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Research Article

Forest Phyto-Diversity Assessment of West Champaran District of Bihar, Eastern India

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Abstract

Regular biodiversity assessment is the key to judicial utilization and conservation of forest plant resources. Forest phyto-diversity in West Chaparan, Bihar, has been investigated in the current research. Assessment was conducted at 10 random forest locations. We estimated Important Value Index (IVI), Shannon and Wiener index, Simpson Index, and Pielou's evenness index. A total of 193 species were reported from the study area. Habit-wise number of species of trees, shrubs, herbs, climbers, grasses, sedges, and bamboo are 87, 27, 38, 16, 22, 02, and 01, respectively. Research revealed highest tree layer variety at Kali Temple and lowest at Watch Tower. Shrubby layer had highest diversity in Dongiparsa site and least in Comp. no. 53 (II) site, whereas in herbaceous layer, highest diversity was reported from Kali Temple site and least from Comp. no. 53 (I). Many biotic and abiotic factors endanger biodiversity. To reverse vegetative status, these elements must be identified and management measures should be adopted.

Keywords

Monitoring, Phyto-diversity, Conservation, Important Value Index, Diversity Indices

1. Introduction

Biological diversity describes the variety and range of all living organisms from all habitats and ecological complexes in which they are found. Biodiversity fulfills global food, fodder, medicinal, fuel, resins, timber, and oil requirements. Indirect services, including climate regulation, pollution management, soil and water conservation, nutrient cycling, pollination, and recreation, are regulated by biodiversity. Biodiversity assessment is seen as a crucial sign of the health of an ecosystem (Mahanand et al., 2022). Environmental factors affect ecosystem vegetation. Rapid decline in biodiversity is considered a major driver of environmental change [3]. Phytosociology assists in clarifying plant community structure and function. Meaningful patterns are explained and predicted (Gautam and Joshi, 2014). Therefore, phytosociology should be investigated for understanding an area's phyto-diversity. In the wild, biodiversity is of immense significance due to species' diverse genotypes, which could be further exploited. It is essential for evaluating and preserving biodiversity of forests, as they are reserves of biodiversity. However, plant resources are under severe pressure due to the growing population and rapid industrialization resulting decline of biodiversity. The requirement for routine biodiversity inventory and monitoring for conservation and sustainable utilization has also been highlighted by Convention on Bio-

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logical Diversity [20].

There are 38 districts in Indian state of Bihar, including West Champaran district. It is located in latitudes 26 °30'-27 °30' N and longitudes 83 °45'-84 °40' E. It covers an area of 5228 km^2. District's entire area covered by forests is 904.66 km^2, or 17.30% of state's total land area. According to density classes, 105.23 km^2 is classified as open forest, 550.24 km^2 as moderately dense forest, and 249.19k m^2 as very dense forest [11].

Numerous researchers have previously conducted in-depth surveys of the floral wealth of Bihar state and neighboring Jharkhand [14, 12, 25, 26, 2, 1, 35]. The dynamics of the area's vegetation can not be assessed only by qualitative state; consequently, quantitative status requires to be determined. Numerous workers have reported diversity indices for different forests [39, 31, 30, 16, 27, 10]. So far, no research has been published on the quantitative status of West Chmparan district's forest sites. Thus, efforts taken for evaluating plant diversity of various forest sites for comparison in current study.

2. Materials and Methods

2.1. Study Area

The study was carried out in forest areas of the West Champaran District of Bihar (Figure 1).

Figure 1. *Location map of study area.*

The climate of the district is broadly divisible into summer season: late March to May; rainy season: June to October; cold season: November to early March. The climate is pleasant during the cold season. The mean temperature is 24° C. The highest temperature of 36°C reaches in April and May and lowest of 4°C in December. The mean humidity is 83 percent. The rainfall is heavier than all other districts of Bihar. The annual average rainfall is 137.16 cm. June and July experience the heaviest showers.

2.2. Study Design (Data Source, Sampling Design and Data Collection and Analysis)

Study was carried out during 2017-18. Ten random forest sites of Nawada district namely: 1. Sector 14, Gobardhana Range, Balmiki Tiger Reserve; 2. Dongiparsa, Gobardhana Range; 3. Compartment No. 13, Gobardhana Range; 4. Kali Temple, Compartment No.4, Gobardhana Range; 5. compartment No. 53 (I), Mangurah Range, Sameswar Block; 6. Compartment No. 53 (II), Mangurah Range Block- Sameswar; 7. Compartment No. 44, Raghia Range; 8. Watch Tower Raghia Range; 9. Compartment 29 (I), Raghia Range; Compartment No. 29 (II), Raghia Range were selected vegetation analysis and field data was collected during 2015-16. Random coordinate points were provided by the GIS cell of the Forest Research Institute, Dehradun for the collection of vegetative data. Quadrat number and size were determined by the running mean method [15] and species-area curve method [23], respectively. Quantitative analysis of vegetation for frequency, density and dominance was calculated following Misra [23]. Ten quadrats were randomly laid on each site. Quadrat size of 10m x 10m, 3m x 3m, and 1m x 1m was kept for trees, shrubs and herbs respectively. In each quadrat, the GBH (girth at breast height at 1.37m above ground level) of each tree was measured and recorded individually. In the case of herb and shrub, the collar diameter was measured at 2.5 cm above ground level. Species were identified with the help of concerned floras and matched with DD herbarium specimens. Plant nomenclature was updated as per Plant of the World Online [29]. Values of Relative frequency, density and dominance were summed to get Importance Value Index (IVI). Different biodiversity indices were estimated as given below:

Species richness index was estimated by the following Margalef [22]:

$$Dmg = S\text{-}1/\ln N$$

Where S is the total number of species and N is the total number of individuals Shannon-Wiener information function –Diversity Index [33] was calculated using the formula:

$$H = - \Sigma \, pi \ln pi$$

Where pi is (N_i/N), N_i = Number of individuals of species i and N= Total number of individuals of all the species.

