International Journal of Ecology and Environmental Sciences 50: 481-490, 2024
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2024.0083

Tree Diversity, Regeneration and Ecological Status in Koppa Forest Division, Central Western Ghats, India

ANUSHREE HEBBER, K.[1*] AND KRISHNASWAMY, K.[2]
[1]*Department of Botany, Kuvempu University, Shankaraghatta, Shivamogga, 577451, Karnataka, India*
[2] *Department of Botany, Sahyadri Science College, Shivamogga, 577203, Karnataka, India*
E-mail: anushreekhebbar@gmail.com, Krishna_swamy_k@yahoo.co.in
***Corresponding author**

ABSTRACT
Forests and their trees support human and animal lives by the provision of food and food-associated materials, fodder and foraging sites for their livestock, and medicinal materials, as well as multiple ecological services. However, unbalanced utilization of these resources and the biotic and abiotic disturbances interrupt their sustainability and ecological functions. We studied the tree population structure, diversity, and regeneration status of tree species in the Koppa Forest Division. The present study reports 207 species of adult trees belong to 140 genera and 49 families were present in the area and nine species were present only as regenerating individuals. The ecological status of the tree species of the region according to International Union for Conservation of Nature, red list indicates that four species are of data deficit, five species are endangered, six are nearly threatened, 17 are vulnerable and 81 species are of least concern. The study concludes that among the recorded 207 tree species, 22 species showed a frequency value of < 0.01 and 185 species showed ≥ 0.01, which indicates that only 10% of the species were less frequently found in the region. This indicates the species richness of the area. To maintain the diversity the rate of survival of regenerating individuals should be increased. This study may pave the way for further research on regeneration potentials of the native species for conservation and enhancement of forests in the future.

Key words: Diversity, Forest, Regeneration, Conservation, Distribution, Western Ghats

INTRODUCTION

Natural forests are biodiversity-rich habitats on the globe because they host diversified flora and fauna species. They support human and animal lives by the provision of various products and services. While forest products include edible fruits, fodder, timber, and medicinal materials, their services cover soil protection and influence water cycles, nutrient cycling, weather amelioration, shelter for animals, nests for birds and quality of recreation sites. These products, services, and roles are important for the rural, urban, forest-based communities, and for human societies in all the developing countries. However, the sustainability of these resources and their functions are continuously influenced by overexploitation, overgrazing, intensive browsing, illegal harvesting, agricultural expansion, urbanization, climate variability, and climate change. Thus, it is important to know the current state of forest tree populations, their dynamics, and the potential disturbances as a pre-requisite towards their sustainable management and species conservation. Furthermore, other environmental issues such as global climate change, habitat fragmentation, land degradation, land use change, and forest canopy gaps due to intensive logging have potential influence on the forest tree populations and their diversity (Mohammed et al. 2021). This study aims to explore the status of tree population, diversity, and natural regeneration, as well as the potential disturbances that may hinder the sustainability of forest resources in Koppa division forests of Western Ghats, which is one of the hotspots of diversity. We compared the tree population's structure (abundance, dominance, frequency, importance value, and species richness) and regeneration status of tree species

MATERIALS AND METHODS

Study area

Koppa Division belongs to Chikkmagaluru district of Karnataka State with a geographical area of 2,000.24 km^2 (Fig. 1). Koppa forest division is situated in central Western Ghats, the south-western part of Karnataka state. The division covers the

Figure 1. Study area (Koppa division)

revenue taluks of Narasimharajpura (N.R. Pura), Koppa and Sringeri. It comprises 89,181 hectares (ha) of forest land constituting about 44.58% of the geographical area of the division (2,000.24 Km²). The division has two sub-divisions, namely, Koppa and Balehonnur, and consists of six ranges, namely, Balehonnur, Chikkagrahara, Kalasa, Koppa, Narasimharajpura (N.R. Pura) and Sringeri. The division has a timber depot at N.R. Pura and Sangameshwara Pete. Forests of Koppa division are principally of semi-evergreen and moist deciduous types with some excellent patches of evergreen forests in Kalasa and Sringeri ranges. In the higher reaches of the evergreen forests, shola vegetation surrounded by grassy blanks is also encountered in the areas adjoining to Kudremukh National Park.

Field work and data analysis

Frequent field visits were under taken in different vegetation types in each forest range to document the diversity of plant species. Before going to the field survey, a basic data about type of forests, total area of available vegetation is collected from the concerned range forest office. In the present work, plantation and soppina betta are not considered for the survey.

Belt transects of size 5 x 100 m were laid in each selected forest block taking into the account of type of forest. Number of transects is based on the area of forest cover. The methodology is designed to sample at least 1 ha of forest in each block to minimize the error. Hence number of transects in each range depended on the total forest cover of that range. As a result, a total of 385 transects were laid in Koppa forest Division to analyse the total floral diversity.

In each transect, trees having ≥30 cm GBH (Girth at Breast Height) are considered as adult trees and their GBH is measured to calculate basal area and relative dominance. The GBH of lianas were also documented. At both ends of each transects, quadrate of 5 x 5 m was laid to document the number of regenerated tree species.

The regenerated tree species are categorized as three classes. Class 1: Seedlings – Regenerating tree species below one feet height; Class 2: Saplings – Regenerating tree species with 1-3 feet height; Class 3: Poles – Regenerating tree species with >3feet height and < 30 cm GBH. Frequency, Density, Abundance, IVI (Importance Value Index) of each species, Shanon diversity value and Simpson's species richness value of trees in the forest range are calculated using standard vegetation analysis methods (Cottam and Curtis 1956, Shanon 1948, Simpson 1949).

