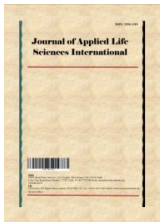

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Phytodiversity Analysis of Tree Species of Kuldiha Wildlife Sanctuary (KWLS), Odisha, India

R. Saravanan[1*], K. A. Sujana[1] and D. Kannan[2]

[1]Central Botanical Laboratory, Botanical Survey of India, Howrah 711103, West Bengal, India.
[2]Department of Botany, Thiagarajar College, Madurai, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author RS performed the field study, the statistical analysis and wrote the first draft of the manuscript. Author DK designed the study, managed the literature searches and wrote the protocol. Author KAS managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The study aimed to investigate tree diversity in Kuldiha wildlife sanctuary of Odisha. Twenty (20) plots of 100 sqm each were established in three different disturbed zones within the forest.
Methodology: Important quantitative analysis such as density, frequency and abundance of tree species were determined along with the diversity indices which would give a better understanding of the forest structure.
Results: The study revealed a total of 118 tree species of 95 genera distributed in 39 families, were recorded in the different study areas of the forest. From the distribution index it was seen that nearly 80% of the species showed contiguous distribution in the core area. The buffer zone exhibited maximum proportion of the species (25%) with random distribution. In tree species, the value of species richness (Dmg) was highest in core area (14.852) and lowest in periphery area (7.114). The value of species diversity (H') in tree species was highest in core area (4.332) and lowest in periphery area (3.115). Simpson index of dominance was calculated by using the important value of the plant species which showed minor variation within the study site. The value

**Corresponding author: E-mail: saravanan0311@gmail.com;*

of dominance (D) in tree species was found to be highest in core area 0.982) and lowest in periphery area (0.931).
Conclusion: The forest of KWLS harbours a rich diversity of flora and these diversity indices would give an important insight on laying the conservation strategies in this forest.

Keywords: Kuldiha Wildlife Sanctuary (KWLS); Odisha; tree species diversity; disturbance zones.

1. INTRODUCTION

Tropical forest plant diversity mainly focuses on trees [1]. Diversity of tree species takes pivotal role in determining diversity of forest ecosystem [2]. At the same time distribution of trees is also a key element of forest diversity [3]. Decline in global biodiversity is an immediate result of loss of tropical forest. Both natural and human disturbances influence forest dynamics and tree diversity at local and regional scales [4,5,6] and affect ecosystem stability [7]. The anthropogenic disturbances greatly affect the biodiversity and structural characteristics of a community [8,9]. Since trees are fundamental structure of a tropical forest [10], as well an identifying feature of vegetation types, continuous monitoring and management is essential towards maintaining species and habitat diversity [11,12]. Phytosociological studies determine the distribution pattern of individual plant species in a particular habitat as well as, it is an indication of the degree of plant diversity. Phytosociological studies in forest help to understand forest dynamics, and also an essential tool to assess the effects of disturbance and climate change on plant diversity [13,14,15]. Thus quantitative floristic analysis aids the planning of further ecological research and interpreting the effect of disturbances [16]. The development of inventories to provide information on diversity as well as distribution of stand structure of a forest will be an important tool to maximize biodiversity conservation that results from deforestation and degradation and sustainable utilization [17].

Phytosociological analysis is important to understand the functioning of any community [18]. The present investigation, attempts to analyze the impact of human interference in the structure of tree communities, composition and diversity of tropical forest of Kuldiha Wildlife Sanctuary, which will help in conservation and sustainable utilization of forest vegetation in future.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

Kuldiha forest land was designated as kuldiha wildlife sanctuary (KWLS) on 04 Jan. 1984; KWLS is situated in the southern part of the district of Balasore of Odisha State, lies between 21º 20' 31" to 21º 29' 08" N latitude and 86º 25' 23" to 86º 44' 50"E longitude 169 m above sea level (Fig. 1).

The sanctuary spreads to an area of 272.75 square kilometers. The forests of the region cover the Nato Hills and the Sukhupata Hills merging with the Similipal National Park, Odisha. It lies close to Nilgiri forest, Balasore district, Odisha towards north and Mayurbhanj forest, Odisha in northwest. Through Gadasahi forests on the south west, Kuldiha have a disjointed link with Baula RF. Some prominent hills that form the landscape include the centrally located Asta Pahar (423 m) Devgiri Pahar (682 m) in south; Ranga matia (629 m) in north; Kolia Parbat (495 m) in east. Ecoclimate is wet and humid with an average annual rainfall of 1,568 mm; mean annual temperature ranges from 130 – 360C. The maximum and minimum relative humidity is 88% and 62% respectively. Three small rivers, Tangna, Kamala and Usatalnala are the main water sources of the sanctuary with tributaries to the rivers. According to Champion and Seth [19] the forest harbours vegetations characteristic of tropical deciduous forest dominated mostly by *Shorea robusta*, but in particular it is intermediate between dry deciduous and moist peninsular type. The lower elevation is predominant with Shorea robusta, but it does not occur in pure formation. It occurs in association with other plant species such as *Anogeissus latifolia, Bombax ceiba, Bridelia retusa, Buchanania lanzan, Chloroxylon swietenia, Dalbergia latifolia, Diospyros melanoxylon, Gardenia latifolia, Haldinia cordifolia, Kydia calycina* and others.

