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Research Article

Plant diversity assessment of selected forest sites of Gaya district of Bihar, India

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Abstract
Regular inventorization and monitoring of biodiversity is paramount for its conservation and sustainable utilization. Gaya district of the Bihar is endowed with rich biodiversity. For proper understanding of plant diversity, quantitative status of the vegetation is essentially required. The aim of the study was to assess different forest sites of the Gaya district of Bihar in India for their plant diversity. Study was carried out in these randomly selected eleven forest sites (Site I to Site XI). A total of 174 species belonging to 150 genera and58 families(48 Dicotyledons, 7 monocotyledons and 3 pteridophytes) were reported from all eleven study sites. Five largest families in the area were Poaceae (22 spp.), Fabaceae (14 spp.), Asteraceae (11 spp.), Rubiaceae (9 spp.) and Acanthaceae (7 spp). Different diversity attributes such as Important Value Index (IVI), Species richness, Shannon Wiener index, Concentration of dominance and Evenness for tree, shrub and herb layers were estimated. For different sites highest IVI values for tree, shrubby and herbaceous layers were reported.Shannon wiener Index values for tree, shrubby and herbaceous layer of Nagobar site were estimated3.376, 1.986 and 2.350 respectively. Tree diversity was highest at Nagobar site whereas shrub and herb diversity was also reasonably better than most of the sites. Hence, it was revealed from the study that Nagobar site was most diverse site in the Gaya district. Study will be immense use for officials of forest department, researcher, students etc. for carrying out conservation and management work. Similar kind of study should be carried out in different forest sites of the country to get capture the status of the plant diversity for conservation and sustainable utilization.

Keywords: Diversity index, Evenness, Important value index, Species richness

INTRODUCTION

Biological diversity means the variety and variability of all living organisms from all sources including terrestrial, marine and other aquatic systems and the ecological complexes of which they are a part. This includes diversity within species and of ecosystems (McNeely *et al.,* 1990). Human demands for food, fodder, fuel, medicine, timber, resins, and oil are directly met by biodiversity (Guar, 1999).Indirect services such as climate regulation, pollution control, soil and water conservation, nutrient cycling, pollination, and recreation (Singh, 2002; Kumar and Sharma, 2015, 2016) are also governed by the biodiversity.

Environment of an area effects the vegetation of an ecosystem (Billings, 1952). The structure and function of the plant community can be understood by phyto-sociological study of the area. It explains and predicts pattern in a meaningful manner (Gautam and Joshi,2014). Therefore, for proper understanding of plant diversity of any area, phyto-sociology aspects should be thoroughly studied. Biodiversity in the wild state has its far reaching importance as species have diverse genotypes which can further be exploited. Forests are storehouse of the biodiversity, therefore, it is need of the hour to assess and conserve the forest

biodiversity. However, owing to burgeoning population coupled with rapid industrialization, plant resources are under tremendous pressure. It has resulted in the decline of plant diversity in the forest ecosystem. Convention of Biological Diversity also asserted the need of regular inventorization and monitoring of biodiversity for sustainable utilization (Leadley *et al*. 2014).

Bihar state and adjoin Jharkhand have been extensively surveyed for its floral wealth by various workers in the past (Wood, 1903; Haines, 1921-1924: Mukharjee, 1947; Mooney, 1950; Paul, 1973; Biswas and Maheshshwari, 1980; Bhatacharya and Sarkar, 1998, Singh *et al.*2001etc.). Qualitative status alone cannot provide the dynamics of vegetation of the area; therefore, quantitative status should be worked out. Diversity indices for various forests have been reported by several workers (Whittakar, 1965; Risser and Rice, 1971; Ralhan *et al.* 1982; Knight, 1963; Peng *et al.,* 2018; Dad, 2019).

Gaya is one of the thirty-eight districts of Bihar state, India. The district has a common boundary with the state of Jharkhand to the south. The district Gaya is situated between 24°30′ and 25°10′ north latitude and between 84°04′ and 85°05′ east longitude. The forest cover in the Gaya district is 590.31 km^2 which is 11.86% of the total geographical area of the state. On the basis of density classes, 134.4 km^2 comes under moderately dense forests and 455.91 km^2 under open forest. There is no very dense forest in the district (FSI, 2019). To date, no work has been reported on different diversity indices of different sites of the Gaya district. Therefore, in the present study, efforts have been made to assess the plant diversity of different forest sites of Gaya District of Bihar, India.

