Original Research Article

Species diversity, Phytosociological attributes and Regeneration status of Pench Tiger Reserve, Maharashtra, India

ABSTRACT

Aims : Pench Tiger Reserve (PTR) is known for its rich biodiversity comprising of tropical deciduous forests as their primary forest type. Tropical deciduous forests are enriched with economically important species. They serve as habitat areas for most of the wild animals for their food and shelter. So, a phytosociological investigation was carried out in PTR to know the information on plant cover dynamics related to human activity, climate change, and all other factors affecting plant development.

Place and Duration of Study: Pench Tiger Reserve (PTR), June 2021 to December 2022.

Methodology: The study was carried out by laying out 47 sample plots in the PTR by dividing Tiger Reserve into 7 ranges. The plot size was 0.1 ha with 31.62 m x 31.62 m quadrats. Varied diversity indices such as Simpson, Shannon–Weiner, species evenness, and IVI were calculated according to standard formulae. Carbon stock, vegetation analysis and IVI value of each species were calculated and analysed.

Results : A total of 102 species, comprising 90 genera and 44 families, were reported. The dominant family in the study area was Leguminosae, followed by Malvaceae and Poaceae. The Shannon–Weiner index was 2.92 and the Simpson index was 0.103, indicating moderate diversity with less dominance of trees, saplings, and herb layer in the area. Top five species holding highest IVI value are *Tectona grandis* (66.20), *Lagerstroemia parviflora* (20.44), *Chloroxylon swietenia* (19.91), *Lannea coromandelica* (18.35), and *Terminalia tomentosa* (16.62).

Conclusions – As a part of long–term monitoring programme for the tree communities in the Pench Tiger Reserve, the current study has generated baseline data that will be used to evaluate the current ecological effects of ongoing and future climate change.

Key words: *IVI, Maharashtra, Pench Tiger Reserve, Phytosociology, Shannon–Weiner index and Simpson index.*

1. INTRODUCTION

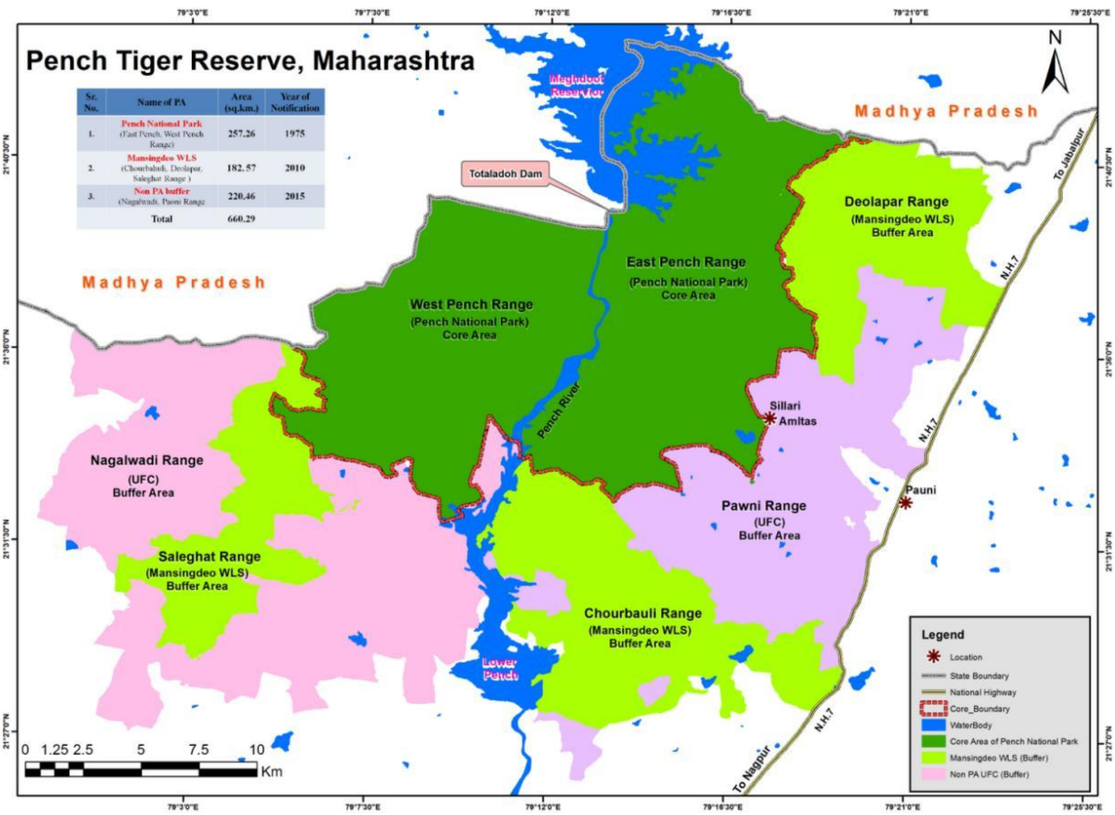
Phytosociology is a part of vegetation science which deals with plant community studies at a spatial grain size of vegetation stands. The major objectives are the delimitation and characterization of vegetation types based on the complete floristic composition. It helps to study all life forms and involve in the assessment of various analytical traits such as frequency, density, basal area, evenness, Importance Value Index (IVI) and diversity indices to compare various parameters and find more productive ones [1]. Phytosociological studies of dominant tree species help to understand the potential function of the tree species in capturing the most carbon and aids in climate change mitigation [2]. Understanding the dynamics of the forest ecosystem absolutely requires knowledge of the floristic composition, diversity and plant biomass [3, 4]. Tropical forests are the most biologically diverse communities on the planet and they are home to a major amount of the world's biodiversity [5, 6]. Tropical forests occupy highest diversity among terrestrial ecosystem [7, 8, 9]. occupying about 38% of total forest area of India [10]. It is necessary to understand the phytosociological parameters i.e., the diversity indices, species diversity, species richness, species evenness and distribution pattern to implement sustainable management. The analytical results provide comprehensive information about species composition, complex relationship between different communities and ecosystems, sustainability of resources and ecosystem changes due to environmental factors. There is a need to make proper management practices for sustainable maintenance of its biodiversity.