2.3 Quantitative Analysis

The entire study area was divided into three study sites on the basis of disturbance gradient i.e. periphery area, buffer area and core area for studying the status of plant diversity and community structures. Table 1 provides the details of geographical location and altitude of the study sites.The study was carried out during rainy season when majority of the plants were at the peak of their growth. In every study site, 20

quadrates of 10 m X 10 m (100 sq m) size were randomly laid to survey tree species. The tree species include all the saplings, poles and trees present in the study area. The voucher specimens were identified using regional floras Flora of British India [20,21,22] and were confirmed using herbarium specimens available at Central National Herbarium (CAL). The nomenclatures were further verified using International Plant Name Index [23].

Table 1. Location of prominent structures shown as waypoints with their GPS details of experimental area of KWLS

Name of the Waypoint	Latitude	Longitude	Altitude (M)
Ampada	N 21^{0}24’16’’	E 86^{0}35’25’’	250
Ampada Pond	N 21°24'28"	E 086°35'20"	317
Ampada Nala	N 21^{0}24’23’’	E 86^{0}35’21’’	240
Andheri Nala	N 21°24'22"	E086°35'18"	220
Ashunchua	N 21^{0}24’19’’	E 86^{0}34’13’’	244
Bagudi- Mine area	N 21°21'05"	E 086°39'34"	107
Bhaibhoni Ghatti	N 21°23'57"	E 086°35'35"	320
Bonun Chowk	N 21°25'06"	E 086°34'43"	292
Bulagadia	N 21°20'38"	E 086°42'06"	17
Champo- Soro	N 21°21'05"	E 086°40'38"	80
Guajhari Nala	N 21°24'21"	E 086°35'35"	252
Guajhari Nuarasta	N 21^{0}23’44’’	E 86^{0}35’26’’	282
Guajhari Pahad	N 21^{0}23’44’’	E 86^{0}35’28’’	326
Gudisai	N 21°24'27"	E 086°43'28"	93
Haathikulia	N 21°23'47"	E 086°39'49"	61
Haathikulia Dam-Road	N 21°24'06"	E 086°39'53"	73
Jodachua	N 21^{0}24’04’’	E 86^{0}35’00’’	242
Jodachua beat Chowk	N 21°24'10"	E 086°34'53"	294
Jodachua F.R.H	N 21°24'06"	E 086°34'58"	223
Jodachua Gate	N 21^{0}24’02’’	E 86^{0}35’00’’	255
Jodachua Ghatti	N 21°24'34"	E 086°34'55"	342
Kanchipaani	N 21°23'52"	E 086°34'35"	305
Kenduna	N 21°24'33"	E 086°43'28"	64
Koimutiya	N 21°24'19"	E 086°43'28"	88
Kuldiha beat Rasta	N 21°24'50"	E 086°36'10"	286
Kuldiha FRH	N 21^{0}22’44’’	E 86^{0}34’26’’	272
Kuldiha Pahad	N 21^{0}24’00’’	E 86^{0}35’36’’	278
Kuldiha-Balianal	N 21°27'19"	E 086°37'05"	108
Nanadgutta Rasta	N 21^{0}24’35’’	E 86^{0}34’54’’	251
Nandugutta	N 21^{0}23’38’’	E 86^{0}34’13’’	257
Nilgiri Rasta	N 21°24'43"	E 086°44'49"	38
Nuarasta Chowk	N 21°24'29"	E 086°35'43"	231
Nuasai	N 21°24'27"	E 086°43'39"	67
Nuasai	N 21°24'25"	E 086°43'40"	63
Pahadi Rasta	N 21°24'15"	E 086°35'38"	311
Panchalingeshwar	N 21°24'39"	E 086°43'11"	148
Panchalingeshwar Pahad Top	N 21°24'38"	E 086°43'17"	210
Panchalingeswar Pahad	N 21°24'39"	E 086°43'10"	163
Pancharjuna Pond	N 21°24'52"	E 086°34'16"	296
Panjarjuna Rasta	N 21^{0}24’49’’	E 86^{0}34’22’’	202
Parchondi	N 21°24'25"	E 086°43'20"	98
Rangamatia	N 21°22'42"	E 086°40'02"	123
Salt peat Rasta	N 21°24'17"	E086°35'15"	192

