
30.	*Atalantia racemosa* Wight & Arn.	Rutaceae	II	PD	Evergreen	Fl P: October-January
31.	*Chloroxylon swietenia* DC.	Rutaceae	I & II	PD	Deciduous	Not known
32.	*Helietta apiculata* Benth.	Rutaceae	III	PR	Dry deciduous	Not known
33.	*Melicope elleryana* F.Muell. T.G.Hartley	Rutaceae	III	PR	Deciduous / semi evergreen	Fl P: November to February
34.	*Murraya paniculata* (L.) Jack	Rutaceae	III	PD	Evergreen	Fl P: April – October
35.	*Naringi crenulata* (Roxb.) Nicolson	Rutaceae	I, II & III	PD	Deciduous	Fl P –April – May
36.	*Pleiospermium alatum* (Wight &Arn.) Swingle	Rutaceae	II	PD	Dry deciduous	Fl P: January-April
37.	*Balanites roxburghii* Planchon	Balanitaceae	I, II & III	PD	Evergreen	Not known
38.	*Ochno obtusata* DC.	Ochnaceae	III	PR	Deciduous	Fl P: March – July
39.	*Bursera penicillata* (D.C) Engl.	Burseraceae	III	PD	Deciduous / semi evergreen	Fl P: March – June
40.	*Boswellia glabra* Roxb.	Burseraceae	III	PD	Dry deciduous	Fl P: February-March
41.	*Commiphora caudata* (Wight &Arn.) Engl.	Burseraceae	II & III	PD	Deciduous	Fl P: April-June
42.	*Amoova canarana* Hiern	Meliaceae	II	IM	Evergreen	Not known
43.	*Aglaia roxburghiana* Miq. Hiern	Meliaceae	II & III	IM	Evergreen	FL P: November-August
44.	*Chukrasia tabularis* A.Juss	Meliaceae	II & III	IR	Deciduous	Fl P: May-March
45.	*Melia azedarach* L.	Meliaceae	I	IR	Deciduous	Fl P: May-December
46.	*Swietenia mahagoni* (L.)	Meliaceae	III	PP	Semi-evergreen	Fl P: April-November.
47.	*Toona ciliata* M.Roem.	Meliaceae	II & III	PD	Deciduous	Fl P: February-March
48.	*Ximemia Americana* L.	Olacaceae	II	PR	Deciduous	Not known
49.	*Opilia amentacea* Roxb.	Opiliaceae	II	PD	Deciduous	Fl P: February-July
50.	*Ilex wightiana* Wall ex Wt.	Aquifoliaceae	III	PR	Evergreen	Not known
51.	*Glyptopetalum lawsonii* Gamble	Celastraceae	II	PD	Evergreen	Fl P: September - December
52.	*Maylenus heyneana* (Roth) Roju & Babv	Celastraceae	II & III	PD	Evergreen	Fl P: July-February
53.	*Pteurostylia opposita* (Wallich)Alston	Celastraceae	II	PD	Evergreen	Fl P: April-May
54.	*Euonymus japonicas* Thunb.	Celastraceae	II & III	PD	Evergreen	Fl P: May – June
55.	*Maesopsis eminii* Engl.	Rhamnaceae	I, II & III	PP	Deciduous	Fl P: September-April
56.	*Allophyllus serratus* Radlk	Sapindaceae	II	PR	Evergreen	Fl P: August-December
57.	*Dimocarpus longan Lour*	Sapindaceae	II	IR	Evergreen / semi-evergreen	Fl P: March-August
58.	*Filicium decipiens* (Wight & Arn.)Thwaites	Sapindaceae	II & III	PD	Evergreen / semi-evergreen	Fl P: October - February
59.	*Schleichera oleosa* (Lour.) oken	Sapindaceae	I, II & III	PD	Evergreen	Fl P: January - February
60.	*Meliosma pinnata* (Roxb.) Maxim.	Sabiaceae	II & III	PD	Deciduous / Evergreen	Fl P: April - June
61.	*Meliosma simplicifolia* (Roxb.) Walp.	Sabiaceae	II	PR	Evergreen	Fl P: December-August
62.	*Buchanania axillaris* (Desr.) T.P.Ramamoorthy	Anacardiaceae	III	PR	Dry deciduous	Fl P: May-June
63.	*Lannea coromandelia* (Houtt.) Merr.	Anacardiaceae	I	PP	Deciduous	Fl P: January-May.