The estimation of biomass eventually helps to determine the carbon stock of a region in the current scenario of global climate change [11, 12, 13, 14, 15]. For accurate and consistent reporting of forest carbon inventories, it is crucial to establish appropriate biomass estimating methodologies that minimize errors [16].Dry deciduous forests retain the most carbon, followed by tropical moist deciduous and tropical semi-evergreen forests [17]. The main carbon pool in a tropical forest ecosystem is made up of the live biomass of the trees refers to both above ground and below ground biomass, the understory plants, and deadwood, which comprises standing deadwood and fallen deadwood such as fallen stems and branches, woody debris, and soil organic matter. The above-ground biomass of trees, which is primarily the largest carbon pool of the ones stated above and is immediately impacted by deforestation and forest degradation [18]. Estimating above-ground biomass (AGB) is important for understanding carbon stocks, the impact of deforestation, and carbon sequestration on the global carbon cycle. It also offers important insights into a variety of global challenges [19, 20]. Below-ground biomass studies were also conducted to improve the understanding of carbon allocation and storage in the studied terrestrial forest ecosystem. For scientific and managerial concerns including forest productivity, nitrogen cycling, and inventories of fuel wood and pulp, estimates of carbon stock are crucial. Furthermore, above ground biomass plays an important role in the yearly and long-term variations in the global terrestrial carbon cycle and other earth system interactions [21]. In this context, the purpose of this study is to understand and examine the vegetation's structure, species diversity, and composition, as well as the function that PTR plays in carbon sequestration, which is crucial for the efficient management of forests.

2. MATERIALS AND METHODS

2.1 Study area

Fig1: Map of the study area, Pench Tiger Reserve, Maharashtra



The present study was carried out in the Pench Tiger Reserve, Maharashtra during 2021-22 (July-September). The Pench Tiger Reserve is named after the Pench river, which is running through the Satpura's low-lying southern hill ranges from North to South. Geographically, the Pench Tiger Reserve is located between $79^{0}03'46''$ to $79^{0}21'20''$ East to $21^{0}11'58''$ to $21^{0}43'16''$ North and is situated beside Nagpur District's northern border, next to Madhya Pradesh's Seoni and Chhindwara districts. [22]. The Pench Tiger Reserve covers a total area of 741.22 km^2, including its core area (257.26 km^2) and buffer area (483.96 km^2). The Tiger reserve is portioned into 2 parts namely East and West Pench which are separated by the Pench River. East Pench sub division consists of four ranges namely, Chorbahuli, Paoni, Deolapar, and East Pench, while West Pench has three ranges namely West Pench, Saleghat, and Nagalwadi.

The major forest type in the Tiger Reserve is a Southern tropical dry deciduous type, with a significant amount of teak. The Pench Tiger Reserve, Maharashtra occupies very dense forest, moderate dense forests and open forest in 223.87 sq. km, 320.32 sq. km & 65.09 sq. km respectively. The reserve has 82.53% forest cover of total forest area. The Tiger, Leopard, Wild Dog, Jackal, Hyena and Jungle Cat are some of the significant carnivores found in this region. Whereas, Sambar, Nilgai, Gaur, Chital, Barking deer, Chausinga, Wild boar, Bear, etc. are examples of herbivores in the reserve. An essential combined conservation unit is formed by the Pench Tiger Reserve and the surrounding woods of the Pench Tiger Reserve (M.P.). The park's woodlands serve as main catchments for the Totladoh reservoir, ensuring its long-term expectant.

The study area was inventoried by laying of 47 sample plots on the basis of stratified random sampling method, dividing the tiger reserve into 7 ranges with a standard sampling intensity method. The phytosociological analysis of each sample grid of Pench Tiger Reserve was conducted by using randomly chosen 31.62m x 31.62 m quadrats. The design of sample plot was set up in accordance with the National Working Plan Code, 2014 & Forest Survey of India, Dehradun. The aforementioned plot was 0.1ha size. In sample plot, the woody species having a girth at breast height >10 cm were taken measurements.

2.2 Layout of sample plots

After arriving at the sampling plot, a 0.1 ha (primary plot) was laid out by measuring 22.36 m horizontally (half of the diagonal) at 45° in the north-east, 135° in the south-east, 225° in the south-west, and 315° in the north-west corners of the plot. Nested quadrats of sizes 3m x 3m and 1m x 1m were spaced out at a distance of 30 meters from the centre of the plot in all four directions along diagonals in the non-hilly region for the enumeration of shrubs (including regeneration status) and herbs/grasses. From all of the 0.1 ha sample plots that have been identified, all trees with a diameter of 10 cm (>10 cm) were counted, species-wise and diameter-class-wise, and reported in the data sheets.

2.3 Statistical Analysis

Several quantitative indices have been designed to provide information on different aspects of biodiversity viz. The Simpson Index [23]. Shannon–Weiner Index [23, 24]. IVI and Margalef Index [25]. The indices provide the biodiversity values and help to compare it between plant communities or ecosystems. The equations are as follows:

2.3.1 Simpson's Diversity Index

$(D) = 1 - \Sigma (n/N)^2$

where n = the total number of organisms of a particular species, N = the total number of organisms of all species

2.3.2 Shannon Diversity index

$(H) = \Sigma\, pi \ln pi$ (or) $H' = -\Sigma (ni/N) \times \log (ni/N)$

where p_i=The proportion of the entire community made up of species *i*

The diversity of species increases in a given community with increasing H value and vice versa.

2.3.3 Species Evenness Index

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

where H=Shannon Diversity Index, S=The total number of unique species

This value ranges from 0 to 1.