KWLS: Kuldiha wildlife Sanctuary

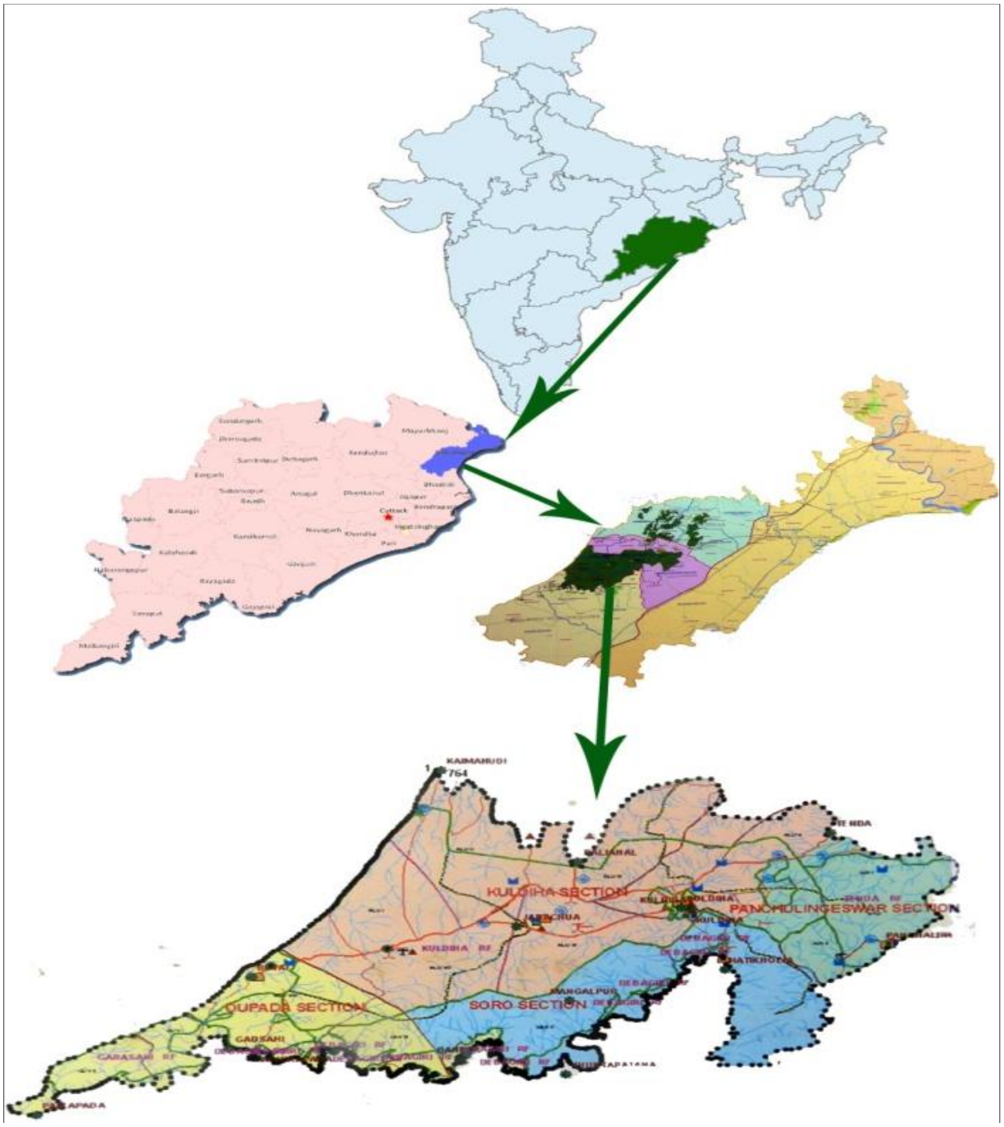

Fig. 1. Map showing the study location

The important quantitative analysis such as density (Total number of individuals of a species in all quadrats/ Total number of quadrats studied), frequency (Total number of quadrats in which the species occurred/Total number of quadrats studied) and abundance (Total number of individuals of a species in all quadrats/Total number of quadrats in which the species occurred) of tree species were determined as per Curtis and McIntosh [24]. Distributional Index (DI) was calculated as the ration between abundance and frequency.

$$DI = \frac{\text{Abundance}}{\text{Frequency}}$$

2.4 Importance Value Index (IVI)

This index was used to determine the overall importance of each species in the community structure. In calculating this index, the percentage values of the relative frequency, relative density and relative dominance were summed up together and this value was designated as the Importance Value Index or IVI of the species [25].

IVI = FREQsp + DENSsp + DOMsp

FREQsp = Relative frequency, DENSsp= Relative density, DOMsp= Relative dominance.

Relative density is the study of numerical strength of a species in relation to the total number of individuals of all the species (Number of individual of the species/ Number of individual of all the species×100). Relative frequency is the degree of dispersion of individual species in an area in relation to the number of all the species occurred (Number of occurrence of the species/ Number of occurrence of all the species×100). Dominance of a species is determined by the value of the basal cover. Relative dominance is the coverage value of a species with respect to the sum of coverage of the rest of the species in the area (Total basal area of the species/ Total basal area of all the species×100). The total basal area was calculated from the sum of the total diameter of immerging stems. In trees, poles and saplings, the basal area was measured at breast height (1.3 m) and by using the formula πr^2 (where r = radius derived from gbh).

2.5 Similarity and Dissimilarity Indices

Indices of similarity and dissimilarity were calculated by using formulae as per Misra [26] and Sorensen [27] as follows:

Index of similarity (S) = 2C/A+B

Where,

A= Number of species in the community A
B = Number of species in the community B
C= Number of common species in both the communities.

Index of dissimilarity = 1-S

2.6 Species Richness, Diversity and Dominance Indices

The species richness, diversity and dominance indices were determined using the following methods:

2.6.1 'Margalef's index of richness'

The species richness of the vascular plants was calculated by using the method 'Margalef's index of richness' (Dmg) [28] .

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

Where,

S = Total number of species.
N = Total number of individuals.

2.6.2 Shannon–weaver index of diversity

The formula for calculating the Shannon diversity [29] index was.

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

Where,

H' = Shannon index of diversity
pi = the proportion of important value of the i^{th} species (pi = ni/N, ni is the important value index of i^{th} species and N is the important value index of all the species).

2.6.3 Simpson index of dominance

The equation used to calculate Simpson's index [30] was

$$D = \Sigma \, (pi)^2$$

Where,

D = Simpson index of dominance
pi = the proportion of important value of the i^{th} species (pi = ni/N, ni is the important value index of i^{th} species and N is the important value index of all the species).

As D increases, diversity decreases and Simpson's index was therefore usually expressed as 1 – D or 1/ D.