RESULTS AND DISCUSSION

A total of 216 tree species belong to 146 genera and 49 families are documented in Koppa Forest Division. Among the documented species, 153 species were observed in both regenerating and adult tree condition, 54 species were observed only in tree condition, and nine species were observed only in regenerating conditions within the study area (Table 1).

Table 1. Diversity of tree species in Koppa Division

S.No.		Pole				Sapling				Seedling				Tree				
	Species name	**A**	**D**	**F**	**IVI**	**A**	**D**	**F**	**IVI**	**A**	**D**	**F**	**IVI**	**A**	**D**	**F**	**BA**	**IVI**
1	*Acrocarpus fraxinifolius* Arn.	..	..	..	..	..	..	..	..	..	..	..	..	5.00	0.01	0.00	0.13	0.06
2	*Acronychia pedunculata* (L.) Miq.	3.96	0.14	0.04	2.27	8.00	0.01	0.00	0.27	..	..	..	..	1.95	0.28	0.15	28.64	2.01
3	*Actinodaphne lanceolata* Dalzell & A.Gibson	2.31	0.12	0.05	2.61	3.27	0.06	0.02	2.55	1.40	0.02	0.01	2.13	1.37	0.15	0.11	3.39	1.29
4	*Adina cordifolia* (Roxb.) Brandis	1.00	0.00	0.00	0.05	..	..	..	..	..	..	..	..	1.65	0.22	0.14	54.89	1.85
5	*Afraegle paniculata* (Schumach. & Thonn.) Engl.	1.20	0.01	0.01	0.28	..	..	..	..	..	..	..	..	8.50	0.04	0.01	0.47	0.17
6	*Aglaia edulis* (Roxb.) Wall.	1.00	0.00	0.00	0.05	..	..	..	..	1.00	0.00	0.00	0.16	2.17	0.07	0.03	2.22	0.44
7	*Aglaia elaeagnoidea* (A.Juss.) Benth.	..	..	..	..	..	..	..	..	..	..	..	..	2.00	0.15	0.07	15.77	1.02
8	*Ailanthus altissima* (Mill.) Swingle	1.00	0.00	0.00	0.05	1.00	0.00	0.00	0.12	..	..	..	..	1.00	0.00	0.00	0.00	0.03
9	*Ailanthus triphysa* (Dennst.) Alston	1.67	0.01	0.00	0.18	..	..	..	..	..	..	..	..	1.31	0.05	0.04	1.25	0.47
10	*Albizia amara* (Roxb.) Boivin	..	..	..	..	..	..	..	..	..	..	..	..	1.42	0.09	0.06	4.23	0.74
11	*Albizia chinensis* (Osbeck) Merr.	1.00	0.00	0.00	0.05	..	..	..	..	15.00	0.02	0.00	1.96	1.30	0.11	0.09	10.09	1.00
12	*Albizia lebbeck* (L.) Benth.	1.00	0.00	0.00	0.11	..	..	..	..	..	..	..	..	1.00	0.06	0.06	2.17	0.62
13	*Albizia saman* (Jacq.) Merr.	..	..	..	..	..	..	..	..	..	..	..	..	2.33	0.02	0.01	0.27	0.11
14	*Alseodaphne semecarpifolia* Nees	1.00	0.00	0.00	0.16	1.00	0.00	0.00	0.12	..	..	..	..	1.00	0.01	0.01	0.00	0.05
15	*Alstonia scholaris* (L.) R. Br.	1.24	0.03	0.02	0.95	1.00	0.00	0.00	0.12	..	..	..	..	1.24	0.07	0.05	5.32	0.62
16	*Annona reticulata* L.	1.25	0.01	0.01	0.22	..	..	..	..	..	..	..	..	1.50	0.01	0.01	0.00	0.06
17	*Anthoshorea roxburghii* (G.Don) P.S.Ashton & J.Heck.	7.03	0.26	0.04	3.36	8.91	0.13	0.01	3.17	9.43	0.09	0.01	8.70	4.18	0.53	0.13	148.96	3.05
18	*Antidesma montanum* var. wallichii (Tul.) Petra Hoffm.	..	..	..	..	..	..	..	..	..	..	..	..	1.50	0.01	0.01	0.00	0.06
19	*Aphanamixis polystachya* (Wall.) R.Parker*	1.91	0.03	0.01	0.69	..	..	..	..	..	..	..	..	..	..	..	..	..
20	*Aporosa cardiosperma* (Gaertn.) Merr.	3.63	0.34	0.09	5.81	2.74	0.17	0.06	7.47	3.26	0.13	0.04	14.00	3.39	1.37	0.40	463.94	8.66
21	*Archidendron bigeminum* (L.) I.C.Nielsen	1.75	0.01	0.01	0.24	..	..	..	..	..	..	..	..	1.00	0.01	0.01	0.00	0.05
22	*Ardisia solanacea* (Poir.) Roxb.	3.17	0.02	0.01	0.46	..	..	..	..	..	..	..	..	1.00	0.01	0.01	0.07	0.13
23	*Artocarpus gomezianus* Wall. ex Trécul	..	..	..	..	..	..	..	..	..	..	..	..	1.20	0.08	0.06	8.31	0.74
24	*Artocarpus heterophyllus* Lam.	1.00	0.01	0.01	0.21	..	..	..	..	..	..	..	..	1.58	0.18	0.12	25.64	1.50
25	*Artocarpus hirsutus* Lam.	1.94	0.04	0.02	1.07	1.25	0.01	0.01	1.02	1.00	0.00	0.00	0.48	1.77	0.40	0.23	202.63	3.56
26	*Artocarpus lacucha* Buch.-Ham.	..	..	..	..	..	..	..	..	..	..	..	..	1.14	0.06	0.05	4.12	0.60
27	*Azanza lampas* (Cav.) Alef.	..	..	..	..	..	..	..	..	..	..	..	..	1.20	0.02	0.01	0.22	0.14
28	*Baliospermum solanifolium* (Burm.) Suresh	1.63	0.02	0.01	0.48	1.00	0.00	0.00	0.24	1.67	0.01	0.00	0.74	1.00	0.01	0.01	0.00	0.05
29	*Bauhinia racemosa* Lam.	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.03	0.03	0.14	0.27
30	*Bauhinia variegata* L.*	1.00	0.00	0.00	0.05	..	..	..	..	..	..	..	..	..	..	..	..	..
31	*Beilschmiedia wightii* (Nees) Benth. ex Hook.f.	15.50	0.04	0.00	0.41	..	..	..	..	..	..	..	..	1.00	0.00	0.00	0.00	0.03
32	*Bergera koenigii* L.	11.43	0.45	0.04	4.85	11.93	0.46	0.04	10.56	13.88	0.45	0.03	45.37	1.14	0.02	0.02	0.17	0.20
33	*Bischofia javanica* Blume	..	..	..	..	2.00	0.00	0.00	0.14	..	..	..	..	2.67	0.06	0.02	7.15	0.38
34	*Bombax ceiba* L.	1.00	0.00	0.00	0.05	..	..	..	..	..	..	..	..	1.25	0.04	0.03	2.14	0.35