64.	*Mangifera indica* L.	Anacardiaceae	I	PP	Evergreen	Fl P: September-April
65.	*Nothopegia heyneana* Gamble	Anacardiaceae	II & III	PR	Evergreen	Fl P: May-June
66.	*Rhus mysorensis* G. Don	Anacardiaceae	II & III	PD	Dry deciduous	FlP: November-January.
67.	*Semicarpus anacardium* Linn	Anacardiaceae	I, II & III	PR	Deciduous	Fl P: February-April
68.	*Spondias mangifera* Wild	Anacardiaceae	I, II & III	PR	Ever green / Deciduous	Fl P: April-May
69.	*Spondias pinnata* (L.f.)Kurz.	Anacardiaceae	II	PR	Deciduous	Fl P: March – December
70.	*Toxicodendron radicans* (L.) Kuntze	Anacardiaceae	II	PR	Deciduous	Fl F: February-May
71.	*Moringa concanesis* Nimmo ex Dalz.& Gibson	Moringaceae	I, II & III	PR	Evergreen	Fl P: January – April
72.	*Alysicarpus bupleurifolius* (L.) DC.	Papilionoideae	III	PD	Evergreen	Fl P: February to August
73.	*Dalbergia lanceolaria*	Papilionoideae	II	IR	Deciduous	Fl P: January-March
74.	*Dalbergia sissoo* Roxb.	Papilionoideae	II	IR	Deciduous	Fl P January-April
75.	*Dalbergia sps*	Papilionoideae	II	IR	Deciduous	Fl P: August-September
76.	*Erythrina stricta* Roxb.	Papilionoideae	III	PP	Deciduous	Fl P: January-May
77.	*Erythrina variegate* L.	Papilionoideae	III	PR	Deciduous	Fl P: February--March.
78.	*Gliricida sepium* (Jacq.) Walp.	Papilionoideae	III	PP	Dry deciduous	Fl P: March–May
79.	*Pongamia pinnata* (L.)	Papilionoideae	I	PP	Evergreen / deciduous	FlP: February-June
80.	*Pterocarpus mersupium* Roxb.	Papilionoideae	II & III	PR	Deciduous	Fl P: September-October
81.	*Wisteria sps*	Papilionoideae	III	IR	Deciduous	Not Known
82.	*Bauhinia recemosa* Lam.	Caesalpiniodeae	II	PP	Deciduous	Fl P: March- June
83.	*Saraca indica* L.	Caesalpiniodeae	II	PR	Evergreen / semi-evergreen	Fl P: February -April
84.	*Senna septemtrinalis* (Vir) H.S. Irwin& Barneby	Caesalpiniodeae	II	IM	Dry deciduous	Fl P: February –March
85.	*Tamarindus indica* L.	Caesalpiniodeae	I	PP	Evergreen / semi-evergreen	Fl P:September - April
86.	*Acacia gaumeri* S.F. Blake	Mimosoideae	I, II & III	PP	Evergreen	Fl P: February-March
87.	*Acacia polycantha* Willd.	Mimosoideae	I, II & III	PD	Deciduous	Fl P: September – December
88.	*Albizia amara* (Roxb.) Boivin	Mimosoideae	I	PR	Deciduous	Fl P: February–April
89.	*Albizia lebbeck*	Mimosoideae	II & III	IM	Evergreen	Fl P: April-September
90.	*Dichrostachys cinevea* (L.) Wight & Arn.	Mimosoideae	I, II & III	PD	Deciduous	Fl P: May – September
91.	*Prunus ceylanica* (Wight) Miq.	Rosaceae	III	PD	Evergreen	Fl P: September-April
92.	*Prunnus cerasoides* D. Don	Rosaceae	III	PD	Deciduous	Fl P: December - February
93.	*Prunus gardneri* Hook.f.	Rosaceae	III	PD	Evergreen	Fl P: September-April
94.	*Pygeum wightianum* Blume	Rosaceae	III	PD	Evergreen	Fl P: March – April
95.	*Anogeissus latifolia* (DC.) Wallich exGuill. & per.	Combretaceae	II	PR	Deciduous	Fl P: April-July
96.	*Terminalia chebula* Retz.	Combretaceae	II	IR	Deciduous	Fl P: May-June
97.	*Eucalyptus grandis* Hill ex Maiden	Myrtaceae	II	PP	Evergreen	Fl P: September – April
98.	*Eucalyptus torelliana* F. Muell	Myrtaceae	II	PP	Evergreen	Fl P: September to October
99.	*Eugenia bracteata* Roxb.	Myrtaceae	II	IM	Evergreen	Fl P: March-April
100.	*Psidium guajava* L.	Myrtaceae	III	PP	Evergreen	FlP: March-May
101.	*Syzygium cumini* (L.) Skeels	Myrtaceae	III	PP	Evergreen	L Fa: January-March
102.	*Careya arborea* Roxb.	Leucythidaceae	I, II & III	PR	Deciduous	Fl P: March – April
103.	*Memecylon umbellatum* Burn. f.	Melastomataceae	I, II & III	PD	Evergreen	Fl P: February – March

104.	*Memecylon edula* Roxb.	Melastomataceae	I, II & III	PD	Evergreen	Fl P: April - June
105.	*Carica papaya* L.	Caricaceae	I	PP	Evergreen	Fl P: February–March
106.	*Alangium solvifolium* (L.f.) Wangerin	Alangiaceae	III	PD	Deciduous	Fl P: February -April
107.	*Lasianthus verticillatus* (Lour.)	Caprifoliaceae	II	PR	Evergreen	Fl P:December-May
108.	*Viburnum punctatum* Buch.-Ham. ex D. Don	Caprifoliaceae	II	PD	Evergreen	Fl P: March-October
109.	*Randia candolleana* Wight & Arn.	Rubiaceae	III	PD	Semi evergreen	Fl P: April-March
110.	*Ixora notoniana* Wallich ex Don	Rubiaceae	II	PR	Evergreen	Fl P: July - August
111.	*Canthium dicoccum* (Gaertn.) Merr.	Rubiaceae	III	PD	Semi-evergreen	Fl P: January-March
112.	*Gardenia latifolia* Aiton	Rubiaceae	II	PD	Deciduous	Fl P: February-April
113.	*Gardenia resinifera* Roth.	Rubiaceae	II	PD	Deciduous	Fl P: September-January
114.	*Haldenia cordifolia* (Roxb.)	Rubiaceae	II	PR	Deciduous	Fl P: December-March
115.	*Knoxia corymbosa* Willd	Rubiaceae	III	PD	Semi evergreen	Not Known
116.	*Morinda coreia* Buch.-Ham.	Rubiaceae	II	PR	Evergreen	Fl P: March-June
117.	*Morinda tinctoria* Roxb.	Rubiaceae	I	PR	Evergreen	Fl P: March-June
118.	*Pavetta blanda* Bremek	Rubiaceae	II	PD	Evergreen	Fl P: May – June
119.	*Plectronia didyma* Kurz	Rubiaceae	II	PD	Evergreen	Fl P: February-August
120.	*Wendlandia thyrsoidea* (Roth.) Steud.	Rubiaceae	II	PR	Evergreen	Fl P: February-April
121.	*Pentanema indicum* (L.) Ling	Astraceae	II & III	PD	Evergreen	Fl P:November-February
122.	*Vernonia monosis* CB. Clarke	Astraceae	II & III	PP	Semi-evergreen	Fl P: October-December
123.	*Vaccinium neilgherrense* Wight	Vacciniaceae	II & III	PR	Evergreen	Fl P:February-April
124.	*Maesa indica* (Roxb.) A.DC.	Myrsinaceae	II	PR	Evergreen / semi-deciduous	Fl P: January -March
125.	*Chrysophyllum roxburghii* Don.	Sapotaceae	III	PR	Evergreen	Fl P: April-November
126.	*Donella lanceolata* (Blume) Aubrev.	Sapotaceae	III	PR	Evergreen	Fl P: April-November
127.	*Mimosops elangi* L.	Sapotaceae	III	PP	Evergreen	Fl P: March-April
128.	*Symplocos spicuta* Roxb.	Symplocaceae	III	PR	Evergreen	Fr P: March-May
129.	*Ligustrum japonicum* Thunb.	Oleaceae	III	PR	Evergreen	Fl P: February-June
130.	*Ligustrum robustum* (Roxb.) Blume	Oleaceae	III	PR	Evergreen	Fl P: February-May
131.	*Ligustrum walker* Decne	Oleaceae	III	PR	Evergreen	Fl P: April – May
132.	*Linociera intermedia* Wight.	Oleaceae	III	PD	Evergreen	Not known
133.	*Linociera ramiflora* (Roxb.) Wall.	Oleaceae	III	PD	Evergreen	Fl P: February-May
134.	*Olea glandulifera* wallich.	Oleaceae	III	PD	Deciduous	Fl P:February - April
135.	*Olea paniculata* R.Br.	Oleaceae	I, II & III	PD	Evergreen	Fl P: February-April
136.	*Schrebera swietenioides* Roxb.	Oleaceae	III	PD	Deciduous	Fl P: March - April
137.	*Holarrhena sps*	Apocyanaceae	III	PR	Deciduous	Fl P: Mach-May
138.	*Stryehnos potatorcum* L.f.	Loganiaceae	I, II & III	PD	Deciduous	Fl P: February -March
139.	*Cordial collococca* L.	Boraginaceae	III	PD	Deciduous	Fl P: May - October
140.	*Ehretia laevis* Roxb.	Boraginaceae	III	PR	Deciduous	Fl P: January to April
141.	*Solanum riparium* Pers.	Solanaceae	III	PD	Semi-deciduous / semi evergreen	Fl P: June to October
142.	*Dolichandrona arcuata* (Wight)	Bignoniaceae	III	PR	Deciduous	Fl P: October on wards
143.	*Callicarpa formosana* Rolfe	Verbanaceae	III	PR	Evergreen	Fl P: October to November
144.	*Gmelia arborea* Roxb.	Verbanaceae	III	PR	Deciduous	Fl P: February–March
145.	*Premna tomentosa* willd.Sp.	Verbanaceae	III	PR	Semi evergreen	Fl P: January – March
146.	*Tectona grandis* L.f.	Verbanaceae	I, II & III	PP	Deciduous	Fl P: January onwards
147.	*Vitex altissima* L.f	Verbanaceae	III	PR	Semi-evergreen / Deciduous	Fl P: June onwards

