



Qualitative and quantitative assessment of plant diversity of Chandaka-Damapara Sanctuary with special emphasis on identification of useful, keystone and threatened species

Tirthabrata Sahoo¹, Subrat Kumar Kar¹, Samarendra Narayan Mallick¹, Kedar Kumar Swain² and Pratap Chandra Panda^{1*}

¹ Taxonomy & Conservation Division
Regional Plant Resource Centre, Bhubaneswar 751 015, Odisha

² Divisional Forest Office, Chandaka Wildlife Division, Bhubaneswar, Odisha

ARTICLE INFO

Article history:

Received : 21 September 2018

Revised : 12 November 2018

Accepted : 10 December 2018

Keywords:

Plant Biodiversity
Quantitative assessment,
Threatened plants,
Chandaka WL Sanctuary.

ABSTRACT

An exhaustive survey of flora and vegetation of Chandaka-Dampada Sanctuary revealed the occurrence of 655 species of angiospermic plants belonging to 454 genera under 119 families. Of these, *Uvaria lurida*, *Uvaria hamiltonii*, *Cycas sphaerica*, *Pterocarpus marsupium*, *Alphonsea maderaspatana*, *Litsea glutinosa*, *Salacia chinensis* and *Oroxylum indicum* were classified as threatened species needing immediate attention for conservation. Besides, several wild relatives of crop plants, parasites, epiphytes, lithophytes, insectivorous plants and botanically interesting species were also identified during the study. Quantitative assessment of 113 species of trees (GBH e"30cm) was made by laying 79 sample quadrates in the sanctuary and stand density of 222.21 stems/ ha and stand basal area of 11.2 m²/ ha were recorded. The values of diversity indices such as Shannon-Weiner Index, Simpson Index and Evenness Index were calculated as 3.962, 0.03 and 0.83 respectively. The sanctuary was found to be rich in terms of biological diversity of plants.

© 2018 Orissa Botanical Society

1. Introduction

Lying between 20°12' 30"-20°26' 03" N latitudes and 85°49'35"-85°34'42" E longitudes, Chandaka-Damapara Sanctuary occupies part of Khurda and part of Cuttack District of Odisha state (Figs.1). The district boundary runs SW-NE almost in the middle of the sanctuary. The sanctuary is situated in a close proximity of the state capital, Bhubaneswar and spreads over an area of 193.39 sq.km. The legal boundary has been duly described by forest block boundaries in the State Govt. Notification No. 13482/FFAH, dated 10.06.1988 comprising of Reserved Forests, Demarcated Protected Forests, revenue lands, private lands and human settlements (Table-1).

1.1. General physiography, soil, geology and climate

The oldest-rock exposed in the area is Athagarh sand stones belonging to Gondwana group and found in western

and northern sectors. The sand stone is medium grained, grey to pink in colour. This is overlaid with laterite caps. On the top, lies lateritic red loamy soil or sand-silt-clay deposits. Bulk of the sanctuary urea is covered with the latter with lateritic soil dominating in Bharatpur-Jagannaihprasad and Kodanmnda blocks. Soil depth is generally good and sub soil moisture is sufficient to promote good forest cover but soil humus is very poor due to forest fire and over-grazing.

The land is generally undulating, broken by low hills of moderate slope exceeding 35° with abrupt sleep slopes at places. The valleys are narrow and spread in linger like projections in the centre. Hills lying to the west and North-west are moderate to steep while those on the East and South-east side are of gentle to moderate slope (Figs. 3-4). The altitude varies from 35m in Jagannathprasad block (near Baraman) and Chudanga block (near Ranipokhari enclave)