3. RESULTS AND DISCUSSION

Phyto-sociological data help in understanding forest structure. The population dynamics, forest composition and structure are an indication of the degree of disturbance and factors that influence in change of forest structure. Trees are the basis of tropical forest ecosystem and are therefore the important indicator of abiotic or biotic changes of the forest. During the study period, a total of 118 tree species of 95 genera distributed in 39 families, were recorded in the different study areas of the forest. The findings of this study are in accordance with that of different ecosystems under tropical climates. Studies of Thakur [31] in tropical dry deciduous forest in Sagar district, Madhya Pradesh reported a total of 36 trees, 8 shrubs and 34 herbs. Similarly, tree species diversity in Hulikal state forest was reported to be 96 [32]. A total of 3.9% area has been shown by geospatial modelling to cover with very high plant richness, followed by high (21%), medium (42%) and low (32.8%) in the sanctuary [33].

The vegetation in the district ranges from tropical semi-evergreen to dry-deciduous to grasslands with varying species composition.

3.1 Community Structure Analysis

A major portion of the KWLS is represented by tropical decidous forest with large number of tree species. Therefore, a community structure study has been initiated for the tree species of this region. The community structure recorded and analyzed at three different levels based on human interference, core zone, buffer zone and peripheral zone. Density, Frequency and abundance were the three important quantitatve parameters used to describe the general nature of vegetation. Density is numerical strength of a species in a community and relates to the counting of individuals per unit area. Frequency is the measure of degree of dispersion of individual species in an area. Abundance is also a measure of dominance represented as no. of species per no. of quadrates studied. Importance Value Index (IVI) expresses dominance and ecological success of any species.

In the peripheral zone a total of 35 tree species were identified. The density ranged between 142 to 3428 individuals/ ha (Table 2). In the buffer zone a total of 63 tree species were identified. The density ranged between 166 to 2333 individuals/ ha (Table 3). In the core zone, a total of 105 tree species were identified. In the buffer zone a total of 63 tree species were identified. The density ranged between 90 to 4363 individuals/ ha (Table 4). Tree density studied in the different tropical forest was observed to range between 550-1800 individuals/ ha [34] and in neotropical dry forests the tree density was 3700 individuals/ ha [35]. In a study on Simlipal biospere reserve [36], the tree density ranged from 650 to 970 individuals/ ha, which was comparable to the present data recorded in this study. Tree density were higher in the core area (undisturbed sites) compared to buffer or periphery area (disturbed sites).

Conglomeration of varied species contributes the composition of the forest and hence its type. The distribution of the species depends on various factors, like seed dispersal, microclimate, and other biotic factors. Frequency measures the uniformity of the distribution of a particular species. Species exhibiting a low frequency indicates its irregular distribution or rarity in the forest [37]. The high percentage frequency indicates its continuous distribution as well as its wide range of niche preferences and capability to establish over a large area. Frequency of the tree species like *C. persimilis*, *S. robusta* and *G. lanceolarium* were found to be 100% in the peripheral area. However, the most abundant tree species was *C. persimilis* (4.800) followed by *C. digyna* (4.000), *Z. oenopolia* (4.000), *S. cumini* (3.667) and *S. colais* (3.200) (Table 2). Frequency of the tree species like *C. persimilis*, *H. pubescens and M. peltata* were found to be 100% in the buffer zone, whereas, the most abundant tree species was *S. robusta* (8.000) followed by *T. crenulata* (7.000), *M. peltata* (6.400) and *P. pinnata* (5.000) (Table 3). Frequency of the tree species like *S. cumini* (81.818), *C. graveolens* (72.727%) and *C. coromandelicum* (72.727%) were found to be high in the core zone. The most abundant tree species was *S. robusta* (35.428) followed by *M. ovatum* (17.000) (Table 4).

The importance value index (IVI) depicts the importance of the species in terms of its dominance and ecological success [38]. The IVI of *Shorea robusta* (55.647), *Croton persimilis* (29.870), *Diospyros melanoxylon* (26.102), *Syzygium cumini* (17.157) and *Glochidion lanceolarium* (14.930) were noted to be highest in the periphery area (Table 2). The IVI of *Diospyros malabarica* (21.161), *Macaranga peltata* (16.645), *Holarrhena pubescens* (12.128) and *Melia azedarach* (10.306) were noted to be highest in the buffer area (Table 3). The IVI of *Shorea robusta* (9.802) and *Sterculia guttata* (12.199) were noted to be highest in the core area (Table 4). Importance value index of *Shorea robusta* in the present study area ranged from 9.802 to 55.647 which were comparable with the IVI of 37 to 149 for *Shorea robusta* from Simlipal Biosphere Reserve [36]. The IVIs of the dominant species increased from the undisturbed to the highly disturbed stand, which was in conformity with the findings of Visalakshi [34], Kadavul and Parthasarathy [39], and others who studied the forests of peninsular India. The change in IVI among the study sites can be attributed to the change in species composition and degree of disturbance and altitude [40]. Dry deciduous forest of Boudh district, Odisha was also dominated by *Shorea robusta* with IVI of 43 [41]. The other plants with high IVI in the core area included *Mangifera indica* (8.859) and *Croton persimilis* (7.706) (Table 4).