148.	*Myristica beddonnei* King.	Myristicaceae	III	PD	Evergreen	Fl P: September–November
149.	*Myristica datyloides* Gaertn.	Myristicaceae	III	PD	Evergreen	Not Known
150.	*Alseodaphna semicorpifolia* Nees.	Lauraceae	III	PD	Evergreen	Not Known
151.	*Beilschmiedia bourdillonii* Brandis	Lauraceae	III	PD	Evergreen	Fl P: January-June.
152.	*Cinnamomum verum* J. Presl	Lauraceae	III	PD	Evergreen	Fl P: March-April
153.	*Litsea decanensis* Gamble	Lauraceae	III	PD	Semi evergreen	Fl P: November – December
154.	*Litsea oleoides* (Meissner) Hook.f.	Lauraceae	III	PD	Evergreen	Fl P: October-April.
155.	*Litsea sps*	Lauraceae	III	PR	Evergreen / semi-evergreen	Fl P: July-September
156.	*Machilus macrantha* Nees	Lauraceae	III	PR	Evergreen	Fl P: February-April
157.	*Neolitsea scrobiculata* Gamble	Lauraceae	III	PR	Evergreen	Fl P: March-April
158.	*Phoeba wightii* Meissner.	Lauraceae	III	PD	Evergreen	Fl P: March-April
159.	*Elaeagnus kologa* D.F.K. Schldl.	Elaeagnaceae	III	PD	Deciduous	Fl P: January-February
160.	*Santalum album* L.	Santalaceae	II	PP	Dry deciduous	Fl P: December-April
161.	*Antidesma ghaesembilla* Gaertner	Euphorbiaceae	III	PD	Evergreen	Fl P: March-September
162.	*Putrnjiva roxburghii* Wall.	Euphorbiaceae	III	PD	Evergreen	Fl P: March-August
163.	*Agrostistachys borneensis* Becc.	Euphorbiaceae	III	PD	Evergreen	Fl P: December-March
164.	*Fluggea sps*	Euphorbiaceae	III	PR	Semi-evergreen	Not Known
165.	*Breynia patens* Rolfe.	Euphorbiaceae	II & III	PD	semi evergreen	Fl P: February-September
166.	*Cleistanthus collinus* (Roxb.) Benth.ex	Euphorbiaceae	II & III	PD	Evergreen	Not Known
167.	*Excoecaria robusta* Hook.f.	Euphorbiaceae	III	PR	Evergreen	Fl P: November-February
168.	*Virosa Roxb* ex wild	Euphorbiaceae	III	PD	Semi-evergreen	Fl P: April–July
169.	*Givotia rottleriformis* Griff. ex-Wight	Euphorbiaceae	III	PD	Semi evergreen	Fr P: May -June
170.	*Macranga peltata* Muel.	Euphorbiaceae	III	PD	Evergreen / semi-evergreen	Fl P: January-February
171.	*Mallotus intermedius (Baillon)*	Euphorbiaceae	III	PD	Semi-evergreen	Fl P: January-March
172.	*Trewia polycarpa* Benth.	Euphorbiaceae	II & III	PD	Semi-evergreen	Fr P: November-March
173.	*Bischofia javanica* Blume	Bischofiaceae	III	PD	Semi evergreen	FL P: August – November
174.	*Celtis cinnamomea* Lindey	Urticaceae	III	PD	Evergreen	FL P: January – March
175.	*Terma orientalis* Blume	Urticaceae	III	PR	Evergreen	FL P: January – March
176.	*Trema micrantha* (L.) Blume	Cannabaceae	II & III	IR	Evergreen	Fl P: January – March
177.	*Artocarpus heterophyllus* Lam.	Moraceae	III	PP	Evergreen	FL P: March - April
178.	*Ficus infectoris* Roxb	Moraceae	III	PR	Deciduous	Not known
179.	*Ficus retusa* L.	Moraceae	III	PD	Evergreen	Not known
180.	*Ficus tomontosa* Roxb.	Moraceae	III	PR	Deciduous	Fl P: January-April
181.	*Ficus Virens* W.T.Aiton	Moraceae	III	PR	Deciduous	Fl P: January to March
	Caryota urens L.	Arecaceae	III	PR	Evergreen / semi-evergreen	Fl P: January-April
182.	*Phoenix sylvestris* (L.) Roxb	Arecaceae	III	PR	Dry deciduous	Fl P: April – December