The concentration of dominance (CD) was measured by Simpson Index [34].

Pielou's evenness index [28] was calculated using the formula:

$$J = H/\ln (S)$$

Where '*H'* is Shannon Weiner diversity index and '*S'* is the total number of species

3. Results

3.1. Species Richness

For comparison between differeent regions and species, diversity indices seek to characterize general features of communities. Table 1 provides diversity indices for different growth types at various locations in the West Champaran district, including Shannon-Wiener Concentration of Dominance (CD), Diversity Index (H), Evenness (E), and Species Richness (SR). Higher species diversity is indicated by higher species richness value. From the study sites, 193 species have been identified. In relation to habitat, there had been 87, 27, 38, 16, 22, 02, and 01 species of trees, shrubs, herbs, climbers, grasses, sedges, and bamboo, respectively. Tables 1, 2, 3, 4, and 5 provide a list of species that have been reported from area. Kali Temple Site had highest SR in tree layer (35 species), followed by Comp. No.29 (I) (27 spp), Comp. No.13 (25 spp), etc., and lowest in Comp. No.29 (II) (09 spp). Dongiparsa (36 spp) had the highest SR in shrubby layer, followed by Comp. No.13 (35 spp), Sector -14 (26 spp), etc., and lowest in Comp. No.29 (II) (10 spp). Maximum SR has been identified in herbaceous layer in Dongiparsa (33 spp), followed by Comp No.14, Kali Temple, and Comp. No.29 (I) (both 29 spp), while lowest had been found in Comp. No.53 (I) site (9 spp.).

Table 1. *Tree species reported from study sites.*

S.N.	Species	Family
1.	*Acacia catechu* (L.f.) Willd.	Mimosaceae
2.	*Adina cordifolia* (Roxb.) Hook.f. ex Brandis	Rubiaceae

S.N.	Species	Family
3.	*Aegle marmelos* (L.) Corr. in Trans. L. Soc.	Rutaceae
4.	*Alangium salvifolium* (L.f.) Wang.	Alangiaceae
5.	*Albizia lebbeck* (L.) Benth.in Hook	Mimosaceae
6.	*Albizia procera* (Roxb.) Benth.	Mimosaceae
7.	*Alstonia scholaris* (L.) R.Br.	Apocynaceae
8.	*Anogeissus latifolia (*Roxb. ex DC.) Wall. ex Guill. & Perr.	Combretaceae
9.	*Aphanamixis polystachya* (Wall.) Parker	Meliaceae
10.	*Bauhinia variegata* L.	Caesalpiniaceae
11.	*Bombax ceiba* L.	Bombacaceae
12.	*Bridelia retusa* (L.) Spreng.	Euphorbiaceae
13.	*Buchanania lanzan* Spreng.	Anacardiaceae
14.	*Butea monosperma* (Lam.) Taub.	Fabaceae
15.	*Careya arborea* Roxb.	Barringtoniaceae
16.	*Casearia graveolens* Dalz.	Flacortiaceae
17.	*Casearia tomentosa* Roxb.	Flacortiaceae
18.	*Cassia fistula* L.	Caesalpiniaceae
19.	*Cassine glauca* (Rottb.) Kuntze	Celastraceae
20.	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae
21.	*Cordia dichotoma* Forster	Boraginaceae
22.	*Cordia macleodii* (Griff.) Hook. f. & Thoms.	Boraginaceae
23.	*Croton roxburghii* Balak	Euphorbiaceae
24.	*Dalbergia latifolia*	Fabaceae
25.	*Dalbergia sissoo* Roxb.	Fabaceae
26.	*Dillenia pentagyna* Roxb.	Dilleniaceae
27.	*Ehretia laevis* Roxb.	Boraginaceae
28.	*Eriolaena hookeriana* Wight & Arn.	Sterculiaceae
29.	*Ficus arnottiana* (Miq.) Miq.	Moraceae
30.	*Ficus benghalensis* L.	Moraceae
31.	*Ficus hispida* L.	Moraceae
32.	*Ficus religiosa* L.	Moraceae
33.	*Ficus rumphii* Blume	Moraceae
34.	*Firminia fulgens* (Wall. Ex Mast) K. Schum.	Sterculiaceae
35.	*Flacourtia indica* (Burm.f.) Merr.	Flacortiaceae
36.	*Garuga pinnata* Roxb.	Burseraceae
37.	*Glochidion velutinum* Wight	Euphorbiaceae
38.	*Gmelina arborea* Roxb.	Verbenaceae
39.	*Grewia asiatica* L.	Tiliaceae
40.	*Heteropanax fragrans* Seem.	Araliaceae
41.	*Holarrhena pubescens* (Buch.-Ham.) Wall.ex.G.Don	Apocynaceae