* Corresponding author; Email: pcpanada2001@yahoo.co.in

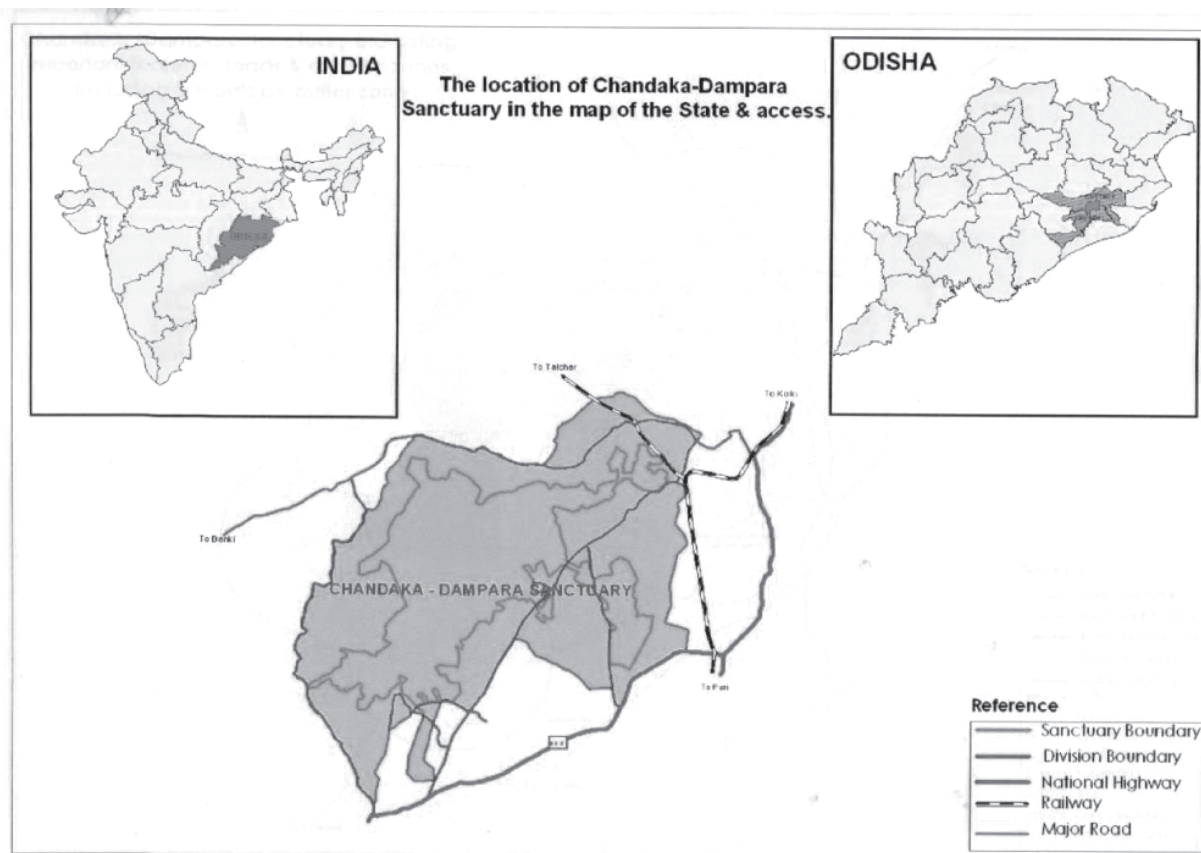


Fig. 1: Location map of Chandaka-Dampara Sanctuary in the map of Odisha and India

Table 1

Details of area coverage and classification of forests

Type/ classification of land	Area
Reserved Forests (7 nos. of RFs)	9,140.81 ha
Demarcated P.F. (11 nos. of DPFs)	9,219.19 ha
Private land acquired	53.87 ha
Bhalunka corridor	19.00 ha
Garjit village	195.52 ha
Other land area connecting Ratanpur and Kodumunda DPFs, Bhola & Daspur RFs, Jagannathprasad & Dalua DPFs	710.61 ha
Total area	19,339.00 ha

to 219m at Pandari mundia in Sunakhani-II D.P.F. Some other prominent hills (mundias) are Kansal (204m), Tarkei (203m), Barapita (194m) and Bathua (191m). In all, there are 32 small hillocks.

The climate of the area is tropical climate with three distinct and well marked seasons i.e. summer, rainy season and winter. The monsoon normally commence from mid

June and lasts till mid October. Winter is short lived from mid November to and January. Hot and humid weather continues till the onset of monsoons. Average annual rainfall at Bhubaneswar is about 1560 mm.

Though there are no natural wetlands and marshes within the protected area, some seasonal marshes are found near Haridamada, Kalajhar, Saurabila and Kankadajhar. However, there are man-made reservoirs like Kumarkhunti and Deras within the area and Jhumuka, Guptapada, Kajalaganda (Manpur) Maclua (Bhjipt), Dulanapur, Baghua, Ashok Bandh and Jaria near the periphery of the sanctuary. Kushpangi pata, Jaripata, Chudanga pata (Chandiprasad) and Kanjia pata (lake) are natural marshes on the northern periphery of the sanctuary.

2. Study of flora and vegetation: Past and present

One can find occasional reference to the plants collected from Chandaka in "The Botany of Bihar and Orissa" (Haines, 1921-25) and nothing at all in its "Supplement" (Mooney, 1950). Biswal *et al.* (2005) made an inventory of plants of Chandaka Wildlife Sanctuary and listed 542 angiosperms, 16 pteridophytes and 1 gymnosperm species from the area. Behera *et al.* (2008) conducted an

ethnobotanical study of the plant resources of the area. However, absolutely no information is yet available on the population size and structure, diversity, distribution pattern, abundance, frequency and rarity of any species. Quite a good number of exotic species have been planted as avenue trees and forestry plantations. Several alien weeds like *Mikania micrantha*, *Parthenium hysterophorus*, *Cleome rutidosperma*, *Euphorbia heterophylla*, have invaded a wide range of habitats in Chandaka especially along the roads adversely affecting the indigenous flora. It is essential that the present status of flora need be documented in quantitative terms with thrust on identification of critical habitats and conservation-worthy species before further deterioration takes place.

In the present study, the trees, shrubs, climbers and herbs occurring in the entire area were collected, identified and listed. For quantitative ecological study, the area was divided into smaller sampling grids and transects of 1000 m X 5 m (0.5 ha) were laid in representative vegetation types to capture maximum diversity. For each transect, data on geographical coordinates, soil types, forest types and general information about the sites were collected. All species occurring in each transect were enumerated and field level data on density, abundance, frequency, regeneration potential, use value of each of them were recorded. Each species was photographed and GPS data of place of occurrence were recorded in case of rare and economically important species so that the species can be relocated. Emphasis was laid on plant biodiversity documentation in special habitats and recording data on special groups of plants like weeds, epiphytes, lithophytes, grasses, wetland plants etc.

3. Methodology

3.1. Study site

The floristic inventory of the entire 193 sq. km area under the jurisdiction of Chandaka-Damapara Wildlife Sanctuary was made which included 9140.81 ha of Reserved Forests (7 RFs), 9219.19 ha of DPFs (11 DPFs) distributed in four forest ranges.

3.2. Plant collection, identification and preservation:

The entire area coming under Chandaka-Damapara Wildlife Sanctuary was divided into smaller units for floristic inventory. Multi-seasonal survey (summer, rainy and winter) will be conducted in these floristic survey units and all trees, shrubs, climbers and herbs were collected, preserved as herbarium specimens and identified. As far as possible, the flowering and fruiting specimens were collected for study of detailed morphology and botanical description and also for preservation as herbarium specimens. Standard field and

herbarium methods (Jain & Rao, 1977 and Bridson & Forman, 1998) were followed for plant collection and preservation of voucher specimens. Landscape level photographs of habitats and plant association were taken in the field besides photograph of each plant species encountered during the survey. The plantation crops, avenue plants and introduced species were also listed in the enumeration of taxa.