MATERIALS AND METHODS

Survey and vegetation data

The study was conducted at the Gaya district of Bihar (Fig. 1). The climate of the district is characterized by mild cold winter, hot dry summer, hot and humid summer. Month of May is the hottest with mean maximum temperature at about 40.50ºC and mean minimum temperature at 25.90ºC. The day temperature may go above 450ºC in a day. January is the coldest month with man maximum temperature at 23.50ºC and mean minimum temperature at about 8.90ºC. The average rainfall in the district is 91.3mm. The district gets about 88% of the normal rainfall during the monsoon months (June to September). Highest rainfall receives in the month of July, with average rainfall of 267.7mm. Eleven random forest sites of Gaya viz. Titri, Aamas Jhari, Patluka Murrai Pahar, Bharamyoni Mandir, North Alakdiha, South Alakdiha, Kurwa Dan Baba 2, Kurwa Dan Baba, Nagobar, Singh pursadar, Sundhaha were selected for the vegetation analysis. Random coordinating

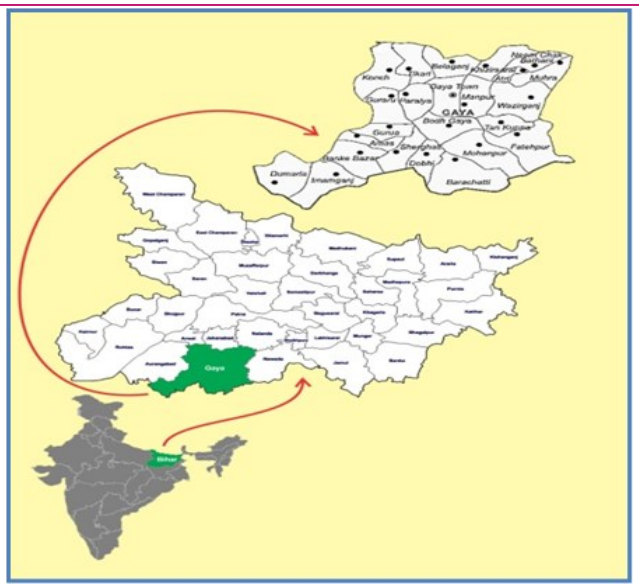

Fig. 1. *Location map of study area, Gaya district.*

points were provided by the GIS cell of the Forest Research Institute, Dehradun for the collection of vegetative data. Details of sites are given in Table 1.Study was carried out during 2014-15. Quantitative analysis of vegetation for frequency, density and dominance was calculated following Misra (1968). Quadrate number and size were determined; respectively by the running mean method (Kershaw, 1973) and species area curve (Misra, 1968). Ten quadrats were randomly laid in each site. Quadrate size of 10 x 10m, 3x3m and 1x1m was kept for trees, shrubs and herbs respectively. In each quadrat, g.b.h. (girth at breast height at 1.37m above ground level) of each tree was measured and recoded individually. In the case of herb and shrub, the diameter was measured 2.5 cm above ground level. Species were identified with the help of concerned floras and matched with Dehradun(DD) Herbarium specimens. Plant nomenclature was updated as per the Plant List(Anonymous, 2013). Values of Relative frequency, density and dominance were summed to get Importance Value Index (IVI). Different biodiversity indices were estimated as given below:

S= Species richness

Total number of species

Shannon-Wiener information function (Shannon & Wiener, 1963) was calculated using the formula:

$H = -\sum pi \ln pi$ …Eq.1

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

Concentration of dominance (cd) was measured by Simpson Index (Simpson, 1949).

$Cd = \sum (pi)^2$ …Eq. 2

Pielou's evenness index (Pielou, 1966) was calculated using formula:

$J = H'/\ln(S)$ ….Eq. 3

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

RESULTS AND DISCUSSION

Plant species vary in their responses to environmental factors. A given species will have a unique set of tolerances to environmental variables, such as light, temperature, moisture, and nutrients. The status of a species is an important indicator for its conservation and sustainable utilization. Importance Value Index (IVI) is a measure of how dominant a species is in a given forest area. Highest IVI species in different sites for tree, shrubby and herbaceous layers are presented in Fig. 2, 3 and 4 respectively for better understanding of plant population structure of the forest site. In tree layer, highest IVI value was estimated as 200.99 (Site-I, *Butea monosperma*), followed by 153.19 (Site- VII, *Shorea robusta*), 103.36 (Site-X, *Boswellia serrata*), 95.80, (Site-III, *Casearia tomentosa*), 93.66 (Site-IV, *Sterculia urens*), 69.74 (Site-VIII, *Boswellia serrata*), 48.09 (Site-V, *Madhuca longifolia* var. *latifolia*), 45.47 (Site-XI, *Shorea robusta*), 42.28 (Site-VI, *Anogeissus latifolia*) and 30.98 (Site-IX, *Ficus benghalensis*) (Fig.2). In case of shrubby layer, site I had only one dominant species i.e. *Butea monosperma* with IVI value of 300. Least IVI value of 61.88 was estimated for site-VII (*Pavettac rassicaulis*) (Fig.3). In herbaceous layer, highest IVI value was reported of 105.91 (Site-VIII, *Wrightia tinctoria*) and lowest of 38.84 (Site-III, *Tridex procumbens*) (Fig. 4). Presence of *Butea monosperma* in tree as well as shrubby layer reflects the good regeneration of the plant at the site.

