Journal of Agriculture & Forestry Research | JAFR |
Volume no.3, Issue no. 3, Year 2024
www.sarpo.net

Research Article
Open access

Floristic Composition, Structure and Diversity of Urban Reserve Forests: An Implication for Biodiversity Conservation and Forest Management

Gisandu K. Malunguja [1]* and Ashalata Devi [2]

[1] *Department of Earth science, Mbeya University of Science and Technology, 131, Mbeya, Tanzania*
Email: gmalunguja77@gmail.com
Phone: +255 763 628343
ORCID: 0000-0002-1853-5068
[2] Department of Environmental Science, Tezpur University, PIN-784028, Tezpur, Assam, India
Email: ashalatadevi12@gmail.com
ORCID: 0000-0002-1445-2492.
Phone: +9194357493540
Corresponding author: Gisandu K. Malunguja
E-mail: gmalunguja77@gmail.com

ABSTRACT

The establishment of forested areas adjacent to urban centers, known as reserve forests (RFs), is increasing and gaining importance in India. However, there is limited understanding of their role in supporting biodiversity. To address this, a study using phytosociological techniques was conducted in three RFs near Tezpur city in Assam, India, to evaluate their contribution to biodiversity. A total of 204 plant species from 180 genera and 64 families were identified. The cumulative curve showed irregularities with asymptotic trends. Species with high importance value indices (IVI) included *Cynodon dactylon* and *Cymbopogon nardus* for grasses, *Clitoria ternatea* and *Chromolaena* among forbs, *Mikania micrantha* and *Piper betle* among climbers, *Lantana camara* and *Clerodendrum viscosum* among shrubs, and *Tectona grandis* and *Shorea robusta* among trees. The basal area was lowest in grasses (0.04-0.13 m^2 ha^{-1}) and highest in trees (29.18-63.61 m^2 ha^{-1}). Diversity indices ranged from 2.06 to 3.34 (Shannon), 0.04 to 0.17 (Simpson), 0.72 to 0.94 (Pielou's), and 1.3 to 14.62 (Margalef). The Whitford index indicated a contagious distribution pattern. Sørensen similarity was highest between Bhomoraguri and Balipara for grasses (60.87%), shrubs (81.97%), and trees (54.79%), and between Bhomoraguri and Sengelimari for forbs (37.93%) and climbers (54.55%). The floristic composition recorded in RFs suggests a viable strategy for biodiversity conservation in these areas.

Keywords: Biodiversity conservation, Floristic composition, Forest management, Diversity indices, Reserve forests, Urban greening.

• **Received:** 12.07.2024 • **Received in revised form:** 30.07.2024 • **Accepted**: 31.07.2024

To cite this article: Malunguja, G.K.; Devi, A. Floristic composition, structure and diversity of urban reserve forests: an implication for biodiversity conservation and forest management. *J. Agric. For. Res.,* 2024, 3(3), 34-60.

1. INTRODUCTION

India is experiencing a growing trend in establishing forests adjacent to urban centers, known as reserve forests (RFs) or urban forests. Understanding species composition, structure, and diversity is crucial for managing these urban forests (Yan and Yang 2017). Indian forests, including those in Assam, are recognized for their rich biodiversity (Barbhuiya et al. 2013; Dibaba et al. 2019). Reserve forests (RFs) serve as critical habitats for species diversity (Kanagaraj et al. 2017; Nohro and Jayakumar 2020) and help offset CO_2 emissions through carbon sequestration (Enríquez-de-Salamanca 2020; Malunguja et al. 2020; Caviedes and Ibarra 2017). They are also effective in protecting species from extinction (Deori and Talukdar 2015). Like other protected areas, RFs host native species and local endemics, providing various ecosystem goods and services (Giri et al. 2019; Gogoi and Sahoo 2018; Paudel et al. 2022). Reserve forests are designated for specific purposes where human activities are highly restricted. Studies highlight the role of forests, whether urban or rural, in biodiversity conservation (Dri et al. 2024; Baul et al. 2022; Borah et al. 2015; Caviedes and Ibarra 2017; Kanagaraj et al. 2017). Ecological monitoring of forest ecosystems is crucial to estimate their contribution to species sustainability (Flores-Galicia et al. 2024; Anitha et al. 2010; Buragohain and Swargiari 2016; Echeverría et al. 2007; Hubálek 2000; Matuszkiewicz et al. 2013; Malunguja et al. 2020; Naveenkumar et al. 2017; Paudel et al. 2022; Sala et al. 2000; Wade et al. 2003).

In India, reserve forests support species biodiversity and sustainability, as addressed in the Constitution of India, Act 1976 (Kumar et al. 2020). There is a continuous effort to develop a scientific basis for sustainable forest management through forest management plans (Kumar et al. 2020). These plans aim to increase forested areas, particularly reserve forests, adjacent to developing cities as part of an urban greening strategy. Currently, approximately 33.42% of India's total land area is covered by reserve forests (FSI 2019; Gandhi and Sundarapandian 2017). Despite their extensive coverage, there is a lack of studies elucidating the role of reserve forests in biodiversity. This lack of information hinders the evaluation of their ecological well-being. Existing studies on RFs are often specific to certain topics (Bhattacharjee et al. 2014; Borah et al. 2020; Dutta and Devi, 2013; Malunguja and Devi 2022) and focus on other forest categories like biosphere reserves, national parks, and wildlife sanctuaries (Behera et al. 2017; Bora et al. 2017; Dar and Sundarapandian 2015; Deori and Talukdar 2015; Gogoi and Sahoo 2018; Gogoi et al. 2017; Duchok et al. 2005; Giri et al. 2019; Kar et al. 2019; Kalita and Kalita 2014; Sharma et al. 2010; Sumita et al. 2015). Consequently, these data do not provide a complete ecological characterization of reserve forests. A detailed phytosociological study was conducted to create a floristic baseline for better forest management. The study aimed to (i) conduct a floristic inventory of plant species and (ii) assess plant community structure and diversity. Beyond urban greening, the findings of this study will help policymakers, ecologists, and environmentalists develop effective conservation strategies to enhance biodiversity conservation.

2. MATERIALS AND METHODS

2.1 Study area

The current study was conducted in three reserve forests (RFs) in the Sonitpur district of Assam, a state in northeast India. The RFs—Balipara, Bhomoraguri, and Sengelimari—were chosen due to their proximity to Tezpur City, an urban area experiencing rapid industrialization and urbanization. These forests are also connected to one of the busiest National Highways (NH-15), which operates year-round. The district is situated between 92° 16' E and 93° 43' E longitudes and 26° 30' N to 27° N latitudes (Nath et al. 2013). It has a subtropical climate, with seasonal temperatures ranging from a minimum of 7°C to a maximum of 36°C (Saxena et al. 2014). A map showing the locations of the three studied RFs is provided in Fig. 1.

2.2 Vegetation sampling

A total of 105 circular plots with a 15 m radius (covering an area of 707.14 m²) were systematically established along transects (45 in Balipara RF, 30 in Bhomoraguri RF, and 30 in Sengelimari RF). Within each plot, two sub-plots with a 10 m radius (area of 314.29 m²) and a 5 m radius (area of 78.57 m²) were established to record shrubs and herbaceous plants, respectively, following a modified method from Zahabu (2008). The general layout of transect lines and plots is illustrated in Fig. 2. Woody individuals with a diameter at breast height (dbh) of less than 5 cm, characterized by single or multiple stem branches at ground level were recorded as shrubs. Those with a dbh of 5 cm or more were recorded as trees. The frequency of herbaceous species (%) was determined using the quadrat method (Pieper 1988; Rubanza et al. 2006). Four metal frames of 0.5 m × 0.5 m (area of 0.25 m²) were placed within the 5 m radius sub-plot to record herbaceous composition. If the frame landed on a previously sampled point or in a dense shrub layer, it was re-thrown to avoid these factors (Czapiewska and Dyderski 2019). Plant species were identified based on their local and botanical names with the help of local botanists and relevant floras. For species difficult to identify in the field, specimens were collected and herbarium samples were prepared for further identification at the Department of Environmental Sciences, Ecology Laboratory, Tezpur University, India.

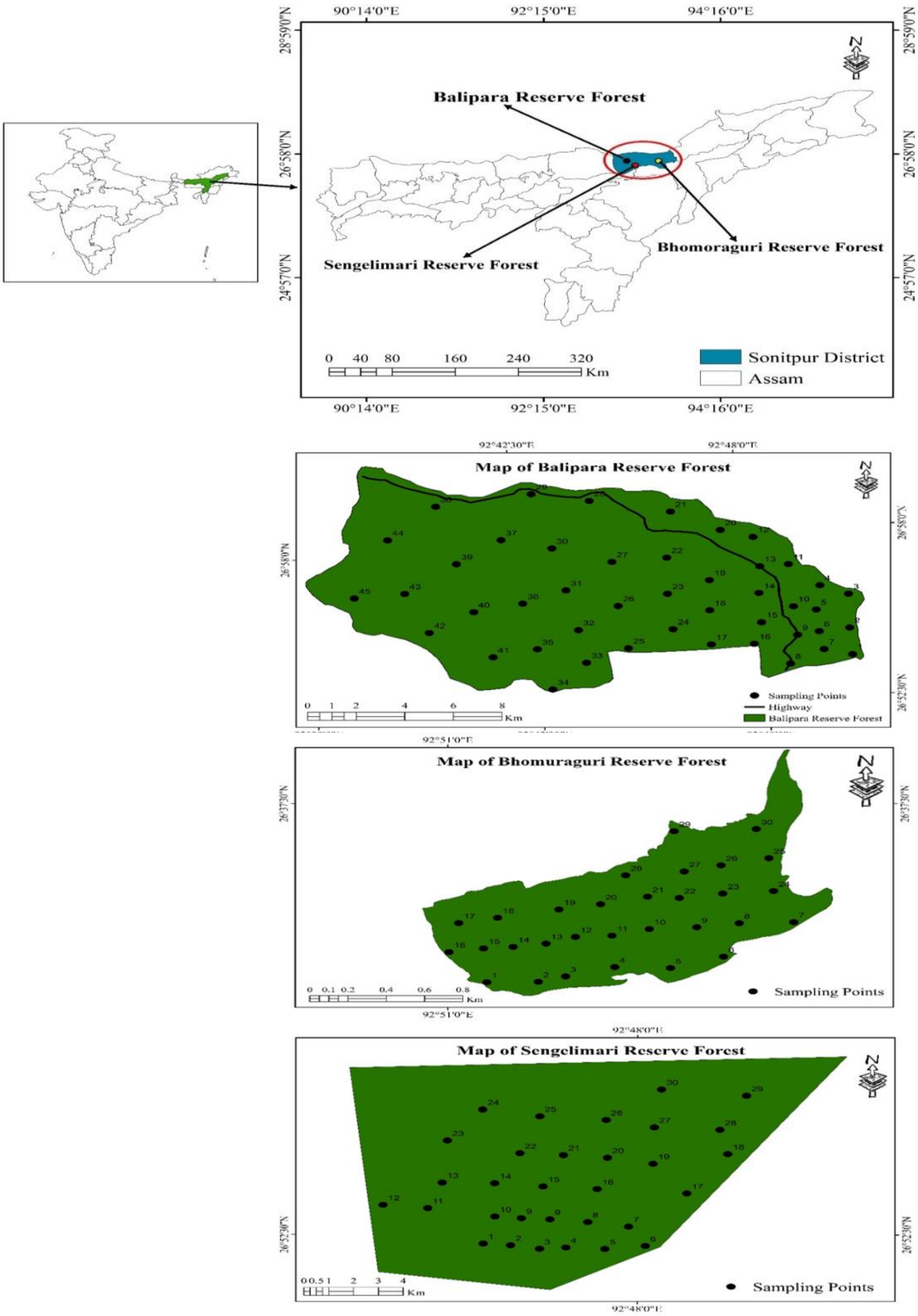


Figure 1: Map showing the location and sampling points of the studied RFs.

2.3 Floristic composition and diversity

Quantitative community attributes and phytosociological characteristics, including species density, abundance, relative frequency, relative density, and relative dominance, were calculated according to Curtis and McIntosh (1950). The basal area was determined using the allometric method (Kanagaraj et al. 2017). The importance value index (IVI) of individual species was calculated following Misra (1989), which involves summing the relative frequency, relative density, and relative dominance. Plant diversity indices such as the Shannon-Wiener index (Shannon and Weaver 1949), Simpson's dominance index (Simpson 1949), Pielou's evenness index (Pielou 1966), Margalef's index (Margalef 1969), and Sørensen similarity index (1948) were used to quantify phytosociological attributes. The plant distribution pattern was analyzed based on the abundance to frequency ratio (Whitford 1949).

2.4 Statistical analysis

Multivariate analysis was used to determine significant differences in plant diversity both across and within forests. The Shapiro-Wilk and Levene tests were employed for parametric tests to ensure that data fit normal distribution conditions and was homogeneous, respectively. The Fisher's Least Significant Difference (LSD) test was used to determine whether the means were statistically different at $P \leq 0.05$. The Pearson correlation coefficient was employed to examine the relationships between plant life forms (grasses, forbs, climbers, shrubs, and trees). Statistical analyses were performed using the SPSS software package (version 20, Chicago, IL). Additionally, graphs were created using the Origin Pro software package (trial version 8.5) and Microsoft Excel.

3. RESULTS

3.1. Plant species recorded in RFs

The present investigation identified 204 plant species (i.e., 24 grasses, 62 forbs, 19 climbers, 40 shrubs and 59 trees) belonging to 180 genera and 64 families in the three studied reserve forests (RFs). Table 1 enlisted all the plant species enumerated in this study based on their life forms. The results showed that, some species were recorded in all the studied forests like *Cynodon dactylon*, and *Brachiaria reptans* for grasses; *Amaranthus spinosus* and *Centella asiatica* for forbs; *Argyreia speciosa* and *Cissus rotundifolia* for climbers; *Gloriosa superba and Alangium chinense* for shrubs; *Eugenia orbiculata* and *Bombax ceiba* for trees. Species that were only found in one of the studied sites are *Aristida adscensionis* (Sengelimari RF) and *Arundo donax* (Bhomoraguri RF) for grasses; *Achyranthes aspera* and *Chamaecrista rotundifolia* (Bhomoraguri RF) for forbs; *Cissus quadrangularis* (Sengelimari RF) and *Hedyotis scandens* (Balipara RF) for climbers; *Lantana camara* and *Solanum spinosum* (Bhomoraguri RF) for shrubs; and *Acacia retinodes* (Sengelimari RF), and *Caesalpinia pulcherrima* (Bhomoraguri RF) for trees.

Additionally, the present study recorded a variability of plant life forms between the reserve forests. For instance, grasses recorded 24 species from 22 genera and 2 families in three studies reserve forests. Forbs enumerated 63 species from 59 genera and 25 families. Climber recorded 19 species from 17 genera and 11 families, while shrub recorded 40 species from 37 genera and 21 families. Furthermore, trees enumerated 59 species from 53 genera and 29 families. As stated previously, some species were recorded in all three studied reserve forests, some in two or in only one. Such phenomenons lead into variability of individual species in the studied forests. For such reasons, Bhomoraguri RF recorded 123 plant species (13 grasses, 39 forbs, 9 climbers, 31 shrubs, and 31 trees). While, Balipara RF recorded 121 plant species (10 grasses, 29 forbs, 10 climbers, 30 shrubs, and 42 trees). Then, Sengelimari RF recorded 83 plant species (12 grasses, 19 forbs, 12 climbers, 17 shrubs, and 23 trees).

