Biological Forum – An International Journal **13(1): 01-09(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Phyto-diversity Assessment of Nalanda Forest Division of Bihar

A. Chandra, H. B. Naithani, P.K. Verma, J. Saxena, S. Kishwan and R. Saini
Forest Botany Division,
Forest Research Institute, Dehradun- 248006, India.

(Corresponding author: A. Chandra)
(Received 02 November 2020, Accepted 11 January, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Phyto-sociological study of Nalanda forest division of Bihar was carried out. Quantitative parameters such as density, frequency, IVI and different diversity indices were estimated. Highest tree density (T ha^{-1}) was reported for Jamuni site (980) followed by Amjhar sub-beat (910) and Ghora Katora beat (630). Highest tree species richness (SR) was reported for Jamuni site (38 spp.) followed by Amjhar Sub-beat (29 spp.) and Ghora Katora Beat (18 spp.). Species richness of shrubby and herbaceous layer was also reported highest for the Jamuni site. Highest IVI value of tree layer for Amjhar Sub-beat site, Jamuni and Ghora Katoria site were 59.84 (*Shorea robusta*), 36.65 (*Boswellia serrata*) and 39.22 (*Ficus mollis*) respectively. Highest diversity index of tree layer, shrubby layer and herbaceous layers was estimated for Jamuni site (3.254), Ghora Katora Beat (2.408) and Jamuni (2.969) respectively. It reveals from the study that Jamuni site is more diverse site in the area. Study also reveals that *Lantana camara* var. *aculeata* a invasive is showing its presence in the area, it can adversely impact the indigenous species in future. Both qualitative and quantitative assessment of vegetation are essential for assessing present status of diversity and developing future conservation strategies. Hence, it is recommended that similar kind of study should be regularly carried out in different forest sites for conservation and sustainable utilization of plant diversity.

Keywords: Important Value Index, Diversity index, Species richness, Evenness.

INTRODUCTION

Forest biodiversity means the variety and variability of all living organisms in the forest including plants, animals and microorganisms. It provides wide variety of ecological services that are important to human well being. Plant diversity is a source of new crops, improvement of exiting crops, valuable medicine, raw material for many industries etc. It also provides various services such as protection of watersheds, mitigation of erosion, moderation of climate and shelter and food for animals. Burgeoning population coupled with rapid industrialization and over exploitation of plant resources have put tremendous pressure on the forest vegetation. It has resulted decline of plant diversity in forest ecosystem.

Vegetation is primary source for energy which transfer to other trophic levels. Environment of an area effects the vegetation of an ecosystem (Billings, 1952). Structure and function of plant community can be understood by phyto-sociological study of the area. It explains and predicts pattern in a meaningful manner (Braun Blanquet, 1932, Odum, 1971). Therefore, for proper understanding of plant diversity of any area, phyto-sociology aspects should be thoroughly studied. Convention of Biological Diversity also asserted the need of regular inventorization and monitoring of biodiversity for sustainable utilization.

The state of Bihar has recorded forest area of 6877 km^2, which is 7.3% of its geographical area. The Reserve, Protected and Unclassified Forests are 693 km^2, 6183 km^2 and 1 km^2 respectively. The forest cover in the state is 7306 km^2 which is 7.76% of the total geographical area of the state. On the basis of density classes, 333.13 km^2 is under very dense forest, 3280.32 km^2 under moderately dense forests and 3692.54 km^2 under open forest. The Nalanda District is one of the thirty eight district of Bihar state. Nalanda district is a part of Patna Division. The forest cover in the Nalanda district 31.85 km^2 which is 1.35% of the total geographical area of the state. On the basis of density classes 6.86 km^2 under moderately dense forests and 24.99 km^2 under open forest. There is no very dense forest in the district, most of area (78%) is under open forest (FSI, 2019).

Bihar state has been extensively survey for its floral wealth by various workers in the past (Anderson, 1863; Hooker, 1872-1897; Wood, 1903; Haines, 1921-1924: Mukhrjee, 1947; Mooney, 1950 Paul, 1973; Biswas and Maheshshwari, 1980; Bhatacharya and Sarkar,

1998, Singh *et al.,* 2001, etc.). Quantitative assessment of vegetation diversity of different forests sites have been estimated by various workers have been estimated different (Sharma and Mishra, 2009; Verma, 2017; Chandra and Kewat , 2017; Chandra *et al*., 2019, Kumar *et al.,* 2020, etc.). However, till date no work has been reported on quantitative assessment of different species in the region. Therefore, in the present study efforts have been made to quantify the status of different species in the forest area of the district.

MATERIALS AND METHODS

Fig. 1. Location map of study area

Study site

The Nalanda District is the one of the thirty eight district of Bihar, India. It has geographical extension from 24' to 25° 27' N latitude and from 85° 18' to 85° 65' E longitude. District is popularly known as Biharsharif. Biharsharif town is the district headquarter.