A total of 174 species belonging to 150 genera and 58 families (48 Dicotyledons, 7 monocotyledons and 3 pteridophytes) were reported from all eleven study sites. Five largest families in the area were Poaceae (22 spp.), Fabaceae (14 spp.), Asteraceae (11 spp.), Rubiaceae (9 spp.) and Acanthaceae (7 spp.). Habit-wise, there were 71 trees (Table 2), 9 shrubs (Table 3), 20 climbers (Table 4), 49 herbs (Table 5), 20 grass, 2 sedges and 3 pteridophytes' (Table 6) species in all eleven sites. However, Sahu *et al*. (2012) recorded 57 species in dry deciduous forests of Eastern Ghats. Studies from the tropical dry deciduous forest in Sagar district reported a total of 36 trees, 8 shrubs, and 34 herbs (Thakur, 2015). A total of 29 tree species belonging to 17 families were recorded from six sites of tropical dry deciduous forests of Central India (Joshi and Dhyani, 2019) and 14 tree species under 10 families were reported from Amarkutir, tropical dry deciduous forest of West Bengal (Kumar *et al*., 2020). Himanshi and Jakhar (2020) reported 76 plant species belonging to 37 families from south-west Haryana. The higher number of species in the present work may be because

Table 1. Diversity indices for different growth forms at different forest sites of Gaya District, Bihar.

Site No.	Name of site	Tree Layer				Shrubby Layer				Herbaceous Layer			
		SR	H	Cd	E	SR	H	cd	E	SR	H	cd	E
I.	Titri, Imanganj Range	3	0.335	0.850	0.305	1	0	1	0	17	1.786	0.287	0.631
II.	AamasJhari, Imamganj Range	-	-	-	-	7	1.557	0.250	0.800	19	2.467	0.118	0.838
III.	PatlukaMurraiPahar, Bara Chatti Range	6	1.314	0.310	0.734	8	1.278	0.443	0.615	32	2.668	0.101	0.770
IV.	BharamyoniMandir	12	2.109	0.160	0.849	12	1.955	0.184	0.815	23	2.223	0.178	0.709
V.	North Alakdiha, Gurpa Range	18	2.501	0.113	0.866	20	2.328	0.165	0.778	26	2.739	0.093	0.841
VI.	South Alakdiha, Gurpa South Beat, Gurpa Range	22	2.788	0.083	0.902	26	2.281	0.179	0.700	26	2.719	0.087	0.835
VII.	Kurwa Dan Baba 2, Atri Range	10	1.337	0.437	0.581	16	2.273	0.142	0.820	14	2.392	0.109	0.907
VIII.	Kurwa Dan Baba, Atri Range	20	2.599	0.098	0.868	15	2.123	0.175	0.784	12	2.226	0.127	0.896
IX.	Nagobar, Banka Bazar Beat, Imam Ganj Range	38	3.376	0.047	0.929	18	1.986	0.242	0.687	37	2.350	0.189	0.651
X.	Singhpursadar Sub-beat (Behind Naka), Banka Bazar Beat, ImamaGanj Range	14	2.174	0.165	0.824	7	1.541	0.260	0.792	21	2.362	0.133	0.776
XI.	Sundhaha Sub-beat,Banka Bazar Beat, ImamaGanj Range	23	2.513	0.122	0.802	17	1.951	0.276	0.689	36	2.843	0.107	0.794

Table 2. Tree species reported from eleven forest sites of Gaya district.