3.2. Community structure analysis

The sampling effort made for studying community structure analysis helps in understanding the rate of accumulation of new species over the increasing sampling units. The species cumulative curve portrayed an irregular along with asymptotic notations to all plant life forms (Fig. 3). The number of shrub and tree species increased along with the increase in number of sampling plots for all studied forests. Such observation suggests presence of diverse species in the community for forbs, shrubs and trees. Furthermore, it was found that in Bhomoraguri RF, grass species only 15 studied plots were enough to record their richness, while, new species was accumulated up to 35 of sampling units in Balipara RF. Similar trend was also observed among forb species for all studied forests. Climber species, on the other hand, were recorded mostly within 15 plots in Sengelimari RF. Such results suggest that, species richness (number of different species), specifically, for grasses and climbers was small as compared to other plant life forms (forbs, shrubs and trees) (Fig. 3).

Table 1: List of plant species recorded in Bhomoraguri RF (1), Balipara RF (2), and Sengelimari RF (3) RFs

Sl. No.	Scientific name	Family	Life form	1	2	3
1	*Aristida adscensionis* L.	Poaceae	Grass	x	x	✓
2	*Arundo donax* L.	Poaceae	Grass	✓	x	x
3	*Axonopus compressus* (Sw.) P.Beauv.	Poaceae	Grass	✓	x	x
4	*Brachiaria reptans* (L.) C.A. Gardner.	Poaceae	Grass	✓	✓	✓
5	*Centotheca lappacea* (L.) Desv.	Poaceae	Grass	✓	x	x
6	*Cymbopogon nardus* (L.) Rendle	Poaceae	Grass	x	✓	x
7	*Cymbopogon schoenanthus* (L.) Spreng	Poaceae	Grass	x	x	✓
8	*Cynodon dactylon* (L.) Pers.	Poaceae	Grass	✓	✓	✓
9	*Cyperus rotundus* L.	Cyperaceae	Grass	✓	✓	x
10	*Cyrtococcum patens* (L.) A. Camus	Poaceae	Grass	x	✓	x
11	*Digitaria ciliaris* (Retz.) Koeler	Poaceae	Grass	✓	✓	x
12	*Eleusine indica* (L.) Gaertn.	Poaceae	Grass	x	x	✓
13	*Eragrostis amabilis* (L.) Wight	Poaceae	Grass	✓	x	x
14	*Eragrostis atrovirens* (Desf.) Trin. ex Steud.	Poaceae	Grass	x	x	✓
15	*Fimbristylis miliacea* (L.) Vahl	Cyperaceae	Grass	✓	✓	x
16	*Hemarthria compressa* (L.f.) R.Br.	Poaceae	Grass	✓	x	✓
17	*Imperata cylindrica* (Linn.) Beauv.	Poaceae	Grass	✓	✓	x
18	*Leersia hexandra* Sw.	Poaceae	Grass	✓	✓	x
19	*Lipocarpa chinensis* (Osbeck) J.Kern	Cyperaceae	Grass	x	x	✓
20	*Lophatherum gracile* Brongn.	Poaceae	Grass	x	x	✓
21	*Paspalum conjugatum* P.J. Bergius	Poaceae	Grass	x	x	✓
22	*Poa angustifolia* L.	Poaceae	Grass	✓	x	x
23	*Thysanolaena latifolia* (Roxb. ex Hornem.)	Poaceae	Grass	x	✓	✓
24	*Tripogon bromoides* Roth	Poaceae	Grass	x	x	✓
Total	No. of species = 24, genus = 22	Family = 2		13	10	12
25	*Abelmoschus moschatus* Medik.	Malvaceae	Forb	✓	x	x
26	*Achyranthes aspera* L.	Amaranthaceae	Forb	✓	x	x
27	*Acilepis saligna* (DC.) H. Robinson	Asteraceae	Forb	x	x	✓
28	*Adiantum capillus-veneris* L.	Pteridaceae	Forb	x	✓	x
29	*Aerva lanata* (L.) Schult.	Amaranthaceae	Forb	x	✓	x
30	*Ageratum conyzoides* L.	Asteraceae	Forb	✓	x	✓
31	*Ajuga decumbens* Thunb.	Lamiaceae	Forb	✓	x	x
32	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	Forb	✓	x	x
33	*Amaranthus spinosus* L.	Amaranthaceae	Forb	✓	✓	✓
34	*Arum maculatum* L.	Araceae	Forb	✓	x	x
35	*Bidens pilosa* L.	Asteraceae	Forb	✓	x	x
36	*Blumea holosericea* DC.	Asteraceae	Forb	x	✓	x
37	*Cardiospermum halicacabum* L.	Sapindaceae	Forb	x	✓	x
38	*Cassia absus* L.	Fabaceae	Forb	✓	x	x
39	*Centella asiatica* (L.) Urban	Apiaceae	Forb	✓	✓	✓

40	*Chamaecrista rotundifolia* (Pers.) Greene	Fabaceae	Forb	✓	x	x
41	*Chenopodium album* L.	Amaranthaceae	Forb	x	✓	x
42	*Chlorophytum tuberosum* (Roxb.) Baker	Asparagaceae	Forb	x	✓	x
43	*Chromolaena odorata* (L.) R.M.King.	Asteraceae	Forb	✓	✓	✓
44	*Cicuta virosa* L.	Apiaceae	Forb	✓	x	x
45	*Colocasia esculenta* (L.) Schott	Araceae	Forb	✓	✓	✓
46	*Commelina benghalensis* L.	Commelinaceae	Forb	✓	x	x
47	*Corchorus olitorius* L.	Malvaceae	Forb	✓	x	x
48	*Coriandrum sativum* L.	Apiaceae	Forb	✓	x	x
49	*Cyathea cooperi* (Hook. ex F. Muell.)	Cyatheaceae	Forb	✓	✓	✓
50	*Datura stramonium* L.	Solanaceae	Forb	✓	x	x
51	*Diplazium esculentum* (Retz.) Sw	Athyriaceae	Forb	✓	✓	x
52	*Drymaria cordata* (L.) Willd. ex Schult.	Caryophyllaceae	Forb	x	✓	x
53	*Drynaria quercifolia* (L.) J. Sm.	Polypodiaceae	Forb	x	✓	x
54	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	Amaranthaceae	Forb	x	x	✓
55	*Eclipta prostrata* L.	Asteraceae	Forb	x	✓	x
56	*Elsholtzia griffithii* Hookf	Lamiaceae	Forb	x	x	✓
57	*Enydra fluctuans* Lour.	Asteraceae	Forb	✓	x	x
58	*Euphorbia hirta* L.	Euphorbiaceae	Forb	x	✓	x
59	*Galinsoga parviflora* Cav.	Asteraceae	Forb	x	✓	x
60	*Grona triflora* (L.) H.Ohashi & K.Ohashi	Fabaceae	Forb	✓	x	x
61	*Heliotropium indicum* L.	Boraginaceae	Forb	x	✓	✓
62	*Hydrocotyle sibthorpioides* Lam.	Araliaceae	Forb	✓	✓	✓
63	*Jussiaea suffruticosa* L.	Onagraceae	Forb	x	✓	x
64	*Lagenaria siceraria* Hook.f.	Cucurbitaceae	Forb	✓	x	x
65	*Leucas aspera* (Willd.) Link	Lamiaceae	Forb	✓	✓	✓
66	*Leucas zeylanica* (L.) R.Br.	Lamiaceae	Forb	✓	x	x
67	*Lippia geminata* H. B. & K.	Verbenaceae	Forb	x	x	✓
68	*Malva sylvestris* L.	Malvaceae	Forb	✓	x	x
69	*Mirabilis jalapa* L.	Nyctaginaceae	Forb	x	x	✓
70	*Ocimum basilicum* L.	Lamiaceae	Forb	x	✓	✓
71	*Ocimum gratissimum* L.	Lamiaceae	Forb	✓	x	x
72	*Ocimum tenuiflorum* L.	Lamiaceae	Forb	✓	x	x
73	*Oxalis articulata* Savign	Oxalidaceae	Forb	✓	x	x
74	*Oxalis corniculata* L.	Oxalidaceae	Forb	✓	x	x
75	*Persicaria strigosa* (R.Br.) Nakai	Polygonaceae	Forb	x	✓	✓
76	*Physalis peruviana* L.	Solanaceae	Forb	✓	✓	x
77	*Ranunculus multifidus* Forssk.	Ranunculaceae	forb	✓	x	x
78	*Rumex acetosa* L.	Polygonaceae	Forb	✓	x	x
79	*Scoparia dulcis* L.	Plantaginaceae	Forb	✓	✓	✓
80	*Sida acuta* Burm. f	Malvaceae	Forb	x	✓	x
81	*Sphaeranthus indicus* L.	Asteraceae	Forb	✓	x	x

82	*Sphagneticola calendulacea* (L.) Pruski	Asteraceae	Forb	✓	✓	x
83	*Stachytarpheta indica* (L.) Vahl	Verbenaceae	Forb	x	✓	x
84	*Stellaria Apetala* Ucria ex Roem.	Caryophyllaceae	Forb	x	x	✓
85	*Tragia involucrata* L.	Euphorbiaceae	Forb	✓	x	x
86	*Urtica dioica* L.	Urticaceae	Forb	✓	x	✓
Total	No. of species = 62, genus = 59	Family= 25		39	29	19
87	*Argyreia argentea* (Roxb.) Arn. ex Choisy	Convolvulaceae	Climber	✓	✓	✓
88	*Argyreia speciosa* (L.f.) Sweet	Convolvulaceae	Climber	✓	✓	✓
89	*Centrosema brasilianum* (L.) Benth.	Fabaceae	Climber	x	✓	x
90	*Cissampelos pareira* L.	Menispermaceae	Climber	x	✓	x
91	*Cissus quadrangularis* L.	Vitaceae	Climber	x	x	✓
92	*Cissus rotundifolia* Vahl	Vitaceae	Climber	✓	✓	✓
93	*Cucumis anguria* L.	Cucurbitaceae	Climber	✓	x	✓
94	*Dioscorea hoffa* Cordem.	Dioscoreaceae	Climber	x	x	✓
95	*Clitoria ternatea* L.	Fabaceae	Climber	x	✓	x
96	*Hedyotis scandens* Roxb.	Rubiaceae	Climber	x	✓	x
97	*Ipomoea cheirophylla* O'Donell,	Convolvulaceae	Climber	x	✓	✓
98	*Merremia umbellata* (L.) Hallier f.	Convolvulaceae	Climber	✓	x	x
99	*Mikania micrantha* Kunth	Asteraceae	Climber	x	✓	✓
100	*Coronilla varia* L.	Fabaceae	Climber	x	x	✓
101	*Paederia foetida* L.	Rubiaceae	Climber	✓	x	✓
102	*Piper betle* L.	Piperaceae	Climber	✓	x	✓
103	*Smilax ovalifolia* Roxb. ex D.Don	Smilacaceae	Climber	x	✓	x
104	*Thunbergia grandiflora* (Roxb. ex Rottler) Roxb	Acanthaceae	Climber	x	✓	✓
105	*Tinospora sinensis* (Lour.) Merr.	Menispermaceae	Climber	✓	x	x
Total	No. of species = 19, genus = 17	Family =11		9	10	12
106	*Abelmoschus manihot* (L.) Medik	Malvaceae	Shrub	✓	✓	✓
107	*Abrus maculatus* Noronha	Fabaceae	Shrub	x	x	✓
108	*Abutilon indicum* L.	Malvaceae	Shrub	✓	x	x
109	*Alangium chinense* (Lour.) Harms	Cornaceae	Shrub	✓	✓	✓
110	*Antidesma acidum* Retz.	Phyllanthaceae	Shrub	✓	✓	✓
111	*Baliospermum solanifolium* (Burman) Suresh	Euphorbiaceae	Shrub	✓	✓	✓
112	*Capparis spinosa* L.	Capparaceae	Shrub	✓	✓	x
113	*Clerodendrum indicum* (L.) Kuntze	Lamiaceae	Shrub	✓	✓	x
114	*Clerodendrum infortunatum* L.	Lamiaceae	Shrub	✓	✓	x
115	*Clerodendrum viscosum* Vent	Lamiaceae	Shrub	✓	✓	✓
116	*Coffea benghalensis* B.Heyne ex Schult.	Rubiaceae	Shrub	✓	✓	x
117	*Crotalaria albida* Roth	Fabaceae	Shrub	✓	✓	x
118	*Crotalaria sessiliflora* L.	Fabaceae	Shrub	✓	✓	x
119	*Croton caudatus* Geiseler	Euphorbiaceae	Shrub	x	✓	x
120	*Datura metel* L.	Solanaceae	Shrub	✓	x	x
121	*Deeringia amaranthoides* (Lam.) Merr.	Amaranthaceae	Shrub	x	x	✓

122	*Desmodium griffithianum* Benth.	Fabaceae	Shrub	✓	✓	x
123	*Gloriosa superba* L.	Colchicaceae	Shrub	✓	✓	✓
124	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	Shrub	✓	✓	x
125	*Grewia eriocarpa* Juss.	Malvaceae	Shrub	✓	✓	x
126	*Holarrhena pubescens* Wall. ex G.Don	Apocynaceae	Shrub	x	✓	✓
127	*Holmskioldia sanguinea* Retz.	Lamiaceae	Shrub	x	x	✓
128	*Justicia adhatoda* L.	Acanthaceae	Shrub	x	✓	x
129	*Lantana camara* L.	Verbenaceae	Shrub	✓	x	x
130	*Lawsonia inermis* L.	Lythraceae	Shrub	✓	✓	✓
131	*Ludwigia hyssopifolia* (G. Don) A.W. Exell	Onagraceae	Shrub	x	✓	x
132	*Maesa indica* (Roxb.) A. DC.	Primulaceae	Shrub	✓	✓	x
133	*Melastoma malabathricum* L.	Melastomataceae	Shrub	✓	✓	✓
134	*Meyna laxiflora* Robyns	Rubiaceae	Shrub	✓	✓	x
135	*Millettia pachycarpa* Bentham	Fabaceae	Shrub	✓	✓	x
136	*Mimosa pudica* L.	Fabaceae	Shrub	✓	✓	x
137	*Mucuna pruriens* (L.) DC.	Fabaceae	Shrub	x	✓	x
138	*Murraya koenigii* (L.) Sprengel	Rutaceae	Shrub	x	✓	✓
139	*Mussaenda roxburghii* Hook.f	Rubiaceae	Shrub	✓	✓	✓
140	*Nerium oleander* L.	Apocynaceae	Shrub	✓	✓	✓
141	*Phlogacanthus thyrsiflorus* Nees	Acanthaceae	Shrub	✓	✓	✓
142	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Apocynaceae	Shrub	✓	✓	x
143	*Schefflera venulosa* (Wight & Arn.) Harms	Araliaceae	Shrub	✓	x	x
144	*Solanum spinosum* L.	Solanaceae	Shrub	✓	x	x
145	*Tamarix dioica* Roxburgh ex Roth	Tamaricaceae	Shrub	✓	x	x
Total	No. of species = 40, genus = 37	Family = 21		31	30	17
146	*Acacia retinodes* Schltdl	Fabaceae	Tree	x	x	✓
147	*Aegle marmelos* (L.) Corrêa	Rutaceae	Tree	✓	✓	x
148	*Albizia lucidor* (Steud.) I.C. Nielsen	Fabaceae	Tree	✓	x	x
149	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	Tree	✓	✓	x
150	*Altingia excelsa* Noronha	Altingiaceae	Tree	x	✓	✓
151	*Annona reticulata* L.	Annonaceae	Tree	✓	x	x
152	*Anthocephalus cadamba* (Roxb.) Miq.	Rubiaceae	Tree	✓	✓	✓
153	*Artocarpus heterophyllus* Lam.	Moraceae	Tree	✓	x	✓
154	*Averrhoa carambola* L.	Oxalidaceae	Tree	x	x	✓
155	*Baccaurea ramiflora* Lour.	Phyllanthaceae	Tree	x	✓	✓
156	*Bombax ceiba* L.	Malvaceae	Tree	✓	✓	✓
157	*Bridelia retusa* (L.) A.Juss.	Phyllanthaceae	Tree	x	✓	✓
158	*Caesalpinia pulcherrima* (L.) Sw.	Fabaceae	Tree	✓	x	x
159	*Careya arborea* Roxb.	Lecythidaceae	Tree	x	✓	x
160	*Cassia fistula* L.	Fabaceae	Tree	x	✓	x
161	*Castanopsis indica* (Roxburgh ex Lindl.) A. DC.	Fagaceae	Tree	x	✓	x
162	*Cedrela sinensis* Juss.	Meliaceae	Tree	✓	✓	x