Whitford [42] first demonstrated the distribution pattern of species as contiguous, random and

regular, based on the abundance and frequency. From the distribution index it was seen that nearly 80% of the species showed contiguous distribution in the core area. The buffer zone exhibited maximum proportion of the species (25%) with random distribution. Odum [43] opined that under natural conditions, a contiguous distribution of plants is normal. Random distribution is experienced in uniform environment and regular distribution occurs where severe competition exists between individuals. Regularly distributed species were least in all the studied zones (Fig. 2). High degree of contiguous distribution in the core area was an indication of stability of the ecosystem. A higher degree of random distribution of species was an evidence of uniformity of the environment in the buffer and periphery zone which may be due to disturbances such as grazing and felling in the natural forest.

Table 2. Density, frequency, abundance and IVI of tree species in the periphery area of KWLS

S. No.	Name of the Species	Density (species/ ha)	Frequency (%)	Abundance	IVI
1	*Aegle marmelos*	142.857	14.286	1.000	3.803
2.	*Antidesma acidum*	285.714	14.286	2.000	5.043
3	*Antidesma ghaesembilla*	142.857	14.286	1.000	8.063
4	*Caesalpinia dygyna*	571.429	14.286	4.000	5.155
5	*Canthium coromandalicum*	285.714	28.571	1.000	5.124
6	*Careya arborea*	285.714	14.286	2.000	3.656
7	*Casearia graveolens*	428.571	42.857	1.000	7.845
8	*Cassia fistula*	285.714	14.286	2.000	12.657
9	*Clerodendrum indicum*	142.857	14.286	1.000	2.620
10	*Croton persimilis*	3428.571	71.429	4.800	29.724
11	*Dalbergia latifolia*	428.571	28.571	1.500	7.709
12	*Diospyros melanoxylon*	428.571	28.571	1.500	26.043
13	*Flacourtia indica*	142.857	14.286	1.000	3.019
14	*Getonia floribunda*	142.857	14.286	1.000	2.556
15	*Glochidion lanceolarium*	857.143	71.429	1.200	14.784
16	*Holarrhena pubescens*	714.286	42.857	1.667	9.725
17	*Litsea glutinosa*	142.857	14.286	1.000	2.816
18	*Litsea monopetala*	142.857	14.286	1.000	2.583
19	*Macaranga peltata*	857.143	28.571	3.000	8.875
20	*Miliusa tomentosa*	142.857	14.286	1.000	3.956
21	*Mitragyna parvifolia*	285.714	28.571	1.000	5.870
22	*Ochna obtuse*	285.714	14.286	2.000	4.017
23	*Pavetta indica*	142.857	14.286	1.000	2.974
24	*Phyllanthus emblica*	285.714	14.286	2.000	4.007
25	*Polyalthia cerasoides*	142.857	14.286	1.000	2.693
26	*Psychotria adenophylla*	285.714	14.286	2.000	3.383
27	*Schleichera oleosa*	142.857	14.286	1.000	8.540
28	*Shorea robusta*	2285.714	71.429	3.200	55.501
29	*Sterospermum colais*	428.571	28.571	1.500	11.284
30	*Syzygium cumini*	1571.429	42.857	3.667	17.070
31	*Tamilnadia uliginosa*	142.857	14.286	1.000	5.277
32	*Terminalia arjuna*	142.857	14.286	1.000	2.891
33	*Terminalia bllirica*	142.857	14.286	1.000	2.721
34	*Ziziphus jujube*	142.857	14.286	1.000	2.899
35	*Ziziphus oenoplia*	571.429	14.286	4.000	5.119

KWLS: Kuldiha Wildlife Sanctuary, IVI: Importance value index

Table 3. Density, frequency, abundance and IVI of tree species in the buffer area of KWLS