The specimens were pressed in between blotters of field press applying light pressure and some representative samples were kept in polythene bags for dissection and diagnosis in the camp or laboratory. On return from a day's trip, the plants pressed in the field press were pruned to convenient sizes, poisoned by dipping them in 2% solution of mercuric chloride in absolute alcohol and plant parts were well-spread to reveal morphological details. Again the specimens were pressed in blotters for drying and the blotters were frequently changed to facilitate quick drying of specimens. After complete drying, the specimens were mounted on to standard mount boards of 42 x 28 cm. size using animal glue. The specimens were often stitched with cotton thread to attach entire or parts of specimens to mounting board, especially thick twigs and large fruits. The detached leaves, flowers, fruits, seeds or other parts were put in specially prepared paper capsules and mounted on the sheet for future study. The data recorded in the field were transferred to herbarium labels, which were then pasted on the lower right corner of the herbarium sheets. The field and herbarium methods followed during the present work were as per the guidelines provided by Jain & Rao (1977) and Bridson & Forman (1989).

Regional floras such as Haines (1921-25), Gamble and Fischer (1915-1935), Saxena and Brahmam (1994-1996), Mooney (1950) were used besides expertise available at the institute for identifying plants, and voucher specimens were housed in the Herbarium of Regional Plant Resource Centre (RPRC), Bhubaneswar. Trained research workers and surveyors undertook the field work.

3.3. Quantitative assessment of plant diversity

3.3.1. Sampling protocol

The entire Sanctuary area was divided into smaller grids, which formed the sampling plots for quantitative assessment of plant biodiversity (Fig. 5). In each grid, random quadrates of 20 m X 20 m were laid fixing GPS points for enumeration of all standing trees e"30cm girth at breast height (gbh). Tree seedlings/ saplings, shrubs and climbers/ lianas were enumerated from one 5 m X 5 m plot within the quadrate. Quantitative data in respect of herb

species were collected from one small sample plot measuring 1m X 1 m.

For each species, data on number of individual in each quadrat, associated taxa, phenology, regeneration potential, maturity classes and local uses were also recorded. While enumerating tree species, measurements of height and DBH were noted. In case of herbaceous elements where counting of number of individuals was impracticable, percentage of area covered by each taxon was calculated. The density, frequency, dominance of each species was derived using standard ecological methods. Quantitative data was collected in data sheets designed depending on the requirement of the project.

3.3.2. Data analysis

For tree species in the wild, phytosociological characteristics of plant communities like; a) Frequency (percent of all transects in which a species was present), b) density (ratio of total number of trees to total number of transects) and c) abundance (ratio of total number of trees to total number of transects of occurrence) were recorded. Importance Value Index (IVI) was calculated following Curtis and Macintosh (1950). The dominance was determined by Simpson's index ($Cd = \sum(n_i/N)^2$), and diversity as Shannon's Index ($H = -\sum(n_i/N) \log(n_i/N)$), where n_i = importance value index of species i , N = sum of importance value index for the community. Evenness Index was calculated by Pielou's index ($D = -\sum p_i^2 / \ln S$), where S is the species richness of the community (Magurran, 1988). The girth (GBH) was converted into basal area (BA) as $BA = GBH^2/4\delta$ for deriving biodiversity indices.

4. Results and discussion

4.1. Study of flora and vegetation

4.1.1. Natural vegetation

The flora of Chandaka-Dampada Sanctuary was observed to be moderately diverse with intimate mixture of evergreen and deciduous elements. The area comes under semi-evergreen forest zone but the interplay of biotic factors has changed the original character of the vegetation. The resultant secondary growth is stunted in nature, which seldom goes beyond 10m in height, There is preponderance of thorny bushes and weed growth (*Chromolaena odorata*) as understorey in the forest, wherever there are permanent gaps. Species composition is heterogeneous. Thorny bamboo (*Bambusa bambos*) occurs as pure formations in valleys and mixed with tree growth on hill slopes. Based on the species composition, the natural forests can be broadly classified under "Moist Bamboo brakes", "Secondary moist bamboo brakes", "Lateritic semi evergreen forests",

"Peninsular (coastal) Sal forests", "Northern Secondary moist mixed deciduous forests" and "Tropical Dry evergreen forests" as per the forest type classification of Champion & Seth (1968). However, (i) Lateritic semi-evergreen forests dominated by *Xylia xylocarpa* (ii) Moist bamboo brakes and (iii) Secondary sal forests are the three dominant types in the sanctuary.