163	*Cryptocarya amygdalina* Nees	Lauraceae	Tree	✓	✓	✓
164	*Dalbergia sissoo* Roxb.	Fabaceae	Tree	✓	x	x
165	*Dillenia indica* L.	Dilleniaceae	Tree	✓	✓	✓
166	*Duabanga grandiflora* (Roxb. Ex DC.) Walpers	Lythraceae	Tree	✓	x	x
167	*Elaeocarpus serratus* L.f.	Elaeocarpaceae	Tree	x	x	✓
168	*Eugenia orbiculata* Lam.	Myrtaceae	Tree	✓	✓	✓
169	*Ficus elastica* Roxb. ex Hornem	Moraceae	Tree	x	✓	x
170	*Ficus hirta* Vahl	Moraceae	Tree	✓	✓	x
171	*Ficus nervosa* B. Heyne ex Roth	Moraceae	Tree	✓	x	x
172	*Ficus religiosa* L.	Moraceae	Tree	x	✓	x
173	*Garcinia lanceifolia* Roxb.	Clusiaceae	Tree	x	x	✓
174	*Garcinia pedunculata* Roxb. ex Buch. Ham.	Clusiaceae	Tree	x	✓	x
175	*Gmelina arborea* Roxb.	Lamiaceae	Tree	✓	✓	x
176	*Kayea floribunda* Wall.	Clusiaceae	Tree	✓	✓	✓
177	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae	Tree	✓	✓	✓
178	*Macaranga denticulata* (Blume) Müll.Arg.	Euphorbiaceae	Tree	x	✓	x
179	*Melia azedarach* L.	Meliaceae	Tree	✓	x	x
180	*Mesua ferrea* L.	Clusiaceae	Tree	x	✓	x
181	*Michelia champaca* L.	Magnoliaceae	Tree	✓	✓	x
182	*Millettia pinnata* (L.) Panigrahi	Fabaceae	Tree	x	✓	x
183	*Mimusops elengi* L.	Sapotaceae	Tree	x	✓	x
184	*Moringa oleifera* Lam.	Moringaceae	Tree	✓	✓	✓
185	*Morus laevigata* Wall.	Moraceae	Tree	✓	✓	x
186	*Oroxylum indicum* (L.) Benth. ex Kurz	Bignoniaceae	Tree	x	✓	x
187	*Phyllanthus distichus* Müll.Arg.	Phyllanthaceae	Tree	x	✓	x
188	*Psidium guajava* L.	Myrtaceae	Tree	x	x	✓
189	*Pterospermum acerifolium* (L.) Willd.	Malvaceae	Tree	✓	✓	✓
190	*Pterospermum lanceifolium* Roxb.	Malvaceae	Tree	✓	x	x
191	*Pyrus pyrifolia* (Burm.) Nak.	Rosaceae	Tree	x	✓	x
192	*Sapindus mukorossi* Gaertn.	Sapindaceae	Tree	x	x	✓
193	*Senna siamea* (Lam.) Irwin et Barneby	Fabaceae	Tree	✓	✓	✓
194	*Shorea robusta* Roth	Dipterocarpaceae	Tree	✓	✓	✓
195	*Spondias pinnata* (L.f.) Kurz	Anacardiaceae	Tree	x	✓	x
196	*Sterculia villosa* Roxb. ex Sm.	Malvaceae	Tree	x	✓	x
197	*Stereospermum chelonoides* DC.	Bignoniaceae	Tree	x	✓	x
198	*Syzygium cumini* (L.) Skeels.	Myrtaceae	Tree	x	✓	✓
199	*Tectona grandis* L.f.	Verbenaceae	Tree	✓	x	x
200	*Terminalia arjuna* (Roxb.) Wight & Arn.	Combretaceae	Tree	✓	✓	✓
201	*Terminalia chebula* Retz.	Combretaceae	Tree	x	✓	x
202	*Trewia nudiflora* (Linn.)	Euphorbiaceae	Tree	✓	✓	x
203	*Zanthoxylum oxyphyllum* Edgew.	Rutaceae	Tree	x	✓	x
204	*Ziziphus mauritiana* Lam.	Rhamnaceae	Tree	✓	x	x

Total	No. of species = 59, genus = 53	Family = 29	31	42	23
Note: ✓ indicate presence of a species, x absence of a species					

Table 2: Phytosociological attributes of plants inventoried in Bhomoraguri RF, Balipara RF, and Sengelimari RFs

Life form	Community parameters	Reserve forests			Statistics (ANOVA)	
		Bhomo-raguri	Balipara	Senge-limari	F ratio	P value
Grasses	No. of species	13	10	12	-	-
	No. of genus	13	10	12	-	-
	No. of family	2	2	2	-	-
	Margalef index (R)	1.81	1.30	1.6	1.141	0.332
	Density (individual ha^{-1})	265618	368594	351147	0.193	0.826
	Basal area (m^2 ha^{-1})	0.15	0.04	0.13	6.131	0.006*
	Shannon Weiner index (H')	2.34	2.19	2.18	0.816	0.451
	Simpson index (C_D)	0.12	0.13	0.14	0.117	0.89
	Pielou evenness index (J)	0.91	0.94	0.83	2.155	0.132
	Whitford index (WI)	0.84	0.89	1.58	1.283	0.291
Forbs	No. of species	39	29	19	-	-
	No. of genus	36	28	19	-	-
	No. of family	19	22	13	-	-
	Margalef index (R)	4.77	3.64	2.71	51.847	0.000
	Density (individual ha^{-1})	375157	283183	410547	0.87	0.423
	Basal area (m^2 ha^{-1})	0.35	2.28	0.66	12.255	0.000*
	Shannon Weiner index (H')	3.34	3.13	2.79	8.255	0.001*
	Simpson index (C_D)	0.04	0.06	0.07	1.564	0.215*
	Pielou evenness index (J)	0.88	0.83	0.92	19.678	0.000*
	Whitford index (WI)	3.58	2.05	1.4	1.837	0.166
Climbers	No. of species	9	10	12	-	-
	No. of genus	8	9	10	-	-
	No. of family	7	8	9	-	-
	Margalef index (R)	1.25	1.38	1.66	12.53	0*
	Density (individual ha^{-1})	115732	95813	116870	0.039	0.962
	Basal area (m^2 ha^{-1})	2.04	3.62	1.34	4.643	0.018*
	Shannon Weiner index (H')	2.06	2.11	2.34	0.594	0.559
	Simpson index (C_D)	0.14	0.14	0.11	0.29	0.751
	Pielou evenness index (J)	0.93	0.92	0.94	1.94	0.163
	Whitford index (WI)	0.83	1.1	0.84	1.31	0.286
Shrubs	No. of species	31	30	17	-	-
	No. of genus	29	26	17	-	-
	No. of family	18	16	14	-	-
	Margalef index (R)	4.22	4.66	3.09	3.334	0.041*
	Density (individual ha^{-1})	1608	1747	1565	3.80	0.027*
	Basal area (m^2 ha^{-1})	2.88	2.79	3.23	0.75	0.476
	Shannon Weiner index (H')	2.65	2.72	2.44	3.336	0.041*
	Simpson index (C_D)	0.12	0.1	0.14	0.374	0.689
	Pielou evenness index (J)	0.78	0.77	0.86	6.84	0.002*
	Whitford index (WI)	9.76	14.62	3.77	6.579	0.002*
Trees	No. of species	31	42	23	-	-
	No. of genus	29	39	23	-	-

	No. of family	20	26	17	-	-
	Margalef index (R)	5.02	7.02	4.44	10.158	0.000*
	Density (individual ha^{-1})	588	464	313	2.299	0.042*
	Basal area (m^2 ha^{-1})	52.21	63.61	29.18	5.677	0.005*
	Shannon Weiner index (H')	2.49	2.71	2.7	4.08	0.02*
	Simpson index (C_D)	0.17	0.16	0.1	0.039	0.962
	Pielou evenness index (J)	0.72	0.72	0.85	8.149	0.001*
	Whitford index (WI)	7.1	14.07	6.18	2.737	0.07*

Note: * indicates significant at p ≤ 0.05

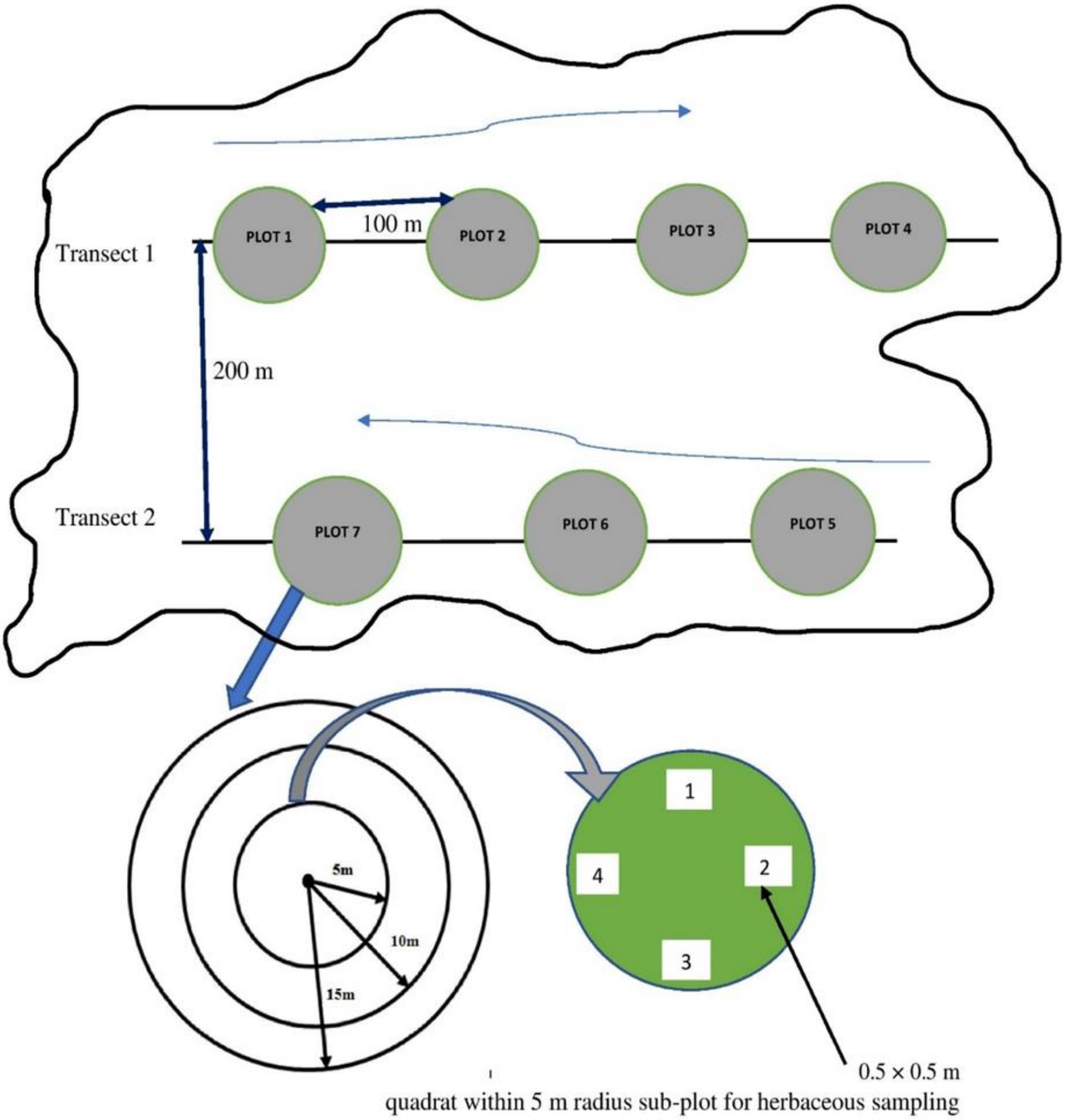


Figure 2: Diagrammatic representation of plots layout and line transects

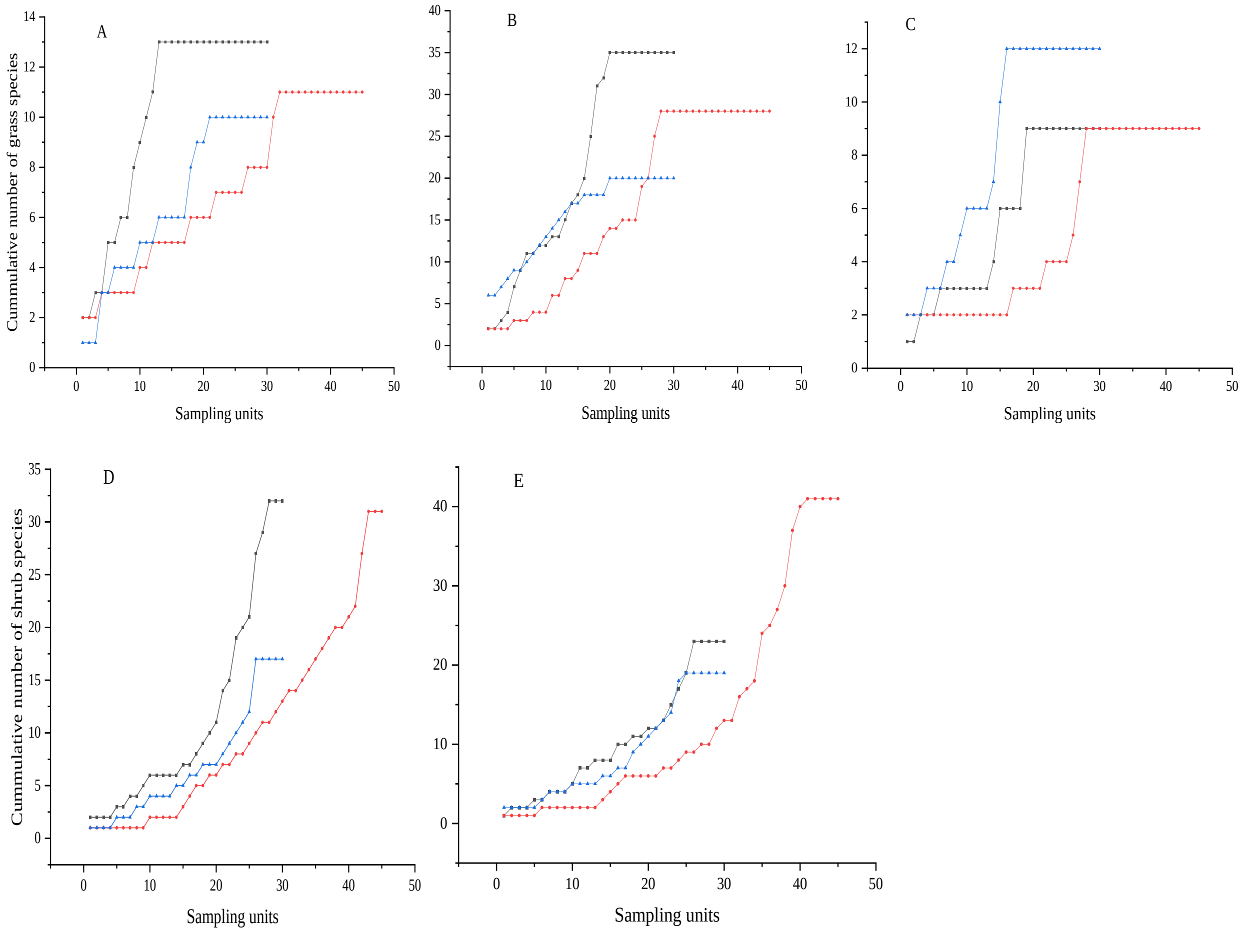


Figure 3: Species-accumulative curve of grass (A), forbs (B), climber (C), shrub (D) and tree (E) species recorded in Bhomoraguri RF ( ), Balipara RF ( ) and Sengelimari RF ( ).