2.3.4 Margalef Index

$(D) = (S-1)/\ln N$

where S=No. of species in a sample and N=the total individuals

2.3.5 Important Value Index (IVI)

The analysis of the vegetation data was done using characters such as Abundance (A), Frequency (F), Density (D), Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDO), Basal Area (BA), and Importance Value Index (IVI) in accordance with the standard formulae.

$$\text{Frequency} = \frac{\text{No.of quadrats in which species occurred}}{\text{Total no.of Sampling Unit Studied}}$$

$$\text{Relative Frequency} = \frac{\text{Frequency of the species}}{\text{Total frequency of all species}} \times 100$$

$$\text{Density} = \frac{\text{No. of individuals of the species}}{\text{Total area studied}}$$

$$\text{Relative density} = \frac{\text{Density of the species}}{\text{Total density of all the species}} \times 100$$

$$\text{Abundance} = \frac{\text{Total no. of individuals of the species in all quadrats}}{\text{No. of quadrats in which species occurred}}$$

$$\text{Relative dominance} = \frac{\text{Dominance (cover) of the species}}{\text{Total dominance of all species}} \text{x}100$$

IVI is calculated by adding relative density, relative dominance, and relative frequency values for each species [26].

Important Value Index (IVI) = Relative Dominance + Relative Density + Relative Frequency

2.3.6 Carbon stock estimation

Basal area of individual trees was calculated by using the formula

Basal area (A) = $\frac{\pi}{4}d^2$

where d = diameter at breast height (DBH); π = 3.14

Volume of Standing Trees (V)

As per Pressler's formula (1860), the volumes of standing trees were computed. It measures in cubic meters.

Volume of standing trees (V) = ff x h x g

where V = Volume of the standing tree, ff = Form Factor, h = height of the tree, and g = Basal area

Form Factor (ff)

The value was computed as per [27, 28].

ff $=2h1/3h$

where h1 = Height at which diameter is half of DBH and h = Total height of the tree

Biomass Estimation

Using forest type specific volume equations, biomass in different pools have been determined. Specific gravity and carbon content in biomass for different forest species as available in varied literature including IPCC 2006 have been used in estimation of forest carbon.

Above Ground Biomass = Specific gravity of stem wood x volume

Below ground biomass (BGB)= Above ground biomass x Root: shoot ratio [29].

Specific gravity

The specific gravity value of each species is specific and values were procured from published literature and Forest Research Institute, Dehradun.

Carbon estimation

The carbon storage of dry matter was calculated by multiplying the total biomass with constant factor [29].

Carbon stock = Total Biomass x 0.47

3. RESULTS

3.1 Vegetation structure

Table 1. Showing the IVI of the study area

S. No	Name of the Species	RA	RD	RB	IVI
1	*Acacia chundra* (Rottler) Willd	3.23	3.23	2.829	9.282
2	*Acacia leucophloea* (Roxb.) Willd	0.74	0.69	0.525	1.961
3	*Aegle marmelos* (L.) Corrêa	3.72	1.67	1.396	6.79
4	*Alangium salviifolium* (L.f.) Wangerin	0.25	0.17	0.078	0.499
5	*Albizia odoratissima* (L.f.) Benth	0.74	0.4	0.415	1.563
6	*Anogeissus latifolia* (Roxb. Ex DC.) Wall. Ex Guillem. &Perr	5.21	4.38	5.469	15.06
7	*Bauhinia malabarica* Roxb.	3.23	1.9	1.202	6.33
8	*Bombax ceiba* L.	0.74	0.17	0.9	1.818
9	*Boswellia serrata* Roxb. Ex Colebr	0.74	0.69	2.402	3.838
10	*Bridelia retusa* (L.) A.Juss.	0.25	0.06	0.179	0.485
11	*Buchanania cochinchinensis (Lour.) M.R.Almeida*	4.47	3.4	2.648	10.52
12	*Butea monosperma* (Lam.) Taub	1.99	1.38	0.822	4.191
13	*Cassia fistula* L.	2.48	0.69	0.303	3.476
14	*Chloroxylon swietenia* DC	5.46	7.61	6.846	19.91

15	*Cleistanthus collinus* (Roxb.) Benth. Ex Hook.f	0.5	3.57	2.016	6.086
16	*Cordia macleodii* Hook.f. & Thomson	0.25	0.06	0.091	0.397
17	*Dalbergia lanceolaria* subsp. *paniculata* (Roxb.) Thoth	2.48	0.75	1.798	5.029
18	*Dalbergia latifolia* Roxb	0.25	0.06	0.019	0.325
19	*Desmodium oojeinense* (Roxb.) H.Ohashi	0.74	0.58	0.605	1.926
20	*Diospyros homboidei* Roxb	0.25	0.06	0.016	0.322
21	*Diospyros melanoxylon* Roxb	5.71	3.86	2.569	12.14
22	*Ehretia laevis* Roxb	0.5	0.12	0.083	0.695
23	*Ficus homboid* L	0.25	0.06	0.323	0.629
24	*Firmiana simplex* (L.) W.Wight	0.25	0.12	0.066	0.429
25	*Flacourtia indica* (Burm.f.) Merr	0.99	0.4	0.146	1.542
26	*Gardenia latifolia* Aiton	1.49	1.27	0.906	3.663
27	*Gardenia resinifera* Roth	0.99	0.4	0.183	1.579
28	*Garuga pinnata* Roxb.	0.5	0.23	0.611	1.338
29	*Grewia asiatica* L.	0.74	0.29	0.246	1.279
30	*Gymnosporia emarginata* (Willd.) Thwaites	0.99	0.29	0.109	1.39
31	*Haldina cordifolia* (Roxb.) Ridsdale	0.5	0.17	0.224	0.893
32	*Holoptelea integrifolia* Planch	0.74	0.4	0.656	1.804
33	*Hymenodictyon orixense* (Roxb.) Mabb	0.25	0.06	0.176	0.482
34	*Ixora pavetta* Andr	1.74	2.19	1.09	5.017
35	*Kydia calycina* Roxb.	0.74	0.35	0.085	1.175
36	*Lagerstroemia parviflora* Roxb	6.7	8.01	5.729	20.44
37	*Lannea coromandelica* (Houtt.) Merr	6.2	5.01	7.141	18.36
38	*Madhuca longifolia* var. *latifolia* (Roxb.) A.Chev.	1.49	1.27	1.073	3.829
39	*Miliusa tomentosa* (Roxb.) J.Sinclair	5.71	4.67	2.815	13.19
40	*Mitragyna parvifolia* (Roxb.) Korth	3.23	1.38	1.48	6.089
41	*Phyllanthus emblica* L	1.24	0.35	0.292	1.878
42	*Pterocarpus marsupium* Roxb	0.25	0.06	0.029	0.335
43	*Schleichera oleosa* (Lour.) Merr	1.24	0.87	2.132	4.237
44	*Soymida febrifuga* (Roxb.) A. Juss	1.99	1.84	1.832	5.661
45	*Strychnos nux-vomica* L	0.99	0.29	0.286	1.567
46	*Strychnos potatorum* L.f	0.25	0.06	0.033	0.339
47	*Tamarindus indica* L	0.5	0.29	0.581	1.365
48	*Tectona grandis* L. f	7.69	27.3	31.24	66.25
49	*Terminalia bellirica* (Gaertn.) Roxb	0.5	0.12	0.066	0.677