S. No.	Name of the species	Density (species/ ha)	Frequency (%)	Abundance	IVI
1	*Barringtonia acutangula*	333.333	16.667	2.000	6.710
2	*Briedelia retusa*	166.667	16.667	1.000	1.399
3	*Bombax ceiba*	166.667	16.667	1.000	5.127
4	*Caesalpinia digyna*	166.667	16.667	1.000	1.490
5	*Canthium coromandalicum*	833.333	33.333	2.500	4.855
6	*Careya arborea*	1833.333	66.667	2.750	8.731
7	*Casearia graveolens*	166.667	16.667	1.000	1.779
8	*Cassia fistula*	166.667	16.667	1.000	2.621
9	*Chionanthus ramiflorus*	166.667	16.667	1.000	3.104
10	*Cleistanthus collinus*	833.333	16.667	5.000	3.318
11	*Combretum latifolium*	1166.667	66.667	1.750	6.511
12	*Cosmostigma cordatum*	333.333	16.667	2.000	1.855
13	*Croton persimilis*	1000.000	83.333	1.200	7.987
14	*Dalbergia latifolia*	1166.667	50.000	2.333	7.278
15	*Dalbergia volubilis*	666.667	16.667	4.000	3.053
16	*Diospyros montana*	166.667	16.667	1.000	21.161
17	*Diospyros sylvatica*	666.667	50.000	1.333	5.660
18	*Entada rheedei*	166.667	16.667	1.000	4.906
19	*Getonia floribunda*	1166.667	50.000	2.333	6.366
20	*Glycosmis pentaphylla*	333.333	33.333	1.000	2.473
21	*Haldinia cordifolia*	166.667	16.667	1.000	1.314
22	*Hedyotis neesiana*	166.667	16.667	1.000	1.808
23	*Holarrhena pubescens*	3166.667	83.333	3.800	12.128
24	*Holoptelea integrifolia*	166.667	16.667	1.000	1.416
25	*Hymenodictyon orixense*	166.667	16.667	1.000	1.262
26	*Jasminum scandens*	333.333	33.333	1.000	2.644
27	*Lagerstroemia parviflora*	333.333	33.333	1.000	6.642
28	*Leea indica*	333.333	33.333	1.000	2.594
29	*Litsea glutinosa*	333.333	33.333	1.000	3.174
30	*Macaranga peltata*	5333.333	83.333	6.400	16.645
31	*Melia azedarach*	666.667	66.667	1.000	10.306
32	*Madhuca longifolia*	166.667	16.667	1.000	5.509
33	*Miliusa tomentosa*	500.000	50.000	3.000	3.684
34	*Millettia racemosa*	333.333	33.333	1.000	2.610
35	*Mitragyna parvifolia*	166.667	16.667	1.000	1.930
36	*Ochna obtusata*	666.667	33.333	2.000	3.732
37	*Phanera vahlii*	333.333	33.333	1.000	3.310
38	*Polyalthia cerasoides*	833.333	66.667	1.250	5.528
39	*Pongamia pinnata*	833.333	16.667	5.000	4.591
40	*Premna tomentosa*	166.667	16.667	1.000	1.470
41	*Pterospermum acerifolium*	1000.000	33.333	3.000	4.324
42	*Schleichera oleosa*	833.333	66.667	1.250	7.174
43	*Shorea robusta*	5333.333	66.667	8.000	17.558
44	*Sterculia guttata*	166.667	16.667	1.000	6.585
45	*Sterospermum colais*	500.000	16.667	3.000	2.185
46	*Streblus asper*	166.667	16.667	1.000	1.531
47	*Strobilanthes scaber*	166.667	16.667	1.000	1.281
48	*Strychnos potatorum*	333.333	16.667	2.000	1.665
49	*Suregada multiflora*	166.667	16.667	1.000	3.962
50	*Syzygium cumini*	1500.000	66.667	2.250	9.098
51	*Syzygium nervosum*	666.667	33.333	2.000	3.431
52	*Terminalia bellirica*	666.667	50.000	1.333	5.254
53	*Terminalia alata*	2333.333	33.333	7.000	8.447

S. No.	Name of the species	Density (species/ ha)	Frequency (%)	Abundance	IVI
54	*Terminalia chebula*	166.667	16.667	1.000	7.214
55	*Trema orientale*	333.333	33.333	1.000	3.617
56	*Trevia nudiflora*	500.000	16.667	3.000	2.668
57	*Uvaria hamiltonii*	166.667	16.667	1.000	2.135
58	*Ventilago maderaspatana*	166.667	16.667	1.000	1.868
59	*Vitex altissima*	666.667	50.000	1.333	5.132
60	*Vitex pinnata*	166.667	16.667	1.000	1.996
61	*Wrightia arborea*	166.667	16.667	1.000	1.575
62	*Xantolis tomentosa*	166.667	16.667	1.000	1.399
63	*Ziziphus oenoplia*	166.667	16.667	1.000	1.224

KWLS: Kuldiha Wildlife Sanctuary, IVI: Importance value index

Table 4. Density, frequency, abundance and IVI of tree species in the core area of KWLS

S. No.	Name of the species	Density (species/ ha)	Frequency (%)	Abundance	IVI
1	*Acronychia pedunculata*	181.818	18.182	1.000	1.706
2	*Aegle marmelos*	181.818	18.182	1.000	1.434
3	*Anogeissus latifolia*	181.818	18.182	1.000	2.186
4	*Albizia lebbeck*	363.636	27.273	1.333	1.934
5	*Albizia odoratissima*	90.909	9.091	1.000	1.233
6	*Anacardium occidentale*	272.727	9.091	3.000	0.689
7	*Anodendron paniculatum*	181.818	18.182	1.000	0.828
8	*Antidesma acidum*	1090.909	36.364	3.000	2.979
9	*Antidesma bunius*	272.727	18.182	1.500	1.069
10	*Antidesma ghaesembilla*	2181.818	27.273	8.000	3.624
11	*Barringtonia acutangula*	1272.727	9.091	14.000	2.726
12	*Bombax ceiba*	181.818	18.182	1.000	3.020
13	*Briedelia retusa*	454.545	27.273	1.667	4.965
14	*Caesalpinia digyna*	272.727	27.273	1.000	1.294
15	*Canthium coromandelicum*	2181.818	72.727	3.000	5.097
16	*Canthium glabrum*	363.636	18.182	2.000	1.133
17	*Careya arborea*	4000.000	54.545	7.333	6.372
18	*Casearia graveolens*	2090.909	72.727	2.875	4.767
19	*Cassia fistula*	1000.000	63.636	1.571	3.711
20	*Catunaregam spinosa*	1363.636	45.455	3.000	3.175
21	*Celastrus paniculatus*	363.636	27.273	1.333	1.426
22	*Ceriscoides turgida*	636.364	18.182	3.500	1.645
23	*Chionanthus ramiflorus*	90.909	9.091	1.000	1.365
24	*Chionanthus zeylanicus*	272.727	9.091	3.000	4.214
25	*Cissus latifolia*	545.455	36.364	1.500	2.055
26	*Cleistanthus collinus*	2545.455	27.273	9.333	3.775
27	*Cleistanthus patulus*	909.091	18.182	5.000	1.735
28	*Clerodendrum indicum*	909.091	27.273	3.333	1.889
29	*Cochlospermum religiosum*	90.909	9.091	1.000	0.849
30	*Combretum latifolium*	4363.636	45.455	9.600	6.332
31	*Croton persimilis*	6181.818	63.636	9.714	8.518
32	*Dalbergia lanceolaria*	90.909	9.091	1.000	1.331
33	*Dalbergia latifolia*	3545.455	63.636	5.571	6.416
34	*Dalbergia sissoo*	454.545	18.182	2.500	1.852
35	*Dalbergia volubilis*	2818.182	54.545	5.167	5.238
36	*Dillenia aurea*	454.545	18.182	2.500	2.081
37	*Dillenia pentagyna*	454.545	27.273	1.667	4.045
38	*Diospyros ebenum*	272.727	9.091	3.000	1.616