Most part of the sanctuary is covered with lateritic semi-evergreen forests characterised by the presence of *Xylia xylocarpa*, which does not form homogenous crop and all the trees are found in pole stage due to lot of biotic pressure on the forest over past years. The chief associates of *Xylia* are *Lagerstroemia parviflora*, *Strychnos nux-vomica*, *Aegle marmelos*, *Bridelia retusa*, *Pterocarpus marsupium*, *Madhuca latifolia*, *Alangium salvifolium*, *Terminalia bellirica*, *Careya arborea*, *Cassia fistula* etc. The second storey is composed of a number of small trees and shrubs, of which *Suregada multiflora*, *Polyalthia cerasoides*, *Cipadessa baccifera*, *Helicteres isora*, *Tarenna asiatica* and *Holarrhena pubescens* deserve special mention. Usually, climbers are plenty and are represented by *Combretum roxburghii*, *Gouania leptostachya*, *Ichnocarpus frutescens*, *Spatholobus parviflorus*, *Hemidesmus indicus*, *Ampelocissus latifolia*, *Argyrea nervosa*, *Atylosia scarabaeoides*, *Lygodium flexuosum* and many such others. Scattered trees of mango, figs (*Ficus* spp.) and clumps of spiny bamboo *Bambusa bambos* are also not uncommon. The only gymnospermous member *Cycas sphaerica* is sparsely distributed throughout the drier regions. Several herbaceous taxa like *Desrnodium gangeticum*, *Dicliptera bupleuroides* var. *roxburghiana*, *Eranthemum capense*, *Phaulopsis imbricata* and *Peristrophe paniculata* in association with some grasses and sedges compose the vegetation of forest floor. Along shady streams, *Terminalia arjuna*, *Barringtonia acutangula* and *Diospyros malabarica* occur as a narrow fringe. In disturbed areas, however, alien weeds like *Chromolaena odorata*, *Lantana camara* var. *aculeata*, *Cassia tora* and *Parthenium hysterophorus* etc. occupy the place of other herbs and adversely affect the indigenous flora.

On exposed sand-stone hills, *Xylia xylocarpa*, *Vitex pinnata*, *Lepisanthes tetraphylla*, *Strychnos nux-vomica*, *Pterospermum xylocarpum* and *Diospyros montana* in association with shrubs like *Eugenia rothii*, *Hugonia mystax*, *Tarenna asiatica* and *Diospyros ferrea* form an interesting plant community.

Few patches of mixed sal forests of secondary nature are scattered in the sanctuary area on drier habitats where the soil is clayey and with grits and pebbles. The Sal (*Shorea robusta*) occurring here is of coppiced origin and plants hardly reach more than 10 m. in height. *Soymida febrifuga*,

Table 2

Comparative list of ten dominant angiosperm plant families in Chandaka Dampada Sanctuary, erstwhile Puri district, Odisha and British-India

Chandaka Dampada Sanctuary (Present work)	Puri district (Undivided) (Panda & Patnaik, 1997)	Orissa (Saxena & Brahmam, 1994-96)	British India (Hooker, 1904)
Fabaceae (86 spp.)	Fabaceae	Fabaceae	Orchidaceae
Poaceae (59 spp.)	Poaceae	Poaceae	Fabaceae
Euphorbiaceae (34 spp.)	Cyperaceae	Cyperaceae	Poaceae
Acanthaceae (28 spp.)	Euphorbiaceae	Orchidaceae	Rubiaceae
Rubiaceae (29 spp.)	Acanthaceae	Asteraceae	Euphorbiaceae
Asteraceae (21 spp.)	Rubiaceae	Euphorbiaceae	Acanthaceae
Cyperaceae (21 spp.)	Asteraceae	Rubiaceae	Asteraceae
Scrophulariaceae (17 spp.)	Scrophulariaceae	Acanthaceae	Cyperaceae
Convolvulaceae (16 spp.)	Convolvulaceae	Scrophulariaceae	Lamiaceae
Amaranthaceae (14 spp.)	Lamiaceae	Lamiaceae	Urticaceae & Verbenaceae

Table 3

Ten dominant angiosperm plant families in Chandaka-Dampada Sanctuary with number of genera, species and habit category.

Family	No. of species	No. of genera	Trees	Herbs	Shrubs	Climbers
Fabaceae (including Caesalpiniaceae and Mimosaceae)	86	47	28	26	17	15
Poaceae	59	43	2	57	0	0
Euphorbiaceae	34	17	11	16	7	0
Acanthaceae	28	20		22	5	1
Rubiaceae	29	20	12	14	3	0
Asteraceae	21	21	0	20	1	0
Cyperaceae	21	9	0	21	0	0
Scrophulariaceae	17	9	0	17	0	0
Convolvulaceae	16	6	0	7	1	8
Amaranthaceae	14	8	0	14	0	0

Table 4

Habit-wise classification of plant species occurring in Chandaka-Damapada Sanctuary

Life forms	No. of species	No. of genera	No. of families
Trees	161	123	47
Shrubs	93	70	42
Climbers	69	57	27
Herbs	332	236	66
Total	655	454	119

Table 5

Diversity of different plant groups representing the flora of Chandaka Dampada Sanctuary

Plant groups	Genera	Species	Families
Angiosperms			
Monocot	93	129	20
Dicotyledons	357	522	95
Gymnosperms	1	1	1
Pteridophytes	3	3	3
Total	454	655	119

Table 6

Biodiversity parameters of tree species enumerated from Chandaka Wildlife Sanctuary

No. of tree species	113
No. of genera	83
No. of families	36
Number of individuals	2108
Stand Density (No. of stems ha-1)	222.21
Total Basal Area (m ²)	34.52
Stand Basal Area (m ² ha-1)	11.2
Maximum tree GBH (cm)	120
Mean tree GBH (cm)	43.7
Shannon-Weiner Index	3.96
Simpson Index	0.03
Evenness Index	0.83

Acacia leucophloea, *Cleistanthus collinus*, *Diospyros melanoxylon*, *Chloroxylon swietenia*, *Phyllanthus emblica*, *Woodfordia fruticosa*, *Albizia odoratissima*, *Acacia pennata* etc. are found in association with sal. The under growth has bushes of *Phoenix acaulis*, *Flacourtia indica*, *Diospyros chloroxylon*, *Carissa spinarum* and the ground flora is composed of *Pentanema indicum*, *Blumeopsis flava*, *Isleima prostratum*, *Cynodon dactylon*, *Digitaria granularis* and *Atylosis scarabaeoides*. The two leafless total parasites found in profusion here are *Cassytha filiformis* and *Cuscuta reflexa*. Plantations of cashew (*Anacardium occidentale*) exist at several locations.