Survey and vegetative data

Three random forest sites were selected for the vegetation analysis. Random coordinating points were provided by the GIS cell of the Forest Research Institute, Dehradun for collection of vegetative data. Quantitative analysis of vegetation for frequency, density and dominance was calculated following Mishra (1968). 10 quadrats were randomly laid in each site. Quadrate size of 10 × 10m, 3 × 3m and 1×1m 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 case of herb and shrub, diameter was measured 2.5 cm above ground level. Values of Relative fervency, 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:

$$\mathbf{H= - \sum pi \ ln \ pi}$$

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).

$$\mathbf{Cd = \sum (pi)^2}$$

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

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

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. It is a standard tool used to inventory a forest. IVI is estimated for tree, shrubby and herbaceous layers. A high importance value indicates that species is well represented in the area.

Quantitative analysis for tree, shrubby and herbaceous layers of Amjhar Sub-Beat, Rajgir Range site in presented table 1, 2 and 3. In tree layer, 29 species were observed with total density (T ha^{-1}) of 910. Maximum density (Tha^{-1}) was recorded for *Shorea robusta* (230) followed by *Aegle marmelos* (150), *Mallotus philippensis* (80), *Acacia pennata* (50) etc. Highest frequency was recorded for *Shorea robusta* and *Aeglemarmelos* (50% each) followed by *Mallotus philippensis* and *Ehretia laevis* (30% each), *Acacia pennata* and *Buchanania lanzan* (20% each) etc. Total basal area (TBA) (m^2ha^{-1}) was found to be 24.60. Maximum IVI was recorded for *Shorea robusta* (59.84) followed by *Aegle marmelos* (37.98), *Mallotus philippensis* (26.06), *Acacia pennata* (15.08), *Bombax ceiba* (12.93) etc. and minimum for*Gardenia latifolia* (3.92).

The shrubby layer was represented by 19 species with total density (S ha^{-1}) of 7,667. Highest density (S ha^{-1}) was observed in *Shorea robusta* (1,667) followed by *Combretumroxburghii* (1,444), *Mallotus philippensis* (1,111), *Carissa opaca* (778), *Acacia pennata* (556) etc.Highest frequency was observed for *Combretum roxburghii* (70%) followed by *Shorea robusta* (60%), *Mallotus philippensis* (30%) etc. Total basal area (TBA) (m^2 ha^{-1}) was found to be 4.04. On the basis of

Important value index (IVI), *Shorea robusta* (58.82) was the most dominant species in the area followed by *Combretum roxburghii* (53.69), *Mallotus philippensis* (28.81), *Carissa opaca* (27.51) etc. and least was *Helicteres isora* (4.53).

A total of 13 species were reported in herbaceous layer from the area with total density (H ha^{-1}) of 70,000. Maximum density (H ha^{-1}) was observed for *Shorea robusta* (32,000) followed by *Combretum roxburghii* (8,000), *Carissa opaca* (6,000), *Capparis zeylanica* (5,000), *Ixora pavetta* (4,000) etc. Total basal area (TBA) (m^2ha^{-1}) was found to be 0.68. Highest IVI value was found for *Shorea robusta* (82.99) and lowest for *Hemidesmus indicus* (5.39).

Table 1: Quantitative analysis of tree layers of Amjhar sub-beat, Rajgir Range.

S.No.	Species (Tree Layer	Density (T ha^{-1})	Frequency %	TBA (m^2 ha^{-1})	IVI
1.	*Shorea robusta* Roxb. ex Gaertn.	230	50	5.64	59.84
2.	*Aegle marmelos* Corr.	150	50	2.43	37.98
3.	*Mallotus philippensis* (Lam.) Muell.-Arg.	80	30	2.53	26.06
4.	*Acacia pennata* (L.) Willd.	50	20	1.21	15.08
5.	*Bombax ceiba* L.	20	10	2.07	12.93
6.	*Ehretia laevis* Roxb.	30	30	0.63	12.82
7.	*Syzygium cumini* (L.) Skeels.	40	10	1.49	12.76
8.	*Buchanania lanzan* Spreng.	30	20	0.58	10.29
9.	*Pithecellobium dulce* (Roxb.) Benth.	10	10	1.15	8.08
10.	*Madhuca longifolia* var. *latifolia* (Roxb.) A. Chev.	20	10	0.75	7.59
11.	*Firmiana colorata* (Roxb.) B.Br.	10	10	0.83	6.79
12.	*Ventilago denticulate* Willd.	30	10	0.26	6.70
13.	*Butea parviflora* Roxb.	20	10	0.52	6.64
14.	*Litsea glutinosa* (Lour.) Robin.	30	10	0.24	6.61
15.	*Holoptelea integrifolia* (Roxb.) Planch.	10	10	0.64	6.05
16.	*Garuga pinnata* Roxb.	10	10	0.63	5.99
17.	*Ziziphus xylopyra* (Retz.) Willd.	20	10	0.20	5.32
18.	*Alangium salviifolium* (L.f.) Wang.	10	10	0.41	5.10
19.	*Wrightia tinctoria* (Roxb.) B.Br.	10	10	0.35	4.84
20.	*Cordia dichotoma* Forster	10	10	0.29	4.59
21.	*Crateva adansonii* ssp. *odora* (Buch.-Ham.) Jacobs	10	10	0.28	4.55
22.	*Haldinia cordifolia* (Roxb.) Ridsd.	10	10	0.27	4.51
23.	*Bridelia retusa* (L.) Spreng.	10	10	0.22	4.30
24.	*Dalbergia lanceolaria* L.f.	10	10	0.21	4.28
25.	*Flacourtia indica* (Burm.f.) Merr.	10	10	0.21	4.27
26.	*Lannea coromandelica* (Houtt.) Merr.	10	10	0.18	4.18
27.	*Dalbergia volubilis* Roxb.	10	10	0.14	4.00
28.	*Oroxylum indicum* (L.) Vent.	10	10	0.12	3.93
29.	*Gardenia latifolia* Ait.	10	10	0.12	3.92
	Total	**910**		**24.60**	**300.00**