S.No.		Pole				Sapling				Seedling				Tree				
	Species name	**A**	**D**	**F**	**IVI**	**A**	**D**	**F**	**IVI**	**A**	**D**	**F**	**IVI**	**A**	**D**	**F**	**BA**	**IVI**
35	*Bridelia retusa* (L.) A.Juss.	1.00	0.01	0.01	0.21	4.00	0.01	0.00	0.19	1.00	0.00	0.00	0.16	2.00	0.01	0.00	0.00	0.03
36	*Buchanania lanzan* Spreng.	2.33	0.01	0.00	0.20	..	..	..	..	..	..	..	..	2.62	0.20	0.08	13.39	1.19
37	*Butea monosperma* (Lam.) Kuntze	1.13	0.01	0.01	0.44	1.50	0.00	0.00	0.27	1.00	0.00	0.00	0.16	1.68	0.08	0.05	3.52	0.62
38	*Callicarpa tomentosa* (L.) L.	3.58	0.11	0.03	1.92	1.00	0.00	0.00	0.12	..	..	..	..	1.18	0.03	0.03	0.13	0.31
39	*Calophyllum apetalum* Willd.	9.63	0.10	0.01	1.14	1.17	0.01	0.01	0.76	1.00	0.01	0.01	0.65	1.00	0.01	0.01	0.01	0.05
40	*Calophyllum inophyllum* L.	..	..	..	..	..	..	..	..	..	..	..	..	1.67	0.01	0.01	0.45	0.10
41	*Calophyllum polyanthum* Wall. ex Choisy	3.33	0.01	0.00	0.23	..	..	..	..	1.00	0.00	0.00	0.16	4.33	0.07	0.02	6.14	0.34
42	*Canarium strictum* Roxb.	1.50	0.02	0.02	0.70	..	..	..	..	..	..	..	..	1.40	0.13	0.09	38.77	1.18
43	*Capparis decidua* (Forssk.) Edgew.	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.00	0.00	0.00	0.03
44	*Carallia brachiata* (Lour.) Merr.	1.33	0.01	0.01	0.34	..	..	..	..	..	..	..	..	1.16	0.06	0.05	2.08	0.54
45	*Careya arborea* Roxb.	2.25	0.01	0.01	0.27	1.50	0.00	0.00	0.27	..	..	..	..	1.41	0.16	0.11	7.30	1.35
46	*Caryota urens* L.	1.73	0.03	0.02	0.92	1.83	0.03	0.02	1.68	3.00	0.21	0.07	22.17	1.52	0.17	0.11	12.00	1.40
47	*Casearia zeylanica* (Gaertn.) Thwaites	4.41	0.79	0.18	12.25	2.67	0.03	0.01	1.42	4.00	0.01	0.00	0.55	1.33	0.06	0.05	0.72	0.53
48	*Cassia fistula* L.	1.36	0.02	0.02	0.80	2.87	0.06	0.02	2.42	1.25	0.01	0.01	0.77	1.53	0.19	0.12	5.56	1.47
49	*Catunaregam spinosa* (Thunb.) Tirveng.	1.93	0.07	0.04	1.83	1.00	0.00	0.00	0.12	..	..	..	..	1.55	0.17	0.11	4.03	1.32
50	*Celtis timorensis* Span.	1.20	0.02	0.02	0.83	1.40	0.01	0.01	0.65	1.33	0.02	0.01	1.84	1.31	0.12	0.09	6.25	1.05
51	*Chionanthus mala-elengi* subsp. mala-elengi	1.33	0.01	0.00	0.17	..	..	..	..	2.00	0.00	0.00	0.29	1.40	0.05	0.04	0.76	0.45
52	*Chukrasia tabularis* A.Juss.	1.33	0.01	0.01	0.34	..	..	..	..					1.00	0.01	0.01	0.01	0.08
53	*Cinnamomum malabatrum* (Burm.f.) J.Presl	2.39	0.19	0.08	4.14	2.35	0.08	0.03	3.92	3.46	0.13	0.04	13.38	1.37	0.25	0.18	15.73	2.16
54	*Cinnamomum sulphuratum* Nees	1.07	0.04	0.04	1.46	..	..	..	..	..	..	..	..	1.20	0.02	0.01	0.06	0.14
55	*Cinnamomum verum* J.Presl	1.00	0.01	0.01	0.27	..	..	..	..	..	..	..	..	1.47	0.07	0.05	1.81	0.59
56	*Citharexylum affine* D.Don*	1.00	0.00	0.00	0.05	..	..	..	..	..	..	..	..	..	..	..	..	..
57	*Clausena anisata* (Willd.) Hook.f. ex Benth.	5.73	0.49	0.09	6.76	4.43	0.17	0.04	5.83	5.25	0.05	0.01	5.66	1.18	0.07	0.06	0.52	0.62
58	*Clausena indica* (Dalzell) Oliv.	1.50	0.02	0.01	0.59	1.10	0.01	0.01	1.25	1.00	0.02	0.02	2.42	3.00	0.01	0.00	0.02	0.04
59	*Coffea arabica* L.*	1.00	0.00	0.00	0.16	1.00	0.01	0.01	0.61	1.50	0.01	0.01	1.35	..	..	..	..	..
60	*Cordia myxa* L.	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.01	0.01	0.02	0.05
61	*Crateva religiosa* G.Forst.	..	..	..	..	..	..	..	..	..	..	..	..	1.25	0.01	0.01	0.11	0.12
62	*Cryptocarya wightiana* Thwaites	..	..	..	..	..	..	..	..	2.00	0.01	0.00	0.58	1.00	0.01	0.01	0.03	0.05
63	*Dalbergia latifolia* Roxb.	2.70	0.07	0.03	1.42	3.83	0.09	0.02	3.27	3.06	0.07	0.02	7.24	1.81	0.34	0.19	80.95	2.70
64	*Dillenia pentagyna* Roxb.	..	..	..	..	..	..	..	..	..	..	..	..	1.46	0.22	0.15	40.41	1.87
65	*Dimocarpus longan* Lour.	6.15	1.04	0.17	13.88	4.14	0.31	0.07	10.73	5.57	0.38	0.07	39.63	2.92	0.76	0.26	211.04	4.91
66	*Diospyros candolleana* Wight	..	..	..	..	1.00	0.00	0.00	0.12	..	..	..	..	1.33	0.01	0.01	0.02	0.09
67	*Diospyros ebenum* J.Koenig ex Retz.	..	..	..	..	..	..	..	..	..	..	..	..	2.10	0.05	0.03	1.02	0.36
68	*Diospyros montana* Roxb.	2.88	0.16	0.06	3.14	3.79	0.30	0.08	11.04	2.61	0.13	0.05	13.97	1.80	0.30	0.17	20.42	2.18
69	*Diospyros ovalis* Hiern	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.00	0.00	0.01	0.03
70	*Diospyros paniculata* Dalzell	..	..	..	..	5.00	0.01	0.00	0.21	..	..	..	..	1.00	0.00	0.00	0.00	0.03
71	*Diospyros pruriens* Dalzell	..	..	..	..	..	..	..	..	2.00	0.00	0.00	0.29	1.00	0.00	0.00	0.00	0.03
72	*Diospyros saldanhae* Kosterm.	1.00	0.00	0.00	0.05	..	..	..	..	1.00	0.00	0.00	0.16	1.00	0.00	0.00	0.00	0.03
73	*Diospyros sylvatica* Roxb.	5.87	0.29	0.05	3.95	4.80	0.09	0.02	3.03	1.00	0.00	0.00	0.32	1.91	0.11	0.06	4.71	0.80