Moist bamboo brakes dominated by a single species of thorny bamboo *Bambusa bambos* are found in the western portion of the sanctuary on slopes and sheltered localities. The bamboos form dense clumps and hardly allow any other plant to come up underneath except few bulbous perennials, shrubs and grasses. There is apparently no weed growth on the forest floor due to low light and sufficient litter deposition. However, *Chromolaena odorata*, *Cassia tora*, *Cassia occidentalis*, and *Lantana camara* var. *aculeata* are the weeds invading the area where the canopy is considerably open. Bulbous or cormous perennials like *Curcuma* sp., *Geodorum densiflorum*, *Costos speciosus*, *Amorphophallus paeoniifolius* and *Asparagus racemosus* inhabit the floor and send off shoots with the first conventional shower of rain. They are very often associated with shade tolerant species viz. *Antidesma ghaesernbilla*, *Clerodendrum viscosum*, *Oplismenus compositus* and *Oplismenus burmanii*. Straggling amongst the clumps of bamboo are the climbers *Dioscorea wallichii*, *Smilax zeylanica*, *Abrus precatorius*, *Calamus viminalis*, *Cayratia trifolia* and few others.

Several groves of mango are seen near human settlements, a little away from core area of the sanctuary. *Scindapsus officinalis*, *Vanda* spp., *Acampe praemorsa* and *Dendrophthoe falcata* are the epiphytes on mango trees. Several acres of land have been brought under plantation in recent years besides the existing old plantation.

4.1.2. Statistical analysis of the flora

An exhaustive floristic survey of Chandaka Dampada Sanctuary has revealed the occurrence of 655 species of angiosperms belonging to 454 genera under 119 families. Table-2 & 3 give the comparative account of 10 dominant angiospermic plant families in the British-India, Bihar-Orissa, and undivided Puri District and Chandaka Dampada Sanctuary and their classification according to habit. It is observed that Fabaceae (including Papilionaceae, Caesalpiniaceae and Mimosaceae) and Poaceae occupy first two positions in order of species diversity in the flora of Chandaka, Puri District and Orissa. However, in British-India, the first position is taken by Orchidaceae, which does not figure in the list of 10 dominant plant families either in the present work but occupy fourth position in the State flora for Odisha. Asteraceae (Compositae), the largest family in the world adorns 6th position in Chandaka and 7th in Puri district. The Convolvulaceae, which does not find a place in the list for British India occupies 9th position in the flora of the region under reference. In general, the dominance of angiospermic plant families in Chandaka Sanctuary is very much similar to that recorded for the flora of Orissa except for the family Orchidaceae (only 5 species in Chandaka), the members of which are predominantly forest dwellers. The habit-wise distribution of species, genera and families are presented in Table-4.

The ratio of monocot families to dicot families; monocot genera to dicot genera and monocot species to dicot species are 1:4.75, 1:3.839 and 1:4.046 respectively. A statistical analysis of the flora shows the percentage of dicotyledonous and monocotyledonous plants as 75.29: 24.71 as against 81.30: 18.70 in the World flora. This shows relatively less number of monocotyledonous plant species in the flora of Chandaka as compared to flora of Odisha where this ratio is 70.75: 29.25. This is mainly due to the occurrence of large number of grasses and sedges in the flora. Of the 129 species of monocotyledonous plants collected during the present work, 80 species belong to two families namely Poaceae and Cyperaceae and the remaining 18 monocot families are represented by only 49 species. The genus-species ratio is 1: 1.443 as against 1: 1.7 for undivided Puri District, 1: 2.59 for Orissa and 1:7 for British-India. Evidently, therefore, in Chandaka region less number of species occurs under a particular genus in comparison to

Table 7

No. of individuals, GBH, basal area, density, frequency, dominance and IVI of tree species in Chandaka Wildlife Sanctuary