S.N.	Species	Family	S.N.	Species	Family
1.	*Acacia catechu* (L.f.) Willd.	Mimosaceae	37	*Garuga pinnata* Roxb.	Burseraceae
2	*Adina cordifolia* (Roxb.) Hook.f. ex Brandis	Rubiaceae	38	*Gmelina arborea* Roxb.	Verbenaceae
3	*Aegle marmelos*(L.) Corr. in Trans. L. Soc.	Rutaceae	39	*Grewia asiatica* L.	Tiliaceae
4	*Ailanthus excelsa*Roxb.	Simarubiaceae	40	*Haplophragmaadenophyllum* (DC.) Dop	Bignoniaceae
5	*Alangiumchinense*(Lour.) Harms	Alangiaceae	41	*Helicteresisora*L.	Sterculiaceae
6	*Albizia lebbeck*(L.) Benth.in Hook	Mimosaceae	42	*Holarrhenapubescens*(Buch.-Ham.) Wall.ex.G.Don	Apocynaceae
7	*Anogeissus latifolia (*Roxb. ex DC.) Wall. ex Guill. &Perr.	Combretaceae	43	*Holoptelea integrifolia* (Roxb.) Planch	Ulmaceae
8	*Azadirachta indica* A. Juss.	Meliaceae	44	*Hymenodictyonorixense*(Roxb.) Mabb.	Rubiaceae
9	*Balanites roxburghii*Planch.	Balanitaceae	45	*Ixora pavetta*Andr	Rubiaceae
10	*Bauhinia racemosa*Lam.	Caesalpiniaceae	46	*Lagerstroemia parviflora* Roxb.	Lythraceae
11	*Bombax ceiba* L.	Bombacaceae	47	*Lanneacoromandelica*(Houtt.) Merr.	Anacardiaceae
12	*Borassus flabellifer* L.	Arecaceae	48	*Madhuca longifolia* (Koenig) Macbr.*var.latifolia*	Sapotaceae
13	*Boswellia serrata* Roxb. ex Colebr	Burseraceae	49	*Mallotusphilippensis*(Lam.) Muell.-Arg	Euphorbiaceae
14	*Bridelia retusa* (L.) Spreng.	Euphorbiaceae	50	*Manilkara hexandra*(Roxb.) Dubard	Sapotaceae
15	*Buchananialanzan*Spreng.	Anacardiaceae	51	*Miliusa tomentosa* (Roxb.) Finet&Gagenpain	Annonaceae
16	*Butea monosperma*(Lam.) Taub.	Fabaceae	52	*Mitragynaparvifolia*(Roxb.) Korth	Rubiaceae
17	*Casearia graveolens* Dalz.	Flacortiaceae	53	*Murrayapaniculata*(L.) Jack, Malayan	Rutaceae
18	*Casearia tomentosa* Roxb.	Flacortiaceae	54	*Nyctanthesarbor-tristis* L.	Oleaceae
19	*Cassia fistula* L.	Caesalpiniaceae	55	*Phoenix sylvestris (L.) Roxb.*	Arecaceae
20	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	56	*Phyllanthus emblica*L.	Phyllanthaceae
21	*Cochlospermumreligiosum*(L.) Alston, Handb. Fl.Ceyl.	Cochlosperma-ceae	57	*Premna latifolia* Roxb.	Verbenaceae
22	*Croton roxburghii*Balak	Euphorbiaceae	58	*Pterocarpus marsupium* Roxb.	Fabaceae
23	*Dalbergia sissoo* Roxb.	Fabaceae	59	*Schleicheraoleosa*(Lour.) Oken	Sapindaceae
24	*Dilleniapentagyna*Roxb.	Dilleniaceae	60	*Semecarpus anacardium* L.	Anacardiaceae
25	*Diospyros cordifolia* Roxb.	Ebenaceae	61	*Shorearobusta*Gaertn.f., Fruct.	Dipterocarpace-ae
26	*Diospyros melanoxylon*Roxb.	Ebenaceae	62	*Sterculia urens*Roxb., Pl. Coram	Sterculiaceae
27	*Diospyros melanoxylon* Roxb.var.*tupru*(Buch.-Ham.) V.Singh	Ebenaceae	63	*Sterospermumchelonoides*(L.f.) DC.	Bignoniaceae
28	*Ehretia acuminata* R.Br.var. *ser-rata* (Roxb.) Johnston	Boraginaceae	64	*Streblus asper* Lour.	Moraceae
29	*EhretialaevisRoxb.*	Boraginaceae	65	*Syzygiumcumini*(L.) Skeels	Myrtaceae
30	*Erythrina variegata*L.	Fabaceae	66	*Tamarindus indica* L.	Caesalpiniaceae
31	*Ficus arnottiana*(Miq.) Miq.	Moraceae	67	*Terminalia alata*Heyne ex Roth	Combretaceae
32	*Ficus benghalensis*L.	Moraceae	68	*Terminalia arjuna* (Roxb. ex DC.) Wight. &Arn.	Combretaceae
33	*Ficus mollis*Vahl	Moraceae	69	*Terminalia bellirica*(Gaertn.) Roxb.	Combretaceae
34	*Ficus racemosa*L.	Moraceae	70	*Wrightia tinctoria* (Roxb.) R.Br.	Apocynaceae
35	*Flacourtia indica* (Burm.f.) Merr.	Flacortiaceae	71	*Ziziphus mauritiana*v-ar.*mauritiana*Lam.	Rhamnaceae
36	*Gardenia latifolia* Ait.	Rubiaceae			

of more sites and large area covered under the study. Diversity indices aim to describe general properties of communities that are used to compare different regions and taxa. Diversity indices viz., Shannon-Wiener Diversity Index (H), Concentration of Dominance (cd), Evenness (E) and Species Richness (SR) for different growth forms at different sites of Gaya district is presented in Table 1. The higher value of species richness indicates higher diversity of species. In the tree layer, Nagobar site showed the highest Species Richness (SR) of 38 spp. followed by Sundhaha Sub-beat (23 spp.), South Alakdiha (22 spp.) etc. and the lowest was recorded in Titri (3 spp.). In the case of shrubby layer, the highest Species Richness (SR) value was reported for South Alakdiha (26 spp.) followed by North Alakdiha (20 spp.), Nagobar (18 spp.) etc. and lowest for Titri (1 spp.). The herbaceous layer had highest Species Richness (SR) in Nagobar (37 spp.) followed by Sundhaha