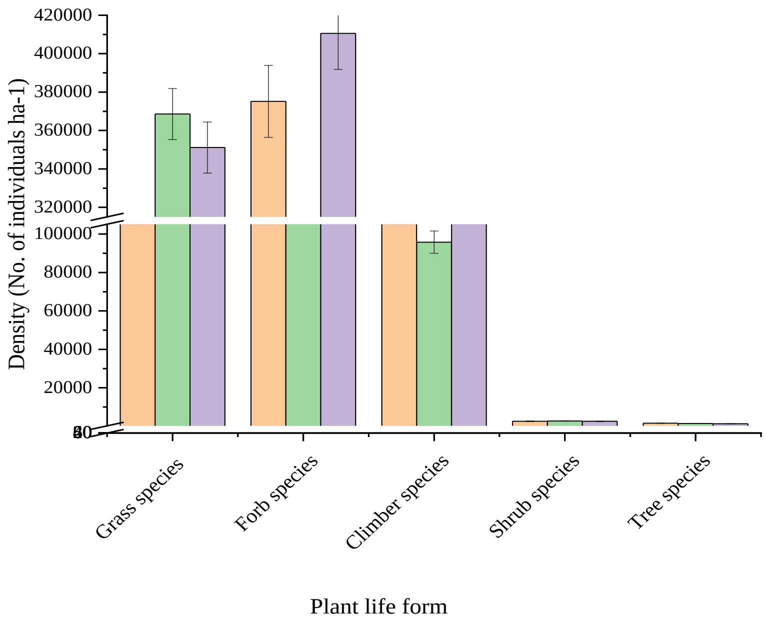


Figure 4: Estimated density (ha-1) of all studied plant life forms in RFs

Bhomoraguri RF Balipara RF Sengelimari RF

3.3 Density (individual's ha^{-1}) and basal area (m^2 ha^1) in RFs

Density and basal area are the two important quantitative data which largely determine the dominance of species in a particular forest ecosystem. The overall number of individuals per hectare (individual's ha^{-1}) differed significantly ($p < 0.05$), between forests and plant life forms (grasses, forbs, climbers, shrubs and trees). Analysis of variance (ANOVA) revealed that individual ha^{-1} in the studied reserve forests was significant for trees (F = 2.299, p = 0.042), and shrub species (F = 3.802, p = 0.027), but insignificant for grasses (F = 30.193, p = 0.8.26), forbs (F = 0.87, p = 0.423), and climbers (F = 0.039, p = 0.962). The phytosociological attributes of plants inventoried in Bhomoraguri RF, Balipara RF, and Sengelimari RF is summarized in Table 2. Among the herbs, highest density was recorded in forb species than other plant life forms in all the forests. A total of 375157 individual ha^{-1} for forbs were recorded in Bhomoraguri RF, 283183 in Balipara RF, and 410547 individuals' ha^{-1} in Sengelimari RF. Meanwhile, the lowest individual's ha^{-1} was recorded in tree species. For tree species, Bhomoraguri RF recorded 588 stem ha^{-1} followed by Balipara RF (464 stem ha^{-1}) and the lowest stem was recorded in Sengelimari RF having 313 ha^{-1} (Fig. 4.). For shrub and tree species, Sengelimari RF contributed the least number of individuals ha^{-1} and highest was recorded in Balipara RF for shrubs (1747 ha^{-1}) and Bhomoraguri RF for trees (588 ha^{-1}).

Basal area varied significantly between forests which ranged from 0.04 m2 ha^{-1} (as minimum in grasses) to 63.61 m2 ha-1 (as maximum in trees) (Fig. 5.). The analysis results indicated significant for grasses (F = 6.131, p = 0.006), forbs (F = 12.26, p = 0.000), climbers (F = 4.643, p = 0.018) and for trees (F = 5.677, p = 0.005); but insignificant for shrubs (F = 0.749, p = 0.476). The highest basal area of 63.61 m^2 ha^{-1} for tree was recorded in Balipara RF, followed by 52.21 m^2 ha^{-1} in Bhomoraguri RF, and the lowest was recorded in Sengelimari RF (28.87 m^2 ha^{-1}) (Fig. 5.). Among the herbs, the lowest basal area was recorded in grass species for all the studied forests (0.15, 0.04, and 0.13 m2 ha^{-1} for Bhomoraguri RF, Balipara RF, and Sengelimari RF, respectively.

3.4 Dominant plant species in RFs

Species exhibiting high important value index (IVI) values does contribute high values either for density or basal area, or both in the community. The dominant plant species varied from one forest to another ($p < 0.05$). The top most dominant grasses, forbs, climbers, shrubs and trees species based on greater IVI values in Bhomoraguri RF, Balipara RF and Sengelimari RF are presented in Fig. 6a, Fig. 6b, Fig. 6c, Fig. 6d and Fig. 6e, respectively. For Bhomoraguri RF, species with great IVI for grasses were *Cynodon dactylon* (40.28), *Imperata cylindrica* (35.82) and *Brachiaria reptans* (33.56); while *Datura stramonium* (22.21) and *Chromolaena odorata* (14.93) were dominant forbs. *Clitoria ternatea* (52.22), and *Piper betle* (51.28) recorded as dominant climber species. *Lantana camara* (43.48) and *Melastoma malabathricum* (23.88) were dominant shrub species. Nevertheless, tree species such as *Tectona grandis* (58.34%) and *Ficus hirta* (25.09) recorded the high IVI values indicating dominant tree species in Bhomoraguri RF.

Similarly, for Balipara RF, the dominant grass species were *Cymbopogon nardus* (49.08), *Cynodon dactylon* (41.72) and *Cyperus rotundus* (37.81). While *Chromolaena odorata* (19.36), *Colocasia esculenta* (23.78), and *Drymaria cordata* (19.28) were the dominant forbs. *Hedyotis scandens* (46.26) and *Mikania micrantha* (50.27) recorded high IVI values for climbers. Moreover, shrubs species like *Clerodendrum viscosum* (45.09), *Justicia adhatoda* (24.09) and *Melastoma malabathricum* (23.94) were dominant in Balipara RF; while tree species such as *Syzygium cumini* (19.26), *Ficus hirta* (19.63) and *Shorea robusta* (60.71) dominated Balipara RF.

On the other hand, species that recorded high IVI values for Sengelimari RF were *Cynodon dactylon* (44.38), *Lophatherum gracile* (33.96) and *Paspalum conjugatum* (33.25) for grasses. *Chromolaena odorata* (22.33) and *Colocasia esculenta* (38.97) for forbs. Species such as *Piper betle* (36.12), *Paederia foetida* (35.45) and *Argyreia speciosa* (30.63) were dominant climbers. For shrubs, *Antidesma acidum* (23.69) and *Melastoma malabathricum* (49.67) were dominant species and *Artocarpus heterophyllus* (50.22) and *Eugenia orbiculata* (38.69) recorded dominated tree species in Sengelimari RF.

3.5 Diversity indices

3.5.1 Shannon-Wiener diversity and Simpson index

Results on Shannon-Wiener index (H') and Simpson index (C_D) recorded in the three studied reserve forests of Assam differed significantly between species ($p < 0.05$). Comparative analysis of species diversity index (Shannon-

Wiener index) between plant life forms (i.e., grasses, forbs, climbers, shrubs and trees) revealed variables results for each plant life form (Table 3). A significant different was recorded between species of different life forms in Bhomaraguri RF (*F* =13.90, *p* < 0.001). Furthermore, significant values of *F* =18.95, *p* < 0.001, and *F* = 3.67, *p* = 0.009 for plant life forms was recorded for Balipara RF and Sengelimari RF, respectively. On the other hand, analysis between forests indicated no significant different for grass species (*F* = 0.79, *p* = 0.46), and climbers (*F* = 0.59, *p* = 0.559). However, forbs, shrubs and trees differed significantly between forests (*F* = 8.255, *p* = 0.001 for forbs; *F* = 3.336, *p* = 0.041 for shrub; and *F* = 4.08, *p* = 0.022 for trees).

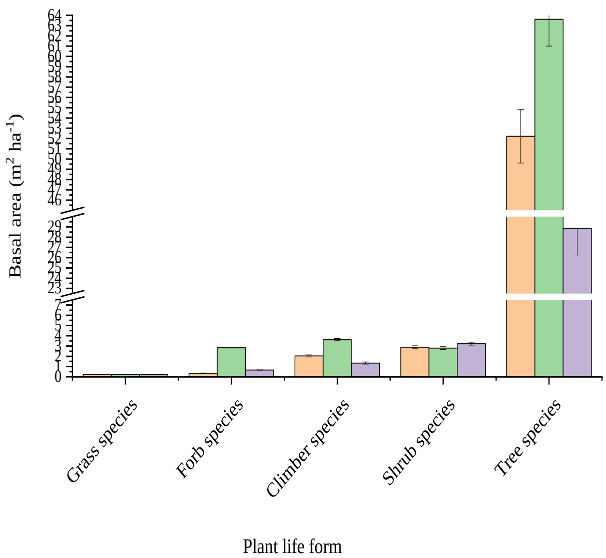


Figure 5: Estimated basal area (m2ha-1) of all studied plant life forms in RFs

Bhomoraguri RF Balipara RF Sengelimari RF

For Bhomoraguri RF, forb species recorded the highest diversity (H' = 3.34) and lowest diversity was recorded in climber species (H' = 2.06). A similar trend was also observed in Balipara RF, having greatest diversity in forb species (H'= 3.13); whereby Simpson index ranged from 0.06-0.16, being highest in trees and lowest in forbs (Fig. 7.). Furthermore, forb species recorded great diversity in Sengelimari RF (H' = 2.79; CD = 0.07) followed by tree species (H' = 2.70; CD = 0.11) and the least was recorded by grasses (H' = 2.18; CD = 0.14). Among the studied reserve forests, Bhomoraguri recorded higher diversity for grass, forb and shrub species than Balipara and Sengelimari RFs. Similarly, Balipara RF recorded higher diversity for shrub and tree species than Bhomaraguri and Sengelimari RFs. However, climber species was recorded more diverse in Sengelimari RF than Bhomoraguri and Balipara RFs.

3.5.2 Whitford, Pielous' evenness, Margalef richness indices and Similarity index

The spatial distribution pattern of the species based on abundance and frequency ratio (Whitford index) depicts contagious distribution. Species distribution patterns range from 0.84 to 9.76 (0.84, 3.58, 0.83, 9.76 and 7.10 for grasses, forbs, climbers, shrubs and trees, respectively) in Bhomoraguri RF (Fig. 8). Similar pattern is found in Balipara RF and Sengelimari RF therein it ranges from 0.89 to 14.62 (0.89, 2.05, 1.10, 14.62, and 14.07 for grasses, forbs, climbers, shrubs and trees, respectively) in Balipara RF (8and from 0.84 to 6.18 (1.58, 1.40, 0.84, 3.77, and 6.18 for grasses, forbs, climbers, shrubs and trees, respectively) in Sengelimari RF (Fig. 8). The calculated values fall within the contagious categories of species distribution pattern, suggesting that the studied forests exhibit contagious patterns for all plant life forms.

Pielous' evenness index (J) portrayed a range of 0.72 to 0.93 (i.e., 0.91, 0.88, 0.93, 0.78 and 0.72 for grasses, forbs, climbers, shrubs and trees, respectively) for all plant life forms in Bhomoraguri RF (Fig. 8). Balipara RF, on the other hand, recorded 0.94 for grasses, 0.83 for forbs, 0.92 for climbers, 0.72 for shrubs and 072 for trees; which ranged from 0.72 to 0.94 (Fig. 8). Moreover, a range of 0.83 to 0.94 (0.83, 0.92, 0.94, 0.86, and 0.85 for grasses, forbs, climbers, shrubs and trees, respectively) was recorded in Sengelimari RF (Fig. 8). The Margalef species richness index (R) justifies effective number of species in a particular habitat. Relatively high values are recorded in forbs followed by shrubs and trees. In Bhomoraguri RF, the values ranged from 1.25 to 4.7; 1.3 to 7.2 in Balipara RF, and 1.6 to 4.44 in Sengelimari RF. Forbs recorded 4.77 in Bhomoraguri RF followed by shrubs (R = 4.22) and trees (R = 5.02). Similarly, in Balipara RF, Margalef species richness index values were 3.64 for forbs, 4.66 for shrubs and 7.02 for trees (Fig. 8). And lowest value of forbs is recorded in Sengelimari RF with R = 2.71 followed by shrubs R = 3.09 and trees R= 4.44 (Fig. 8).

The SØrensen similarity index, which is used to measure the degree to which species composition is alike; the higher the value the greater similarity. The result index indicated a maximum similarity between Bhomoraguri RF and Balipara RF (60.87, 81.97 and 54.79% for grasses, shrubs and trees, respectively), and between Bhomoraguri RF and Sengelimari RF (37.93 and 54.55% for forbs and climbers) (Table 4). The maximum similarity for grasses (60.87%) was recorded between Bhomoraguri and Balipara RFs, and the least (24.00%) was recorded between Bhomoraguri and Sengelimari RFs. For forbs, the maximum (37.93%) was recorded between Balipara and Sengelimari RFs, while the lowest (28.21%) was between Bhomoraguri and Balipara RFs. On the other hand, Sengelimari and Bhomoraguri RFs, recorded the maximum (57.14%) for climbers and lowest (31.58%) was between Bhomoraguri and Balipara RFs. Trees and shrubs recorded maximum between Bhomoraguri and Balipara, while the least was between Sengelimari and Bhomoraguri RFs (Table 4). Multivariance analysis (MANOVA) revealed variables results between forests. For instance, Pielous' evenness index was significant for grasses (F =23.038, p = 0.000), forbs (F =19.078, p = 0.000), shrubs (F = 6.84, p = 0.002), and tree (F =8.149, p = 0.001), but insignificant for climbers (F =1.94, p = 0.163).