Name of the Taxon	Family	No. of Individuals	Total GBH (cm)	Total Basal area in m ²	Frequency	Density	Relative Frequency	Relative Density	Relative Dominance	IVI
<i>Xylocarpus xylocarpa</i>	Mimosaceae	279	12045	4.370	58.442	90.584	5.085	13.235	12.659	30.979
<i>Diospyros sylvatica</i>	Ebenaceae	104	4340	1.548	54.545	33.766	4.746	4.934	4.485	14.164
<i>Aegle marmelos</i>	Rutaceae	107	4214	1.388	54.545	34.740	4.746	5.076	4.021	13.842
<i>Careya arborea</i>	Barringtoniaceae	70	3653	1.651	40.260	22.727	3.503	3.321	4.783	11.606
<i>Strychnos potatorum</i>	Strychnaceae	82	3579	1.327	41.558	26.623	3.616	3.890	3.845	11.351
<i>Tectona grandis</i>	Verbenaceae	92	4335	1.756	18.182	29.870	1.582	4.364	5.086	11.033
<i>Strychnos nux-vomica</i>	Strychnaceae	85	3749	1.391	33.766	27.597	2.938	4.032	4.030	11.000
<i>Lagerstroemia parviflora</i>	Lythraceae	83	3328	1.158	38.961	26.948	3.390	3.937	3.354	10.681
<i>Holarrhena pubescens</i>	Apocynaceae	56	2320	0.793	45.455	18.182	3.955	2.657	2.296	8.908
<i>Cassia fistula</i>	Caesalpinaceae	49	2033	0.714	36.364	15.909	3.164	2.324	2.068	7.556
<i>Terminalia bellirica</i>	Combretaceae	49	2191	0.826	32.468	15.909	2.825	2.324	2.394	7.543
<i>Terminalia alata</i>	Combretaceae	48	2227	0.901	16.883	15.584	1.469	2.277	2.611	6.357
<i>Mangifera indica</i>	Anacardiaceae	37	2236	1.104	15.584	12.013	1.356	1.755	3.199	6.310
<i>Alangium salvifolium</i>	Alangiaceae	35	1618	0.673	23.377	11.364	2.034	1.660	1.949	5.643
<i>Azadirachta indica</i>	Meliaceae	32	1548	0.634	25.974	10.390	2.260	1.518	1.837	5.614
<i>Polyalthia cerasoides</i>	Annonaceae	44	1749	0.584	20.779	14.286	1.808	2.087	1.692	5.587
<i>Syzygium cumini</i>	Moraceae	29	1424	0.601	24.675	9.416	2.147	1.376	1.741	5.263
<i>Pterospermum xylocarpum</i>	Sterculiaceae	33	1446	0.539	23.377	10.714	2.034	1.565	1.560	5.160
<i>Madhuca indica</i>	Sapotaceae	38	1835	0.764	12.987	12.338	1.130	1.803	2.214	5.147
<i>Lannea coromandelica</i>	Anacardiaceae	24	1143	0.490	24.675	7.792	2.147	1.139	1.420	4.705
<i>Streblus asper</i>	Moraceae	31	1376	0.513	19.481	10.065	1.695	1.471	1.487	4.653
<i>Lagerstroemia reginae</i>	Lythraceae	27	1247	0.479	20.779	8.766	1.808	1.281	1.389	4.477
<i>Bridelia retusa</i>	Euphorbiaceae	25	1168	0.475	16.883	8.117	1.469	1.186	1.376	4.031
<i>Zizyphus xylopyrus</i>	Rhamnaceae	25	1052	0.374	19.481	8.117	1.695	1.186	1.084	3.964
<i>Vitex pinnata</i>	Verbenaceae	40	1514	0.478	6.494	12.987	0.565	1.898	1.384	3.847
<i>Diospyros montana</i>	Ebenaceae	25	1001	0.338	18.182	8.117	1.582	1.186	0.978	3.746
<i>Naringi crenulata</i>	Rutaceae	25	934	0.287	19.481	8.117	1.695	1.186	0.832	3.712
<i>Cleistanthus collinus</i>	Euphorbiaceae	32	1221	0.379	9.091	10.390	0.791	1.518	1.099	3.408
<i>Pongamia pinnata</i>	Fabaceae	21	1126	0.510	10.390	6.818	0.904	0.996	1.477	3.377
<i>Acacia leucophloea</i>	Mimosaceae	21	900	0.353	14.286	6.818	1.243	0.996	1.023	3.262
<i>Suregada multiflora</i>	Euphorbiaceae	20	763	0.248	18.182	6.494	1.582	0.949	0.718	3.249
<i>Buchanania lanzan</i>	Anacardiaceae	24	1112	0.440	9.091	7.792	0.791	1.139	1.276	3.205
<i>Terminalia chebula</i>	Combretaceae	18	803	0.302	16.883	5.844	1.469	0.854	0.876	3.198
<i>Diospyros melanoxylon</i>	Ebenaceae	15	624	0.214	16.883	4.870	1.469	0.712	0.621	2.802
<i>Antidesma ghaesembilla</i>	Euphorbiaceae	18	805	0.312	11.688	5.844	1.017	0.854	0.903	2.774
<i>Catunaregam spinosa</i>	Rubiaceae	20	699	0.200	14.286	6.494	1.243	0.949	0.579	2.771
<i>Shorea robusta</i>	Dipterocarpaceae	17	1061	0.542	2.597	5.519	0.226	0.806	1.571	2.604
<i>Casearia elliptica</i>	Flacourtiaceae	15	554	0.170	15.584	4.870	1.356	0.712	0.492	2.559
<i>Xantolis tomentosa</i>	Sapotaceae	18	773	0.273	9.091	5.844	0.791	0.854	0.792	2.437
<i>Lepisanthes tetraphylla</i>	Sapindaceae	13	507	0.163	14.286	4.221	1.243	0.617	0.472	2.332