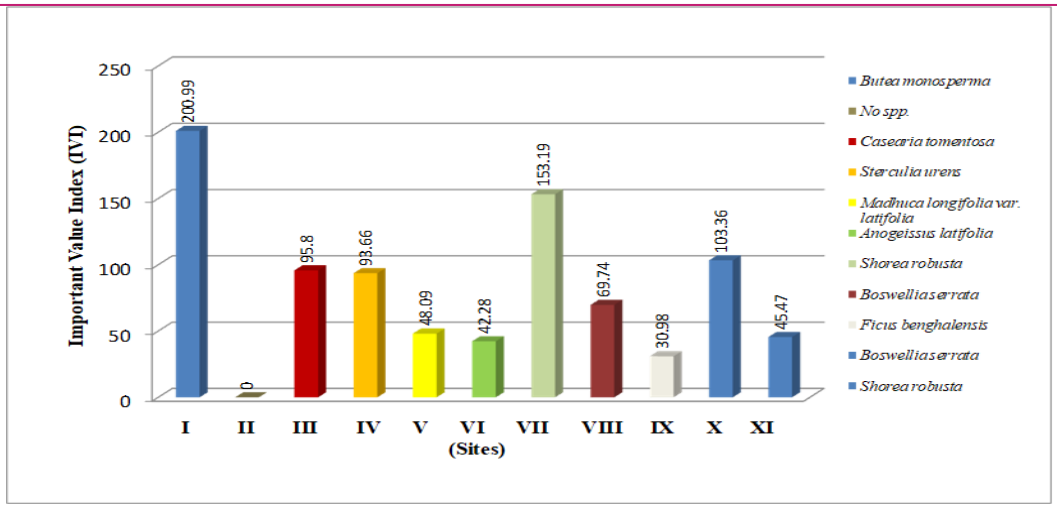

Fig. 2. *Highest Important Value Index (IVI) of tree speciesin different sites (I: Titri site, II- AamasJhari, III- Patluka Murrai Pahar, IV: Bharamyoni Mandir, V: North Alakdiha, VI: South Alakdiha, VII: Kurwa Dan Baba 2, VIII: Kurwa Dan Baba, IX: Nagobar, X: Singhpursadar, XI: Sundhaha).*

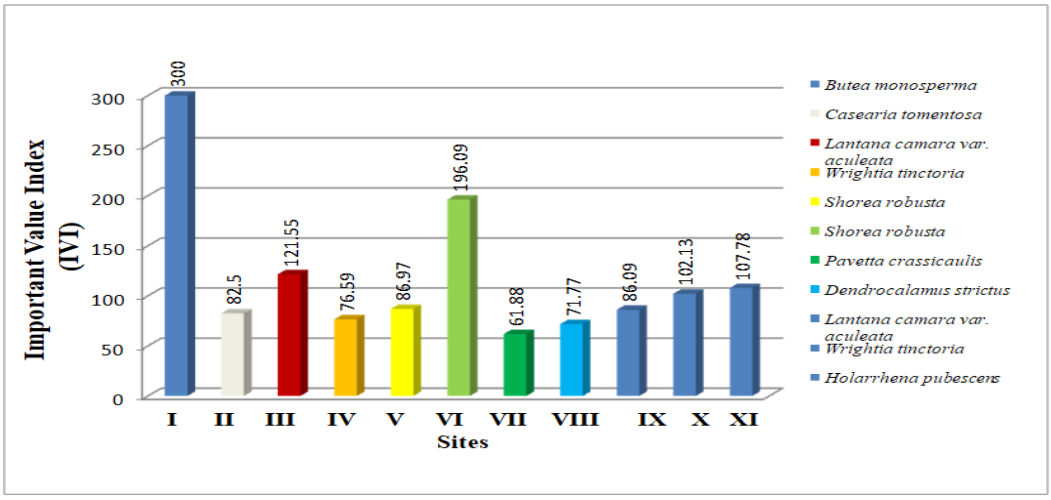

Fig. 3. *Highest Important Value Index (IVI) of shrubby layer species in different sites (I: Titrisite, II- AamasJhari, III- Patluka Murrai Pahar, IV: Bharamyoni Mandir, V: North Alakdiha, VI: South Alakdiha, VII: Kurwa Dan Baba 2, VIII: Kurwa Dan Baba, IX: Nagobar, X: Singhpursadar, XI: Sundhaha).*