S. No.	Name of the species	Density (species/ ha)	Frequency (%)	Abundance	IVI
39	*Diospyros melanoxylon*	363.636	18.182	2.000	2.409
40	*Diospyros montana*	181.818	18.182	1.000	1.073
41	*Diospyros sylvatica*	363.636	18.182	2.000	1.644
42	*Entada rheedei*	181.818	18.182	1.000	4.921
43	*Erycibe paniculata*	90.909	9.091	1.000	0.543
44	*Erythrina stricta*	272.727	9.091	3.000	2.494
45	*Flacourtia indica*	90.909	9.091	1.000	0.543
46	*Gardenia gummifera*	363.636	9.091	4.000	0.741
47	*Getonia floribunda*	272.727	18.182	1.500	1.582
48	*Glochidion lanceolarium*	2727.273	36.364	7.500	4.075
49	*Grewia tiliifolia*	181.818	18.182	1.000	2.311
50	*Haldinia cordifolia*	727.273	36.364	2.000	2.438
51	*Helicteres isora*	1090.909	18.182	6.000	1.874
52	*Holarrhena pubescens*	2090.909	45.455	4.600	4.113
53	*Hymenodictyon orixense*	90.909	9.091	1.000	0.896
54	*Ixora brachiata*	636.364	9.091	7.000	0.965
55	*Kydia calycina*	363.636	18.182	2.000	2.061
56	*Lagerstroemia parviflora*	181.818	9.091	2.000	0.598
57	*Litsea glutinosa*	181.818	18.182	1.000	0.905
58	*Macaranga peltata*	4727.273	63.636	7.429	7.005
59	*Madhuca longifolia*	1454.545	54.545	2.667	4.352
60	*Mallotus philippensis*	272.727	27.273	1.000	1.347
61	*Mangifera indica*	363.636	18.182	2.000	8.806
62	*Melia azedarach*	272.727	18.182	1.500	2.909
63	*Melastoma malabathricum*	1454.545	18.182	8.000	2.121
64	*Memecylon edule*	1545.455	9.091	17.000	2.196
65	*Millettia racemosa*	454.545	36.364	1.250	1.881
66	*Miliusa tomentosa*	454.545	36.364	1.250	1.872
67	*Mitragyna parvifolia*	1272.727	72.727	1.750	4.487
68	*Ochna obtusata*	181.818	18.182	1.000	1.355
69	*Olax scandens*	545.455	27.273	2.000	2.867
70	*Oroxylum indicum*	272.727	27.273	1.000	1.899
71	*Pavetta indica*	90.909	9.091	1.000	0.418
72	*Phanera vahlii*	363.636	27.273	1.333	2.854
73	*Phyllanthus emblica*	1545.455	63.636	2.429	3.960
74	*Polyalthia cerasoides*	1090.909	36.364	3.000	3.650
75	*Pongamia pinnata*	363.636	9.091	4.000	4.715
76	*Premna tomentosa*	181.818	18.182	1.000	1.579
77	*Psydrax dicoccos*	545.455	18.182	3.000	1.513
78	*Pterocarpus marsupium*	272.727	27.273	1.000	2.851
79	*Pterospermum acerifolium*	909.091	45.455	2.000	3.260
80	*Salacia chinensis*	90.909	9.091	1.000	0.427
81	*Schleichera oleosa*	1363.636	54.545	2.500	3.634
82	*Shorea robusta*	7454.545	63.636	11.714	10.782
83	*Smilax lanceifolia*	90.909	9.091	1.000	0.433
84	*Sterculia guttata*	272.727	27.273	1.000	12.235
85	*Sterospermum colais*	90.909	9.091	1.000	0.741
86	*Strychnos potatorum*	636.364	27.273	2.333	1.699
87	*Suregada multiflora*	272.727	18.182	1.500	1.164
88	*Symplocos racemosa*	545.455	9.091	6.000	0.878
89	*Syzygium cumini*	3454.545	81.818	4.222	7.306
90	*Syzygium nervosum*	90.909	9.091	1.000	6.386
91	*Terminalia alata*	3727.273	45.455	8.200	6.207

S. No.	Name of the species	Density (species/ ha)	Frequency (%)	Abundance	IVI
92	*Terminalia arjuna*	272.727	18.182	1.500	1.372
93	*Terminalia bellirica*	1454.545	63.636	2.286	4.601
94	*Trema orientale*	181.818	18.182	1.000	2.578
95	*Uvaria eucincta*	90.909	9.091	1.000	0.433
96	*Ventilago maderaspatana*	272.727	18.182	1.500	1.611
97	*Vitex pinnata*	2454.545	63.636	3.857	5.536
98	*Wrightia arborea*	727.273	18.182	4.000	1.602
99	*Xantolis tomentosa*	90.909	9.091	1.000	0.761
100	*Ziziphus funiculosa*	90.909	9.091	1.000	2.459
101	*Ziziphus jujube*	272.727	27.273	1.000	2.148
102	*Ziziphus oenoplia*	545.455	45.455	1.200	2.242