S.N.	Species	Family
42.	*Hymenodictyon oxixense* (Roxb.) Mabb.	Rubiaceae
43.	*Lagerstroemia parviflora* Roxb.	Lythraceae
44.	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae
45.	*Litsea glutinosa* (Lour.) Robins	Lauraceae
46.	*Litsea monoptela* (Roxb.) Pers.	Lauraceae
47.	*Madhuca longifolia* (Koenig) Macbr.var.*latifolia*	Sapotaceae
48.	*Mallotus albus* (Roxb. ex Jack) Mull. Arg.	Euphorbiaceae
49.	*Mallotus philippensis* (Lam.) Muell.-Arg	Euphorbiaceae
50.	*Miliusa tomentosa* (Roxb.) Finet & Gagenpain	Annonaceae
51.	*Miliusa velutina* (Dunal) Hook.f. & Thoms.	Annonaceae
52.	*Mitragyna parvifolia* (Roxb.) Korth	Rubiaceae
53.	*Musa paradisiacal* L.	Musaceae
54.	*Oroxylum indicum* (L.) Vent.	Bignoniaceae
55.	*Ougeinia oojeinensis* (Roxb.) Hochr	Fabaceae
56.	*Phoenix loureiroi* var. *pendunculata*	Arecaceae
57.	*Phyllanthus emblica* L.	Phyllanthaceae
58.	*Piliostigma malabarica* (Roxb.) Benth	Caesalpiniaceae
59.	*Pinus roxburghii* Sargent	Pinaceae
60.	*Premna latifolia* Roxb.	Verbenaceae
61.	*Pterospermum acerifolium* (L.) Willd.	Sterculiaceae
62.	*Putranjiva roxburghii* Wall.	Euphorbiaceae
63.	*Reissantia arborea* (Roxb.) Hara	Hippocrateaceae
64.	*Schleichera oleosa* (Lour.) Oken	Sapindaceae
65.	*Semecarpus anacardium* L.	Anacardiaceae
66.	*Shorea robusta* Gaertn.f., Fruct.	Dipterocarpaceae
67.	*Sterculia villosa* Roxb. ex DC.	Sterculiaceae
68.	*Stereospermum chelonoides*	Bignoniaceae
69.	*Streblus asper* Lour.	Moraceae
70.	*Suregada multiflora* (Juss.) Baill.	Phyllanthaceae
71.	*Symplocos racemosa* Roxb.	Symplocaceae
72.	*Syzygium cumini* (L.) Skeels	Myrtaceae
73.	*Syzygium nervosum* DC.	Myrtaceae
74.	*Tamilnadia uliginosa* (Retz.) Tirveng. & Sastre	Rubiaceae
75.	*Terminalia alata* Heyne ex Roth	Combretaceae
76.	*Terminalia arjuna* (Roxb. ex DC.) Wight. &Arn.	Combretaceae
77.	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae
78.	*Terminalia chebula* Retz.	Combretaceae
79.	*Toona ciliata* Roem.	Meliaceae
80.	*Trema orientalis* (L.) Blume	Ulmaceae

S.N.	Species	Family
81.	*Wendlandia heynei* (Roem. &Schult.) Sant. &Merch	Rubiaceae
82.	*Woodfordia fruticosa* (L.) Kurz	Lythraceae
83.	*Wrightia tinctoria* (Roxb.) R.Br.	Apocynaceae
84.	*Xantolis tomentosa* (Roxb.) Rafin.	Sapotaceae
85.	*Xylosma longifolia* Clos.	Flacortiaceae
86.	*Ziziphus mauritiana* var. *mauritiana* Lam.	Rhamnaceae
87.	*Ziziphus xylopyra* (Retz.) Willd.	Rhamnaceae

Table 2. *Shrub species reported from study sites.*

S.N.	Species	Family
1.	*Asparagus adscendens* Roxb.	Liliaceae
2.	*Asparagus recemosa* Willd.	Liliaceae
3.	*Barleria cristata* L.	Acanthaceae
4.	*Barleria strigosa* Willd.	Acanthaceae
5.	*Campylotropis stenocarpa* (Klotz.) Schind.	Fabaceae
6.	*Clausena kanpurensis* Molino	Rutaceae
7.	*Clerodendrum viscosum* Vent.	Verbenaceae
8.	*Colebrookea oppositifolia* Sm.	Lamiaceae
9.	*Cycas pectinata* Griff.	Cycadaceae
10.	*Eranthemum nervosum* (Vahl) R. Br. ex Roem. & Schult.,	Acanthaceae
11.	*Eranthemum purpurascens* Nees	Acanthaceae
12.	*Eriolaena wallichii* DC.	Sterculiaceae
13.	*Flemingia macrophylla* (Willd.) Kuntz ex Merr.	Fabaceae
14.	*Flemingia strobilifera* (L.) R.Br.	Fabaceae
15.	*Grewia hirsuta* Vahl	Malvaceae
16.	*Indigofera cassioides* Rottl. ex DC.	Fabaceae
17.	*Lea asiatica* (L.) Ridsdale	Leeaceae
18.	*Millettia extensa* (Benth.) Baker	Fabaceae
19.	*Murraya koenigii* (L.) Spreng.	Rutaceae
20.	*Ochna obtusata* DC.	Ochnaceae
21.	*Olax scandens* Roxb.	Malvaceae
22.	*Pogostemon benghalensis* (Burm.f.) Kuntze	Lamiaceae
23.	*Rivea laotica* Ooststroom	Convolvulaceae
24.	*Securinega virosa* (Roxb. ex Willd.) Baill.	Phyllanthaceae