Table 3: Comparative analysis of diversity index (Shannon-Wiener diversity) between plant life forms and across forests

		Multiple Comparisons (LSD) values					**ANOVA between plants**
Reserved forests		Grasses	Forbs	Climbers	Shrubs	Trees	
		Sig.	Sig.	Sig.	Sig.	Sig.	
Bhomoraguri RF	Balipara RF	0.236	0.213	0.583	0.957	0.353	F = 13.9, *p* = 0.000
	Sengelimari RF	0.828	0.000	0.271	0.012	0.068	
Balipara RF	Bhomoraguri RF	0.236	0.213	0.583	0.957	0.353	F = 18.95, *p* = 0.000
	Sengelimari RF	0.346	0.002	0.579	0.013	0.006	
Sengelimari RF	Bhomoraguri RF	0.828	0.000	0.271	0.012	0.068	F = 3.67, *p* = 0.009
	Balipara RF	0.346	0.002	0.579	0.013	0.006	
ANOVA between forests		F = 0.816, *p* = 0.451	F = 8.255, *p* < 0.001	F = 0.594, *p* = 0.559	F = 3.336, *p* = 0.041	F = 4.08, *p* = 0.022	

***. The mean difference is significant at the 0.05 level.**

Table 4: Similarity indices (%) of grass, forb, climber, shrub and tree species in RFs

	Grasses			**Forbs**			**Climbers**			**Shrubs**			**Tree**		
	Bhomoraguri RF	Balipara RF	Sengelimari RF	Bhomoraguri RF	Balipara RF	Sengelimari RF	Bhomoraguri RF	Balipara RF	Sengelimari RF	Bhomoraguri RF	Balipara RF	Sengelimari RF	Bhomoraguri RF	Balipara RF	Sengelimari RF
Bhomoraguri RF	-	-	24.00	-	-	34.48	-	-	57.14	-	-	45.83		-	48.15
Balipara RF	60.87	-	-	28.21	-	-	31.58	-	-	81.97	-	-	54.79	-	-
Sengelimari RF	-	27.27	-	-	37.93	-	-	54.55	-	-	55.32	-	-	49.23	-

3.6 Correlation analysis

Relationship between plant diversity from different plant categories (i.e., grasses, forbs, climbers, shrubs and tree) were determined using Pearson's correlation analysis. The degree of correlation ranged from weak positive and negative to relatively strong (Table 5). The results showed that diversity of forb species was negatively associated to tree species diversity for all the studies RFs (r = -50% for Sengelimari RF; r = -8% for Balipara RF; and r = -5% for Bhomoraguri RF). Similar trend was observed in the relationship between shrub species and tree species diversity (r = -22% for Sengelimari RF; r = -13% for Balipara RF; and, r = -18% for Bhomoraguri RF). These indicate that the tree species are inversely related to forbs and shrub and have a significant negative impact on their diversity. Thus, any increase in number of tree species lowers forbs and shrubs diversity. Furthermore, climber species diversity showed a negative correlation with grass species diversity (r = -15%; r = -7%). On the other hand, grass species diversity exhibited a positive correlation with both shrubs and tree diversity, with the coefficient value of 20%, 13% and 9% for tree diversity, and 35%, 47%, and 48% for shrubs, suggesting that grass species diversity was affected with other factors rather than the diversity of tree or shrub species.

Table 5: Pearson correlation analysis for different life form of plant diversity recorded in RFs

	Grass diversity	Forb diversity	Climber diversity	Shrub diversity	Tree diversity
Bhomoraguri RF					
Grass diversity	1	0.351 (*p* = 0.239)	-0.158 (*p* = 0.684)	0.35 (*p* = 0.240)	0.199 (*p* = 0.515)
Forb diversity		1	0.028 (*p* = 0.942)	0.065 (*p* = 0.720)	-0.048 (*p* = 0.797)
Climber diversity			1	-0.245 (*p* = 0.525)	0.158 (*p* = 0.685)
Shrub diversity				1	-0.18 (*p* = 0.333)
Tree diversity					1
Balipara RF					
Grass diversity	1				
Forb diversity	-0.14 (*p* = 0.699)	1			
Climber diversity	-0.068 (*p* =0.853)	0.354 (*p* = 0.315)	1		
Shrub diversity	0.471 (*p* = 0.169)	-0.054 (*p* = 0.765)	0.113 (*p* = 0.756)	1	
Tree diversity	0.129 (*p* = 0.723)	-0.08 (*p* = 0.623)	-0.292 (*p* = 0.413)	-0.132 (*p* = 0.463)	1
Sengelimari RF					
Grass diversity	1				
Forb diversity	0.162 (*p* = 0.634)	1			
Climber diversity	-0.392 (*p* = 0.234)	-0.189 (*p* = 0.556)	1		
Shrub diversity	0.474 (*p* = 0.141)	0.286 (*p* = 0.266)	0.344 (*p* = 0.273)	1	
Tree diversity	0.094 (*p* = 0.784)	-0.498* (*p* = 0.025)	0.233 (*p* = 0.466)	-0.227 (*p* = 0.381)	1

4. DISCUSSION

4.1 Floristic composition in reserve forests

The 204 plant species recorded in this study suggest that the RFs under investigation are potential habitats for rich biodiversity. However, an ever-increasing population and rapid urbanization are driving the demand for forest products, leading to biodiversity loss. The presence of grass species from the genus Aristida and Cenchrus, despite their low frequency and abundance, indicates that the ecosystem of the studied reserve forests is disturbed (Rubanza et al. 2006). Similarly, species like Ipomoea spp. and Sida spp. clearly indicate disturbed habitats, which may be caused by specific types of land degradation (Plate 1). In addition to ecological factors, the study observed several human-induced disturbances, such as agriculture, grazing, fuel-wood collection, medicinal herb harvesting, and forest fires within the reserve forests (Plate 2). These activities have contributed to significant vegetation clearance and forest degradation. The high incidence of forest encroachment observed during field visits, particularly in Sengelimari RF, may have led to lower diversity, although this was not investigated in detail. Such activities likely contributed to the vegetation status documented in the studied forests. The investigation also found that valuable timber tree species have been harvested illegally to the extent that it was rare to encounter mature stems, especially in Sengelimari RF. Tree species like Shorea robusta Roth, Tectona grandis, Dillenia indica, and Bombax ceiba are under threat, as evidenced by the presence of stumps, indicating illegal harvesting of stems.

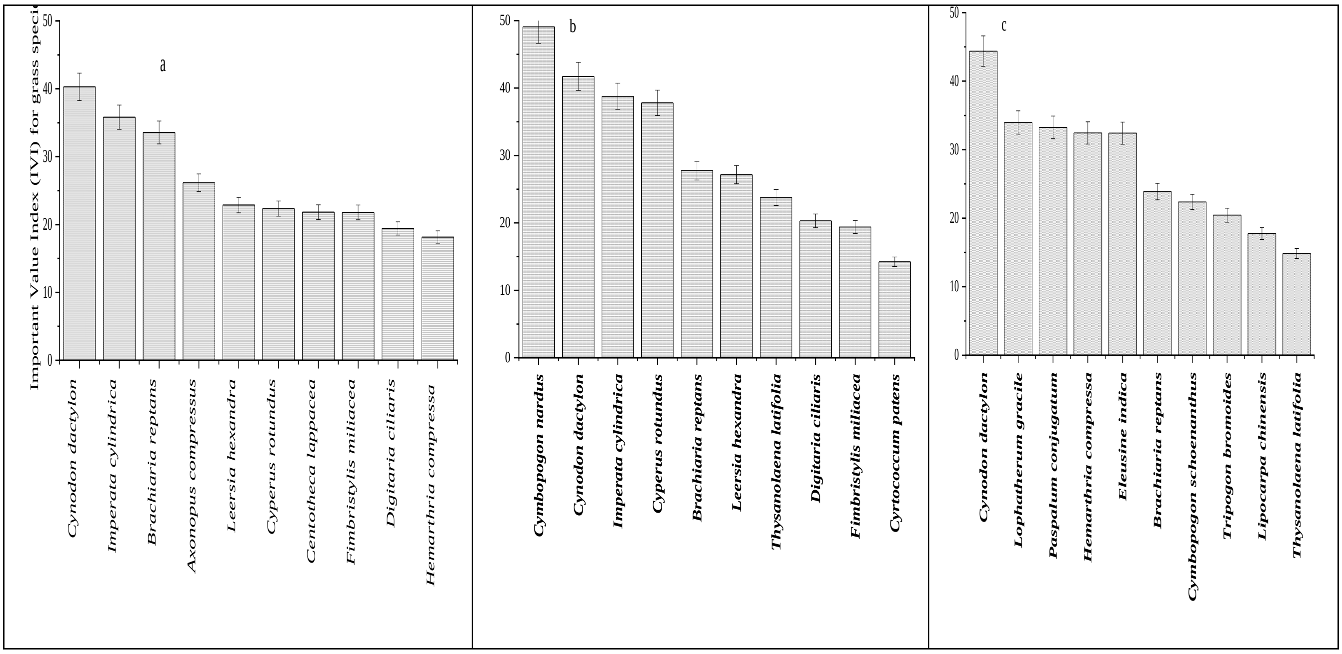


Figure 6a: Top ten dominant grass species based on IVI values in Bhomoraguri RF (a), Balipara RF (b), and Sengelimari RF(c).

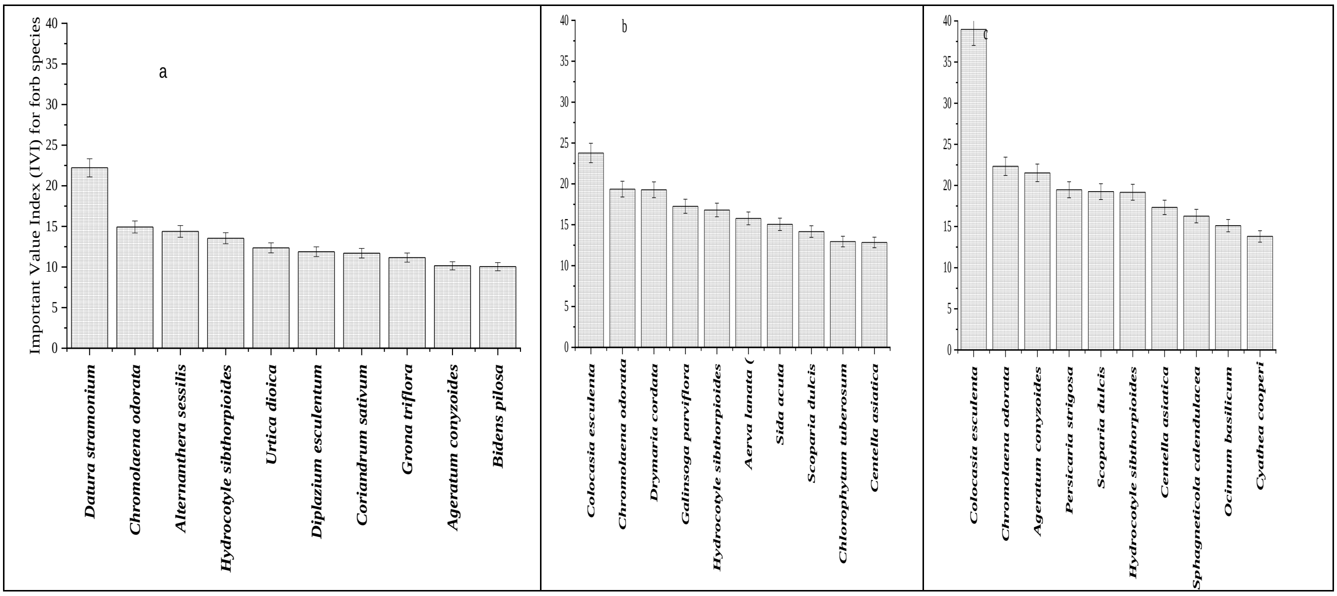


Figure 6b: Top ten dominant forb species based on IVI values in Bhomoraguri RF (a), Balipara RF (b), and Sengelimari RF(c

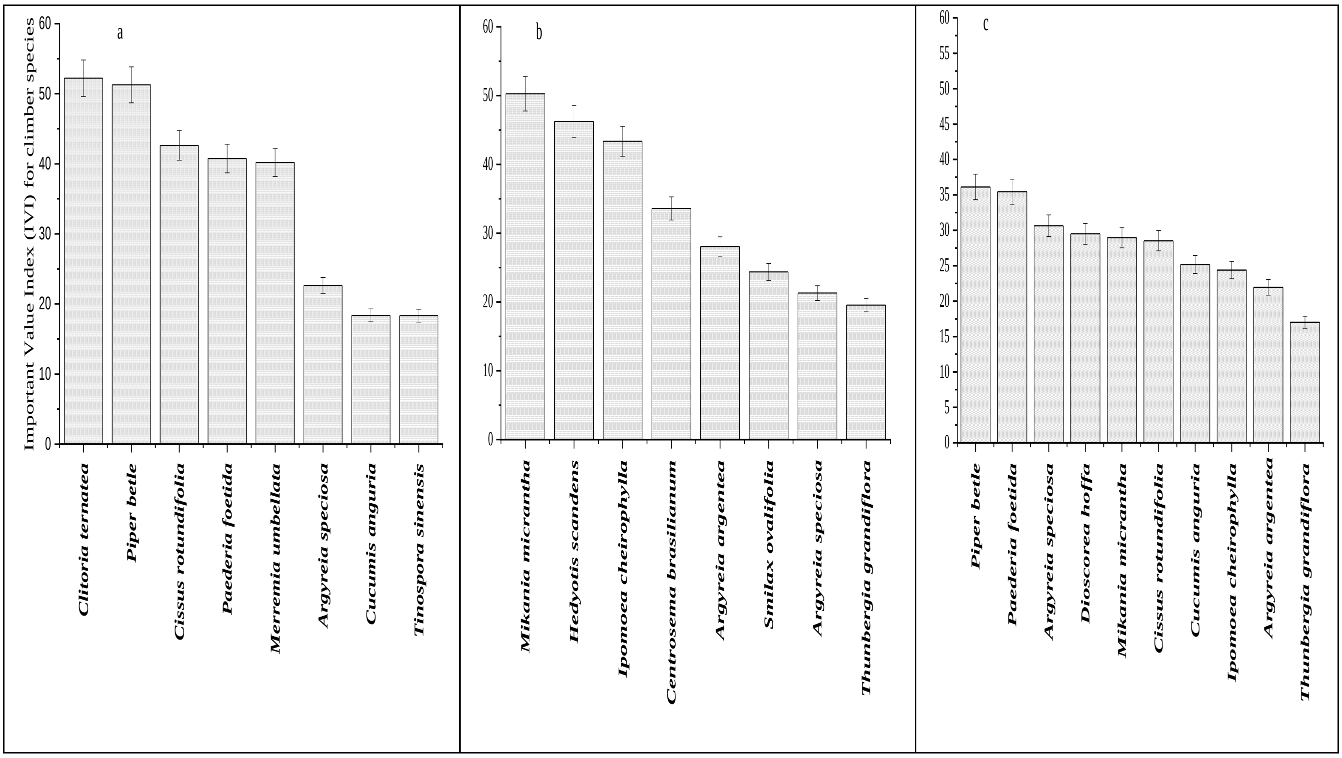


Figure 6c: Top dominant climber species based on IVI values in Bhomoraguri RF (a), Balipara RF (b), and Sengelimari RF(c).