S.No.		Pole				Sapling				Seedling				Tree				
	Species name	**A**	**D**	**F**	**IVI**	**A**	**D**	**F**	**IVI**	**A**	**D**	**F**	**IVI**	**A**	**D**	**F**	**BA**	**IVI**
74	*Dipterocarpus indicus* Bedd.	..	..	..	..	..	..	..	..	..	..	..	..	1.60	0.02	0.01	0.68	0.16
75	*Donella lanceolata* (Blume) Aubrév.	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.01	0.01	0.05	0.05
76	*Elaeocarpus serratus* L.	2.77	0.05	0.02	0.93	2.15	0.04	0.02	1.91	3.42	0.05	0.02	5.66	1.70	0.19	0.11	39.58	1.56
77	*Elaeocarpus tuberculatus* Roxb.	1.33	0.01	0.01	0.34	..	..	..	..	..	..	..	..	1.29	0.06	0.04	3.46	0.51
78	*Elaeodendron glaucum* (Rottb.) Pers.	..	..	..	..	..	..	..	..	..	..	..	..	1.67	0.01	0.01	0.28	0.10
79	*Erythrina suberosa* Roxb.	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.01	0.01	0.07	0.05
80	*Erythrina variegata* L.	..	..	..	..	..	..	..	..	..	..	..	..	1.50	0.01	0.01	0.04	0.06
81	*Eucalyptus globulus* Labill.	..	..	..	..	..	..	..	..	..	..	..	..	1.83	0.06	0.03	2.25	0.41
82	*Eugenia roxburghii* DC.	..	..	..	..	..	..	..	..	..	..	..	..	1.50	0.01	0.01	0.03	0.06
83	*Euonymus indicus* B.Heyne ex Wall.	2.67	0.01	0.00	0.21	..	..	..	..	..	..	..	..	1.00	0.00	0.00	0.00	0.03
84	*Falconeria insignis* Royle	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.00	0.00	0.04	0.03
85	*Ficus arnottiana* (Miq.) Miq.	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.00	0.00	0.04	0.03
86	*Ficus benghalensis* L.	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.01	0.01	0.26	0.08
87	*Ficus drupacea* Thunb.	..	..	..	..	..	..	..	..	..	..	..	..	1.17	0.02	0.02	0.66	0.17
88	*Ficus exasperata* Vahl	1.00	0.00	0.00	0.05	..	..	..	..	..	..	..	..	1.23	0.04	0.03	1.05	0.38
89	*Ficus hispida* L.f.	1.00	0.00	0.00	0.16	..	..	..	..	..	..	..	..	1.30	0.03	0.03	0.17	0.29
90	*Ficus racemosa* L.	..	..	..	..	..	..	..	..	..	..	..	..	2.00	0.02	0.01	0.26	0.14
91	*Ficus religiosa* L.	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.00	0.00	0.01	0.03
92	*Ficus retusa* L.	..	..	..	..	..	..	..	..	..	..	..	..	1.00	0.00	0.00	0.00	0.03
93	*Ficus tsjakela* Burm. f.	..	..	..	..	..	..	..	..	..	..	..	..	1.35	0.19	0.14	53.02	1.81
94	*Ficus virens* Aiton	..	..	..	..	..	..	..	..	..	..	..	..	1.14	0.09	0.08	26.36	0.90
95	*Flacourtia indica* (Burm.f.) Merr.	1.92	0.03	0.02	0.75	..	..	..	..	..	..	..	..	1.40	0.16	0.12	2.87	1.36
96	*Flacourtia montana* J.Graham	1.65	0.08	0.05	2.22	1.83	0.06	0.03	3.36	1.72	0.09	0.05	9.90	1.39	0.28	0.20	19.01	2.34
97	*Garcinia cambogioides* var. cambogioides	6.78	0.08	0.01	1.02	2.00	0.01	0.00	0.29	1.00	0.00	0.00	0.16	1.56	0.17	0.11	12.28	1.38
98	*Garcinia gummi-gutta* (L.) N.Robson	1.48	0.04	0.03	1.34	1.83	0.03	0.02	1.68	1.00	0.00	0.00	0.32	1.77	0.24	0.14	23.45	1.82
99	*Garcinia xanthochymus* Hook.f. ex T.Anderson	..	..	..	..	1.00	0.00	0.00	0.12	..	..	..	..	3.67	0.03	0.01	0.65	0.14
100	*Gardenia latifolia* Aiton	..	..	..	..	..	..	..	..	..	..	..	..	1.38	0.03	0.02	3.74	0.25
101	*Glochidion zeylanicum* (Gaertn.) A.Juss.	1.00	0.00	0.00	0.11	..	..	..	..	..	..	..	..	1.30	0.08	0.06	3.42	0.68
102	*Gmelina arborea* Roxb. ex Sm.	2.00	0.00	0.00	0.06	..	..	..	..	..	..	..	..	1.08	0.07	0.06	4.10	0.67
103	*Grewia serrata* Blanco					..	..	..	..	..	..	..	..	1.09	0.03	0.03	0.32	0.30
104	*Grewia serrulata* DC.	1.00	0.00	0.00	0.16	..	..	..	..	..	..	..	..	1.17	0.04	0.03	0.24	0.34
105	*Grewia tiliifolia* Vahl	1.00	0.00	0.00	0.16	..				1.00	0.00	0.00	0.16	2.04	0.26	0.13	46.41	1.87
106	*Gymnacranthera canarica* (Bedd. ex King) Warb.	18.00	0.05	0.00	0.46	4.00	0.01	0.00	0.19	5.00	0.01	0.00	0.68	11.00	0.09	0.01	4.77	0.33
107	*Harpullia arborea* (Blanco) Radlk.	..	..	..	..	..	..	..	..	..	..	..	..	2.00	0.01	0.00	0.01	0.03
108	*Heynea trijuga* Roxb. ex Sims	1.50	0.00	0.00	0.12	..	..	..	..	..	..	..	..	1.18	0.05	0.04	0.98	0.48
109	*Holarrhena pubescens* Wall. ex G.Don	3.25	0.07	0.02	1.23	2.00	0.01	0.01	0.57	..	..	..	..	1.50	0.04	0.03	0.21	0.31
110	*Holigarna arnottiana* Hook.f.	1.68	0.05	0.03	1.33	2.40	0.02	0.01	0.76	2.25	0.01	0.01	1.29	1.63	0.17	0.10	16.49	1.32
111	*Holigarna beddomei* Hook.f.	2.07	0.04	0.02	0.90	..	..	..	..	..	..	..	..	1.32	0.09	0.06	3.90	0.75
112	*Holigarna ferruginea* Marchand	1.67	0.01	0.00	0.18	..	..	..	..	..	..	..	..	1.67	0.04	0.02	0.83	0.29