Table 2: Quantitative analysis of shrubby layer of Amjhar sub-beat, Rajgir Range.

S.No.	Species (Shrubby Layer)	Density (S ha^{-1})	Frequency %	TBA (m^2 ha^{-1})	IVI
1.	*Shorea robusta* Roxb. ex Gaertn.	1667	60	0.79	58.82
2.	*Combretum roxburghii* Spreng.	1444	70	0.58	53.69
3.	*Mallotus philippensis* (Lam.) Muell.-Arg.	1111	30	0.22	28.81
4.	*Carissa opaca* Stapf. ex Haines	778	20	0.46	27.51
5.	*Acacia pennata* (L.) Willd.	556	10	0.58	24.50
6.	*Ixora pavetta* Andr.	222	20	0.27	15.45
7.	*Ehretia laevis* Roxb.	111	10	0.43	15.10
8.	*Syzygium cumini* (L.) Skeels	444	10	0.08	10.73
9.	*Murraya paniculata* (L.) Jack	111	10	0.23	10.06
10.	*Butea parviflora* Roxb.	222	10	0.17	10.01
11.	*Aegle marmelos* Corr.	111	10	0.05	5.58
12.	*Capparis zeylanica* L.	111	10	0.05	5.55
13.	*Gardenia latifolia* Ait.	111	10	0.04	5.29
14.	*Wrightia tinctoria* (Roxb.) R. Br.	111	10	0.03	5.10
15.	*Cassia fistula* L.	111	10	0.02	4.95
16.	*Diospyros melanoxylon* Roxb.	111	10	0.02	4.89
17.	*Capparis sepiaria* L.	111	10	0.02	4.77
18.	*Olax scandens* Roxb.	111	10	0.01	4.66
19.	*Helicteres isora* L.	111	10	0.01	4.53
	Total	**7667**		**4.04**	**300.00**

Table 3: Quantitative analysis of herbaceous layer of Amjhar sub-beat, Rajgir Range.

S.No.	Species (Herbaceous Layer)	Density (H ha^{-1})	Frequency %	TBA (m^2 ha^{-1})	IVI
1.	*Shorea robusta* Roxb. ex Gaertn.	32000	50	0.12	82.99
2.	*Combretum roxburghii* Spreng.	8000	40	0.06	36.30
3.	*Flacourtia indica* (Burm.f.) Merr.	2000	10	0.20	36.01
4.	*Carissa opaca* Stapf. ex Haines	6000	40	0.03	28.18
5.	*Croton roxburghii* Balak.	3000	20	0.10	27.42
6.	*Ixora pavetta* Andr.	4000	20	0.08	25.22
7.	*Capparis zeylanica* L.	5000	20	0.03	19.25
8.	*Clerodendrum viscosum* Vent.	3000	10	0.02	10.37
9.	*Syzygium cumini* (L.) Skeels	3000	10	0.01	10.30
10.	*Olax scandens* Roxb.	1000	10	0.01	7.24
11.	*Cocculus hirsutus* (L.)Diels	1000	10	0.00	5.89
12.	*Mallotus philippensis* (Lam.) Muell.-Arg.	1000	10	0.00	5.45
13.	*Hemidesmus indicus* L.	1000	10	0.00	5.39
	Total	**70000**		**0.68**	**300.0**

Quantitative analysis for tree, shrubby and herbaceous layers of Jamuni, Base of Byapur giri, Rajgir Range site is presented in table no. 4, 5 and 6. In tree layer, 38 tree species were observed with total density (T ha^{-1}) of 980. Maximum density (T ha^{-1}) of 160 was reported for *Anogeissus latifolia* followed by *Boswellia serrata* (100), *Lannea coromandelica* and *Garuga pinnata* (60 each) etc. Highest frequency of 40% was recorded for three species viz., *Lannea coromandelica, Anogeissus latifolia* and *Boswellia serrata.* Total basal area (TBA) (m^2 ha^{-1}) was found to be 31.29. Maximum IVI was estimated for *Boswellia serrata* (36.65) followed by *Anogeissus latifolia* (34.45), *Lannea coromandelica* (19.05), *Sterculia urens* (13.84), *Garuga pinnata* (13.70) etc.