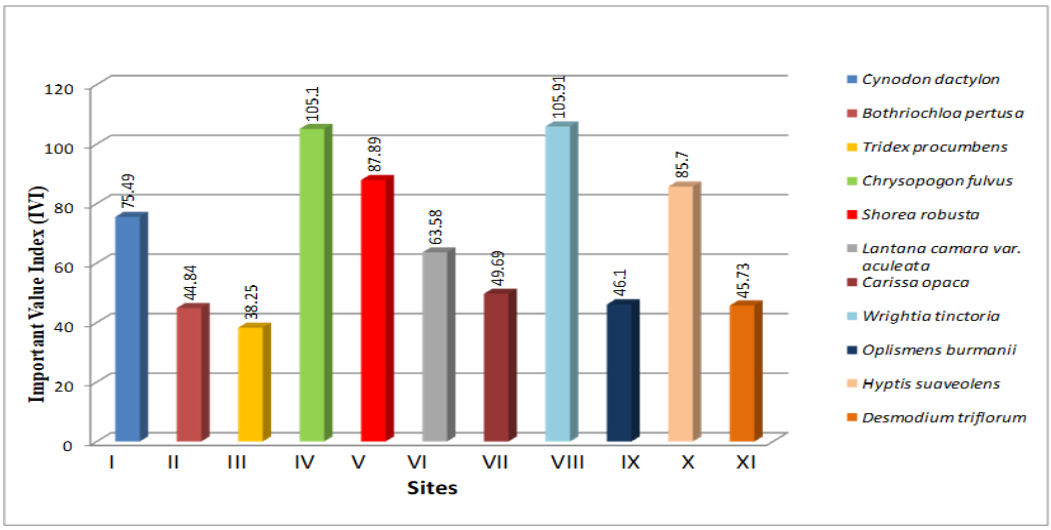

Fig. 4. *Highest Important Value Index (IVI) of herbaceous layer species in different sites (I: Titri site, II- Aamas Jhari, III- Patluka Murrai Pahar, IV: Bharamyoni Mandir, V: North Alakdiha, VI: South Alakdiha, VII: Kurwa Dan Baba 2, VIII: Kurwa Dan Baba, IX: Nagobar, X: Singh pursadar, XI: Sundhaha).*

Table 3. Shrub species reported from eleven forest sites of Gaya district

S.N.	Species	Family
1	*Carissa opaca* Stapf ex Haines	Apocynaceae
2	*Clerodendrumvis-cosum*Vent.	Verbenaceae
3	*Jatropha gossypifolia*L.	Euphorbiaceae
4	*Lantana camara* L. *var. aculeata* (L.) Mold.	Verbenaceae
5	*Mimosa himala-yana*Gamble	Mimosaceae
6	*Pavettacrassi-caulis*Bremek.	Rubiaceae
7	*Securinegavirosa*(Roxb. ex Willd.) Baill.	Phyllanthaceae
8	*Tephrosia purpurea* (L.) Pers.	Fabaceae
9	*Woodfordiafruticosa*(L.) Kurz	Lythraceae

Table 4. Climber species reported from eleven forest sites of Gaya district.

S.N.	Species	Family
1	*Abrusprecatorious*L.	Fabaceae
2	*Acacia pennata* (L.) Willd	Mimosaceae
3	*Asparagus racemosus*Willd.	Liliaceae
4	*Atylosiascarabaeoides*(L.) Benth.	Fabaceae
5	*Butea parviflora* Roxb.	Fabaceae
6	*Capparis zeylanica*L.	Capparaceae
7	*Cissampelos pareira* L. var.*hirsuta*(Buch.-Ham.ex DC.) Forman	Menispermaceae
8	*Cocculus hirsutus*(L.) Diels	Menispermaceae
9	*Combretum roxburghii*Spreng	Combretaceae
10	*Dioscoreabelophylla*(Prain) Voigt ex Haines	Dioscoreaceae
11	*Hemidesmus indicus* (L.) R.Br.	Asclepediaceae
12	*Ichnocarpus frutescens* (L.)	Apocynaceae
13	*Ipomoea hederifolia*L.	Convolvulaceae
14	*Ludwigiaoctovalvis*(Jacq.) Raven	Onagraceae
15	*Millettia extensa* (Benth.) Baker	Fabaceae
16	*Mucuna nigricans* (Lour.) Steud.	Fabaceae
17	*Poranapaniculata*Roxb.	Convolvulaceae
18	*Pupalialappacea*(L.) Juss	Amaranthaceae
19	*Ventilagodenticulata*Willd.	Rhamnaceae
20	*Ziziphus oenoplia*(L.) Mill.	Rhamnaceae

Sub-beat (36 spp.), Patluka Murrai Pahar(32 spp.), North Alakdiha and South Alakdiha (26 spp. each) etc. and lowest in Kurwa Dan Baba (12 spp.).