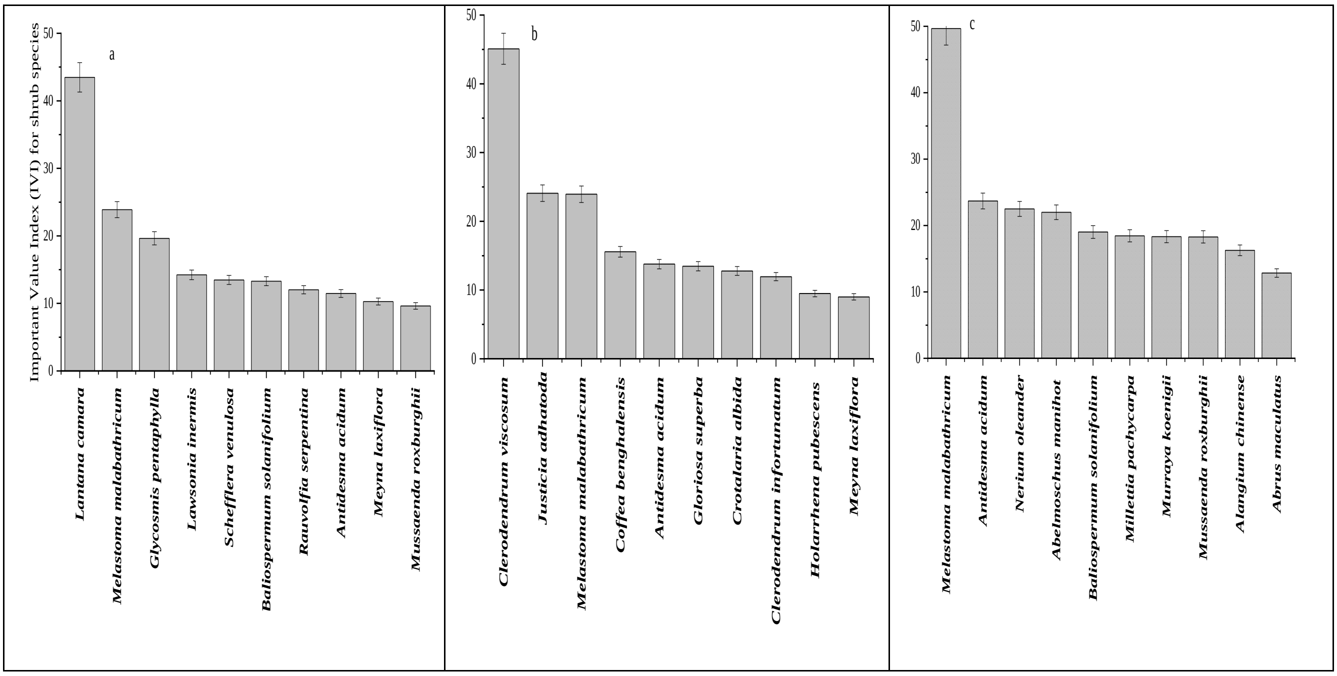


Figure 6d: Top ten dominant shrub species based on IVI values in Bhomoraguri RF (a), Balipara RF (b), and Sengelimari RF(c).

The presence of species like *Chromolaena odorata*, a rapidly growing perennial herb that often acts as a creeper on other vegetation, may have contributed to the poor diversity of grasses and climbers in Bhomoraguri RF. Additionally, the dominance of herbaceous species such as *Hydrocotyle sibthorpioides* and *Cynodon dactylon* reflects their water-loving nature, as these forests frequently experience flooding, favoring the colonization and thriving of such species. Differences in floristic composition from other reported data could be linked to various forms of anthropogenic activities. For instance, Gogoi and Sahoo (2018) reported that the growing population led to extensive exploitation of natural resources in the tropical rainforest of the eastern Himalayas (India), putting forest biodiversity under severe anthropogenic stress. Thus, proper policies should be implemented. Several scholars have recorded a similar number of species in different forest types. Deori and Talukdar (2015) recorded 159 species (37 climbers, 63 shrubs, and 49 trees) in Laokhowa Wildlife Sanctuary of Assam (India). Kar et al. (2019) recorded 144 species (21 grasses, 35 forbs, 34 climbers, 19 shrubs, and 35 trees) in Borail Wildlife Sanctuary of Assam (India). Gogoi and Sahoo (2018) recorded 129 species (24 forbs, 33 shrubs, and 72 trees) in Jeypore Forest of Assam (India). Borah (2020) recorded 37 herb species in Behali Forest, Assam. Bora et al. (2017) recorded 147 species (35 grasses and 112 trees) in Barail Wildlife Sanctuary. Dutta and Devi (2013) recorded 137 species (19 grasses, 34 shrubs, and 84 trees) in disturbed tropical forests (Doboka RF) of Assam, India. Sarkar and Devi (2014) recorded 98 species (23 shrubs and 75 trees) in Gibbon Wildlife Sanctuary, Assam (India). Sarmah and Borthakur (2009) recorded 602 species (51 grasses, 337 forbs, 21 climbers, 97 shrubs, and 96 trees) in Manas National Park of Assam, India. Similar observations were also reported by Kushwaha and Hazarika (2004).

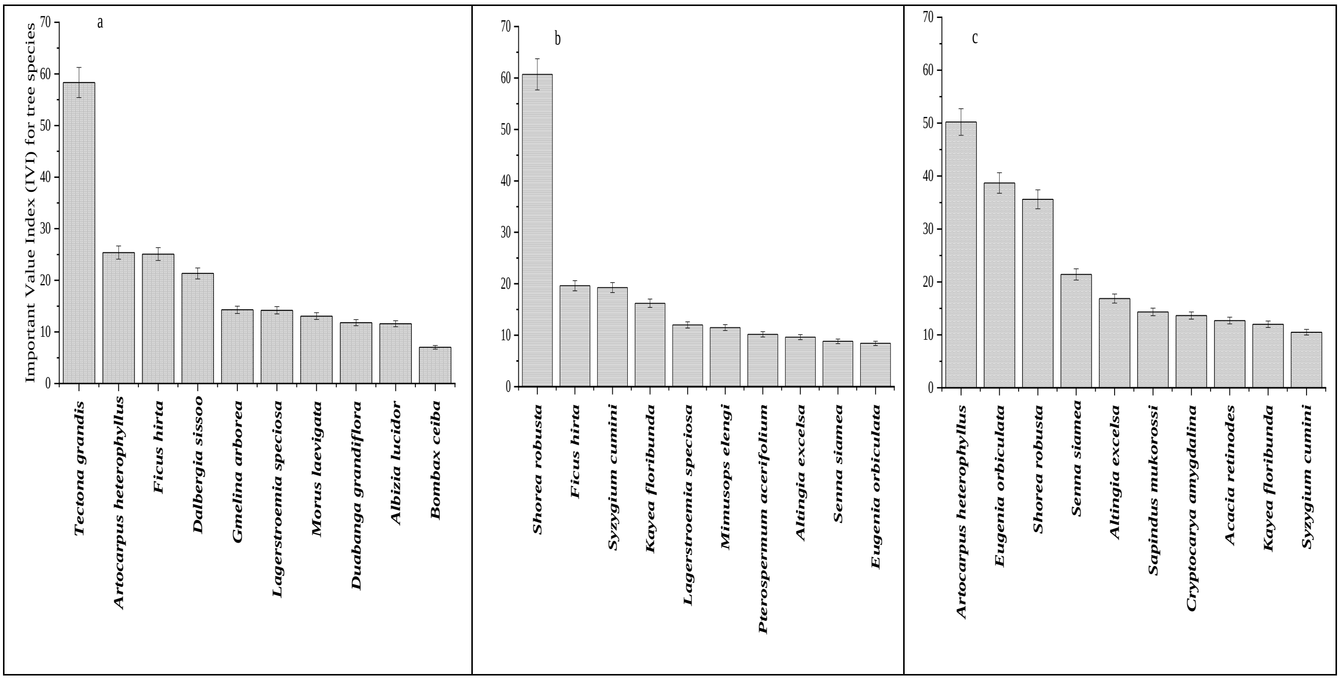


Figure 6e: Top ten dominant tree species based on IVI in Bhomoraguri RF (a), Balipara RF (b), and Sengelimari RF(c).

Furthermore, Kushwaha and Nandy (2012) recorded 477 (230 forb, 113 shrub and 134 tree) species in Moist Sal forests of West Bengal (India). Furthermore, Nath et al. (2005) recorded a range of 14 to 27 and 18 to 50 for shrub and tree species, respectivelly in Tropical wet evergreen forests, Arunachal Pradesh, India, and Parthasarathy, (1999) recorded 114 tree species in Tropical wet evergreen forest of Western Ghat of India. Such studies have reported most of the plant species which are encountered in the present study like, Argyreia spp., Cynodon dactylon, and Brachiaria reptans as dominant, with relatively high density and frequency. The dominat species are Cynodon dactylon., Imperata cylindrica, Brachiaria reptans, and Axonopus compressus for grasses; Datura stramonium, Chromolaena odorata, Alternanthera sessilis and Hydrocotyle sibthorpioides for forbs; Argyreia spp., Cissus rotundifolia and Clitoria ternatea for climbers; Lantana camara, Melastoma malabathricum, Glycosmis pentaphylla and Lawsonia inermis for shrubs; and Artocarpus heterophyllus, Bombax ceiba, Dalbergia sissoo, Duabanga grandiflora, Ficus hirta and Shorea robusta for trees. All these species have contributed to density in the present study.

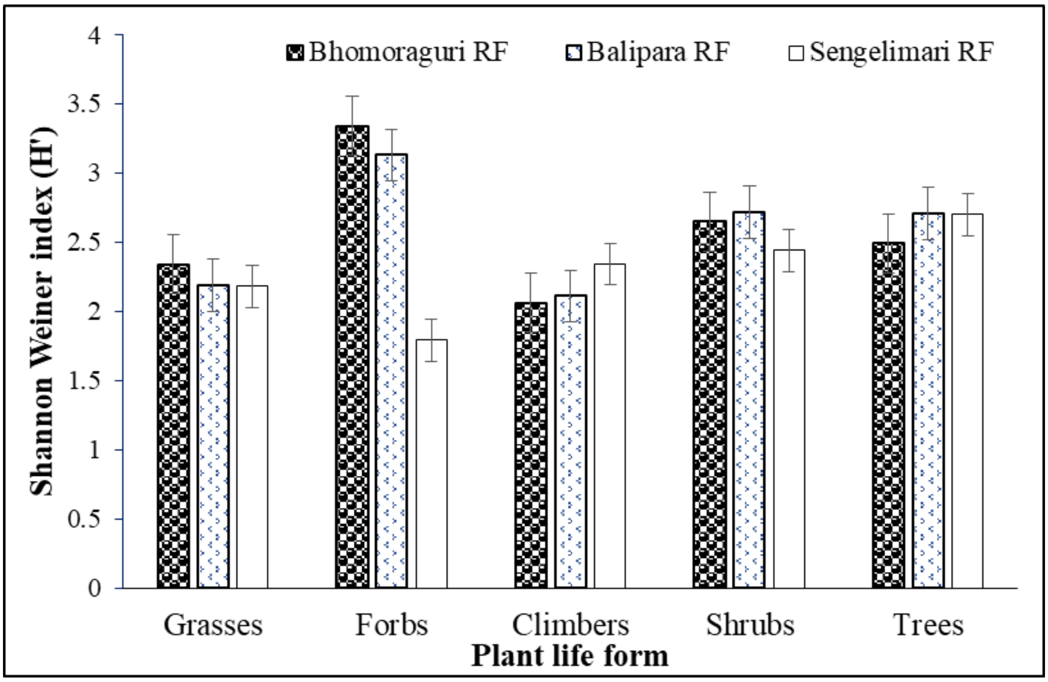


Figure 7: Variability of Shannon-Wiener index (H') in Bhomoraguri RF, Balipara RF, and Sengelimari RF.

Based on the important value index (IVI), studies have reported dominant species that reflected the present study findings. Dutta and Devi (2013) recorded species such as Cynodon dactylon, Ophiuros megaphyllus, Maranta arundinacea, Curcuma amada, Cyperus rotundus, Commelina benghalensis, had relatively high IVI values in Doboka Reserve Forest. Shameem et al. 2010, on the other hand, reported species like Bothriochloa pertusa, C. dactylon, and Stipa sibirica as dominant grasses; while Salvia moorcroftiana, Fragaria nubicola., Galinsoga parviflora and Viola indica as dominant forbs. Furthermore, herbaceous species like Stellaria media, Cynodon dactylon, Persicaria strigosa, Thunbergia grandiflora, Ipomoea cheirophylla, Argyreia nervosa and Ipomoea purpurea were recorded by Kar et al. (2019) in Borail Wildlife sanctuary. The high IVI values and dominant species in Balipara RF such as Dillenia indica (7.94), Sterculia villosa (8.11), Eugenia orbiculate (8.42), Senna siamea (8.83), Altingia excelsa (10.63), Mimusops elengi (11.49), Pterospermum acerifolium (11.78), Kayea floribunda (16.22), Syzygium cumini (19.26), Ficus hirta (19.63), Shorea robusta (60.71) and Lagerstroemia speciosa (12) indicate that these species have more competitive ability to survive and out compete with other tree species. It might also be because of more structural quality through which they can suppress others. Additionally, such species may have better ability to uptake the soil nutrients than others. On the other hand, species like Smilax ovalifolia, Lantana camara and Piper betle are highly resistant and exhibited weed characteristics which increased their dominance and frequency (Naveenkumar et al. 2017). Such species have established themselves as a renowned plant that suppresses the establishment and development of other understory species. Furthermore, Lantana camara is a frequent noxious species in the dry and damp forests (Gogoi and Sahoo 2018; Naveenkumar et al. 2017). It is an aggressive colonizer, especially near forest borders and disturbed ecosystems.

4.2 Density and basal area

The great number of individual ha-1 in the present study was recorded highest in herbs than others plant life forms. Among the herbs; forbs recorded the highest density in Bhomoraguri RF, Balipara RF, and Sengelimari RF. Results on basal area on the other hand, varied significantly for studies plants. For instance, the great trees density and basal area recorded in Bhomoraguri and Balipara RF as compared to Sengelimari RF, could be ascribed by presence of forest security point in Bhomoraguri RF and Balipara RF. This vigilance of forest staff could have reduced people’s movement in and out of these forests compared to Sengelimari RF. The domination of some plant species like Tectona grandis and Shorea robusta, is linked to strategic conservation management by forest department in these RFs, which involves special plantation. The findings from the present study are also comparable to data reported by other scholars from different forest types of India. For instance, Dutta and Devi (2013) recorded a range of 130500 to 237100 individual ha-1 for forbs, 3168 to 5928 individual ha-1 for shrubs, and 138 to 736 individual ha-1 for trees, in Doboka Forest, Gogoi and Sahoo (2018) in Jeypore (36500-16600, 2680-8680 and 235-645 ha-1 for herbs, shrubs and trees, respectively. Other reported data with similar trend includes that of Nohro and Jayakumar (2020) (552.8 ha-1 for trees) in Wetland Forest (India); Nath et al. (2005) (69600-254333, 3080-13280 and 34-610 density ha-1 for herbs, shrubs and trees, respectively) in Tropical wet evergreen forests, Arunachal Pradesh (India); Kushwaha and Nandy (2012) (438 density ha-1 for tree); Parthasarathy (1999) (575-855 density ha-1 for trees) in Tropical wet evergreen forest of Western Ghat, India.