A total of 27 species were recorded in the shrubby layer with total density (S ha^{-1}) of 17444. *Dendrocalamus strictus* had maximum density (S ha^{-1}) of 9889 followed by *Helicteres isora* (1667), *Syzygium cumini* (778), *Flacourtia indica* (667), *Diospyros melanoxylon* (556), *Combretum roxburghii* (444) etc. Highest frequency was observed for *Combretum roxburghii* and *Dendrocalamus strictus* (40% each). Total basal area (TBA) (m^2 ha^{-1}) was found to be 11.57. On the basis of important value index (IVI), *Dendrocalamus strictus* (114.74) was most dominant species in the area followed by *Helicteres isora* (21.15), *Syzygium cumini* (19.69), *Combretum roxburghii* (13.71) etc and least was *Croton roxburghii* (2.97).

The herbaceous layer was represented by 26 species with total density (H ha^{-1}) of 97000. Maximum density (H ha^{-1}) was observed for *Urginea indica* (14000) followed by *Cassia tora* (11000), *Cassia occidentalis* (8000), *Capparis zeylanica* (6000) etc. Total basal area (TBA) (m^2 ha^{-1}) was found to be 2.53. Highest IVI value was reported in *Cassia occidentalis* (39.52) followed by *Urginea indica* (20.15), *Ixora pavetta* (19.22), *Cassia tora* (19.15), *Capparis zeylanica* (19.02) etc.

Table 4: Quantitative analysis of tree layer of Jamuni, Base of Byapur giri, Rajgir Range.

S.No.	Species (Tree Layer)	Density (T ha^{-1})	Frequency %	TBA (m^2 ha^{-1})	IVI
1.	*Boswellia serrata* Roxb. ex Cole.	100	40	6.19	36.65
2.	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guill. & Perr.	160	40	3.58	34.45
3.	*Lannea coromandelica* (Houtt.) Merr.	60	40	1.96	19.05
4.	*Sterculia urens* Roxb.	30	20	2.33	13.84
5.	*Garuga pinnata* Roxb.	60	10	1.85	13.70
6.	*Manilkara hexandra* (Roxb.) Dubard	20	20	2.40	13.05
7.	*Shorea robusta* Roxb. ex Gaertn.	30	20	1.28	10.50
8.	*Strychnos potatorum* L.f.	30	20	1.07	9.81
9.	*Haldinia cordifolia* (Roxb.) Ridsd.	30	30	0.39	9.30
10.	*Gardenia latifolia* Ait.	30	20	0.84	9.09
11.	*Bridelia retusa* (L.) Spreng.	30	20	0.83	9.06
12.	*Barringtonia acutangula* (L.) Gaertn.	30	20	0.72	8.69
13.	*Acacia catechu* (L.f.) Willd.	30	20	0.33	7.46
14.	*Ziziphus xylopyra* (Retz.) Willd.	40	10	0.36	6.90
15.	*Syzygium cumini* (L.) Skeels.	20	20	0.40	6.65
16.	*Flacourtia indica* (Burm.f.) Merr.	20	20	0.34	6.45

17.	*Aegle marmelos* Corr.	20	20	0.21	6.06
18.	*Nyctanthes arbortristis* L.	20	10	0.50	5.30
19.	*Walsura trifoliate* (A. Juss.) Hams.	20	10	0.41	5.03
20.	*Lagerstroemia parviflora* (Roxb.)	20	10	0.38	4.91
21.	*Tamarindus indica* L.	10	10	0.62	4.66
22.	*Pterocarpus marsupium* Roxb.	10	10	0.53	4.37
23.	*Ficus mollis* Vahl.	10	10	0.48	4.21
24.	*Schleichera oleosa* (Lour.) Oken.	10	10	0.38	3.91
25.	*Cochlospermum religiosum* (L.) Alston	10	10	0.36	3.84
26.	*Ehretia laevis* Roxb.	10	10	0.30	3.65
27.	*Madhuca longifolia* var. *latifolia* (Roxb.) A. Chev.	10	10	0.30	3.65
28.	*Ixora pavetta* Andr.	10	10	0.26	3.53
29.	*Mallotus philippensis* (Lam.) Muell.-Arg.	10	10	0.24	3.44
30.	*Cassia fistula* L.	10	10	0.23	3.42
31.	*Buchanania lanzan* Spreng.	10	10	0.23	3.42
32.	*Streblus asper* Lour.	10	10	0.18	3.26
33.	*Carissa opaca* Stapf. ex Haines	10	10	0.17	3.24
34.	*Diospyros Montana* Roxb.	10	10	0.15	3.17
35.	*Euphorbia nivulia* Buch.-Ham.	10	10	0.14	3.15
36.	*Bauhinia racemosa* Lam.	10	10	0.12	3.09
37.	*Terminalia bellirica* (Gaertn.) Roxb.	10	10	0.11	3.05
38.	*Ceriscoides turgid* (Roxb.) Tirveng.	10	10	0.10	3.01
	Total	**980**		**31.29**	**300.00**

Table 5: Quantitative analysis of shrubby layer of Jamuni, Base of Byapur giri, Rajgir Range.