S.N.	Species	Family
25.	*Solanum torvum* Sw.	Solanaceae
26.	*Tamarix dioca* Roxb.	Tamaricaceae
27.	*Tamarix troupii* Hole	Tamaricaceae

Table 3. *Herbaceous species reported from study sites.*

S.N.	Species	Family
1.	*Achyranthes aspera* L.	Amaranthaceae
2.	*Aerva sanguinolenta* (L.) Juss. ex Schultes	Amaranthaceae
3.	*Anisomeles indica* (L.) Kuntze	Lamiaceae
4.	*Blumeopsis flava* (DC.) Gagnep.	Asteraceae
5.	*Boerhavia diffusa* L.	Nyctaginaceae
6.	*Chlorophytum arundinaceum* Baker	Liliaceae
7.	*Commelina benghalensis* L.	Commelinaceae
8.	*Crotalaria albida* Heyne. ex Roth	Fabaceae
9.	*Crotalaria bialata* Schrank	Fabaceae
10.	*Curculigo orchioides* Gaertn.	Hypoxidaceae
11.	*Cynoglossum zeylanicum* (Sw. ex Lehm.) Thunb. ex Brand	Boraginaceae
12.	*Desmodium gangeticum* (L.) DC.	Fabaceae
13.	*Desmodium gyroides* (Roxb. ex Link) DC.	Fabaceae
14.	*Desmodium triflorum* (L.) DC.	Fabaceae
15.	*Desmostachya bipinnata* (L.) Stapf.	Fabaceae
16.	*Equisetum diffusum* D.Don	Equisetaceae
17.	*Eulophia flava* (Lind.) Hook.f.	Orchidaceae
18.	*Eupatorium odoratum* L.	Asteraceae
19.	*Inula cappa* (Buch.-Ham. ex D. Don) DC.	Asteraceae
20.	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal	Asteraceae
21.	*Lepidagathis incurva* Buch.-Ham. ex D. Don	Acanthaceae
22.	*Leucas helicterifolia* Haines	Lamiaceae
23.	*Lygodium flexuosum* (L.) Sw.	Lygodiaceae
24.	*Murdannia nudiflora* (L.) Brenan	Commelinaceae
25.	*Phyllanthus amarus* Schum. & Thonn.	Phyllanthaceae
26.	*Phyllanthus virgatus* Forst.f.	Phyllanthaceae
27.	*Rungia pectinata* (L.) Nees	Acanthaceae

S.N.	Species	Family
28.	*Sida rhombifolia* L.	Malvaceae
29.	*Strobilanthes lanata* Nees	Acanthaceae
30.	*Strobilanthes tomentosa* (Nees) Wood	Gentianaceae
31.	*Swertia angustifolia* Buch.-Ham. ex D.Don	Gentianaceae
32.	*Trichodesma indicum* (L.) R.Br.	Boraginaceae
33.	*Triumfetta rhomboidea* Jacq.	Malvaceae
34.	*Urena lobata* L.	Malvaceae
35.	*Urginea indica* (Roxb.) Kunth	Liliaceae
36.	*Vallaris solanacea* (Roth) Kuntze	Apocynaceae
37.	*Vernonia aspera* Buch.-Ham.	Asteraceae
38.	*Vernonia cinerea* (L.) Less.	Asteraceae

Table 4. *Climber species reported from study sites.*

S.N.	Species	Family
1.	*Acacia pennata* (L.) Willd.	Mimosaceae
2.	*Bauhinia vahlii* Wight & Arn.	Caesalpiniaceae
3.	*Caesalpinia cucullata* Roxb.	Caesalpiniaceae
4.	*Celastrus paniculatus* Willd.	Celastraceae
5.	*Cissampelos Pereira* L.	Menispermaceae
6.	*Cissus assamica* (Lawson) Craib	Vitaceae
7.	*Cissus repanda* Vahl	Vitaceae
8.	*Cryptolepis buchanani* Roem. & Schult.	Apocynaceae
9.	*Dalbergia volubilis* Roxb.	Fabaceae
10.	*Derris scandens* (Roxb.) Benth	Fabaceae
11.	*Ichnocarpus frutescens* (L.) R.Br.	Apocynaceae
12.	*Jasminum multiflorum* (Burm.f.) Andrews	Oleaceae
13.	*Mikania micrantha* Kunth	Asteraceae
14.	*Piper longum* L.	Piperaceae
15.	*Scindapsis officinalis* (Roxb.) Schott	Araceae
16.	*Smilax zeylanica* L.	Smilacaceae