*Species Occurrence Zone:
i) Zone I (Foot hills) – Below 200 MSL
ii) Zone II (Sloop) - 200 – 800 MSL
iii) Zone III (Top hills) – 800 – 1400 MSL

Tree diversity patterns**
1. Individual species (Rare) : IR
2. Individual species (Mixed) : IM
3. Population in (Dominant) : PD
4. Population in (Rare) : PR
5. Population of (Planted) : PP

Phenology
Flowering Period: Fl P

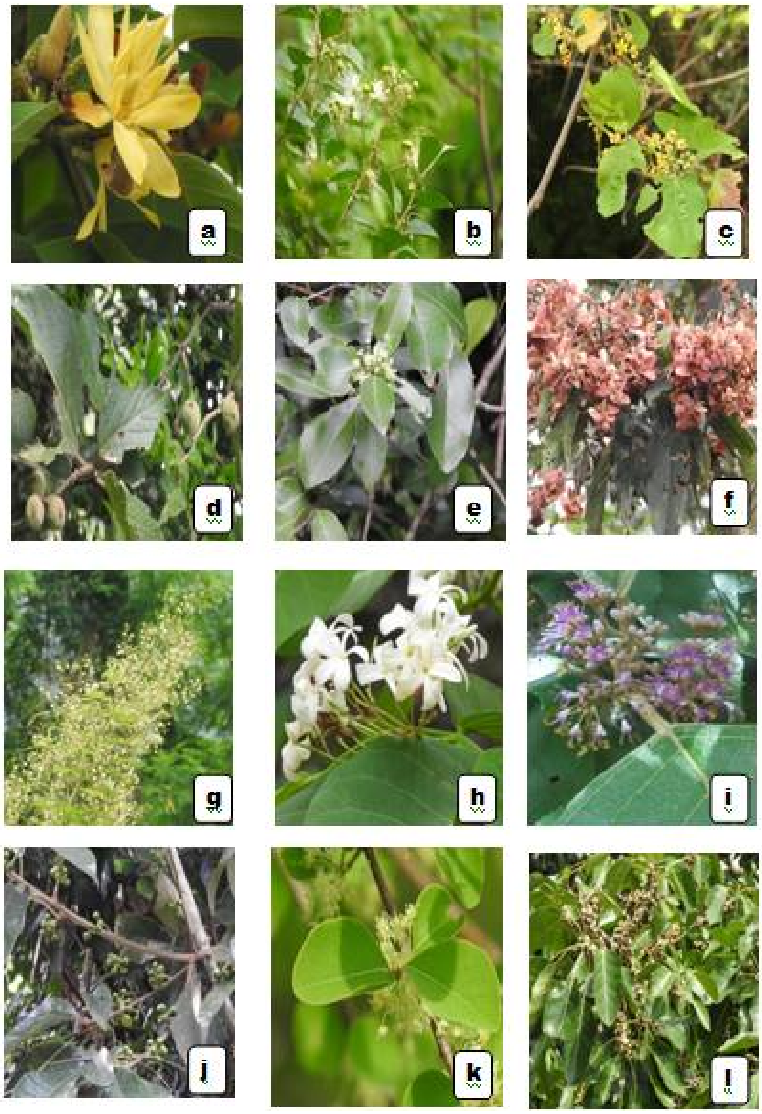

Figure 2: a) *Magnolia champaca* L. (Magnoliaceae) Ever green restricted to hill top and rare population. b) *Capparis grandis* L.f. (Capparaceae) deciduous rare population distribute in foot hills and slopes. c) *Grewia asiatica* L. (Malvaceae) dominant population in all the study area (I, II, III) d) *Grewia hexamita* Burret (Malvaceae) another member Malvaceae, rare population more restricted in hill tops. e) *Euonymus japonicas* Thunb. (Celastraceae) Ever green f) *Saraca indica* L. (Caesalpiniodeae) rare population in the sloppy vegetation flowering on February – April. g) *Acacia gaumeri* S.F. Blake (Mimosoideae) dominant population distributed in all three zones. h) *Holarrhena* sps (Apocyanaceae) distribution restricted to hill top and deciduous. i) *Callicarpa formosana* Rolfe (Verbanaceae) Evergreen and flowering during winter period with prominent inflorescence. j) *Litsea sps* (Lauraceae) restricted hilly region Ever green. k) *Fluggea sps* (Euphorbiaceae) restricted to dry rocky area of deciduous representation. l) *Ficus Virens* W.T.Aiton (Moraceae) population rare on road side on the hills and deciduous tree species.

The vegetation patterns in these forests are stratified by climatic conditions, soil characteristics, and elevation. Angiosperm tree families align ecologically with their environments, contributing to ecosystem stability. Documentation covered the distribution patterns of individual species and overall tree populations, including cultivated and planted varieties, serving as bioindicators in the Kolli Hills Region [15]. Forest ecosystems are characterized by diverse vegetation types (evergreen, semi-evergreen, deciduous, and scrub jungles). The spatial configuration of vegetation is determined by environmental gradients and evolutionarily developed functional traits. Local resource availability and habitat conditions significantly influence functional traits such as photosynthetic efficiency, leaf longevity, and rooting depth. Evergreen species adapt to nutrient-scarce or stable environments through persistent