S.No.	Species (Shrubby Layer)	Density (S ha^{-1})	Frequency %	TBA (m^2 ha^{-1})	IVI
1.	*Dendrocalamus strictus* (Roxb.) Nees.	9889	40	5.69	114.74
2.	*Helicteres isora* L.	1667	30	0.57	21.15
3.	*Syzygium cumini* (L.) Skeels.	778	20	1.25	19.69
4.	*Combretum roxburghii* Spreng.	444	40	0.26	13.71
5.	*Flacourtia indica* (Burm.f.) Merr.	667	30	0.34	13.44
6.	*Diospyros melanoxylon* Roxb.	556	30	0.18	11.44
7.	*Ziziphus xylopyra* (Retz.) Willd.	333	20	0.39	9.71
8.	*Capparis separia* L.	333	20	0.13	7.48
9.	*Buchanania lanzan* Spreng.	222	20	0.14	6.95
10.	*Carissa opaca* Stapf. ex Haines	222	20	0.09	6.52
11.	*Cassia fistula* L.	222	20	0.08	6.44
12.	*Walsura trifoliate* (A. Juss.) Haines	111	10	0.35	5.88
13.	*Gardenia latifolia* Ait.	111	10	0.30	5.43
14.	*Azadirchta indica* A. Juss.	111	10	0.29	5.41
15.	*Lagerstroemia parviflora* Roxb.	111	10	0.26	5.13
16.	*Phyllanthus reticulates* Poir.	333	10	0.11	5.08
17.	*Diospyros montana* Roxb.	111	10	0.23	4.83
18.	*Catunaregam spinosa* (Thunb.) Triveng.	222	10	0.13	4.60
19.	*Acacia catechu* (L.f.) Willd.	111	10	0.13	4.01
20.	*Securinega virosa* (Roxb. ex Willd.) Baill.	111	10	0.13	3.99
21.	*Haldinia cordifolia* (Roxb.) Ridsd.	111	10	0.13	3.96
22.	*Lantana camara* var. *aculeate* (L.) Mold.	111	10	0.10	3.75
23.	*Pterocarpus marsupium* Roxb.	111	10	0.09	3.64
24.	*Strychnos potatorum* L.f.	111	10	0.09	3.61
25.	*Prosopis juliflora* (SW.) DC.	111	10	0.07	3.45
26.	*Ziziphus oenoplia* (L.) Mill.)	111	10	0.02	3.00
27.	*Croton roxburghii* Balak.	111	10	0.01	2.97
	Total	**17444**		**11.57**	**300.00**

Table 6: Quantitative analysis of herbaceous layer of Jamuni, Base of Byapur giri, Rajgir Range.

S.No.	Species (Herbaceous Layer	Density (H ha^{-1})	Frequency %	TBA (m^2 ha^{-1})	IVI
1.	*Cassia occidentalis* L.	8000	10	0.73	39.52
2.	*Urginea indica* (Roxb.) Kunth.	14000	10	0.08	20.15
3.	*Ixora pavetta* Andr.	5000	40	0.09	19.22
4.	*Cassia tora* L.	11000	20	0.06	19.15
5.	*Capparis zeylanica* L.	6000	20	0.19	19.02
6.	*Streblus asper* Lour.	2000	20	0.27	18.13
7.	*Barringtonia acutangula* (L.) Gaertn.	5000	10	0.20	15.53
8.	*Dendrocalamus strictus* (Roxb.) Nees.	5000	10	0.14	13.30
9.	*Combretum roxburghii* Spreng.	4000	20	0.10	13.23
10.	*Capparis separia* L.	3000	20	0.11	12.66
11.	*Ziziphus mauritiana* var. *mauritiana* Bhand. & Bhans.	3000	10	0.16	12.18
12.	*Diospyros melanoxylon* Roxb.	4000	20	0.07	12.11
13.	*Carissa opaca* Stapf. ex Hianes	3000	30	0.02	11.96
14.	*Aerva sanguinolenta* (L.) Bl.	4000	20	0.03	10.65
15.	*Diospyros montana* Roxb.	2000	10	0.10	8.56
16.	*Olax scandens* Roxb.	1000	10	0.11	8.20
17.	*Blepharis maderaspatensis* (L.) Roth.	4000	10	0.00	6.78
18.	*Ichnocarpus frutescens* (L.) R. Br.	3000	10	0.01	5.98
19.	*Flacourtia indica* (Burm.f.) Merr.	2000	10	0.00	4.83
20.	*Helicteres isora* L.	2000	10	0.00	4.78
21.	*Phyllanthus reticulates* Poir.	1000	10	0.02	4.63
22.	*Sida cordata* (Burm.f.) Bora.	1000	10	0.02	4.29
23.	*Sida cordifolia* L.	1000	10	0.01	4.02
24.	*Cocculus hirsutus* (L.) Diels	1000	10	0.00	3.75
25.	*Rungia pectinata* (L.) Nees.	1000	10	0.00	3.67
26.	*Cissampelos pariera* var. *hirsuta* (Buch.-Ham. ex DC.) Forman.	1000	10	0.00	3.67
	Total	**97000**		**2.53**	**300.0**