<i>Mimusops elengi</i>	Sapotaceae	17	886	0.380	3.896	5.519	0.339	0.806	1.100	2.245
<i>Dalbergia paniculata</i>	Fabaceae	14	719	0.326	6.494	4.545	0.565	0.664	0.945	2.174
<i>Memecylon umbellatum</i>	Melastomataceae	16	581	0.172	10.390	5.195	0.904	0.759	0.499	2.162
<i>Canthium dicoccum</i>	Rubiaceae	14	484	0.136	7.792	4.545	0.678	0.664	0.394	1.736
<i>Semecarpus anacardium</i>	Anacardiaceae	11	508	0.195	6.494	3.571	0.565	0.522	0.564	1.651
<i>Gmelina arborea</i>	Verbenaceae	10	495	0.204	5.195	3.247	0.452	0.474	0.591	1.517
<i>Albizia lebbek</i>	Mimosaceae	8	376	0.154	7.792	2.597	0.678	0.380	0.445	1.503
<i>Morinda pubescens</i>	Rubiaceae	9	367	0.122	6.494	2.922	0.565	0.427	0.353	1.345
<i>Hymenodictyon orixense</i>	Rubiaceae	6	330	0.156	5.195	1.948	0.452	0.285	0.451	1.188
<i>Samanea saman</i>	Mimosaceae	9	438	0.182	2.597	2.922	0.226	0.427	0.528	1.181
<i>Ochna obtusata</i>	Ochnaceae	6	211	0.060	7.792	1.948	0.678	0.285	0.173	1.135
<i>Cipadessa baccifera</i>	Meliaceae	8	241	0.058	6.494	2.597	0.565	0.380	0.167	1.112
<i>Phyllanthus emblica</i>	Euphorbiaceae	7	248	0.072	6.494	2.273	0.565	0.332	0.209	1.106
<i>Vitex leucoxydon</i>	Verbenaceae	6	255	0.087	6.494	1.948	0.565	0.285	0.252	1.101
<i>Chloroxylon swietiana</i>	Rutaceae	10	395	0.137	2.597	3.247	0.226	0.474	0.396	1.096
<i>Cassia siamea</i>	Caesalpiniaceae	6	295	0.117	3.896	1.948	0.339	0.285	0.338	0.962
<i>Anogeissum acuminata</i>	Combretaceae	5	230	0.090	3.896	1.623	0.339	0.237	0.262	0.838
<i>Gliricidia sepium</i>	Fabaceae	3	213	0.120	3.896	0.974	0.339	0.142	0.349	0.830
<i>Olex psittacorum</i>	Olacaceae	4	149	0.045	5.195	1.299	0.452	0.190	0.130	0.772
<i>Wrightia arborea</i>	Apocyanaceae	4	128	0.033	5.195	1.299	0.452	0.190	0.095	0.736
<i>Guazuma ulmifolia</i>	Sterculiaceae	4	174	0.064	3.896	1.299	0.339	0.190	0.184	0.713
<i>Limonia acidissima</i>	Rutaceae	5	166	0.044	3.896	1.623	0.339	0.237	0.128	0.704
<i>Tamarindus indica</i>	Caesalpiniaceae	4	215	0.094	2.597	1.299	0.226	0.190	0.271	0.687
<i>Diospyros ferrea</i>	Ebenaceae	3	143	0.055	3.896	0.974	0.339	0.142	0.158	0.640
<i>Anacardium occidentale</i>	Anacardiaceae	3	133	0.048	3.896	0.974	0.339	0.142	0.139	0.621
<i>Fagerlindia fasciculata</i>	Rubiaceae	4	124	0.031	3.896	1.299	0.339	0.190	0.089	0.617
<i>Simarouba glauca</i>	Simmaroubaceae	4	173	0.062	2.597	1.299	0.226	0.190	0.179	0.594
<i>Dalbergia sissoo</i>	Fabaceae	3	115	0.036	3.896	0.974	0.339	0.142	0.104	0.586
<i>Gardenia latifolia</i>	Rubiaceae	3	109	0.033	3.896	0.974	0.339	0.142	0.096	0.577
<i>Mitragyna parvifolia</i>	Rubiaceae	3	108	0.031	3.896	0.974	0.339	0.142	0.091	0.572
<i>Ixora pavetta</i>	Rubiaceae	3	93	0.023	3.896	0.974	0.339	0.142	0.066	0.548
<i>Polyalthia suberosa</i>	Annonaceae	3	133	0.048	2.597	0.974	0.226	0.142	0.139	0.508
<i>Haldinia cordifolia</i>	Rubiaceae	3	128	0.044	2.597	0.974	0.226	0.142	0.127	0.495
<i>Anacardium occidentale</i>	Anacardiaceae	4	169	0.057	1.299	1.299	0.113	0.190	0.166	0.468
<i>Pterocarpus marsupium</i>	Fabaceae	3	113	0.034	2.597	0.974	0.226	0.142	0.099	0.467
<i>Neolamarckia cadamba</i>	Rubiaceae	2	107	0.046	2.597	0.649	0.226	0.095	0.132	0.453
<i>Bridelia monoica</i>	Euphorbiaceae	2	99	0.042	2.597	0.649	0.226	0.095	0.123	0.443
<i>Terminalia arjuna</i>	Combretaceae	3	96	0.025	2.597	0.974	0.226	0.142	0.071	0.439
<i>Cleistanthus patulus</i>	Euphorbiaceae	3	152	0.062	1.299	0.974	0.113	0.142	0.180	0.435
<i>Stereospermum chelonoides</i>	Bignoniaceae	2	83	0.028	2.597	0.649	0.226	0.095	0.081	0.402
<i>Salacia chinensis</i>	Hippocrateaceae	2	82	0.027	2.597	0.649	0.226	0.095	0.078	0.399
<i>Milium velutina</i>	Annonaceae	3	120	0.039	1.299	0.974	0.113	0.142	0.114	0.369
<i>Ehretia laevis</i>	Ehretiaceae	2	62	0.015	2.597	0.649	0.226	0.095	0.044	0.365
<i>Vitex peduncularis</i>	Verbenaceae	2	62	0.015	2.597	0.649	0.226	0.095	0.044	0.365
<i>Diospyros malabarica</i>	Ebenaceae	2	60	0.014	2.597	0.649	0.226	0.095	0.041	0.362