foliage and conservative resource use, thereby enabling continuous growth despite limited resources [16].
These organisms typically dominate regions with consistent and low resource availability, such as high-altitude areas or xeric ridgelines. In contrast, deciduous species adapt to environments with seasonal resource fluctuations, exhibiting rapid photosynthesis during favorable periods and leaf abscission during unfavorable seasons, to minimize water loss and nutrient allocation during drought or winter dormancy. Deciduous species are categorized under the acquisitive strategy with higher photosynthetic rates during active seasons, whereas evergreen species, under the conservative strategy, are better suited to nutrient-poor or drier conditions [17]. Plant biodiversity and variability are influenced by ecological conditions, which lead to diverse growth forms and reproductive cycles. After the establishment of the climax community, plants adapt slowly to their surroundings, with micro-level characteristic modifications. Forest formations, including evergreen, semi-evergreen, deciduous, dry deciduous, scrub jungle, and grassland species, vary in their growth form and reproductive cycle [18]. Many forests exhibit mixed formations, accommodating various evergreen, semi-evergreen, and deciduous species that are influenced by microclimatic variability, soil properties, and water availability. Mixed vegetation adapts to terrain and environmental conditions, with landscape elements, such as shola, slope, terrain, and plains, providing ecological niches for different adaptations [19].
The findings of this study showed a clear distinction in tree species distribution across altitudinal zones, reflecting the influence of altitude on forest composition and plant communities. The exclusion of tree species in different altitudinal zones suggests that altitudinal zonation is influenced by environmental factors. The temperature, moisture, and soil conditions vary with elevation, resulting in distinct vegetation types at different altitudes. Understanding this zonation is essential for understanding species adaptation and community composition across different altitudes [20]. Zone I (200 MSL): The eight tree species unique to this lower-altitude zone reflect climatic conditions specific to lower elevations, such as warmer temperatures, higher solar radiation, and stable moisture availability. These species are adapted to tropical and subtropical environments. Zone II (200–800 MSL): The 35 species exclusive to this middle-altitude range underscore the importance of the transition zone between lower and higher altitudes. This zone experiences varied climatic conditions, fostering diversity of species adapted to moderate climates and variable precipitation [19]. Zone III (800–1400 MSL): The 92 species unique to this high-altitude zone are adapted to cooler temperatures, lower oxygen levels, and seasonal climates typical of montane forests. A high species count suggests greater species richness at higher altitudes owing to the diverse ecological niches in montane ecosystems. Increased species diversity with altitude is common, where temperature and moisture limit species survival [21].
This study also highlights intermingling zones where species from different altitudinal zones coexist. Zones I and II (six species): The overlap of six species between the lower and middle altitudes indicates their tolerance to environmental variability in both zones. These species likely possess adaptations for broad environmental tolerance, enabling them to adjust to varying temperatures and moisture levels [22]. Zones I and III (two species): The few overlapping species between the lowest and highest altitudes (200–1400 MSL) suggest that high-altitude species are adapted to cold climates, whereas low-altitude species are suited to warmer conditions. These two shared species exhibit intermediate adaptations, allowing them to thrive across a broader altitudinal range [23]. Zones II and III (21 species): The greater number of overlapping species between middle and high altitudes indicates these species have a higher capacity for altitudinal migration or adaptability to varying temperature and moisture gradients. This may represent a transition zone where species mix owing to shared ecological conditions [24].
Common Species Across All Zones (19 species): The 19 species common across all zones likely represent generalists well adapted to various altitudes and conditions. Their ecological plasticity allows them to survive in diverse habitats and to maintain ecosystem stability across gradients [25] (Stephens et al. 2016). The distribution of species across altitudinal zones affects ecological processes such as niche differentiation, species interactions, and evolutionary adaptation. Plant species distribution varies by terrain type: rangelands (Zone I), slopes (Zone II), and upper plains (Zone III), and is influenced by biotic (e.g., competition and predation) and abiotic (e.g., soil fertility and water availability) factors [26]. The varied distribution of common and rare species suggests a heterogeneous pattern influenced by habitat specificity, resource availability, or disturbance regimes. Rare species may be limited by their microhabitat conditions. Mixed Patterns of Occurrence: These patterns suggest that some species are generalists capable of thriving in diverse environments [8].
Some species are generalists and thrive in varied environments, whereas others are specialists confined to specific conditions. For example, species in rangelands adapt to open and disturbed areas, whereas those on slopes or upper plains are sensitive to particular soil and moisture conditions. Understanding

the dominant species and their population dynamics is essential for ecological balance [27]. Dominant species have a greater ecological impact, whereas rare species depend on specific conditions for their survival. Dominant species adapt to a broader range of conditions on rangelands and slopes because of their drought resistance, deep roots, rapid regeneration, soil stabilization, and support from other species. Rare species, often in isolated landscape areas, have specialized habitat needs and are vulnerable to environmental changes such as climate change and land use alterations [28].

The interaction between planted trees (e.g., agroforestry species) and seasonal crops with natural vegetation affects the species diversity and distribution. This study examined tree species in a natural undisturbed forest ecosystem at three levels. Prominent Individual Members: Species dominating local niches and consistently observed across sites. Dominant Families: Groups structurally or functionally dominate the forest and contribute significantly to biodiversity and ecosystem processes [29]. Introduced Agro-Based Plants: Species introduced by human activity, integrating into the ecosystem, and influencing native species dynamics. Observations of prominent individual members highlight species that are critical for local ecosystem functioning, such as keystones or foundational species [30].

Species represent high forest biodiversity, which is crucial for ecosystem resilience to climate variability and disturbances. The rarity of certain species underscores the need for targeted conservation efforts owing to their unique ecological and genetic traits [31]. The prevalence of 75 dominant tree taxa indicates their ecological importance in forest structure and their significant contribution to ecosystem services, such as nutrient cycling, carbon storage, and habitat provision. Dominant species shape forest dynamics and resilience to environmental change, but overreliance on them can reduce the overall biodiversity without sustainable management [32]. Rare tree species with smaller populations are more susceptible to extinction from habitat destruction, climate change, and invasive species. These species may have unique ecological roles, genetic resources, or cultural significance, necessitating conservation measures, such as habitat protection, community-based conservation, and propagation programs. The introduction of cultivated species by local and external initiatives highlights human interaction with forest ecosystems, providing economic or subsistence benefits, such as fruit, fodder, or timber.

A study on tree diversity identified 67 rare taxa, emphasizing the urgent need for targeted conservation to prevent biodiversity loss. Rare species, which are indicators of ecological health, contribute to ecosystem resilience through genetic diversity. Research on the tree diversity of Kolli Hills has shown species diversity and population dynamics, with altitudinal variation and landscape elements significantly influencing the occurrence of rare and dominant species. The predominance of certain families under favorable conditions recruits a constancy in the ecosystem. Habitat niche is altered or restricted to rare species. This study examined the dominant families and phenological patterns in the study area. Forest vegetation is influenced by ecological, evolutionary, and anthropogenic factors, which affect species composition and distribution. The Malvaceae, Sterculiaceae, Rutaceae, Meliaceae, Anacardiaceae, Leguminosae, and Rubiaceae families dominate natural forest vegetation, indicating specific environmental conditions [33].