Quantitative analysis for tree, shrubby and herbaceous layers of Ghora-Katora Beat, Rajgir Range site is presented in Table 7, 8 and 9. Tree layer was represented by 18 species total density (T ha^{-1}) of 630. Highest density (T ha^{-1}) was observed for *Ficus mollis, Lannea coromandelica* and *Euphorbia nivulia* (80 each) followed by *Butea monosperma, Careya arborea, Firmiana colorata, Walsura trifoliata, Syzygium cumini* (40% each) etc. Highest frequency of 40 % was recorded for *Ficus mollis, Lannea coromandelica, Euphorbia royleana* and *Firmiana colorata.* Total basal area (TBA) (m^2 ha^{-1}) was found to be 181.27. Maximum IVI was recorded in case of *Ficus mollis* (39.22) and minimum in *Streblus asper* (3.92).

In the shrubby layer, 19 species were recorded with total density (S ha^{-1}) of 18889. Maximum density (S ha^{-1}) was observed in *Dendrocalamus strictus* (4889) followed by *Ziziphus mauritiana* var. *mauritiana* (2444), *Capparis sepiaria* (2222), *Croton roxburghii* (2000), *Eupatorium odoratum* (1557) etc. Highest frequency of (80%) was recorded for *Ziziphus mauritiana* var. *mauritiana.* Total basal area (TBA) (m^2 ha^{-1}) was found to be 59.52. On the basis of Important Value Index (IVI), *Murraya paniculata* (59.64) was most dominant species in the area followed by *Ziziphus mauritiana* var. *mauritiana* (46.09), *Dendrocalamus strictus* (39.34), *and Capparis sepiaria* (23.59) etc and least was *Grewia hirsuta* (4.87).

A total of 18 species was reported in the herbaceous layer from the area with total density (H ha^{-1}), of 254000. Maximum density (H ha^{-1}) was observed for *Tridex procumbens* (68000) followed by *Bothriochloa pertusa* (48000), *Tephrosia purpurea* (42000), *Cynodon dactylon* (30000), *Syzygium cumini* (8000), *Aerva sanguinolenta* (8000) etc. Total basal area (TBA) (m^2 ha^{-1}) was found to be 0.9. Highest IVI value was estimated for *Tridex procumbens* (70.23) followed by *Tephrosia purpurea* (59.88), *Bothriochloa pertusa* (31.17), *Cynodon pertusa* (18.03), *Syzygium cumini* (8,000), *Aerva sanguinolenta* (8,000), *Cassia tora* (8,000) etc and lowest in *Scoparia dulcis* (4.88) for each.

Table 7: Quantitative analysis of tree layers in Ghora-Katora Beat, Rajgir Range.

S.No.	Species (Tree Layer)	Density (T ha^{-1})	Frequency %	TBA (m^2 ha^{-1})	IVI
1.	*Ficus mollis* Vahl.	80	40	31.21	39.22
2.	*Lannea coromandelica* (Houtt.) Merr.	80	40	23.18	34.79
3.	*Euphorbia nivulia* Buch.-Ham.	80	40	11.75	28.48
4.	*Butea monosperma* (Lam.) Taub.	40	20	24.59	24.57
5.	*Careya arborea* Roxb.	40	20	21.37	22.79
6.	*Firmiana colorata* (Roxb.) R. Br.	40	40	8.17	20.16
7.	*Walsura trifoliate* (A. Juss.) Ham.	40	20	16.50	20.11
8.	*Syzygium cumini* (L.) Skeels	40	20	4.42	13.44
9.	*Sterculia urens* Roxb.	20	20	10.05	13.37
10.	*Boswellia serrata* Roxb. ex Cole.	20	20	5.65	10.94
11.	*Terminalia bellirica* (Gaertn.) Roxb.	20	20	5.28	10.74
12.	*Grewia tiliifolia* Vahl.	20	20	4.25	10.17
13.	*Cochlospermum religiosum* (L.) Alston.	20	20	4.25	10.17
14.	*Phoenix sylvestris* (L.) Roxb.	20	20	3.93	9.99
15.	*Mallotus philippensis* (Lam.) Muell.-Arg.	20	20	2.27	9.08
16.	*Ehretia laevis* Roxb.	20	20	2.27	9.08
17.	*Lagerstroemia parviflora* Roxb.	20	20	2.15	9.01
18.	*Streblus asper* Lour.	10	10	0.00	3.92
	Total	**630**		**181.27**	**300.00**

Table 8: Quantitative analysis of shrubby layer of Ghora-Katora Beat, Rajgir Range.