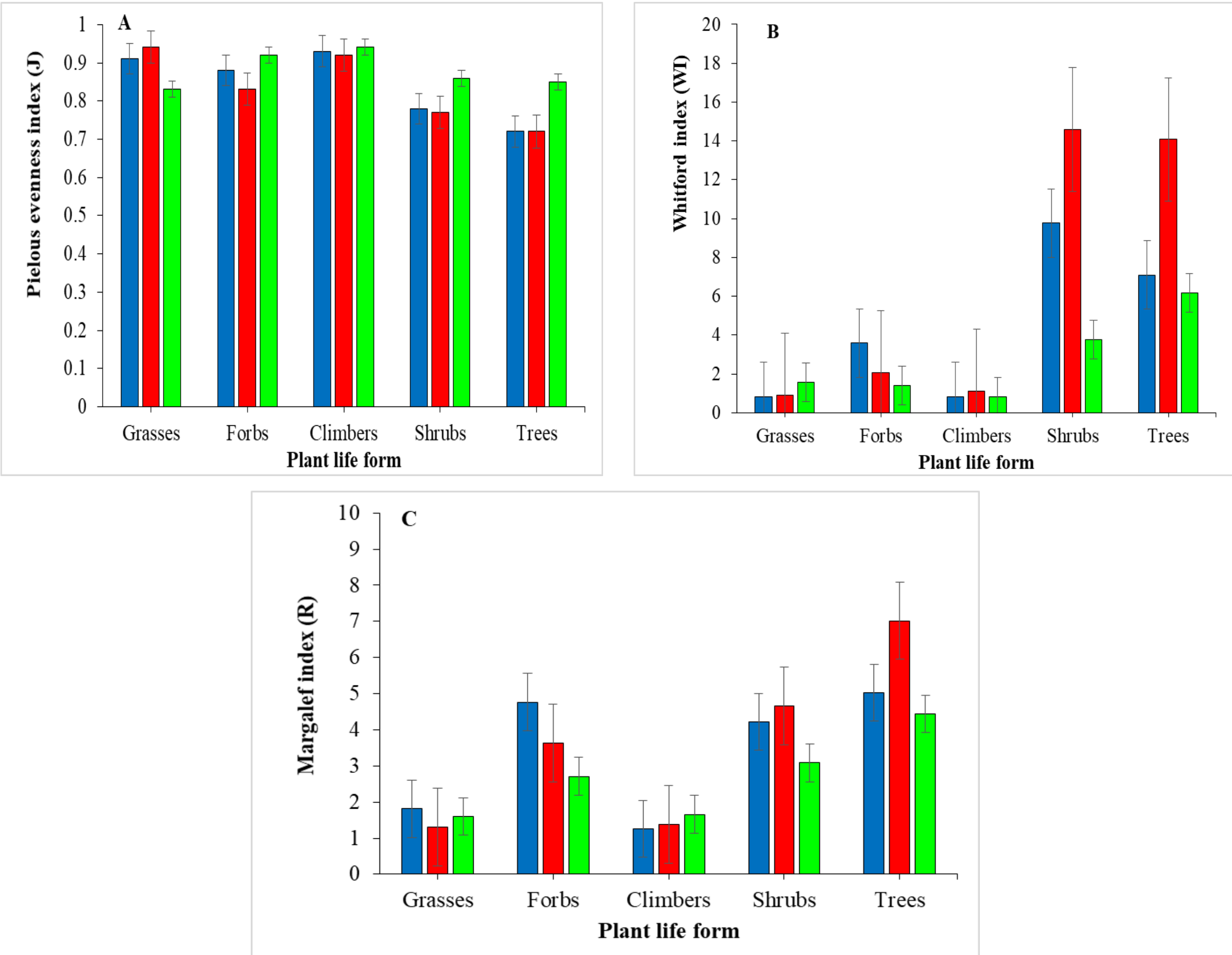
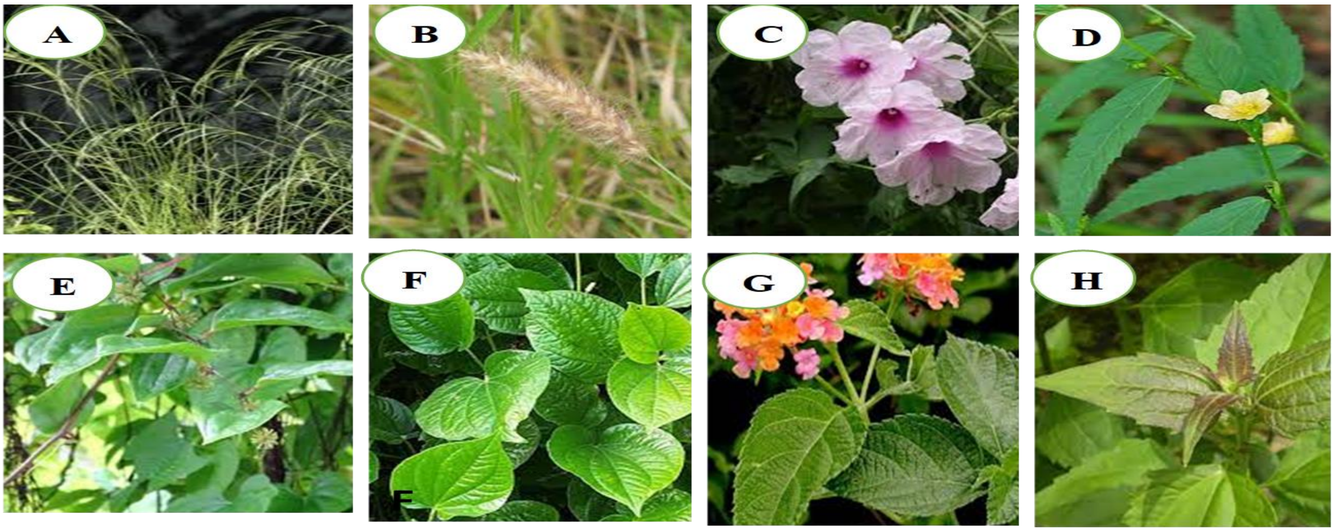


Figure 8: Pielou evenness index (A), Whitford index (B) and Margalef species richness index (C) in Bhomoraguri RF, Balipara RF, and Sengerimari RF.

Results on basal area (m2 ha-1) on the other hand, varied significantly. These results were within the data reported by other scholars from different forest types of India. For example, Kushwaha and Nandy (2012) recorded a basal are of 56.52 m2 ha-1 for tree; Nath et al. (2005) recorded a range of 0.63 to 3.77 m2 ha-1 for shrubs, and 7.81 to 98.58 m2ha-1 for tree species in Tropical wet evergreen forests of Arunachal Pradesh (India); Gogoi and Sahoo, (2018) recorded a range of 0.6 to 2.4 m2 ha-1 for shrubs, and 19.55-108.02 m2 ha-1 for trees, in Jeypore RF. The findings from the present study, reflects the general characteristics of most tropical dry forests of India. However, the differences in terms of individuals ha-1 and basal area (m2 ha-1) of the present results, when compared from other reported data could be due to different in forest types, and maturation as well as the levels of anthropogenic activities. The high level of human intrusion observed requires a quick reaction; otherwise, they may convert these RFs into other land use system. Special attention should be given to Sengelimari RF, which is spontaneously become a treeless forest and soon will be a history.



***Aristida* spp. (A), *Cenchrus ciliaris* L. (B*), Ipomoea cheirophylla* O'Donell (C), *Sida acuta* Burm.f. (D), *Smilax ovalifolia* Roxb. ex D. Don (E), *Piper betle* L. (F), *Lantana camara* L. (G), and *Chromolaena odorata* (L.) R.M.King & H.Rob.(H).**

Figure 9: Species that indicate disturbed ecosystems (A, B, C, and D), and those that exhibits weed characteristics (E, F, G, and H) recorded in RFs.

Forest fire observed in Balipara RF (A), Trespass observed in Bhomoraguri RF (B), Bundles of firewood seen in the borders of Bhomoraguri RF (C), Tree stump observed in Sengelimari RF (D), Small scale rice field (farms) observed in Sengelimari RF (E), and harvesting of cultivated crops observed in Balipara RF (F).

Figure 10: Observed anthropogenic activities in studied RFs.

4.3 Analysis of diversity indices

Although results on species diversity varied significantly between plant life form and forests. However, the analysis of diversity indices illustrated a promising floristic diversity in the studied reserve forests. Shannon index (H') and Simpson diversity index (CD) were used to determine diversity and richness of a species present in the studied forests.

Higher values of H' indicate diverse and equally distributed community, and lower values represent less diverse community. Simpson diversity index (CD) on the other hand, the lower CD values represent higher diversity (Giri et al. 2019). Whitford index (WI) which is the ratio of abundance and frequency ratio (A/F) was used to assess the distribution pattern of species, while Pielou evenness index assessed species evenness. The high Shannon index (H') values for forbs in Bhomoraguri RF (3.34, dominated by Tectona grandis) and in Balipara RF (3.13, dominated by Shorea robusta) indicates that, the dominant tree species have less suppressing power on understory species. They provide an excellent opportunity for other plant species to coexist and populate the habitat. The present study's findings revealed a reasonably high flora species diversity that differed considerably ($p < 0.05$). Forb species showed a significantly higher diversity in all the studied RFs. Such results imply a relatively promising vegetation coverage in the studied RFs, which was within the range of 1.85 to 5.68 reported from other India's forests (Dibaba et al. 2019; Raha et al. 2020). For example, Nohro and Jayakumar (2020) reported Shannon index values of 3.73; Gogoi and Sahoo (2018) reported a range of 2.44 to 3.37; Dutta and Devi (2013) in Doboka Reserve Forest, recorded a range of 2.02 to 2.43; Karki et al. (2016) recorded a range of 2.65 to 3.47 in Central Himalaya Forest of Assam (India); Kushwaha and Nandy (2012) recorded (H' = 3.08-3.10); and Deori and Talukdar (2015) (H' = 3.61-4.01). Anthropogenic activities were the mostly reported factors which affected plant diversity (Begum et al. 2011; Konwar et al. 2009; Sumita et al. 2015). The indiscriminate felling of the species coupled with poor regeneration is likely to cause species to be vulnerable to extinction.

Species distribution patterns varied between forests, in Bhomoraguri RF (0.84-9.76), Balipara (0.89-14.62) and Sengelimari RF (0.84-6.18). The calculated values fall within the contagious categories of species distribution pattern, suggesting that the studied forests exhibit contagious patterns to all plant life forms. Pielous' evenness index (J), on the other hand, varied between forests in Bhomoraguri RF (0.72-0.93), Balipara (0.72-0.94) and Sengelimari RF (0.83-0.94). The Margalef index which justifies effective number of species in a particular habitat, differed between forest and plant life forms. In Bhomoraguri RF (1.25-4.7), Balipara (1.3-7.2) and Sengelimari RF (1.6-4.44). The Whitford index revealed that most of the species were contagiously distributed, suggesting that species in the studied forests performed contagious pattern of distribution. The domination of contagious distribution may be due to the fact that the majority of species reproduce vegetatively in addition to their sexuality (Shameem et al. 2010). An abundance of species on the other hand, increased proportionately with the value of Margalef index. The results suggested for the number of effective species in the studied forests. For instance, despite large number of tree species (n = 42) in Balipara RF, only 6 species namely Shorea robusta Roth, Syzygium cumini, Ficus hirta, Lagerstroemia speciosa, Altingia excelsa and Kayea floribunda were dominating more effectively in the entire ecosystem. These findings are comparable with the data reported by Gogoi and Sahoo (2018) (1.63-2.92 for herbs, 2.2-3.27 for shrubs, and 4.67-10.91 for tree) in Jeypore reserve forest of Assam, India.

4 CONCLUSION

Understanding species distribution, structure, and diversity patterns in reserve forests is essential for their effective planning, management, and sustainable use. The present study highlighted that reserve forests are potential biodiversity centers and play a significant role in floristic composition. However, the presence of species from the genus Aristida and Cenchrus, which are typically good indicators of disturbed ecosystems, suggests specific types of land degradation, mainly due to anthropogenic activities. The distribution of these species may have been accelerated by human encroachment. Therefore, immediate action is required; otherwise, these forests may be converted to other land uses. If the appropriate authorities do not take action, even the notable recorded forest biodiversity may become stressed by human activities.

ACKNOWLEDGEMENTS

The first author gratefully acknowledges financial support from the Indian Council of Cultural Relations (ICCR) for the fellowship. Thanks are also extended to the Forest Department's West Division in Sonitpur district for allowing the study in their protected forests and to the Department of Environmental

Sciences at Tezpur University for providing excellent laboratory facilities.

Declarations

Competing interests: The authors of this manuscript state that they have no known competing financial or personal interests.

Ethics approval and consent to participate: Not applicable

Funding: No specific funds were received.

Authors' contributions

All authors contributed equally to this work: Gisandu K. Malunguja drafted the manuscript, conducted fieldwork, collected data, analyzed and interpreted the results, and compiled the findings. Ashalata Devi supervised the study, analyzed data, corrected errors, typeset the text, and assisted with fieldwork-related materials.

REFERENCES

Anitha, K.; Joseph, S.; Chandran, R.J.; Ramasamy, E.V.; Prasad, S.N. Tree Species Diversity And Community Composition In A Human-Dominated Tropical Forest of Western Ghats Biodiversity Hotspot, India. Ecological Complexity, 2010, 7(2), 217–224. https://doi.org/10.1016/j.ecocom.2010.02.005.

Baruah, M.K.; Chakraborty, G.; Choudhury, M.D. Contribution To The Flora of Barak Valley : Conservation Status and Economic Potential of Herbaceous Plant Resources of Cachar district of Assam, India. International Journal of Bio-resource and Stress Management, 2013, 4(2). 137-146.

Barbhuiya, H.A.; Dutta, B.K.; Das, A.K.; Baishya, A.K. An Annotated Checklist of the Grasses (Poaceae) of Southern Assam. Check List, 2013, 9(5), 980–986. https://doi.org/10.15560/9.5.980

Baul, T.K.; Chowdhury, A.I.; Uddin, M.J.; Hasan, M.K.; Schmidt, L.H.; Nandi, R.; Nath, T.K. Diversity and Phytosociology of Natural Regeneration in a Sub-tropical Forest of Chittagong Hill Tracts, Bangladesh: Implications for Conservation. Journal of Sustainable Forestry. 2022, 41(9), 895-908. https://doi.org/10.1080/10549811.2022.2059517

Begum, S.S.; Roy, H.; Nath, M.; Borthakur, S.K. A Sketch of the Flora of Nameri National Park , Assam : II. Phytogeography. Pleione, 2011, 5(1), 10–22.

Behera, S.K.; Sahu, N.; Mishra, A.K.; Bargali, S.S.; Behera, M.D.; Tuli, R. Aboveground Biomass and Carbon Stock Assessment In Indian Tropical Deciduous Forest and Relationship with Stand Structural Attributes. Ecological Engineering, 2017, 99, 513–524. https://doi.org/10.1016/j.ecoleng.2016.11.046

Bhattacharjee, K.; Boro, A.; Das, A.K.; Dutta, U.; Sarma, G.C. Phytogeography of Chirang Reserve Forest under Manas Biosphere Reserve in Assam (India). Pleione, 2014, 8(2). 374–380.

Bora, A.; Devi, M.; Bhattacharyya, D. Grasses and bamboos of Barail Wildlife Sanctuary in Assam, India. Pleione, 2017, 11(2), 440.https://doi.org/10.26679/pleione.11.2.2017.440-454

Borah, D.; Tangjang, S.; Prasad Das, A.; Upadhaya, A.; Mipun, P. Assessment of Non-Timber Forest Products (NTFPs) in Behali Reserve Forest, Assam, Northeast India. Ethnobotany Research and Applications, 2020, 19, 43. https://doi.org/10.32859/era.19.43.1-15

Borah, M.; Das, D.; Kalita, J.; Deka Boruah, H.P.; Phukan, B.; Neog, B. Tree Species Composition, Biomass and Carbon Stocks in Two Tropical Forest of Assam. Biomass and Bioenergy, 2015, 78: 25–35. https://doi.org/10.1016/j.biombioe.2015.04.007

Buragohain, R.; Swargiari, B.N. Diversity and conservation of Ficus Linnaeus (Moraceae) in Chakrashila Wildlife Sanctuary, Kokrajhar District of Assam, India. Pleione, 2016, 10(2), 10(2), 302–309.