Malvaceae, widely distributed in tropical and subtropical regions, adapts to diverse climates and soils. Similarly, Sterculiaceae, which is often related to Malvaceae, is prominent in forests with specific ecological attributes. The absence of Tiliaceae trees in these forests is notable; typically associated with moist, stable environments, their absence might reflect local changes, competitive exclusion, or disturbances altering the ecosystem composition [34]. Understanding these patterns is crucial for gaining insights into ecological processes, dominant family roles, and biodiversity implications. Examination of floristic composition highlights the factors driving vegetation patterns. Studying Malvaceae and Sterculiaceae dominance and Tiliaceae absence provides information on soil characteristics, climate conditions, and successional stages, aiding sustainable forest management and conservation [35].

Rutaceae's predominance is significant due to its ecological versatility, aromatic compounds, and contributions to ecosystem services such as fauna habitats and pollinator support. Their dominance may reflect favorable conditions, such as soil nutrients, climatic factors, or competitive advantages in reproduction and dispersal mechanisms [36]. The dominance of Meliaceae and the absence of other tree families offer valuable insights into forest ecosystems, informing studies on species interactions, habitat preferences, and environmental pressure effects on forest composition. This highlights the importance of biodiversity assessment in guiding conservation and sustainable forest management strategies [37]. Understanding these patterns is crucial for maintaining the ecological balance and resilience in natural forests. The predominance of *Celastraceae*, *Anacardiaceae*, *Rubiaceae*, and the absence of other families are essential for interpreting forest ecology and biodiversity, providing insights into adaptive strategies, ecological processes, and environmental factors influencing species distribution [38].

The widespread presence of Leguminosae in forests is due to effective seed dispersal mechanisms that allow the occupation of diverse habitats. Legume species produce fruits adapted to various dispersal modes, including wind, animals, and mechanical release, aiding forest regeneration and biodiversity enhancement [39]. Many legumes are capable of self-pollination, which is beneficial in environments with few pollinators or unpredictable conditions, ensuring high seed production and successful establishment [40].

The dominance of Euphorbiaceae in arid scrub forests is crucial for understanding plant drought resistance and xerophytic adaptation. Euphorbiaceae species in desert environments often have succulent stems or modified leaves to conserve water, thus playing key roles in xeric ecosystems [41]. Adaptation to Harsh Conditions: This family includes C4 and CAM plants, which have evolved unique photosynthetic pathways to minimize water loss during extreme temperatures [42]. Their presence in arid scrub jungles indicates specialization for low rainfall and high-temperature conditions, contributing to ecosystem resilience. Euphorbiaceae stabilizes arid ecosystems by providing habitat and sustenance for diverse species, despite limited resources. The prevalence of Lauraceae and Oleaceae in the hilltop vegetation indicates their climatic preferences and the influence of elevation on plant distribution. Moisture and Temperature: Hilltops receive increased precipitation due to orographic lift and have cooler temperatures, which favor families sensitive to temperature extremes and prefer temperate climates. Lauraceae thrives in humid tropical environments and is common in montane forests [43]. Adaptation to Canopy and Soil Conditions: Hilltops typically have shallower soils that favor families adapted to such environments. Oleaceae, including olives, adapt to nutrient-poor rocky soils at higher elevations, which explains their dominance on hilltops [44]. Nutrient Cycling: These species are crucial for nutrient cycling on hilltops, influencing the forest structure and ecological balance.

Phenological patterns of flowering and fruiting in trees, such as those studied in the Kolli Hills, provide critical insights into ecosystem dynamics and their responses to climatic and ecological factors. Flowering and fruiting times are influenced by environmental factors such as temperature, photoperiod, and rainfall [45]. The march and April indicate a response to favorable climatic conditions, likely related to temperature and water availability [46]. Global warming has been shown to shift phenological events, causing earlier flowering and fruiting in many species, thereby disrupting plant-pollinator interactions and affecting biodiversity and ecosystem functioning [47]. Phenological processes are influenced by the genetic and epigenetic mechanisms that govern reproductive strategies and resource allocation in perennial trees. Understanding these mechanisms at the molecular level is essential for predicting tree adaptations to environmental changes. Phenology significantly supports ecosystem services, such as pollination and fruit production, and influences forest management and conservation planning for ecosystem sustainability [48].

The steady increase in flowering from January, peaking in March and April, is synchronized with environmental factors, such as temperature, day length, and rainfall, maximizing pollination success when pollinators are most active. The decline in flowering after April reflects the species' adjustment to resource availability and the optimization of reproduction [49]. Pollination and Fruiting Cycles: Defined flowering periods followed by prolonged fruiting ensure resource continuity for pollinators, seed dispersers and other organisms. Overlapping flowering and fruiting seasons in some species promotes diverse ecological interactions [50]. This process involves interactions between environmental factors, plant characteristics, and ecological mechanisms, including the synchronization of flowering, pollination, and seed dispersal [51]. Phenological phenomena, such as flowering duration and seed production cycles, significantly affect species distribution and establishment in forest ecosystems. Extended reproductive cycles, continuous seed setting, and prolonged seed dispersal suggest that forest tree species engage in ongoing reproduction, thereby enhancing species persistence and resilience within the ecosystem [52,53].

CONCLUSION

This study elucidated the substantial influence of altitudinal gradients (200–1400 MSL) on tree diversity and distribution in the Kolli Hills. Species richness was positively correlated with altitude, with Zone III (800–1400 MSL) demonstrating the highest diversity, encompassing evergreen and deciduous species that adapted to lower temperatures and heterogeneous microhabitats. Dominant species constitute essential components of forest structure, provide ecosystem services, and ensure resilience. Examples include members of the Malvaceae, Sterculiaceae, and Leguminosae families, which exhibit broad adaptabilities. Conversely, certain tree species are rare, with limited distribution; these require targeted conservation efforts because of their ecological and genetic significance. Flowering and fruiting patterns are synchronized with local climatic conditions, reaching peak activity during favorable periods, such as

March and April. This synchronization ensures successful pollination and seed dispersal, contributing to forest regeneration and ecosystem stability. The documentation of 183 tree species, including 67 rare taxa, underscores the status of Kolli Hills as a critical biodiversity hotspot. These findings emphasize the necessity for conservation strategies, such as habitat protection, community-based initiatives, and propagation programs, to preserve rare species and sustain ecosystem services. This study represents one of the first systematic documentations of tree diversity in the Kolli Hills, providing insights into forest composition, ecological processes, and phenology.