S.No.	Species (Shrubby Layer)	Density (S ha^{-1})	Frequency %	TBA (m^2 ha^{-1})	IVI
1.	*Murraya paniculata* (L.) Jack	1111	60	25.62	59.64
2.	*Ziziphus mauritiana* var. *mauritiana* Bhand. & Bhans.	2444	80	11.23	46.09
3.	*Dendrocalamus strictus* (Roxb.) Nees.	4889	40	3.76	39.34
4.	*Capparis sepiaria* L.	2222	60	0.66	23.59
5.	*Croton roxburghii* Balak.	2000	20	4.57	21.85
6.	*Gardenia latifolia* Ait.	222	20	5.52	14.02
7.	*Combretum roxburghii* Spreng.	1111	40	0.51	13.88
8.	*Eupatorium odoratum* L.	1556	20	0.44	12.54
9.	*Mimosa himalayana* Gamb.	667	20	2.76	11.74
10.	*Crateva adansonii* ssp. *odora* (Buch.-Ham.) Jacobs	222	20	1.92	7.98
11.	*Phoenix sylvestris* (L.) Roxb.	222	20	0.98	6.40
12.	*Carissa opaca* Stapf. ex Haines	444	20	0.27	6.37
13.	*Holarrhena pubescens* (Buch.-Ham.) Wall. ex G. Don	444	20	0.09	6.07
14.	*Alangium salviifolium* (L.f.)Wang.	222	20	0.27	5.19
15.	*Flacourtia indica* (Burm.f.) Merr.	222	20	0.24	5.15
16.	*Woodfordia fruticosa* (L.) Kurz	222	20	0.24	5.15
17.	*Capparis zeylanica* L.	222	20	0.23	5.13
18.	*Ziziphus oenoplia* (L.) Mills.	222	20	0.15	5.00
19.	*Grewia hirsuta* Vahl.	222	20	0.07	4.87
	Total	**18889**		**59.52**	**300.00**

Table 9: Quantitative analysis of herbaceous layer of Ghora-Katora Beat, Rajgir Range.

S.No.	Species (Herbaceous Layer)	Density (H ha^{-1})	Frequency %	TBA (m^2 ha^{-1})	IVI
1.	*Tridex procumbens* L.	68000	80	0.25	70.23
2.	*Tephrosia purpurea* (L.) Pers.	42000	100	0.22	59.88
3.	*Bothriochloa pertusa* (L.) A. Camus.	48000	40	0.04	31.17
4.	*Cynodon dactylon* (L.) Pers.	30000	20	0.02	18.03
5.	*Syzygium cumini* (L.) Skeels.	8000	20	0.06	14.20
6.	*Aerva sanguinolenta* (L.) Bl.	8000	20	0.05	12.22
7.	*Vernonia cinerea* (L.) Less.	6000	40	0.02	12.14
8.	*Grewia hirsute* Vahl.	2000	20	0.07	12.07
9.	*Waltheria indica* L.	4000	20	0.05	10.92
10.	*Cassia tora* L.	8000	20	0.01	8.47
11.	*Croton bonplandianus* Baill.	2000	20	0.03	7.36
12.	*Evolvulus nummularius* (L.) L.	8000	20	0.00	7.06
13.	*Thespesia lampas* (Cav.) Datz.&Gibs.	2000	20	0.02	6.82
14.	*Rungia pectinata* (L.) Nees.	6000	20	0.00	6.50
15.	*Indigofera linifolia* (L.f.) Retz.	6000	20	0.00	6.26
16.	*Sida cordata* (Burm.f.) Bora	2000	20	0.02	6.22
17.	*Operculina turpenthum* (L.) Silva-Manso	2000	20	0.01	5.61
18.	*Scoparia dulcis* L.	2000	20	0.00	4.88
		254000		**0.900**	**300.0**

Table 10: Diversity indices for different growth forms at different sites.

S. No.	Sites	Tree Layer				Shrubby Layer				Herbaceous Layer			
		SR	H	cd	E	SR	H	cd	E	SR	H	cd	E
1.	Amjhar Sub-Beat, Rajgir Range	29	2.734	0.112	0.812	19	2.394	0.127	0.813	13	1.918	0.245	0.748
2.	Jamuni, Base of Byapur giri, Rajgir Range	38	3.254	0.059	0.895	27	1.913	0.339	0.581	26	2.969	0.066	0.912
3.	Ghora-Katora Beat, Rajgir Range	18	2.713	0.078	0.939	19	2.408	0.127	0.818	18	2.213	0.155	0.766
	(SR=species richness; H=Diversity index; cd=Concentration of dominance; E=evenness)												

Diversity indices for different growth forms at different sites are presented in table no.10. Higher value of Species Richness (SR) indicates higher diversity of species. Highest tree species richness (SR) was reported for Jamuni site (38 spp.) followed by Amjhar Sub-beat (29 spp.) and Ghora Katora Beat (18 spp.). Species richness of shrubby and herbaceous layer was also reported highest for the Jamuni site. The higher value of Diversity Index (H) indicates the variability in the type of species and heterogeneity in communities whereas lesser value points to homogeneity in the community. Highest diversity index of tree layer, shrubby layer and herbaceous layers was estimated for Jamuni site (3.254), Ghora Katora Beat (2.408) and Jamuni (2.969) respectively. 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 Concentration of Dominance (cd) indicates that dominance of plant is shared by many species.

Highest value of Concentration of dominance for tree, shrubby and lerbaceous layers was reported for Amjhar Sub Beat site (0.112), Jumuni (0.339) and Amjhar Sub beat (0.245) respectively. Higher value of Evenness (E) indicates that species are evenly distributed and vice-versa.