Caviedes, J.; Ibarra, J.T. Influence of Anthropogenic Disturbances on Stand Structural Complexity in Andean Temperate Forests: Implications for Managing Key Habitat for Biodiversity. PLoS ONE, 2017, 12(1), 1–18. https://doi.org/10.1371/journal.pone.0169450

Curtis, J.; McIntosh, R. The Interrelations of Certain Analytic and Synthetic Phytosociological Characters. Ecology, 1950, 31(3). 434-455.

Czapiewska, N.; Dyderski, M.K. Seasonal Dynamics of Floodplain Forest Understory – Impacts of Degradation, Light Availability and Temperature on Biomass and Species Composition. Forests, 2019, 10(22), 1–16. https://doi.org/10.3390/f10010022

Dar, J.A.; Sundarapandian, S. Variation of Biomass and Carbon Pools with Forest Type in Temperate Forests of Kashmir Himalaya, India. Environmental Monitoring and Assessment, 2015, 187(1), 55. https://doi.org/10.1007/s10661-015-4299-7

Deori, C.; Talukdar, S.R. Floristic Diversity of Laokhowa Wildlife Sanctuary, Assam, India. Nelumbo, 2015, 57(1), 19–28. https://doi.org/10.20324/nelumbo/v59/2017/120449

Dibaba, A.; Soromessa, T.; Workineh, B. Carbon Stock of the Various Carbon Pools in Gerba-Dima moist Afromontane forest, South-western Ethiopia. Carbon Balance and Management, 2019, 14(1): 1–10. https://doi.org/10.1186/s13021-019-0116-x

Dri, G.F.; Fontana, C.S.; de Sales Dambros, C. Suburban Forest Patches Have High Functional and Phylogenetic Diversity in Bird Communities. Urban Ecosyst, 2024, 27, 349–358. https://doi.org/10.1007/s11252-023-01455-4

Duchok, R.; Kent, K.; Khumbongmayum, A.D.; Paul, A.; Khan, M.L. Population Structure And Regeneration Status of Medicinal Tree Illicium Griffithii in Relation to Disturbance Gradients in Temperate Broad-Leaved Forest of Arunachal Pradesh. Current Science, 2005, 89(4). 673–676.

Dutta, G; and Devi, A. Plant diversity and community structure in tropical moist deciduous sal (Shorea robusta Gaertn.) forest of Assam , northeast India. Journal of environmental and applied Bioresearch, 2013, 1(3):1-4, 2013.

Echeverría, C.; Newton, A.C.; Lara, A.; María, J.; Benayas, R.; Coomes, D.A. Impacts of Forest Fragmentation on Species Composition and Forest Structure in the Temperate Landscape of Southern Chile. Global Ecology and Biogeography, 2007, 16(1), 426–439. https://doi.org/10.1111/j.1466-8238.2007.00311.x

Enríquez-de-Salamanca, Á. Contribution to Climate Change of Forest Fires in Spain: Emissions and Loss of Sequestration. Journal of Sustainable Forestry, 2020, 39(4), 417–431. https://doi.org/10.1080/10549811.2019.1673779

FSI. India State of Forest Report. Ministry of Environment, Forest & Climate Change Government of India. Dehradun, Uttarakhand. India, 2019. www.fsi.nic.in. Accessed February 14, 2024.

Flores-Galicia, N.; Gutiérrez, E.; Trejo, I. Effect of Exotic Species Management on the Recovery of Relict Forests through Citizen Participation. Urban Ecosystem, 2024, 1-9. https://doi.org/10.1007/s11252-024-01535-z

Gandhi, D.S.,; Sundarapandian, S. Large-Scale Carbon Stock Assessment of Woody Vegetation in Tropical Dry Deciduous Forest of Sathanur Reserve Forest, Eastern Ghats, India. Environmental Monitoring and Assessment, 2017,189(4), 14-22.

Giri, K.; Buragohain, P.; Konwar, S.; Pradhan, B.; Mishra, G.; Meena, D.K. Tree Diversity and Ecosystem Carbon Stock Assessment in Nambor Wildlife Sanctuary, Assam. Proceedings of the National Academy of Sciences India Section B - Biological Sciences, 2019. 89(4), 1421–1428. https://doi.org/10.1007/s40011-018-01072-8

Gogoi, A.; Sahoo, U.K. Impact of Anthropogenic Disturbance on Species Diversity and Vegetation Structure of A Lowland Tropical Rainforest of Eastern Himalaya, India. Journal of Mountain Science, 2018, 15(11), 2453–2465. https://doi.org/10.1007/s11629-017-4713-4

Gogoi, A.; Sahoo, U.K.; Singh, S.L. Assessment of Biomass and Total Carbon Stock in a Tropical Wet Evergreen Rainforest of Eastern Himalaya along a Disturbance Gradient. Journal of Plant Biology & Soil Health, 2017, 4(1), 1–8. https://doi.org/10.13188/2331-8996.1000014.

Hubálek, Z. Measures of Species Diversity in Ecology: An Evaluation. Folia Zoologica, 2000, 49(4), 241–260.

Kalita, N.; Kalita, M. Ethnomedicinal Plants of Assam, India as an Alternative Source of Future Medicine for Treatment of Pneumonia. International Research Journal of Biological Sciences, 2014, 3(10), 76–82. www.isca.me

Kanagaraj, S.; Selvaraj, M.; Das Kangabam, R.; Munisamy, G. Assessment of Tree Species Diversity and its Distribution Pattern in Pachamalai Reserve Forest, Tamil Nadu. Journal of Sustainable Forestry, 2017, 36(1), 32–46. https://doi.org/10.1080/10549811.2016.1238768

Kar, A.; Boruah, D.; Nath, P.; Goswami, N.K.; Saharia, D. Angiosperm Diversity of Borail Wildlife Sanctuary, Assam, India: Report - II. Pleione, 2019, 13(1), 122–136. https://doi.org/10.26679/pleione.13.1.2019.122-136

Karki, H.; Rana, P.; Bargali, K.; Bargali, S.S.; Rawat, Y. Effect of Biotic Disturbances on Herbaceous Vegetation in Cypress Mixed Oak Forests of Central Himalaya, India. Current World Environment, 2016, 11(2), 413–422. https://doi.org/10.12944/cwe.11.2.09

Kumar, M.; Singh, M.P.; Singh, H.; Dhakate, P.M.; Ravindranath, N.H. Forest Working Plan for the Sustainable Management of Forest and Biodiversity in India. Journal of Sustainable Forestry, 2020, 39(1), 1–22. https://doi.org/10.1080/10549811.2019.1632212

Kushwaha, S.P.S.; Hazarika, R. Assessment of Habitat Loss in Kameng and Sonitpur Elephant Reserves. Current Science, 2004, 87(10),1447-1453.

Kushwaha,S.P.S.; Nandy, S. Species Diversity and Community Structure In Sal (Shorea robusta) Forests of Two Different Rainfall. Biodivers Conserv, 2012, 21(1), 1215–1228. https://doi.org/10.1007/s10531-012-0264-8

Malunguja, G.K.; Devi, A. Quantitative Assessment and Predicting the Effects of Soil Pollutants on Herbaceous Biomass Production in Reserved Forests. Proceedings of the National Academy of Sciences India Section B - Biological Sciences, 2022, 92(1), 105–120. https://doi.org/10.1007/s40011-021-01325-z

Malunguja, G.K.; Devi, A.; Kilonzo, M.; Rubanza, C.D.K. Climate Change Mitigation Through Carbon Dioxide (CO2) Sequestration in Community Reserved Forests of Northwest Tanzania. Archives of Agriculture and Environmental Science, 2020, 5(3), 231–240. https://doi.org/https://doi.org/10.26832/24566632.2020.050301

Malunguja, G.K.; Rubanza, C.K.D.; Devi, A. An Assessment of the Current Status and Regeneration Potential of the Traditional Conserved Forests (Ngitili) in Kishapu District, Tanzania. The Journal of the Society for Tropical Plant Research, 2020, 7(2), 336–356. https://doi.org/10.22271/tpr.2020.v7.i2.040

Marglef, R. Perspectives in Ecological Theory. Univ. Chicago Press, Chicago. Limnology and Oceanography, 1969, 14(2), 313-315.

Matuszkiewicz, J.M.; Kowalska, A.; Kozłowska, A.; Roo-Zielińska, E.; Solon, J. Differences in Plant-Species Composition, Richness and Community Structure in Ancient and Post-Agricultural Pine Forests in Central Poland. Forest Ecology and Management, 2013, 310, 567–576. https://doi.org/10.1016/j.foreco.2013.08.060

Misra, K. Manual of Plant Ecology (3rd ed.)., 1989, Oxford and IBH Publishing Co. Pvt. Ltd.

Nath, M.J.; Bora, A.K.; Yadav, K.; Talukdar, P.K.; Dhiman, S.; Baruah, I.; Singh, L. Prioritizing Areas for Malaria Control Using Geographical Information System in Sonitpur District, Assam, India. Public Health, 2013, 127(6), 572–578. https://doi.org/10.1016/j.puhe.2013.02.007

Nath, P.; Arunachalam, A.; Khan, M.; Arunachalam, K.; Barbhuiya, A.R. Vegetation Analysis and Tree Population Structure of Tropical Wet Evergreen Forests in and Around Namdapha National Park, Northeast India. Biodivers Conserv, 2005, 14, 2109–2135.

Naveenkumar, J.; Arunkumar, K.S.; Sundarapandian, S.M. Biomass and Carbon Stocks of a Tropical Dry Forest of The Javadi Hills, Eastern Ghats, India. Carbon Management, 2017, 8, 351–361. https://doi.org/10.1080/17583004.2017.1362946

Nohro, S.; Jayakumar, S. Tree Species Diversity and Composition of the Pala Wetland Reserve Forest, Mizoram, Indo-Burma hotspot, India. Biocatalysis and Agricultural Biotechnology, 2020, 23(1), 101474. https://doi.org/10.1016/j.bcab.2019.101474

Paudel, D.; Tiwari, K.R.; Raut, N.; Bajracharya, R.M.; Bhattarai, S.; Wagle, B.H.; Sitaula, B. K.; Thapa, S. Species Composition and Carbon Stock in Different Agroforestry Practices in the mid-hills of Nepal. Journal of Sustainable Forestry, 2022, 1–17. https://doi.org/10.1080/10549811.2022.2123350

Pielou, E.C. Species-Diversity and Pattern-Diversity in The Study of Ecological Succession. Journal of Theoretical Biology, 1966, 10(2), 370–383. https://doi.org/10.1016/0022-5193(66)90133-0.

Pieper, R.D. Rangeland Vegetation Productivity and Biomass. In P.T. Tueller (Ed.), Vegetation science applications for rangeland analysis and management. Springer Netherlands. 1988, 449–467 pp.. https://doi.org/10.1007/978-94-009-3085-8_18

Raha, D.; Dar, J.A.; Pandey, P.K.; Lone, P.A.; Verma, S.; Khare, P.K.; Khan, M.L. Variation In Tree Biomass and Carbon Stocks in Three Tropical Dry Deciduous Forest Types of Madhya Pradesh, India. Carbon Management, 2020, 11(2), 109–120. https://doi.org/10.1080/17583004.2020.1712181

Rubanza, C.D.K.; Shem, M.N.; Ichinohe, T.; Fujihara, T. Biomass Production and Nutritive Potential of Conserved Forages in Silvopastoral Traditional Fodder Banks (Ngitiri) of Meatu District of Tanzania. Asian-Australasian Journal of Animal Sciences, 2006, 19(7): 978–983. https://doi.org/10.5713/ajas.2006.978

Sala, O.E.; Chapin, F.S.; Armesto, J.J.; Berlow, E.; Bloomfield, J.; Dirzo, R.; Huber-Sanwald, E.; Huenneke, L.F.; Jackson, R.B.; Kinzig, A.; Leemans, R.; Lodge, D.M.; Mooney, H.A.; Oesterheld, M.; Poff, N.L.R.; Sykes, M.T.; Walker, B.H.; Walker, M.; Wall, D.H. Global Biodiversity Scenarios For The Year 2100. Science, 2000, 287, 1770–1774. https://doi.org/10.1126/science.287.5459.1770

Sarkar, M.; Devi, A. Assessment of Diversity, Population Structure and Regeneration Status of Tree Species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India. Tropical Plant Reaearch, 2014, 1(2), 26–36.

Sarmah, K.K.; Borthakur, S.K. A Checklist of Angiospermic Plants of Manas National Park in Assam , India. Pleione, 2009, 3(2), 190–200.

Saxena, R.; Nagpal, B.N.; Singh, V.P.; Srivastava, A.; Dev, V.; Sharma, M.C.; Gupta, H.P.; Tomar, A.S.; Sharma, S.; Gupta, S.K. Impact of Deforestation on Known Malaria Vectors in Sonitpur District of Assam, India. Journal of Vector Borne Diseases, 2014, 51(3): 211–215.

Shameem, S.A.; Soni, P.; Bhat, G.A. Comparative Study of Herb Layer Diversity in Lower Dachigam National Park, Kashmir Himalaya, India. Int. J. Biodivers. Conserv., 2010, 2(10), 308–315. http://www.academicjournals.org/ijbc

Shannon, C.; Weaver, W. The Mathematical Theory of Communication. Urbana, IL. University of Illinois Press, 1949, p. 117.

Sharma, C.M.; Baduni, N.P.; Gairola, S.; Ghildiyal, S.K.; Suyal, S. Tree Diversity and Carbon Stocks of Some Major Forest Types of Garhwal Himalaya, India. Forest Ecology and Management, 2010, 260(12), 2170–2179. https://doi.org/10.1016/j.foreco.2010.09.014

Simpson, E.H. Measurement of diversity. Nature, 1949, 163(4148), 688 https://doi.org/10.1038/163688a0

SØrensen T. A Method of Establishing Groups of Equal Amplitude in Plant Sociology Based on Similarity of Species Content Det. Kong. Danske Vidensk, Selsk Biology Skr (Copenhagen), 1948, 5, 1-34.

Sumita, R.; Kiran, B.; Bargali, S.B. Assessment of Plant Diversity, Regeneration Status, Biomass and Carbon Stock in A Central Himalayan Cypress Forest. International Journal of Biodiversity and Conservation, 2015, 7(6), 321–329. https://doi.org/10.5897/ijbc2015.0855

Wade, T.G.; Riitters, K.H.; Wickham, J.D.; Jones, K.B. Distribution and Causes of Global Forest Fragmentation. 2003, 1-16 p.

Whitford, P.B. Distribution of Woodland Plants in Relation to Succession and Clonal Growth. Ecology, 1949, 30,199–208.

Yan, P.; Yang, J. Species Diversity of Urban Forests in China. Urban Forestry & Urban Greening, 2017, 28, 160-166. https://doi.org/10.1016/j.ufug.2017.09.005

Zahabu, E. Sinks and Sources a Strategy to Involve Forest Communities in Tanzania in Global Climate Policy.. Ph.D. Thesis, The University of Twente, December 2008.