In the tree layer, highest Diversity Index (H) was observed for Nagobar (3.376) followed by South Alakdiha (2.788), Kurwa Dan Baba (2.599) etc. and lowest for Titri (0.335). There was no tree in the AamasJhari site. In the shrubby layer, highest Diversity Index (H) value was observed for North Alakdiha (2.328) followed by South Alakdiha (2.281), Kurwa Dan Baba- 2 (2.273) etc. and lowest for Patluka Murrai Pahar (1.278). In the herbaceous layer, the highest Diversity Index (H) was observed for Sundhaha Sub-beat (2.843) followed by North Alakdiha (2.739), South Alakdiha (2.719) etc. and lowest for Titri (1.786). The higher value of Diversity Index (H) indicates the variability in the type of species and heterogeneity in communities, whereas the lesser value points to homogeneity in the community. In the present study, the diversity index value range was within 0.67 to 4.03 as reported in tropical forests of the Indian subcontinent by (Kumar *et al*., 2010; Sundarapandian and Swamy, 2000; Verma *et al*., 2015, Himanshi and Jakhar, 2020).

In the tree layer, Concentration of Dominance (cd) was highest in case of Titri site (0.850) followed by Kurwa Dan Baba 2(0.437), Patluka Murrai Pahar (0.310) etc. and lowest in Nagobar (0.047). The shrubby layer had highest value of Concentration of Dominance (cd) in Titri (1.000) followed by Patluka Murrai Pahar (0.443), Sundhaha Sub-beat (0.276) etc. and lowest in Kurwa Dan Baba 2(0.142). In the herbaceous layer, the highest value of Concentration of Dominance (cd) was estimated for Titri (0.287) followed by Nagobar (0.187), Bharamyoni Mandir (0.178) etc. and lowest for South Alakdiha (0.087). The higher value of Concentration of Dominance (cd), the greater is the homogenous nature of community and vice-versa. In other words, such communities are dominant by single species. The lower value of the concentration of dominance indicates that the dominance of plant is shared by many species.

In the case of tree layer, highest Evenness (E) value was estimated for Nagobar site (0.929) followed by South Alakdiha (0.902), Kurwa Dan Baba (0.868) etc. and lowest for Titri (0.305). In the case of shrubby layer, the highest Evenness (E) value was recorded for Kurwa Dan Baba 2 site (0.820) followed by Bharamyoni Mandir (0.815), AamasJhari (0.800) etc. In the herbaceous layer, highest value of Evenness (E) was estimated for Kurwa Dan Baba 2 site (0.907) followed by Kurwa Dan Baba (0.896), North Alakdiha (0.841), Aamas Jhari (0.838) etc. and lowest for Titri (0.631). The higher value of Evenness (E) indicates that species are evenly distributed and vice-versa. In the present study, Pielou Index (E) for tree, shrubby and herbaceous layers showed a similar trend reported by different workers in tropical parts of India viz. Udaipur Rajasthan (Kumar *et al*. 2010), Western Ghat (Sundarapandian and Swamy, 2000), Bundelkhand region of Uttar Pradesh (Verma *et al*, 2015), and South West Haryana (Himanshi and Jakhar 2020).

Table 5. Herb species reported from eleven forest sites of Gaya district.

S.N.	Species	Family	S.N.	Species	Family
1	*Achyranthes aspera* L.	Amaranthaceae	27	*Hyptissuaveolens* (L.) Poit.	Lamiaceae
2	*Aervasanguinolenta* (L.) Bl.	Amaranthaceae	28	*Indigofera linifolia*(L.f.) Retz.	Fabaceae
3	*Ageratum conyzoides* L.	Asteraceae	29	*Justicia diffusa*Willd	Acanthaceae
4	*Alysicarpus vaginalis* (L.) DC.	Fabaceae	30	*Justicia simplex*D. Don	Acanthaceae
5	*Anisomeles indica* (L.) Kuntze	Lamiaceae	31	*Launaea procumbens* (Roxb.) Ramayya& Rajagopal	Asteraceae
6	*Bacopa procumbens* (Miller) Greenman	Scrophulariaceae	32	*Leonotisnepetifolia*(L.) R.Br.	Lamiaceae
7	*Biophytumsensitivum* (L.) DC.	Oxalidaceae	33	*Leucas plukenetii* (Roth) Spreng.	Lamiaceae
8	*Blepharis repens* (Vahl) Roth	Acanthaceae	34	*Lindernia crustacea* (L.)	Scrophulariaceae
9	*Blumeamollis*(D.Don) Merr.	Asteraceae	35	*Nelsoniacanescens* (Lam.) Spreng.	Acanthaceae
10	*Blumeaobliqua*(L.) Druce	Asteraceae	36	*Oxalis corniculata*L.	Oxalidaceae
11	*Boerhaviadiffusa*L.	Nyctaginaceae	37	*Peristrophepaniculata* (Forssk.) Brummit	Acanthaceae
12	*Byttneriaherbacea*-Roxb.	Sterculiaceae	38	*Phyllanthus amarus*S-chum. &Thonn.	Phyllanthaceae
13	*Cassia tora*L.	Caesalpiniaceae	39	*Phyllanthus vir-gatus*Forst.f.	Phyllanthaceae
14	*Celosia argentea* L.	Amaranthaceae	40	*Rungiapectinata*(L.) Nees	Acanthaceae
15	*Crotalaria albida* Heyne. ex Roth	Fabaceae	41	*Sida acuta* Burm	Malvaceae
16	*Curculigoor-chioides*Gaertn.	Hypoxidaceae	42	*Sida cordata* (Burm.f.) Borassum	Malvaceae
17	*Cyathocline purpurea* (Buch.-Ham. ex D.Don) Kuntze	Asteraceae	43	*Spermacocearticu-laris*L.	Rubiaceae
18	*Desmodiumtriflorum* (L.) DC.	Fabaceae	44	*Spermacocepusilla*-Wall.	Rubiaceae
19	*Dipteracanthusprostra-tus*(Poir.) Nees	Acanthaceae	45	*Tridex procumbens* L.	Asteraceae
20	*Elephantopusscaber*L.	Asteraceae	46	*Triumfettarhomboi-dea*Jacq.	Tiliaceae
21	*Emilia sonchifolia*(L.) DC.	Asteraceae	47	*Urena sinuate* L. subsp.*sinuata*(L.) Borassum var.*sinuata.* L	Malvaceae
22	*Eriocaulon quinquan-gulare*L.	Eriocaulaceae	48	*Vernonia cinerea* (L.)	Asteraceae
23	*Euphorbia hirta*L.	Euphorbiaceae	49	*Vicoa indica* (L.) DC.	Asteraceae
24	*Evolvulus-alsinoides* (L.) L	Convolvulaceae			
25	*Evolvulusnummularius* (L.) L	Convolvulaceae			
26	*Gnaphalium pensyl-vanicum* Willd.	Asteraceae			