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Conflict of interest
The authors declare no conflict of interest.

REFERENCES
1. Tseng ML, Chiu ASF, Ashton W, Moreau V. (2019). Sustainable management of natural resources toward sustainable development goals. Resour Conserv. Recycl.,145:419–421..
2. Rahman AU, Khan SM, Khan S, Hussain A, Rahman IU, Iqbal Z, Ijaz F. (2016). Ecological assessment of plant communities and associated edaphic and topographic variables in the Peochar Valley of the Hindu Kush mountains. Mt Res Dev., 36(3), 332–341.
3. Barsoum N, Coote L, Eycott AE, Fuller L, Kiewitt A, Davies RG. (2016). Diversity, functional structure and functional redundancy of woodland plant communities: How do mixed tree species plantations compare with monocultures? Forest Ecol Manage., 382, 244–256.
4. Chou P. (2018). The role of non-timber forest products in creating incentives for forest conservation: a case study of Phnom Prich Wildlife Sanctuary, Cambodia. Resources., 7(3), 41.
5. Carvalho J, Magalhães M, Pena S. (2020). Spatial and temporal variability regarding forest: From tree to the landscape. In: Spatial Variability in Environmental Science – Patterns, Processes, and Analyses. IntechOpen
6. Ramachandra TV, Vinay S, Bharath HA. (2016). Environmental flow assessment in a lotic ecosystem of Central Western Ghats, India. Hydrol Curr Res., 7, 1–14.
7. Moghanloo L, Ghahremaninejad F, Bidarlord M, Norastehnia A. (2023). Diversity and distribution of endemic and threatened plant species in the Sorkhabad Protected Area, Zanjan, NW Iran and identification of the biodiversity hotspots in the area. Nat Croat., 32(1), 17–34.
8. Saikia P, Deka J, Bharali S, Kumar A, Tripathi OP, Singha LB, Dayanandan S, Khan ML. (2017). Plant diversity patterns and conservation status of eastern Himalayan forests in Arunachal Pradesh, Northeast India. Forest Ecosyst., 4, 1–12.
9. Kasodekar AK, Jadhav AD, Bhagat RB, Pawar RM, Gupta VS, Kadoo NY. (2019). The importance of conserving fragmented forest patches with high diversity of flowering plants in the northern Western Ghats: an example from Maharashtra, India. J Threat Taxa., 11(7), 13833–13849.
10. Corlett RT. (2016). Plant diversity in a changing world: status, trends, and conservation needs. Plant Divers., 38(1), 10–16.
11. Naidu MT, Suthari S, Yadav PBS. (2023). Measuring ecological status and tree species diversity in Eastern Ghats, India. Acta Ecol Sin., 43(2), 234–244
12. Vaissi S, Sharifi M. (2019). Integrating multi-criteria decision analysis with a GIS-based siting procedure to select a protected area for the Kaiser's mountain newt, *Neurerguskaiseri* (Caudata: Salamandridae). Glob Ecol Conserv., 20, e00738.
13. Kalaivani P, Gunasekaran C. (2017). Studies on the diversity of butterfly fauna in and around Kotlli Hills, Namakkal district, Tamilnadu. Int J Adv Res Biol Sci., 4(12), 45–50.
14. Guo X, Coops NC, Tompalski P, Nielsen SE, Bater CW, Stadt JJ. (2017). Regional mapping of vegetation structure for biodiversity monitoring using airborne lidar data. Ecol Inform., 38, 50–61.
15. Premavani D, Naidu MT, Venkaiah M. (2014). Tree species diversity and population structure in the tropical forests of north central Eastern Ghats, India. Not Sci Biol., 6(4), 448–453.
16. González-Paleo L, Pastor-Pastor A, Rajnoch G, Ravetta DA. (2019). Mechanisms of nitrogen conservation at the leaf-level in annual and perennial desert forbs: Implications for perennial crops domestication. Flora., 252, 62–68.
17. Volaire F. (2018). A unified framework of plant adaptive strategies to drought: crossing scales and disciplines. Glob Change Biol., 24(7), 2929–2938.
18. Ghollasimood S, Faridah-Hanum I, Nazre M. (2012). Abundance and distribution of climbers in a coastal hill forest in Perak, Malaysia. J Agric Sci., 4(5), 245.
19. Ghafari S, Ghorbani A, Moameri M, Mostafazadeh R, Bidarlord M, Kakehmami A. (2020). Floristic diversity and distribution patterns along an elevational gradient in the northern part of the Ardabil province rangelands, Iran. Mt Res Dev., 40(1), R37.