S.No.	Species name	Pole				Sapling				Seedling				Tree				
		A	D	F	IVI	A	D	F	IVI	A	D	F	IVI	A	D	F	BA	IVI
113	*Holigarna grahamii* (Wight) Kurz	1.50	0.04	0.03	1.17	:	:	:	:	4.00	0.01	0.00	0.55	1.94	0.17	0.09	12.17	1.17
114	*Holigarna nigra* Bourd.	1.00	0.01	0.01	0.27	1.00	0.00	0.00	0.24	:	:	:	:	1.23	0.07	0.06	2.84	0.64
115	*Hopea canarensis* Hole	:	:	:	:	:	:	:	:	:	:	:	:	1.00	0.01	0.01	0.01	0.05
116	*Hopea parviflora* Bedd.	24.60	0.16	0.01	1.49	2.33	0.02	0.01	0.90	1.67	0.01	0.00	0.74	3.25	0.14	0.04	8.45	0.74
117	*Hopea ponga* (Dennst.) Mabb.	1.23	0.04	0.03	1.45	1.89	0.04	0.02	2.54	1.79	0.04	0.02	5.00	8.98	1.03	0.11	313.65	5.00
118	*Humboldtia brunonis* Wall.*	1.00	0.00	0.00	0.16	:	:	:	:	1.00	0.00	0.00	0.16	:	:	:	:	:
119	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	2.20	0.01	0.01	0.33	4.00	0.01	0.00	0.19	:	:	:	:	1.40	0.05	0.04	1.35	0.45
120	*Ixora brachiata* Roxb.	1.00	0.00	0.00	0.05	1.00	0.00	0.00	0.12	:	:	:	:	1.00	0.01	0.01	0.01	0.08
121	*Knema attenuata* (Wall. ex Hook.f. & Thomson) Warb.	2.10	0.08	0.04	1.94	1.27	0.02	0.01	1.41	1.08	0.02	0.02	2.07	2.34	0.21	0.09	13.80	1.35
122	*Kydia calycina* Roxb.	1.00	0.00	0.00	0.05	:	:	:	:	:	:	:	:	1.71	0.09	0.05	2.81	0.69
123	*Lagerstroemia microcarpa* Wight	1.00	0.01	0.01	0.27	1.13	0.01	0.01	1.00	:	:	:	:	2.18	0.84	0.38	1015.1	8.88
124	*Lagerstroemia speciosa* subsp. Speciosa	:	:	:	:	:	:	:	:	:	:	:	:	1.00	0.01	0.01	0.01	0.05
125	*Lannea coromandelica* (Houtt.) Merr.	:	:	:	:	:	:	:	:	:	:	:	:	1.62	0.30	0.18	91.93	2.57
126	*Litsea coriacea* (B.Heyne ex Nees) Hook.f.	1.00	0.00	0.00	0.11	:	:	:	:	:	:	:	:	1.50	0.01	0.01	0.01	0.06
127	*Litsea floribunda* (Blume) Gamble	2.59	0.15	0.06	3.08	2.32	0.09	0.04	4.66	2.45	0.13	0.05	13.91	1.75	0.29	0.17	17.17	2.15
128	*Litsea ghatica* Saldanha*	:	:	:	:	1.00	0.00	0.00	0.24	1.50	0.00	0.00	0.45	:	:	:	:	:

Diversity of adult trees

A total 207 species of adult trees belong to 140 genera and 49 families are documented in the study area. *Xylia xylocarpa* of Fabaceae showed highest abundance (11.67) within the transect area. *Terminalia paniculata* of Combretaceae is the most frequently distributed tree (0.70) showed highest density (4.15) and emerged as the most dominant tree in the study area with maximum Importance Value Index 33.39 (Table 1). The tree species showed the Shannon's diversity index value of 4.06 and Simpson's importance index value of 0.04 shows the species were not uniformly distributed; but dominated by 2 or 3 tree species.

Diversity of seedlings

A total 81 species of regenerated seedlings of trees belong to 62 genera and 32 families are documented in the study area. *Dimocarpus longan* of Sapindaceae is the most frequently distributed seedlings within the transect area. *Xylia xylocarpa* of Fabaceae showed highest abundance, density and emerged as most dominant seedling species in the study area with maximum Importance Value Index 85.41 (Table 1).

Diversity of saplings

A total 93 species of regenerated saplings of trees belong to 73 genera and 37 families are documented in the study area. *Vateria indica* of Dipterocarpaceae showed highest abundance within the transect area, whereas *Xylia xylocarpa* of Fabaceae is most frequently distributed sapling with highest density and is emerged as the most dominant sapling in the study area with maximum Importance Value Index 48.78 (Table 1).

Diversity of poles

A total 148 species of regenerated poles of trees belong to 114 genera and 46 families are documented in Koppa Forest Division. *Hopea parviflora* of Dipterocarpaceae showed highest abundance within the transect area, whereas *Tabernaemontana alternifolia* of Apocynaceae is the most frequently distributed poles. *Xylia xylocarpa* of Fabaceae showed highest density and is emerged as the most dominant pole in the study area with maximum Importance Value Index 27.24 (Table 1).

Tree diversity

The study reveals that, the current forest condition of the Koppa Forest Division. Usually, tropical forests are species rich with low frequent occurrence (Das et al. 2018). However, the study has found less than 10% of the documented tree species comprised of only one individual and about 40% are represented by less than 10 individuals, whereas 12% of the tree species are comprised of more than 100 individuals of total population.

The Shannon–Wiener diversity index of tropical rainforests of Xishuangbanna, China was 3.45 and tropical moist forests of Mizoram, northeast India was 4.37 (Dey and Akther 2020). In the forest areas of Bangladesh, the Shannon–Wiener diversity index values were Fashiakhali WS - 2.06, Sitapahar RF - 2.98, Chunati WS - 3.27-3.58, and Dudhpukuria-Dophachari - WS 4.45 (Das et al. 2018).

Species diversity in the study area (4.06) is higher than tropical rainforests of Xishuangbanna (3.45) and few forests of Bangladesh (Fashiakhali WS - 2.06, Sitapahar RF - 2.98 and Chunati WS - 3.27-3.58), which suggests that the Koppa Forest Division of central Western Ghats, India is in good health.

Regeneration status

The forest wealth depends on the potential regenerative status of species composing the forest stand in space and time. The regeneration of a forest is a vital process in which old trees die and are replaced by young ones in perpetuity. The overall regeneration status was fairly high in the study area. In the parts of reserved forest, there is a restriction to some extent on human activities like tree felling, and collection of fuelwood and litter. This ultimately favoured the regeneration of a maximal number of tree species. In addition, high rainfall, moderate temperature and wide variation in altitude and soil characteristics provided a favourable environment for the luxuriant growth of many tree species (Malik and Bhatt 2016).