50	*Terminalia tomentosa* Wight &Arn	4.96	5.25	6.417	16.63
51	*Wrightia tinctoria* R. Br	0.74	0.4	0.173	1.321
52	*Ziziphus mauritiana* Lam	2.23	1.1	0.649	3.977
	Total	100	100	100	300

The vegetation structure in the Pench tiger reserve was made up of the five dominating tree species *Tectona grandis*, *Lagerstroemia parviflora, Chloroxylon swietenia, Terminalia tomentosa, and Lannea coromandelica*, which together account for 53.19% of all the recorded tree individuals. IVI (Importance Value Index) in the tiger reserve was highest for *Tectona grandis*. Top 10 species holding highest values of IVI follows the trend as *Tectona grandis* (66.20), *Lagerstroemia parviflora* (20.44), *Chloroxylon swietenia* (19.91), *Lannea coromandelica* (18.35), *Terminalia tomentosa* (16.62), *Anogeissus latifolia* (15.06), *Miliusa tomentosa* (13.19), *Diospyros melanoxylon* (12.13), *Buchanania cochinchinensis* (10.51), and *Acacia chundra* (9.28) (Table 1).

Table 2. IVI of the shrubs & herbaceous species in Pench Tiger Reserve, Maharashtra

S.no	Species	RA	RF	RD	IVI
1	*Abelmoschus ficulneus (L.) Wight & Arn*	1.102	0.285	0.094	1.481
2	*Abutilon indicum (L.) Sweet*	4.041	0.570	0.689	5.299
3	*Adianthum spp*	2.571	4.558	3.506	10.636
4	*Allmania nodiflora (L.) R.Br. ex Wight*	0.551	0.285	0.047	0.883
5	*Andrographis paniculata (Burm.f.) Nees*	2.066	2.279	1.409	5.754
6	*Aristida setacea Retz*	2.498	1.425	1.064	4.987
7	*Biophytum sensitivum (L.) DC.*	3.049	1.425	1.299	5.773
8	*Blumea lacera (Burm.f.) DC*	2.469	7.692	5.682	15.843
9	*Brachiaria distachya (L.) Stapf*	2.020	0.570	0.344	2.935
10	*Colocasia esculenta (L.) Schott*	0.184	0.285	0.016	0.484
11	*Commelina benghalensis L*	1.994	1.994	1.190	5.178
12	*Curculigo orchioides Gaertn*	1.873	2.849	1.596	6.319
13	*Curcuma pseudomontana J.Graham*	1.699	3.419	1.737	6.855
14	*Cyanotis cristata (L.) D.Don*	2.550	4.843	3.694	11.087
15	*Cynodon dactylon (L.) Pers*	3.765	2.849	3.209	9.823
16	*Cyperus rotundus L.*	2.525	1.140	0.861	4.526
17	*Dactyloctenium aegyptium (L.) Willd*	3.017	3.989	3.600	10.606
18	*Desmodium triflorum (L.) DC*	1.837	1.140	0.626	3.602
19	*Digitaria abludens (Roem. & Schult.) Veldkamp*	2.571	0.285	0.219	3.075
20	*Dipteracanthus prostratus (Poir.) Nees*	2.893	7.977	6.902	17.773