20. Xu M, Du R, Li X, Yang X, Zhang B, Yu X. (2021). The mid-domain effect of mountainous plants is determined by community life form and family flora on the Loess Plateau of China. Sci Rep., 11(1), 10974.
21. Grytnes JA, et al. (2006). Species richness patterns of vascular plants along altitudinal gradients in the Himalayas. J Biogeogr., 33(2), 291–302.
22. Givnish TJ. (2013). Ecological adaptations to high altitudes in tropical trees. Ann Bot., 112(5), 853–864.
23. Pearson RG, et al. (2009). Shifts in plant species' ranges due to climate change: Implications for conservation. J Ecol., 97(3), 456–467.
24. McCain CM. (2009). Global analysis of bird elevational diversity. Glob EcolBiogeogr., 18(3), 346–360.
25. Stephens ML, et al. (2016). Generalist species at altitudinal extremes: adaptations to variable environments. J Ecol., 104(5), 1075–1085.
26. Niu Y, Zhou J, Yang S, Chu B, Ma S, Zhu H, Hua L. (2019). The effects of topographical factors on the distribution of plant communities in a mountain meadow on the Tibetan Plateau as a foundation for target-oriented management. Ecol Indic., 106, 105532.
27. Yahdjian L, Sala OE, Havstad KM. (2015). Rangeland ecosystem services: shifting focus from supply to reconciling supply and demand. Front Ecol Environ., 13(1), 44–51.
28. Pessarakli M. (2017). Growth responses of sacaton grass (*Sporobolus airoides* Torr.) and seashore paspalum (*Paspalum vaginatum* Swartz) under prolonged drought stress condition. Adv Plants Agric Res., 7(4), 320–326.
29. Haber LT, Fahey RT, Wales SB, Correa Pascuas N, Currie WS, Hardiman BS, Gough CM. (2020). Forest structure, diversity, and primary production in relation to disturbance severity. EcolEvol., 10(10), 4419–4430.
30. Zimmerer KS, de Haan S, Jones AD, Creed-Kanashiro H, Tello M, Carrasco M, Meza K, Amaya FP, Cruz-Garcia GS, Tubbeh R, Olivencia YJ. (2019). The biodiversity of food and agriculture (Agrobiodiversity) in the Anthropocene: research advances and conceptual framework. Anthropocene., 25, 100192.
31. Enquist BJ, Feng X, Boyle B, Maitner B, Newman EA, Jørgensen PM, Roehrdanz PR, Thiers BM, Burger JR, Corlett RT, Couvreur TL. (2019). The commonness of rarity: Global and future distribution of rarity across land plants. Sci Adv., 5(11), 0414.
32. Schuldt A, Assmann T, Brezzi M, Buscot F, Eichenberg D, Gutknecht J, Härdtle W, He JS, Klein AM, Kühn P, Liu X. (2018). Biodiversity across trophic levels drives multifunctionality in highly diverse forests. Nat Commun., 9(1), 2989.
33. Silveira AP, Menezes BSD, Loiola MIB, Lima-Verde LW, Zanina DNE, Carvalho ECDD, Souza BCD, Costa RCD, Mantovani W, Menezes MOTD, Flores LMA. (2020). Flora and annual distribution of flowers and fruits in the Ubajara National Park, Ceará, Brazil. Floresta e Ambiente., 27(2), e20190058.
34. Song X, Cao M, Li J, Kitching RL, Nakamura A, Laidlaw MJ, Tang Y, Sun Z, Zhang W, Yang J. (2021). Different environmental factors drive tree species diversity along elevation gradients in three climatic zones in Yunnan, southern China. Plant Diversity. 1;43(6):433-43.
35. Tiawoun MA, Malan PW, Comole AA. (2022). Effects of soil properties on the distribution of woody plants in communally managed rangelands in Ngaka Modiri Molema District, North-West Province, South Africa. Ecologies., 3(3), 361–375.
36. Farré-Armengol G, Fernández-Martínez M, Filella I, Junker RR, Peñuelas J. (2020). Deciphering the biotic and climatic factors that influence floral scents: a systematic review of floral volatile emissions. Front Plant Sci., 11, 1154.
37. Brockerhoff EG, Barbaro L, Castagneyrol B, Forrester DI, Gardiner B, González-Olabarria JR, Lyver POB, Meurisse N, Oxbrough A, Taki H, Thompson ID. (2017). Forest biodiversity, ecosystem functioning and the provision of ecosystem services. Biodivers Conserv., 26, 3005–3035.
38. Haider MR, Alam S, Mohiuddin M. (2017). Regeneration potentials of native tree species in three natural forests of Sylhet, Bangladesh. J Biodivers Conserv Bioresour Manag., 3(2), 1–10.
39. Vázquez-Yanes C, Orozco-Segovia A. (1993). Patterns of seed longevity and germination in the tropical rainforest. Annu Rev Ecol Syst., 24, 69–87.
40. Sandifer PA, Sutton-Grier AE, Ward BP. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. Ecosystem services. 1;12:1-5.
41. Pausas JG, et al. (2004). Fire and the evolution of Mediterranean ecosystems. Plant Ecol., 171(1), 47–58.
42. Cushman JC, Bohnert HJ. (2007). The role of CAM in plant stress resistance. Physiol Plant., 129(1), 35–41.
43. Silk JWF, et al. (2015). Phylogenetic composition and tree community dynamics in Southeast Asia's montane forests. Glob EcolBiogeogr., 24(10), 1251–1263.
44. van der Warff H. (2004). Systematics and ecology of Oleaceae. Proc Natl Acad Sci USA., 101(47), 16242–16247.
45. Arunkumar K, Chandrashekar KR, Shenoy HSP. (2020). Phenological study on *Polyalthia fragrans* (Dalz.) Bedd.—An endemic species of Western Ghats, India.
46. Wang X, Morin X, Zhang J, Chen G, Mao L, Chen Y, Song Z, Du Y, Ma K. (2023). Geographical patterns and determinants in plant reproductive phenology duration. Front Plant Sci., 14, 1199316.
47. Bartomeus I, Ascher JS, Wagner D, Danforth BN, Colla S, Kornbluth S, Winfree R. (2011). Climate-associated phenological advances in bee pollinators and bee-pollinated plants. Proc Natl Acad Sci USA., 108(51), 20645–20649.
48. Perina BB, Liboni AP, Montanher DR, Messetti AVL, Pimenta JA, Bianchini E. (2019). Phenology of the tree community in a seasonal forest in southern Brazil. Braz J Bot., 42, 477–490.

49. Novák J, Trotsiuk V, Sýkora O, Svoboda M, Chytrý M. (2014). Ecology of *Tilia sibirica* in a continental hemiboreal forest, southern Siberia: An analogue of a glacial refugium of broad-leaved temperate trees?. The Holocene. Aug;24(8):908-18.
50. Chen H, Peng Y, Zhang Y, Corlett RT. (2015). Winter cropping in *Ficus tinctoria*: an alternative strategy. Sci Rep., 5(1), 16496.
51. Albani MC, Coupland G. (2010). Comparative analysis of flowering in annual and perennial plants. Curr Top Dev Biol., 91, 323–348.
52. Henkel, T.W. and Mayor, J.R., (2019). Implications of a long-term mast seeding cycle for climatic entrainment, seedling establishment and persistent monodominance in a Neotropical, ectomycorrhizal canopy tree. Ecological Research, 34(4), pp.472-484.
53. Thuma JA, Duff C, Pitera M, Januario N, Orians CM, Starks PT. (2023). Nutrient enrichment and rainfall affect plant phenology and floral resource availability for pollinators. Frontiers in Ecology and Evolution. 21;11:1150736.