In the present study, the regenerated tree species were categorised into seedlings, saplings and poles, where seedling density ranged about 36 individuals per 10sq.km, while sapling density is 57 individuals per 10 km^2 and pole density is 116 individuals per 10sq.km.The variation in seedling density among the forests and/or species along the altitudinal gradient may be due to change in climatic conditions which could restrict the distribution of some species via the germination and establishment of seedlings.

Aporosa cardiosperma, *Syzygium cumini*, *Terminalia elliptica*, *Terminalia paniculata*, *Xylia xylocarpa* are the top five species with highest number of individuals of trees, among 12983 individuals of documented species. Among all six

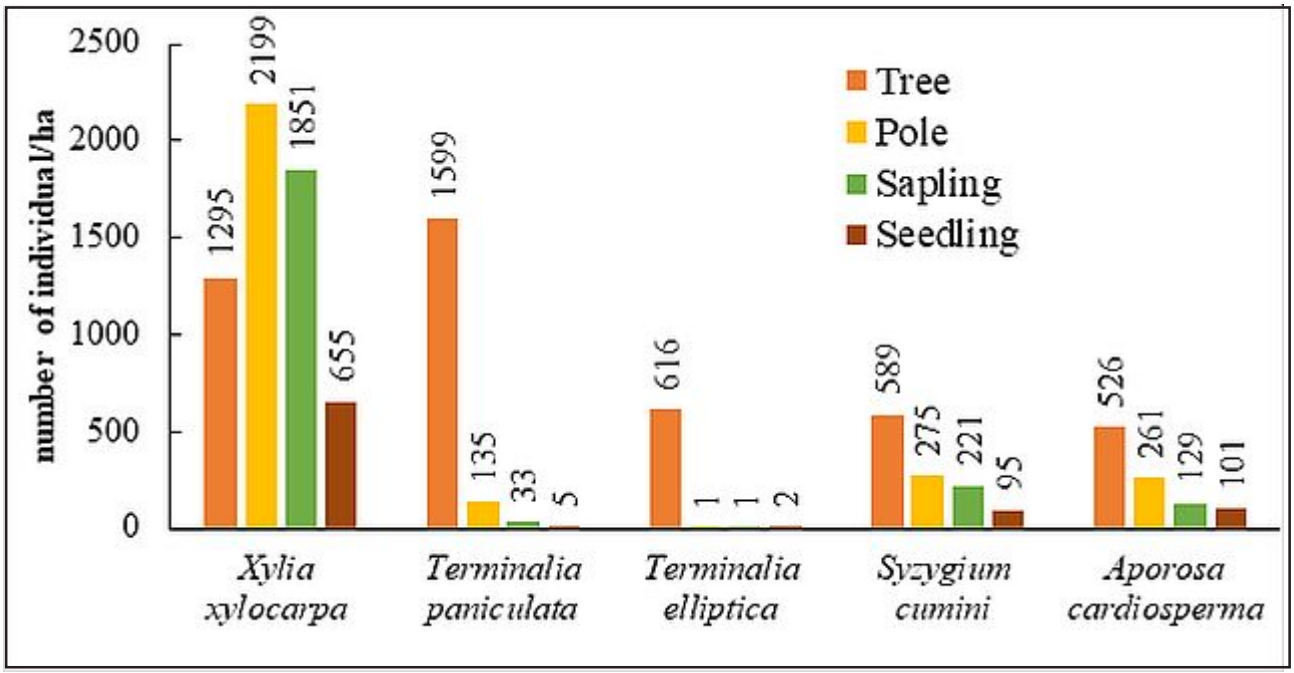

Figure 2. Top five tree species with highest number of individuals and number of their regenerating individuals within the transect area

Table 2. Regeneration and IUCN status of tree species. NA- Not available, LC- Least concern, DD- Data deficit, NT- Near threatened, VU- Vulnerable, EN- Endangered (Values are the number of individuals of species)

S. No	Species name	Family	IUCN status	Trees	Seedling	Sapling	Pole
1	*Actinodaphne lanceolata*	Lauraceae	DD	59	14	49	90
2	*Dimocarpus longan*	Sapindaceae	DD	292	295	236	799
3	*Diospyros ebenum*	Ebenaceae	DD	21	0	0	0
4	*Mangifera indica*	Anacardiaceae	DD	66	4	11	8
5	*Dipterocarpus indicus*	Dipterocarpaceae	EN	8	0	0	0
6	*Hopea canarensis*	Dipterocarpaceae	EN	2	0	0	0
7	*Syzygium caryophyllatum*	Myrtaceae	EN	28	199	14	9
8	*Syzygium stocksii*	Myrtaceae	EN	4	3	0	5
9	*Tectona grandis*	Lamiaceae	EN	77	0	4	19
10	*Aglaia edulis*	Meliaceae	NT	26	1	0	1
11	*Beilschmiedia wightii*	Lauraceae	NT	1	0	0	31
12	*Litsea coriacea*	Lauraceae	NT	3	0	0	0
13	*Litsea floribunda*	Lauraceae	NT	112	98	72	114
14	*Litsea laevigata*	Lauraceae	NT	7	14	8	4
15	*Pterocarpus marsupium*	Fabaceae	NT	259	2	4	11
16	*Aporosa cardiosperma*	Phyllanthaceae	VU	526	101	129	261
17	*Archidendron bigeminum*	Fabaceae	VU	2	0	0	7
18	*Calophyllum apetalum*	Calophyllaceae	VU	2	4	7	77
19	*Cinnamomum sulphuratum*	Lauraceae	VU	6	0	0	29
20	*Cryptocarya wightiana*	Lauraceae	VU	2	4	0	0
21	*Dalbergia latifolia*	Fabaceae	VU	132	52	69	54
22	*Diospyros candolleana*	Ebenaceae	VU	4	0	1	0
23	*Diospyros paniculata*	Ebenaceae	VU	1	0	5	0
24	*Gymnacranthera canarica*	Myristicaceae	VU	33	5	4	36
25	*Hopea ponga*	Dipterocarpaceae	VU	395	34	34	32
26	*Hydnocarpus pentandrus*	Achariaceae	VU	21	0	4	11
27	*Myristica dactyloides*	Myristicaceae	VU	13	0	0	0
28	*Myristica malabarica*	Myristicaceae	VU	14	0	0	10
29	*Psydrax dicoccos*	Rubiaceae	VU	12	0	0	19
30	*Santalum album*	Santalaceae	VU	2	0	0	5
31	*Saraca asoca*	Fabaceae	VU	4	0	0	1
32	*Vateria indica*	Dipterocarpaceae	VU	44	2	76	5