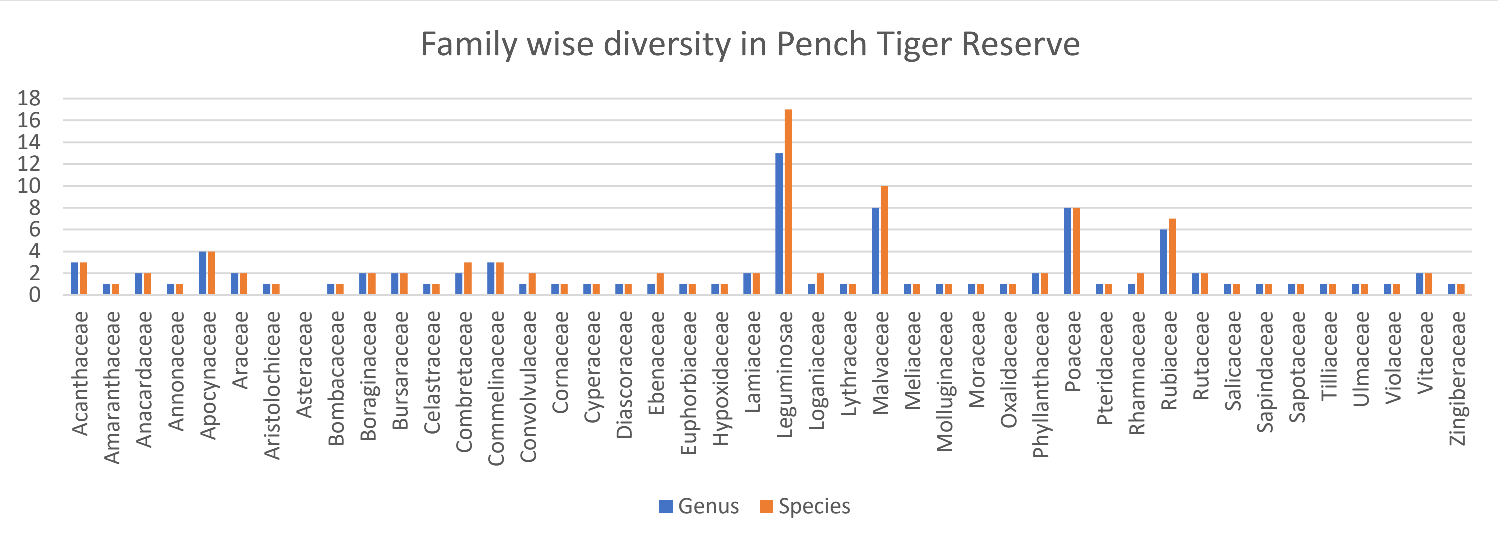
21	*Evolvulus alsinoides (L.) L*	1.837	0.855	0.470	3.161
22	*Evolvulus nummularius (L.) L*	1.898	2.564	1.456	5.918
23	*Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult*	4.347	1.709	2.223	8.279
24	*Hybanthus enneaspermus (L.) F.Muell*	1.959	1.709	1.002	4.670
25	*Indigofera cordifolia Roth*	2.480	1.140	0.845	4.464
26	*Justicia glauca Rottler*	1.791	1.140	0.610	3.541
27	*Malvastrum coromandelianum (L.) Garcke*	1.653	1.140	0.563	3.356
28	*Mollugo pentaphylla L*	1.255	1.709	0.642	3.606
29	*Murdannia spirata (L.) G.Brückn*	1.139	1.425	0.485	3.048
30	*Oplismenus burmanni (Retz.) P.Beauv*	14.143	8.832	37.361	60.336
31	*Orthosiphon rubicundus (D.Don) Benth.*	1.102	1.425	0.470	2.996
32	*Pavonia odorata Willd*	1.653	0.285	0.141	2.079
33	*Phyllanthus amarus Schumach. & Thonn*	0.918	0.285	0.078	1.282
34	*Phyllanthus maderaspatensis L*	1.433	1.425	0.610	3.468
35	*Senna uniflora (Mill.) H.S.Irwin & Barneby*	2.089	4.558	2.849	9.496
36	*Setaria pumila (Poir.) Roem. & Schult*	1.837	0.285	0.157	2.278
37	*Sida acuta Burm.f*	2.221	3.134	2.082	7.436
38	*Sida cordata (Burm.f.) Borss.Waalk*	2.429	8.832	6.417	17.678
39	*Sida cordifolia L*	1.607	1.140	0.548	3.295
40	*Spermacoce articularis L.f*	1.286	0.285	0.110	1.680
41	*Tephrosia purpurea (L.) Pers*	1.561	0.570	0.266	2.397
42	*Triumfetta rhomboidea Jacq.*	1.837	4.274	2.348	8.458
43	*Typhonium spp*	1.148	1.140	0.391	2.679
44	*Zornia diphylla (L.) Pers*	1.102	0.285	0.094	1.481
	Total	**100**	**100**	**100**	**300**

The IVI values of the top five shrubs and herbaceous plants in the tiger reserve are as follows in decreasing order are *Oplismenus burmanni* (47.61) >*Dipteracanthus prostratus* (34.98) >*Sida cordata* (30.17) >*Blumea lacera* (27.55) >*Heteropogon contortus* (11.64) (Table 2).

3.1.1 Family wise diversity

The number of species which are distributed in each family were shown in the (Graph 1) with their genus and species distribution. A total of 102 species, comprising 90 genera and 44 families, were reported. The maximum of the species was reported in Leguminosae family followed by Malvaceae and Poaceae. The top 5 families with highest number of species record with genus: species ratio was followed the trend as Leguminosae (13:17) >Malvaceae (8:10) >Poaceae (8:8) >Rubiaceae (6:7) >Apocynaceae (4:4) (Graph 1).

Graph 1. shows the family wise species diversity in Pench Tiger Reserve, Maharashtra



3.2 Carbon stock determination

Table 3. Showing the carbon stock assessment of the study area

S.No.	Species	AGB t/h	BGB t/h	TB t/h	Carbon t/h
1.	*Acacia chundra* (Rottler) Willd	8.72	2.27	10.98	5.16
2.	*Acacia leucophloea* (Roxb.) Willd	1.07	0.28	1.35	0.64
3.	*Aegle marmelos* (L.) Corrêa	3.31	0.86	4.17	1.96
4.	*Alangium salviifolium* (L.f.) Wangerin	0.11	0.03	0.14	0.07
5.	*Albizia odoratissima* (L.f.) Benth	0.91	0.24	1.15	0.54
6.	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guillem. &Perr	14.28	3.71	17.99	8.45
7.	*Bauhinia malabarica* Roxb.	0.72	0.19	0.91	0.43
8.	*Bombax ceiba* L	2.29	0.59	2.88	1.36
9.	*Boswellia serrata* Roxb. ex Colebr	5.32	1.38	6.70	3.15
10.	*Bridelia retusa (L.) A.Juss.*	0.35	0.09	0.44	0.20
11.	*Buchanania cochinchinensis (Lour.) M.R.Almeida*	4.30	1.12	5.42	2.55
12.	*Butea monosperma* (Lam.) Taub	0.67	0.17	0.84	0.40
13.	*Cassia fistula* L	0.83	0.22	1.05	0.49
14.	*Chloroxylon swietenia* DC	26.75	6.96	33.71	15.84