Table 5. *Grass, sedges and bamboo species reported from study sites.*

S.N.	Species	Family
1.	*Apluda mutica* L.	Poaceae
2.	*Arthraxon lanceolatus* (Roxb.) Hochst.	Poaceae
3.	*Arundinella nepalensis* Trin.	Poaceae
4.	*Arundinella setosa* Trin.	Poaceae
5.	*Arundo donax* L.	Poaceae
6.	*Bothriochloa bladhii* (Retz.) S. T. Blake	Poaceae
7.	*Capillipedium assimile* (Steud.) A. Camus	Poaceae
8.	*Chloris dolichostachya* Lagasca	Poaceae
9.	*Chrysopogon fulvus* (Spr.) Chiov.	Poaceae
10.	*Cymbopogon gidarba* (Buch.-Ham. ex Steud.) Haines	Poaceae
11.	*Cymbopogon jwarancusa* (Jones) Schult.	Poaceae
12.	*Cyperus niveus* Retz.	Cyperaceae {Sedge)
13.	*Cyperus rotundus* L.	Cyperaceae (Sedge)
14.	*Eulalia fastigiata* (Nees ex Steud.) Haines	Poaceae
15.	*Eulaliopsis binata* (Retz.) Hubbard	Poaceae
16.	*Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult.	Poaceae
17.	*Imperata cylindrical* (L.) Raeusch.	Poaceae
18.	*Isachne globosa* (Thunb.) Kuntze	Poaceae
19.	*Oplismenus burmanii* (Retz.) P. Beauv.	Poaceae
20.	*Oplismenus composites* (L.) P. Beauv.	Poaceae
21.	*Phragmites karaka* (Retz.) Trin. ex Steud.	Poaceae
22.	*Pogonatherum paniceum* (Lam.) Hack.	Poaceae
23.	*Saccharum spontaneum* L.	Poaceae
24.	*Thysanolaena maxima* (Roxb.) Kuntze	Poaceae
25.	*Dendrocalamus strictus* (Roxb.) Nees	Poaceae (Bamboo)

3.2. Important Value Index

The environment has an impact on the distribution and composition of species. The primary determinant of a species conservation and sustainable application is its quantitative state. Important Value Index indicates a species level of dominance in a particular region. Figures 2, 3, and 4 illustrate top 5 most prevalent species in tree, shrubby, and herbaceous layers.