It reveals from the study that Jamuni site is more diverse site in the area. Study also reveals that *Lantana camara* var. *aculeata* an invasive is showing its presence in the area, it can adversely impact the indigenous species in future. In addition to qualitative study, quantitative assessment of vegetation is essentially required for holistic picture of plant diversity in the area. Presence study will be of immense use for the field staff of the forest department for conservation and developing future management strategies. Regular inventorization and monitoring of plant diversity is the need of the hour. Therefore, similar kind of studies should regularly be carried out in different forest sites to assess the present status of plant

diversity and making suitable conservation strategies for future.

ACKNOWLEDGEMENT

Authors are thankful to the Director, Forest Research Institute, Dehradun for constant encouragement and support. Authors are also thankful to the PCCF and other Forest officials of Bihar Forest Department for funding and proving necessary support during the study.

REFERENCES

Anderson, T. (1863). On the Flora of Bihar and the mountains of Parasnath with a list of species collected by Messrs Hooer, *J. Asiat. Soc., Bengal,* **32**: 187-218.

Bhatacharya P.K. and Sarkar K. (1998). *Flora of West-Champaran District, Bihar*. Botanical Survey of India, Calcutta

Billings, W.D. (1952). The environment complex in relation to plant growth and distribution *Quarterly Review of Biology,* **27**, 251-265.

Biswas, D.K. and Maheshwari, J.K. (1980). A contribution to the vegetation of Chaibasa, Singhbhum District in South Bihar. *Bull. Bot. Soc. Bengal,* **25** (1 & 2): 43-51.

Braun Blanquet, J. (1932). *Plant Sociology (Conard H.S., Fuller G.D., Trans)*, New York; McGraw-Hill.

Chandra, A. and Kewat, A.K. (2017). Phyto-diversity of selected stress sites of Garhwal Forest Division of Pauri Garhwal, Uttarakhand, India. *Annals of Plant Sciences,* **6.8** (2017) pp. 1658-1663

Chandra, A., Dhakad, A.K., Verma, P.K., Saxena, J. and Raut, A.K. (2019). Assessment of Impact of *Eupatorium adenophorum* Spren. On the Plant Diversity in Tanakpur Range, Champawat Forest Division,Uttarakhand. *Biological Forum – An International Journal* , **11**(1): 95-100.

Forest Survey of India (2019). *State of Forest Report*. Forest Survey of India. Dehradun

Haines, H.H. (1921-24). *The Botany of Bihar and Orissa*. Adlard and Sons, London.

Hooker, J.D. (1872-1897). The Flora of British India (7 Vols.). L. Reeve and Co., London.

Kumar, R., Verma, R.K., Thakur, C., Prakash, R. and Kumar, S. (2020). Diversity of Shrubs in Kibber Beat in Kibber Wildlife Sanctuary of Lahaul & Spiti District, Himachal Pradesh. *International Journal of Theoretical & Applied Sciences*, **12**(2): 1-8.

Misra, R. (1968). *Ecological Workbook*. Oxford Press, New Delhi.

Mooney, H.F. (1950). *Supplement to the Botany of Bihar and Orissa*. Catholic Press, Ranchi

Mukherjee, S.K. (1947). A Botanical Tour in Chhotanagpur. *Bull. Bot. Soc. Bengal,* **1**: 27-28.

Odum, E.P. (1971). *Fundamentals of Ecology, Third ed.,* W.B. Saunders, Philadelphia

Paul, S.R. (1973). On the aquatic and Marsh Flora of Monghyr, Bihar. *Botanique*, 143-152.

Pielou, E.C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology*, **13**, 131-144.

Shannon, C.E., Wiener, W. (1963). *The Mathematical Theory of Communities*. University of Illinois press, Urbana,117.

Sharma, P. and Mishra, N.K. (2009). Diversity, utilization pattern and indigenous uses of plants in and around a cement factory in Bilaspur district of Himachal Pradesh, North-Western Himalaya. *Biological Forum — An International Journal*, **1**(2): 89-91.

Simpson, E.M. (1949). Measurement of diversity. *Nature*, **163**: 688.

Singh, N.P., V. Mudgal, K.K. Khanna, S.C. Srivastava, A.K. Sahoo, S. Bandhopadhay, N. Aziz, M. Das, R.P. Bhattacharya and P.K. Hajra (2001). *Flora of Bihar-Analysis*. Botanical Survey of India, Calcutta

Verma, R.K. (2017). Phyto-diversity studies in Kanasa Valley of Rakchham Chitkul Wild life Sanctuary of District Kinnaur, Himachal Pradesh. *Biological Forum – An International Journal*, **9**(1): 62-69.

Wood, J.J. (1903). Plants of Chotanagpur including Jaspur and Surguza. *Rec. Bot. Sur. India*, **2**: 1-170.

How to cite this article: Chandra, A., Naithani, H. B., Verma, P. K., Saxena, J., Kishwan, S. and Saini, R. (2021). Phyto-diversity Assessment of Nalanda Forest Division of Bihar. *Biological Forum – An International Journal*, **13**(1): 01-09.