15.	*Cleistanthus collinus* (Roxb.) Benth. ex Hook.f	2.31	0.60	2.91	1.37
16.	*Cordia macleodii* Hook.f. & Thomson	0.22	0.06	0.27	0.13
17.	*Dalbergia lanceolaria* subsp. *paniculata* (Roxb.) Thoth	7.74	2.01	9.76	4.59
18.	*Dalbergia latifolia* Roxb	0.02	0.00	0.02	0.01
19.	*Desmodium oojeinense* (Roxb.) H.Ohashi	2.42	0.63	3.05	1.43
20.	*Diospyros chloroxylon* Roxb	0.01	0.00	0.01	0.01
21.	*Diospyros melanoxylon* Roxb	5.91	1.54	7.45	3.50
22.	*Ehretia laevis* Roxb	0.10	0.03	0.13	0.06
23.	*Ficus racemosa* L	1.46	0.38	1.83	0.86
24.	*Firmiana simplex* (L.) W.Wight	0.04	0.01	0.05	0.03
25.	*Flacourtia indica* (Burm.f.) Merr	0.08	0.02	0.10	0.05
26.	*Gardenia latifolia* Aiton	1.02	0.27	1.29	0.61
27.	*Gardenia resinifera* Roth	0.08	0.02	0.10	0.05
28.	*Garuga pinnata* Roxb.	1.26	0.33	1.58	0.74
29.	*Grewia asiatica* L.	0.26	0.07	0.32	0.15
30.	*Gymnosporia emarginata* (Willd.) Thwaites	0.05	0.01	0.06	0.03
31.	*Haldina cordifolia* (Roxb.) Ridsdale	0.37	0.10	0.47	0.22
32.	*Holoptelea integrifolia* Planch	1.28	0.33	1.61	0.76
33.	*Hymenodictyon orixense* (Roxb.) Mabb	0.56	0.15	0.71	0.33
34.	*Ixora pavetta* Andr	0.96	0.25	1.21	0.57
35.	*Kydia calycina Roxb.*	0.11	0.03	0.14	0.06
36.	*Lagerstroemia parviflora* Roxb	14.24	3.70	17.95	8.44
37.	*Lannea coromandelica* (Houtt.) Merr	18.20	4.73	22.93	10.78
38.	*Madhuca longifolia* var. *latifolia* (Roxb.) A.Chev.	6.27	1.63	7.90	3.71
39.	*Miliusa tomentosa* (Roxb.) J.Sinclair	6.06	1.58	7.63	3.59
40.	*Mitragyna parvifolia* (Roxb.) Korth	2.97	0.77	3.74	1.76
41.	*Phyllanthus emblica* L	0.64	0.17	0.80	0.38
42.	*Pterocarpus marsupium* Roxb	0.02	0.00	0.02	0.01
43.	*Schleichera oleosa* (Lour.) Merr	19.69	5.12	24.80	11.66
44.	*Soymida febrifuga* (Roxb.) A. Juss	5.22	1.36	6.58	3.09
45.	*Strychnos nux-vomica* L	1.03	0.27	1.30	0.61
46.	*Strychnos potatorum* L.f	0.06	0.02	0.08	0.04
47.	*Tamarindus indica* L	3.27	0.85	4.12	1.94
48.	*Tectona grandis* L.f	114.01	29.64	143.6 5	67.52
49.	*Terminalia bellirica* (Gaertn.) Roxb	0.10	0.03	0.13	0.06

50.	*Terminalia tomentosa* Wight &Arn	24.41	6.35	30.75	14.45
51.	*Wrightia tinctoria* R.Br	0.16	0.04	0.20	0.09
52.	*Ziziphus mauritiana* Lam	1.12	0.29	1.41	0.66
	Total	**313.33**	**81.47**	**394.79**	185.55

Where BA = Basal Area (m^2); V = Volume (m^3); AGB= Above Ground Biomass (kg); BGB= Below Ground Biomass (kg); TB= Total Biomass (kg) and C = Carbon stock (kg)

The growing stock estimation of the forest reveals that most of the trees fall in the DBH range of 10–20 cm, the carbon stock was determined for all of the DBH classes. The carbon stock estimation is limited to live tree biomass of the study. The AGB, BGB and biomass of the study area all of the tree species recorded was 3,13,329 kg (66,665.74kg ha^{-1}), 81,465.4 kg (17333.06 kg ha^{-1}) and 3,94,794 kg (83998.72 kg ha^{-1}) respectively.

The pattern of AGB for top five species in the tiger reserve are *Tectona grandis* (114008.89), *Chloroxylon swietenia* (26751.70), *Terminalia tomentosa* (24406.12), *Schleichera oleosa* (19685.00), and *Lannea coromandelica* (18196.22) and the total BGB was also reported to be from the top five species of same order as AGB respectively. The total Carbon stock estimation in the tiger reserve was calculated as 185553.20kg which is 39479.40kg ha^{-1}. The major contributed species for carbon stock in the tiger reserve were *Tectona grandis* (67516.06), followed by *Chloroxylon swietenia* (15842.36), *Terminalia tomentosa* (14453.30), *Schleichera oleosa* (11657.46), and *Lannea coromandelica* (10775.80) respectively (Table 3). The results suggest that *Tectona grandis*, which contributed 37% of the biomass and carbon stock, was the major contributor to the total biomass and carbon stock.

3.3 Diversity indices

Table 4. Density, basal area, and tree diversity indices of the Pench Tiger Reserve, Maharashtra.