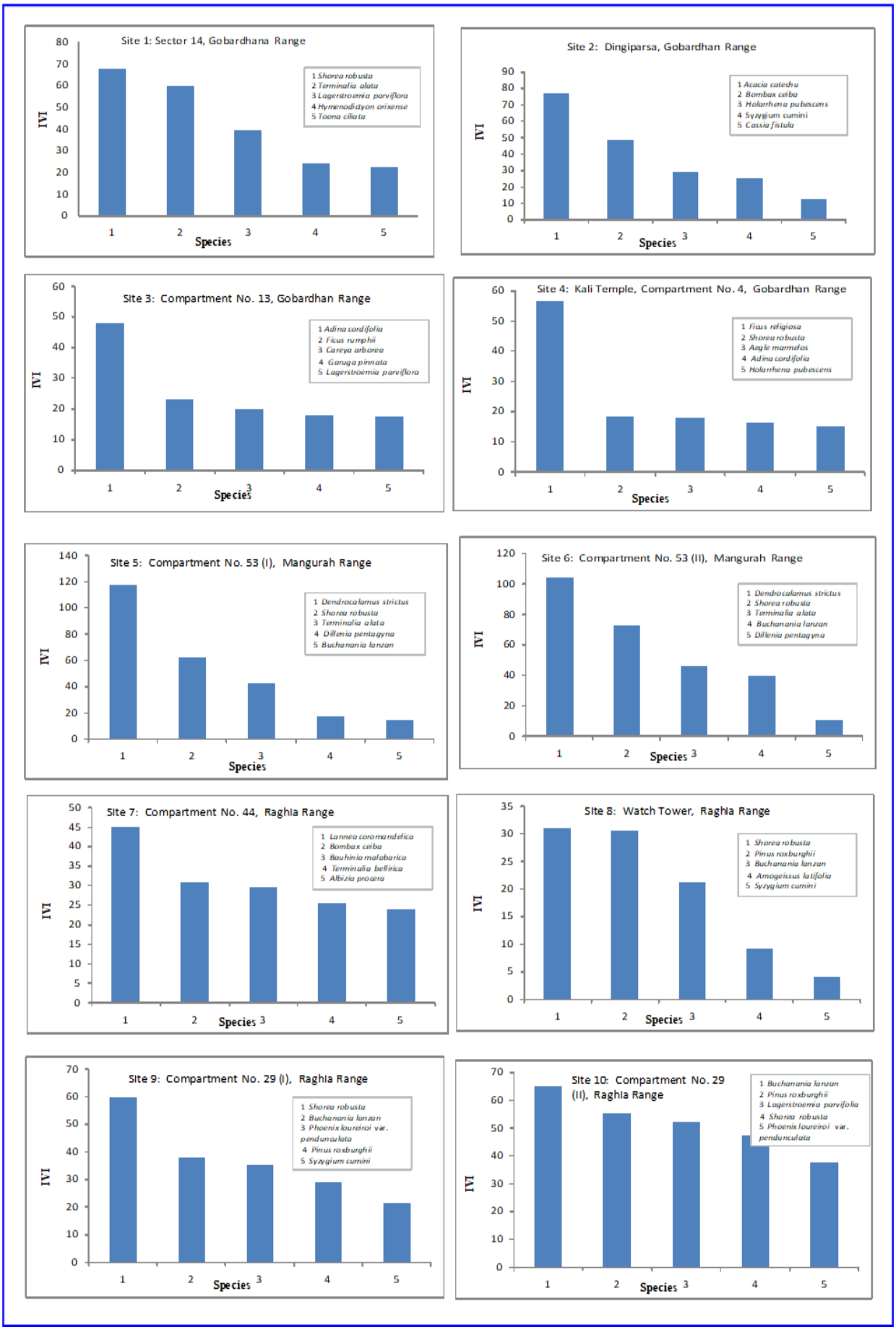

Figure 2. *Top five tree species with IVI values at different sites.*

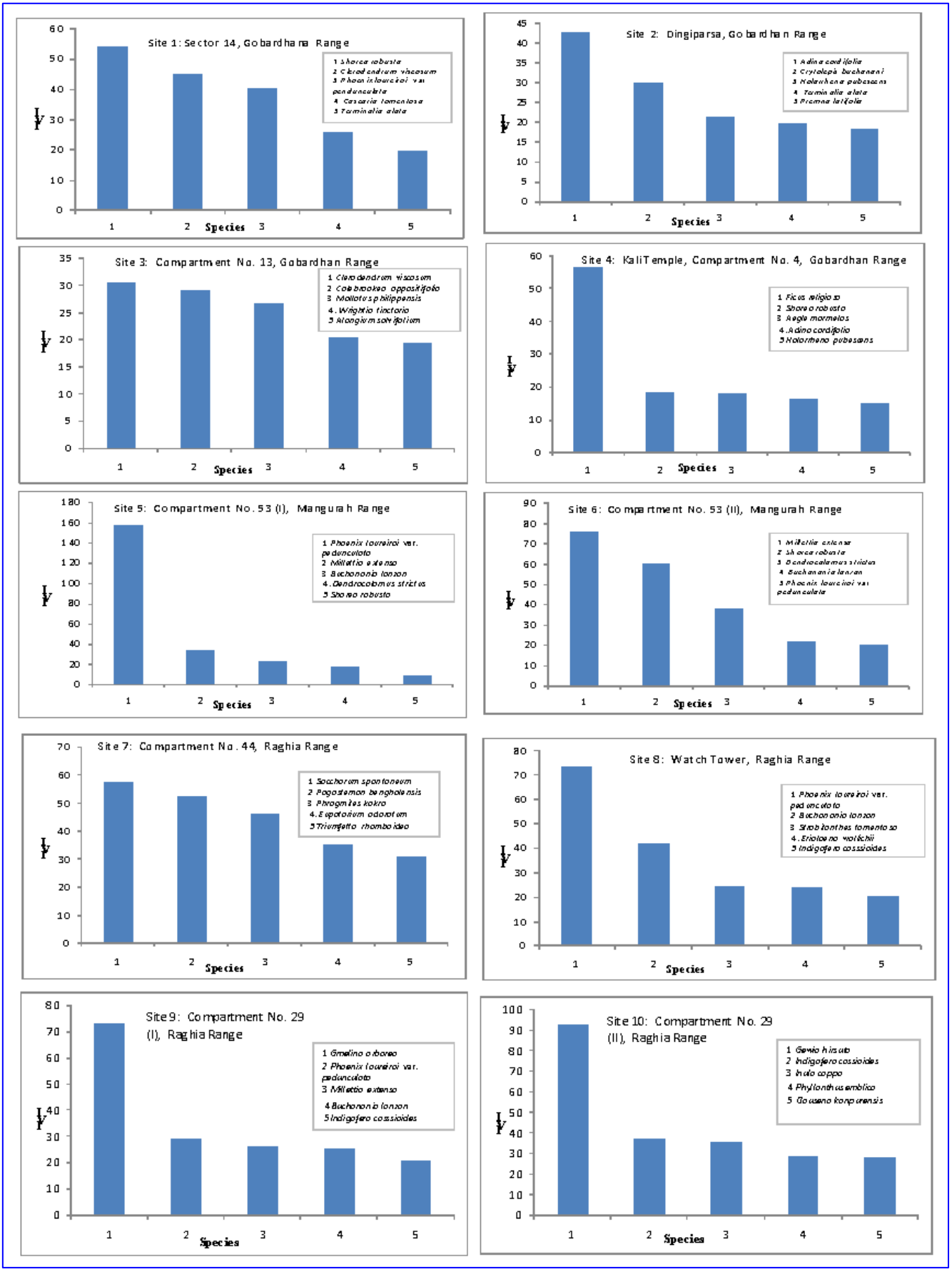

Figure 3. *Top five shrubby layer species with IVI values at different sites.*

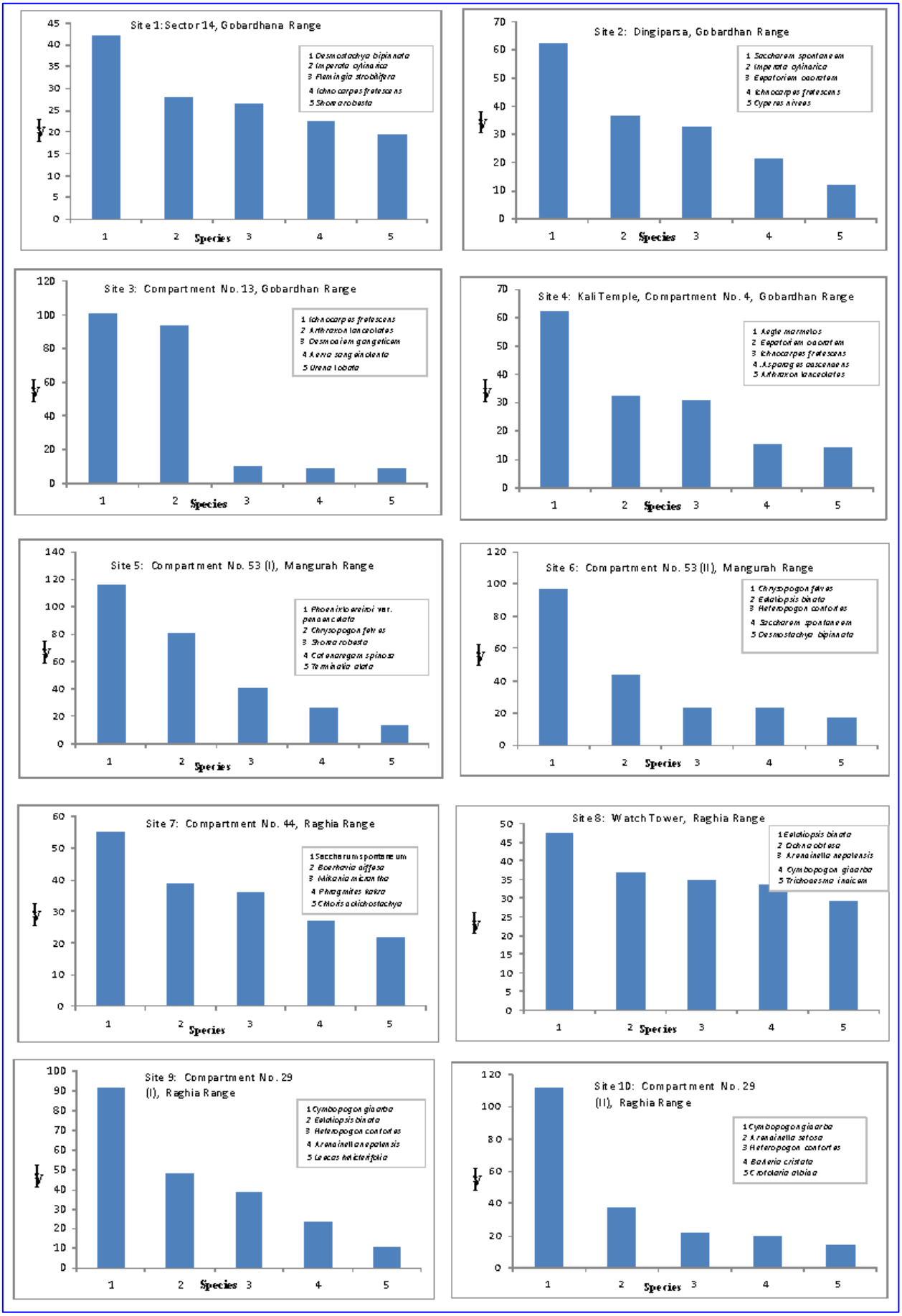

Figure 4. *Top five herbaceous layer species with IVI values at different sites.*

3.3. Diversity Indices

Table 6 displays diversity indices for various growth forms in different forest sites. High species diversity is reflected in a higher species richness index (Dmg). Comp. No. 13 site had been considered to have the maximum species richness in tree layer (5.44), whereas Comp. No. 29 (II) site had lowest (1.39). In Dongiparsa site, shrubby layer had maximum richness value (3.71), whereas in Comp. No. 29 (II) site had lowest (1.00). Dongiparsa site had highest estimated species richness in herbaceous layer (2.71), while Comp. No.53 (I) site had lowest (0.67).

Higher species diversity and community heterogeneity are indicated by higher levels of H, while homogeneity is indicated by lower values. Kali Temple site has highest estimated H in tree layer (3.36), followed by Comp. No. 13 (3.07), Comp. No. 29 (2.76), etc., and lowest in Watch Tower (1.65). Dongiparsa had highest estimated H value (3.11) in shrubby layer, followed by Comp. No. 13 (3.10), Kali Temple (2.64), etc., and lowest in Comp. No. 53 (I) (1.78). Kali Temple had the greatest estimated H in herbaceous layer (2.84), followed by Dongiparsa (2.80), Sector-14 (2.67), etc., and lowest in Comp. No. 13(1.35). Greater CD indicates greater communal homogeneity and vice versa. Thus, single species dominates in these communities.