KWLS: Kuldiha Wildlife Sanctuary, IVI: Importance value index

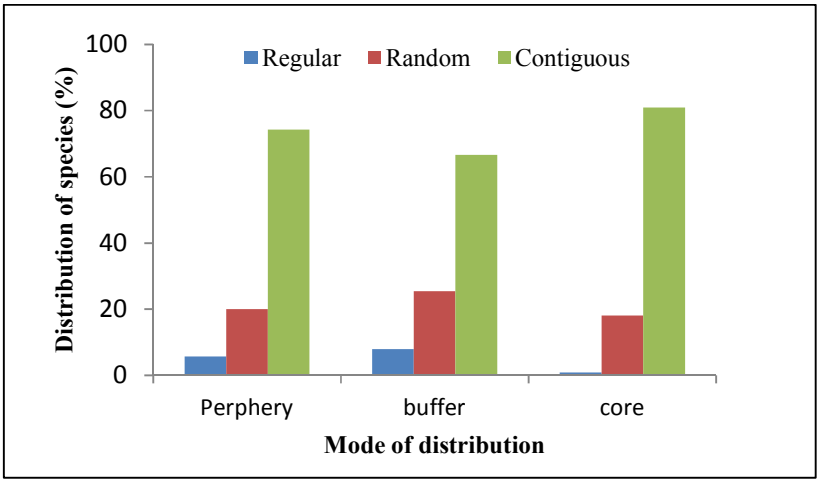

Fig. 2. Distributional pattern of species with respect to three zones in KWLS

3.2 Sorensen's index of similarity (S)

Sorensen's similarity index was used to compare the associations with similar associations studied near the research area. In the present study, Sorensen's index of similarity (IS) among the three study sites varied between 5.254 % and 11.018%. The value of similarity (IS) of the tree species between periphery and buffer region was found to be highest (11.018%) followed by the value (7.211%) between buffer and core region (Table 5).

Table 5. Matrix of similarity (Sorensen's Index) between three zones in KWLS

	Periphery	Buffer	Core
Periphery	100	11.081	5.254
Buffer		100	7.211
Core			100

KWLS: Kuldiha Wildlife Sanctuary

This low value of similarity can be attributed to the varying degree of disturbances between the core and the periphery area. The microclimate, soil characteristics, presence of other species, productivity and competition might have contributed to the variation species similarity between the study sites [44]. A low degree of similarity was also observed in a study of community conserved forest and traditionally conserved forest of central Himalya [45].

3.3 Species Richness, Diversity and Dominance Indices

The species richness index is given as a function of the total number of species and the total number of individuals in the given area. The higher the value of different species, the greater will be the value of the species richness. In tree species, the value of species richness (Dmg) was highest in core area (14.852) and lowest in periphery area (7.114) (Table 6). The Margalef index falls within the range of 4.54-23.41 for tropical forests reported by earlier workers [46,47,48].

Table 6. Floristic richness, diversity, richness and dominance index in three zones of KWLS

	Periphery	Buffer	Core
Total number of species (S)	35	63	105
Total number of individuals (N)	119	260	1099
Margalef's richness (Dmg)	7.114	11.149	14.852
Shannon index of diversity (H')	3.115	3.866	4.332
Simpson index of dominance (D)	0.931	0.974	0.982

KWLS: Kuldiha Wildlife Sanctuary

The higher value of the diversity indices is an obvious indication of high tree species diversity and abundance [49]. Shannon's diversity index was calculated on the basis of important values. The value of species diversity (H') in tree species was highest in core area (4.332) and lowest in periphery area (3.115) (Table 6). This diversity index of tree species is comparable to that found in the tropical forest of Eastern Ghats, Andhra Pradesh ranging between 3.76 - 3.96 [50]. The value of Shannon Wiener's index for tree species in Simlipal Biosphere Reserve was in the range of 1.80 - 3.11 [36] which is lower than the value obtained from this study. The value of Diversity index for Indian forests is in the range of 0.8 to 4.1 [51,52]. The diversity values of tree species obtained in the present study is comparable to the reported range of Indian tropical forests.

Simpson index of dominance was calculated by using the important value of the plant species which showed minor variation within the study site. The value of dominance (D) in tree species was found to be highest in core area 0.982) and lowest in periphery area (0.931) (Table 6). This result is in agreement to the finding of species dominance in tropical forests of Eastern Ghats, Andhra Pradesh which ranged between 0.96-0.97 [50]. The extent of dominance (Simpson's index) in the present study is within a range of 0.21-1.34 in other forests [34,53,54]. It was also reported that the regional patterns of species richness are a collaborative effect of different interacting factors, such as plant productivity, competition, regional species dynamics and species pool, historical development, environmental variables and human activity [44]. The altitude, environmental factors, habitat and soil characteristics may be the main factors which eventually lead to the variations in species diversity and density in the three study sites.

4. CONCLUSION

The forest of KWLS harbours a rich diversity of flora. This study not only focused on the quantitative floristic survey but also dealt with the diversity and abundance variation of all tree species in periphery core and buffer regions of the forests. These differences in vegetation can be related to both to human interference and site variation. KWLS is dominated by different combinations of species, but none of the three study sites is monodominant forest. Diversity indices give an important insight on the conservation strategies for human welfare.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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