Diversity indices	**Value**
Density (Stem ha^{-1})	433.75
Basal area (m^2 ha^{-1})	13.7
Simpson index (D)	0.10
Shannon-Weiner's index (H')	2.92

Species Evenness index	0.73
Margalef's diversity index (R)	6.83
Simpson's reciprocal index	9.62
Simpson index of diversity	0.89

The Simpson index in this area was 0.1039 following low dominance of the species in the study area. The Shannon-Wiener's diversity index in the area was 2.9209 indicating moderate diversity of trees, saplings, and herb layer in the forest. The various other indices have been shown in the table 4.

3.3.1 Structural composition based on diameter & height class distribution

The distribution of DBH classes shows that most of the trees (60.82%) belonged to DBH range 10-20 cm. which was dominated by *Tectona grandis*, *Chloroxylon swietenia* and *Lagerstroemia parviflora*. The number of species and tree individuals was found to decrease with increasing diameter with very little exception. Patterns of height (m) class distribution designate general trends of population dynamics and recruitment process [30]. 5-15 m height class distribution of tree individuals (87.61%) indicates stable population structure or good regeneration wealth in the reserve. That means, as the height class increases, the number of individuals and species are decreasing and indicates that old, mature trees are very scarce in the study area.

3.3.2 Species diversity of the regenerating classes

Table 5. Showing the diversity indices of plant species at different ages

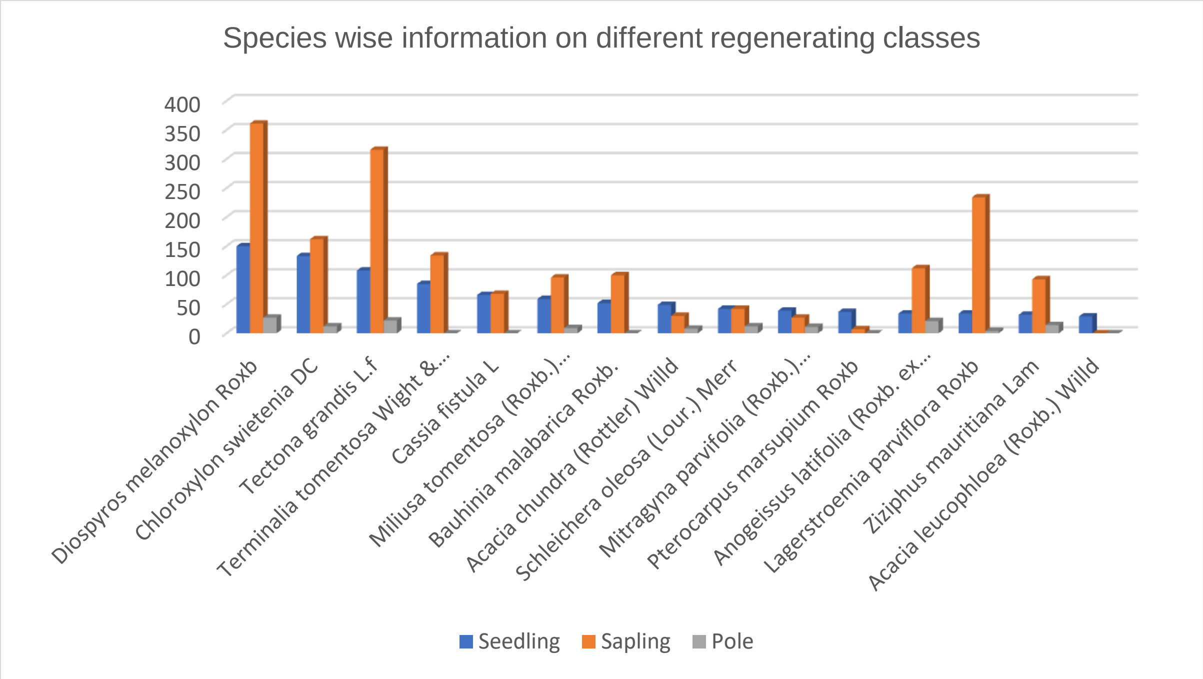
S.no.	Regeneration classes	Species richness	Simpson index	Shannon index	Margalef index	Evenness index
1	Seedling	744	0.052	3.16	4.88	0.88
2	Sapling	1699	0.059	3.21	5.57	0.84
3	Pole	163	0.071	2.73	3.35	0.93
4	Trees	1735	0.104	2.92	6.83	0.73

Natural regeneration is defined as the renewal of a forest crop by self-sown seeds or by coppice or root suckers. Regeneration is also a key process for the existence of species in a community/ecosystem under varied environmental conditions [31]. In forest management, regeneration study not only represent the current status but also indicant about the possible changes in forest composition in the future [32]. Native-species of forest regeneration has the potential to restore soil nutrients availability and cycling levels that were diminished after deforestation. In general, the presence of trees can increase the nutrient status of top soils via litter fall and through the promotion of more rapid decomposition processes, thereby accelerating nutrient cycling and increasing soil mineral nutrient availability [33].

Though, the sample sizes were different for trees, saplings and seedlings (spatial representation), different diversity indices of different regenerating classes have been provided for analysis. The highest number of individuals were observed in tree stand and more or less equivalent to number of saplings. The results show that the forest stand indicates the 1-9 cm diameter class were dominant. The values of Simpson index for different regenerating classes revealed that trees (0.104) show less diverse than other regenerating classes. The Shannon index of trees indicates less diversity among population than seedlings and samplings. The analysis of four different regenerating classes revealed that the future generation (sapling, seedlings & pole) may be much diverse than present generation (Table 5).

Graph 2 shows the species wise information on different regeneration classes such as seedling, sapling, and pole. The highest regeneration percentage was observed in the species *Diospyros melanoxylon* followed by *Tectona grandis, Chloroxylon swietenia, Lagerstroemia parviflora,* and *Terminalia tomentosa* with good regeneration percentage by tolerating varied adverse impacts (Graph 2).