The lower CD demonstrates plant dominance by multiple species. CD observed highest at Watch Tower site (0.28), followed by Comp. No. 53 (I) (0.22), etc., and lowest at Kali Temple (0.04) in the tree layer. Shrubby layer showed highest CD in Comp. No. 53 (I) (0.29), followed by 44 (0.21), 53 (II) (0.27), and lowest in Comp. No. 13 and Dongiparsa (0.06). In the herbaceous layer, Compartment 13 had the highest CD (0.53), followed by Comp. No. 53 (I) (0.30), 53 (II) (0.27), and lowest in Kali Temple (0.09).

Higher E-values indicate more evenly dispersed species and vice versa. Tree layer's E was highest at Comp. 44 site (0.97), followed by Comp. 13, Kali Temple (0.95), and lowest at Sector 14 (0.72). E-values for shrubby layers were highest for Kali Temple (0.88), followed by Comp. No.13, Dongiparsa (0.87), and lowest for Comp. No.44 (0.58). Kali Temple has highest E in herbaceous layer (0.84), followed by Comp. No. 44 (0.82), Dongiparsa (0.80), and lowest in Comp. No. 13 (0.41).

Table 6. *Diversity indices for different growth forms at different forest sites of West Champaran District of Bihar.*

S. N.	Sites	Tree Layer				Shrubby Layer				Herbaceous Layer			
		Dmg	H	CD	E	Dmg	H	CD	E	Dmg	H	CD	E
1	Sector 14, Gobardhana Range	3.75	2.10	0.21	0.72	2.45	2.31	0.16	0.71	2.34	2.67	0.11	0.79
2	Dongiparsa, Gobardhana Range	5.25	2.23	0.21	0.73	3.71	3.11	0.06	0.87	2.71	2.80	0.11	0.80
3	Compartment No. 13, Gobardhana Range	5.44	3.07	0.05	0.95	3.42	3.10	0.06	0.87	1.99	1.35	0.53	0.41
4	Kali Temple, Compartment No. 4, Gobardhana Range	2.89	3.36	0.04	0.95	2.20	2.64	0.10	0.88	2.41	2.84	0.09	0.84
5	Comp. no. 53 (I) Mangurah Range	2.98	1.87	0.22	0.73	1.93	1.78	0.29	0.59	0.67	1.50	0.30	0.68
6	Comp. no. 53 (II) Mangurah Range	2.47	1.75	0.22	0.76	1.61	2.00	0.20	0.71	1.71	1.75	0.27	0.55
7	Comp. No. 44, Raghia Range	3.86	2.57	0.08	0.97	1.84	1.81	0.21	0.58	1.88	2.60	0.10	0.82
8	Watch Tower, Raghia Range	2.98	1.65	0.28	0.72	2.23	2.45	0.13	0.81	1.66	2.34	0.14	0.78
9	Comp.No. 29 (I), Raghia Range	3.27	2.76	0.09	0.84	2.37	2.70	0.09	0.86	2.07	2.03	0.19	0.60
10	Comp. No. 29 (II) Raghia Range	1.39	1.90	0.18	0.86	1.00	1.97	0.17	0.86	1.27	2.09	0.18	0.72

4. Discussion

This survey reported 193species. Out of which, there were 87 trees, 27 shrubs, 38 herbs, 16 climbers, 22 grasses, 02 sedges, and 1 bamboo species. Sahu et al. [32] reported 57 plant species in Eastern Ghats dry deciduous forest. Thakur [37] documented 36 tree, 8 shrub, and 34 herb species from Sagar, Madhya Pradesh. West Bengal tropical dry deciduous forest yielded 14 tree species from 10 families [18]. Chandra et al. [4-9] reported 126, 174, 156, 129, and 190 plant species from Nalanda, Aurangabad, Gaya, Banka, Jamui, and Kaimur districts and Bihar, respectively. Climate, edaphic variables, and study area may explain species variance. Many researchers [36, 13, 4-9] reported Indian Subcontinental tropical forest diversity index. Reported diversity index ranged from 0.10-3.24. This study likewise has diversity index values in the above range. Pielou's E-index for tree, shrubby, and herbaceous layers in our study was similar to that of tropical Indian forests in Udaipur, Rajasthan [17], Western Ghats [36], Bundelkhand region of UP [38], Southwest Haryana [13], Nalanda, Gaya, Banka, Jamui, Aurangabad, and Kaimur districts of Bihar [4-9].

5. Conclusion and Recommendation

Biodiversity must be regularly examined and monitored for sustainable use and conservation. Prior to this, no research has been conducted for evaluating quantitative status of various species in an area. West Champaran district woodland area was used for the current quantitative and qualitative assessment of plant diversity. Study reveals that Kali Temple site had the highest tree layer diversity, while Watch Tower site had the lowest. In herbaceous layer, the highest diversity was recorded from Kali Temple site and lowest from Comp. no. 53 (I), while shrubby layer had highest diversity in Dingiparsa site and the lowest in Comp. no. 53 (II). The biodiversity is under threat from a variety of biotic and abiotic sources. To restore the vegetation's original state, these variables must be recognized, and appropriate management strategies should be established.

Abbreviations

SR	Species Richness
E	Evenness
CD	Concentration of Dominance

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Author Contributions

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Conflicts of Interest

The authors declare no conflicts of interest.

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