Conclusion

It reveals from the study that forest sites of Gaya district possess a significantly high floristic diversity. On the basis of different diversity attributes viz. species richness, diversity index, the concentration of dominance and evenness in the tree layer, Nagobar site is the most diverse site followed by South Alakdiha, Kurwa Dan Baba, North Alakdiha etc. where AamasJhari site is devoid of any tree species. Shrub and herb diversity was also considerably higher than most of the sites in Nagobar site. The low diversity of tree species indicates the disturbance in sites such as AamasJhari, Titri, and Patluka Murrai Pahar. Anthropogenic activities such as tree felling for fuelwood and timber, grazing, encroachment, etc., may be factors for the depletion of plant diversity. Hence, suitable management strategiesshould be developed for the improvement of the diversity of the tree species in the low diversity sites. Villagers living in the fringes of forests should be

Table 6. Sedges, Grass and Pteridophytes reported from eleven forest sites of Gaya district.

S.N.	Species	Family
Sedges		
1	*Cyperus niveus*Retz.	Cyperaceae
2	*Cyperus rotundus*L.	Cyperaceae
Grasses		
1	*Apludamutica*L.	Poaceae
2	*Aristida adscensionis*L.	Poaceae
3	*Bothriochloapertusa*(L.)	Poaceae
4	*Brachiariaramosa*(L.) Stapf	Poaceae
5	*Brachiariareptans*(L.) C.A.Gardner&C.E.Hubb.	Poaceae
6	*Chrysopogon fulvus* (Spr.) Chiov.	Poaceae
7	*Cymbopogon khasianus* (Munro ex Hack.) Stapf ex Bor	Poaceae
8	*Cynodondactylon*(L.) Pers.	Poaceae
9	*Dactylocteniumaegyptium*(L.) Willd.	Poaceae
10	*Dendrocalamusstrictus* (Roxb.) Nees	Poaceae
11	*Desmodiumgangeticum*(L.) DC.	Poaceae
12	*Desmodiumtriflorum*(L.) DC.	Poaceae
13	*Dichanthiumannulatum* (Forssk.) Stapf	Poaceae
14	*Eragrostiellanardoides*(Trin.) Bor	Poaceae
15	*Eragrostistenella*(L.) P.Beauv. ex Roem. &Schult.	Poaceae
16	*Heteropogoncontortus*(L.)	Poaceae
17	*Melanocenchrisjacquemontii*-Jaub. &Spach.	Poaceae
18	*Oplismenusburmannii*(Retz.) P. Beauv	Poaceae
19	*Pennisetum glaucum* (L.) R. Br.	Poaceae
20	*Sporobolus indicus* (L.) R. Br. var.*diander*(Retz.) Jovet. & Guedes	Poaceae
Pteridophytes		
1	*Adiantum incisum*Forssk.	Adiantaceae
2	*Cheilanthesfarinosa*(Forssk.) Kaulf.	Cheilanthaceae
3	*Lygodiumflexuosum* (L.) Sw.	Lygodiaceae

made aware of the importance of forest biodiversity conservation and its sustainable utilization through a mass awareness programme. The finding of the study will be useful for researchers and officials of the State Forest Department for formulation and implementation of future management study of the area.

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Conflict of interest

The authors declare that they have no conflict of interest.

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