Graph 2 Species wise information on different regenerating classes


Species wise information on different regenerating classes
400
350
300
250
200
150
100
50
0
Diospyros melanoxylon Roxb
Chloroxylon swietenia DC
Tectona grandis L.f
Terminalia tomentosa Wight &...
Cassia fistula L
Miliusa tomentosa (Roxb.)...
Bauhinia malabarica Roxb.
Acacia chundra (Rottler) Willd
Schleichera oleosa (Lour.) Merr
Mitragyna parvifolia (Roxb.)...
Pterocarpus marsupium Roxb
Anogeissus latifolia (Roxb. ex...
Lagerstroemia parviflora Roxb
Ziziphus mauritiana Lam
Acacia leucophloea (Roxb.) Willd
Seedling
Sapling
Pole

DISCUSSION

4.1 Tree species abundance

The species composition of Pench Tiger Reserve, Maharashtra found in 47 quadrats (52 were the tree species recorded of 102 total species including regeneration, belonging to 90 genera and 44 families) was higher than many tropical forests, i.e., 38 tree species in Ukhia Range of Cox's Bazar [34], 50 tree species belonging to 28 families in Ramprahar Natural Forest [35]. However, the tree species diversity was comparatively better and five major tree species were dominated and occupied majority of the forest stand. However, considering the results of these similar studies, it can be concluded that the Pench Tiger Reserve possesses relatively well-diversified natural forests with higher number of tree species.

The stem density (433.75 stems ha^{-1}) ranks highest in comparison to 381 stems ha^{-1} in Sitapahar reserve forest of Chittagong Hill Tracts (South) Forest Division [36]. 257 stems ha^{-1} in Ukhia Natural Forests of Cox's Bazar [34], 369 stems ha^{-1} (10 cm and above) in Bamu reserve forests of Cox's Bazar [37], but lower than 709 stems ha^{-1} in Tropical Forest of Eastern Ghats, India [38].

4.2 Basal area and diversity indices

The value of Basal area seems to better in tropical deciduous forests of Central India. The basal area (13.7 m^2 ha^{-1}) of the reserve was much lower than that of 53.5 m^2 ha^{-1} in Sitapahar reserve forests of Chittagong Hill Tracts (South) Forest Division [34]. or 47.02 - 62.16 m^2 ha^{-1} in Tankawati natural forest of Chittagong South Forest Division [39]. The Pench Tiger Reserve was situated in central tract of Indian forests and has sound quantity of basal area when compare to neighbouring occupied forests. The lower basal area indicates that the forest area was struggling from different factors like invasive species, light dependency, low fertile soil, other factors etc. which effect on forest stand growth. The values of Shannon–Wiener's diversity index (2.9209) and Species evenness index (0.73) of the reserve indicate effective and resulting in consideration of conservation and sustainable management of the area. The value of Margalef's diversity index (6.83) indicates proficient presence of tree species in the area. The value of Simpson's index (0.103) also indicates the less dominance of tree species.

4.3 Phytosociological characters of the tree species

The IVI value indicates a complete picture of phytosociological character of a species in the community [40]. The highest IVI was found for *Tectona grandis* (66.20), *Lagerstroemia parviflora*

(20.44), *Chloroxylon swietenia* (19.91), *Lannea coromandelica* (18.35), and *Terminalia tomentosa* (16.62). The IVI value of Teak indicates that the majority area of the tiger reserve in Maharashtra is either teak dominated forest or teak with miscellaneous forests. *Lagerstroemia parviflora*, *Chloroxylon swietenia*, *Lannea coromandelica*, and *Terminalia tomentosa* were considered to be important Teak associates and occupied 53.19% area of the reserve.

4.4 Carbon stock assessment

The carbon stock in this study ranged from 5.3 to 67516.06 kg, and the total carbon stock is 1,85,553.20 kg (39479.40 kg ha^{-1}). The findings of the present study are in good correlation with the average range of C stocks in tropical dry forests of India, which is 77,590 kg ha^{-1} [17]. Our results are on par with the reported values of C stock 18900–42800 kg ha^{-1} in selected tropical forest patches of Tripura, Northeast, India [41], in tropical deciduous forest ecosystems of Madhya Pradesh, India 1890–25,600kg ha^{-1} [42], in tropical dry deciduous forests, Haryana, India with 25,300–42,400 $kgha^{-1}$[43], 33,900–58,900kg ha^{-1}in tropical dry forests of Sivagangai district, Tamil Nadu [7]. The observed results, however, are lower than the values of 1,65,000 kg ha^{-1} in tropical deciduous and evergreen forests of the Western Ghats in India [44], 1,08,400 kg ha^{-1} in tropical forests of Malaysia [45], and in tropical dry deciduous *Boswellia* forest with 1,04,700 kg ha^{-1}. Variations in soil nutrient availability, moisture content, forest type, altitude, slope, aspect, precipitation, age, and stand girth class are all factors that affect the carbon stock in tropical forests [46].

4.5 Tree regeneration such as seedlings and samplings

The structure and species composition of future community could be indicated by the regeneration status of the tree species and their regenerating populations. The lower regeneration success of species *Boswellia serrata, Ficus racemosa, Firmiana simplex, Terminalia bellirica, Strychnos potatorum, Pterocarpus marsupium* and *Bridelia retusa* could possibly due to the lack of pollinators and vectors for seed dispersal [47, 48]. The forest fire and increase in herbivores populations might be influenced in regeneration status of the area.

5. CONCLUSIONS

The pattern of tree distribution and forest structure, which also determines the biomass and carbon stock pattern in the study area, are shown in the current study. According to the study, trees store a significant amount of carbon in their biomass, which significantly aids in carbon sequestration. Also, it has been noted how important *Tectona grandis* is for storing huge amounts of carbon, suggesting that planting teak trees in tropical forests might improve carbon mitigation. This study concludes that these woods have the ability to function as a carbon sink, and that good management and protection of the regeneration will result in the biodiversity conservation throughout the tiger reserve.

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