forest ranges of Koppa Forest Division, Balehonnur, Chikkagrahara, NR Pura, parts of Koppa and Kalasa ranges are majorly covered by moist deciduous type of forest. Therefore, *Xylia xylocarpa* of Fabaceae showed highest number of individuals in all three regeneration categories. *Aporosa cardiosperma* of Phyllanthaceae and *Syzygium cumini* of Myrtaceae showed moderate level of regenerating condition, whereas *Terminalia elliptica* and *Terminalia paniculata* of Combretatceae were represented by a good number of individuals of trees whereas, regeneration condition is very poor (Fig. 2).

Ecological status

Out of the 216 trees species recorded in the present study, four species are of data deficit, five species are endangered, six are nearly threatened, 17 are vulnerable and 84 species are of least concern, as per the IUCN red list status (Table 2). Regeneration status of some endangered and nearly threatened species is good while few species are very poor in seedling numbers. Therefore, more concern towards the conservation and development of those species needs to be considered in the region which would be helpful to maintain the diversity.

CONCLUSIONS

Tree composition and their regeneration status show the overall well-being of the local forest community. The overall aim of the study was to provide quantitative structure of tree composition and regeneration status of Koppa Forest Division is effective and timely measures should be taken to conserve the forests using the latest technologies and adaptable management system. Planning forest policies and decision-making requires up-to-date information on forests and land uses, which can be obtained through continuous assessment and monitoring system. The study may be helpful for the future implementation of forest inventory and silvicultural techniques.

Among recorded 207 tree species, 22 species showed a frequency value of < 0.01 and 185 species showed ≥ 0.01, which shows only 10% of the species were less frequently found. Based on the results, it can be concluded that the forest division supports a high diversity of forest trees and communities. The present condition must be maintained and rate of survival of regeneration should be increased to retain the rich diversity. Due to human intervention, the establishment of new seedlings and their transition to mature stands may become poor. If this happens, the local species diversity will decline followed by the introduction of exotic species. To avoid this, native people who are dependent on the forest for fuel woods and other non-timber products and are often ignorant of the adverse effect this trend of logging on the forest to be made aware regarding these effects. Regulations on logging operation and illegal felling can ensure recovery of forest structure, though it may take a long time. At present Koppa Forest Division shows a good level of distribution of tree diversity. A well-developed management system and enrichment programs can further ensure the achievement of the desired goal. Therefore, regular long-term monitoring is suggested to understand the dynamics of vegetation. In addition, database developed through regular monitoring of these communities would help in developing adequate management plan for their conservation.

ACKNOWLEDGEMENTS

We thank DCF, RFOs, DyRFOs and all staff and workers of Koppa Forest Division of for providing permition and supports to conduct the fieldwork. Authors are also highly thankful to Editor and the anonymous reviewers for their useful comments and suggestions on the earlier draft of this manuscript.

Authors' contributions: Both the authors contributed equally.

Conflict of interest: Authors declare no conflict of interest.

REFERENCES

Cottam, G. and Curtis, J.T. 1956. The use of distance measurements in phytosociological sampling. Ecology, 37, 451-460. https://doi.org/10.2307/1930167

Das, S.C., Alam, M.S. and Hossain, M.A. 2018. Diversity and structural composition of species in dipterocarp forests: a study from Fasiakhali Wildlife Sanctuary, Bangladesh. Journal of Forestry Research, 29(5), 1241-1249. https://doi.org/10.1007/s11676-017-0548-7

Dey, A. and Akther, A. 2020. Tree Species Composition and

Natural Regeneration Status in South Eastern Bangladesh. Journal of Tropical Biodiversity and Biotechnology, 05(01), 27- 34. https://doi.org/10.22146/jtbb.49988

Malik, Z.A. and Bhatt, A.B. 2016. Regeneration status of tree species and survival of their seedlings in Kedarnath Wildlife Sanctuary and its adjoining areas in Western Himalaya, India. Tropical Ecology, 57(4), 677-690.

Mohammed, E.M.I, Hassan, T.T., Idris, E.A. and Abdel-Magid, T.D. 2021. Tree population structure, diversity, regeneration status, and potential disturbances in Abu Gadaf natural reserved forest, Sudan. Environmental Challenges, 5(12) 100366. https://doi.org/10.1016/j.envc.2021.100366

Shannon, C.E. 1948. A Mathematical Theory of Communication. Bell System Technical Journal, 27, 379-423 & 623-656. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Simpson, E.H., Sutherland, G. and Blackwell, D.E. 1949, Measurement of diversity, Nature, 163, 688. https://www.nature.com/articles/163688a0

Received:28th December 2023
Accepted:14th March 2024