<i>Manilkara hexandra</i>	Sapotaceae	2	60	0.014	2.597	0.649	0.226	0.095	0.041	0.362
<i>Grewia tiliifolia</i>	Tiliaceae	2	100	0.040	1.299	0.649	0.113	0.095	0.115	0.323
<i>Litsea glutinosa</i>	Lauraceae	2	91	0.033	1.299	0.649	0.113	0.095	0.096	0.304
<i>Discospermum abnorme</i>	Rubiaceae	4	125	0.031	0.000	1.299	0.000	0.190	0.090	0.280
<i>Litsea monopetala</i>	Lauraceae	1	61	0.030	1.299	0.325	0.113	0.047	0.086	0.246
<i>Ficus glomerata</i>	Moraceae	1	57	0.026	1.299	0.325	0.113	0.047	0.075	0.235
<i>Cassine albens</i>	Celastraceae	1	47	0.018	1.299	0.325	0.113	0.047	0.051	0.211
<i>Vitex glabrata</i>	Verbenaceae	1	47	0.018	1.299	0.325	0.113	0.047	0.051	0.211
<i>Aglaia elaeagnoidea</i>	Meliaceae	1	43	0.015	1.299	0.325	0.113	0.047	0.043	0.203
<i>Barringtonia acutangula</i>	Barringtoniaceae	1	42	0.014	1.299	0.325	0.113	0.047	0.041	0.201
<i>Bauhinia purpurea</i>	Caesalpiniaceae	1	42	0.014	1.299	0.325	0.113	0.047	0.041	0.201
<i>Protium serratum</i>	Burseraceae	1	39	0.012	1.299	0.325	0.113	0.047	0.035	0.195
<i>Atalantia monophylla</i>	Rutaceae	1	37	0.011	1.299	0.325	0.113	0.047	0.032	0.192
<i>Diospyros chloroxylon</i>	Ebenaceae	1	37	0.011	1.299	0.325	0.113	0.047	0.032	0.192
<i>Mallotus philippensis</i>	Euphorbiaceae	1	35	0.010	1.299	0.325	0.113	0.047	0.028	0.189
<i>Ficus benghalensis</i>	Moraceae	1	34	0.009	1.299	0.325	0.113	0.047	0.027	0.187
<i>Acacia arabica</i>	Mimosaceae	1	32	0.008	1.299	0.325	0.113	0.047	0.024	0.184
<i>Pavetta indica</i>	Rubiaceae	1	32	0.008	1.299	0.325	0.113	0.047	0.024	0.184
<i>Acacia auriculiformis</i>	Mimosaceae	1	31	0.008	1.299	0.325	0.113	0.047	0.022	0.183
<i>Acacia nilotica</i>	Mimosaceae	1	31	0.008	1.299	0.325	0.113	0.047	0.022	0.183
<i>Crateva magna</i>	Capparaceae	1	31	0.008	1.299	0.325	0.113	0.047	0.022	0.183
<i>Diospyros ovalifolia</i>	Ebenaceae	1	31	0.008	1.299	0.325	0.113	0.047	0.022	0.183
<i>Manilkara zapota</i>	Sapotaceae	1	31	0.008	1.299	0.325	0.113	0.047	0.022	0.183
<i>Alstonia scholaris</i>	Apocyanaceae	1	30	0.007	1.299	0.325	0.113	0.047	0.021	0.181
<i>Antidesma acidum</i>	Euphorbiaceae	1	30	0.007	1.299	0.325	0.113	0.047	0.021	0.181
<i>Erythrina suberosa</i>	Fabaceae	1	30	0.007	1.299	0.325	0.113	0.047	0.021	0.181
<i>Meyna spinosa</i>	Rubiaceae	1	30	0.007	1.299	0.325	0.113	0.047	0.021	0.181
<i>Ziziphus rugosa</i>	Rhamnaceae	1	30	0.007	1.299	0.325	0.113	0.047	0.021	0.181

Table 8

Girth class distribution according to density and basal area of tree species

Girth Class	Density (Stem ha ⁻¹)	Basal Area (m ² ha ⁻¹)
30-60 cm	618.83	8.613
61-90 cm	63.63	2.445
91-120 cm	1.94	0.149

Puri District or Orissa. A summary of representative plant groups in the flora of the region is shown in Table-5.

4.1.3. Special groups of plants

(a) Threatened plants

Chandaka-Damapada Sanctuary harbours a number of endangered species of Odisha which includes species such as *Uvaria lurida*, *Uvaria hamiltonii*, *Cycas sphaerica*, *Pterocarpus marsupium*, *Alphonsea maderaspatana*, *Litsea*

glutinosa, *Salacia chinensis* and *Oroxylum indicum*.

(b) Parasites

Although a few species of parasitic angiosperms are found to occur in and around the sanctuary, they are an interesting group of plants from ecological stand-point. The parasites occurring in the region belong to two distinct types viz. stem parasites and root parasites and may be total or partial parasites. The stem parasites are represented by *Cuscuta reflexa*, *Cassytha filiformis*, *Dendrophthoe falcata* and *Viscum articulatum*, the first two being leafless total parasites. Besides, *Striga angustifolia* is the only inconspicuous root parasite found in the region.

(c) Insectivorous plants

Drosera burmanii and *Utricularia aurea* are the two

common insectivorous plants found in the area. While the first one is found in sandy soils close to rice fields, the later is common in ponds, ditches and shallow water bodies.

(d) *Wild relatives of crop plants:*

Several wild progenitors of cultivated plants also occur within Chandaka sanctuary which are important as germplasm materials for conservation and use in crop improvement programmes. Some important wild relatives of crop plants known to occur in the region are *Oryza rufipogon*, *Atylosia scarabaeoide*, *Dolichos trilobus*, *Vigna sublobata*, *Vigna trilobata*, *Abelmoschus manihot* ssp. *tetraphyllum*, *Solanum virginianum*, *Solanum nigrum*, *Corchorus aestuans*, *Saccharum spontaneum* etc.

(e) *Epiphytes*

Three species of wild orchids such as *Acampe praemorsa*, *Cymbidium aloifolium* and *Vanda tessellata* were found to occur in the sanctuary area. While most of these orchids were observed on mango (*Mangifera indica*) trees, *Scindapsus officinalis* grows as an epiphyte on a number of host plants and on rock surfaces. *Schefflera venulosa* was a robust epiphyte growing along streams and in damp places.

(f) *Lithophytes*

Sarcostemma acidum and *Anisochilus carnosus* grow as lithophytes on barren rock surfaces in selected habitats of the sanctuary and sustain themselves with whatever little amount of organic matter available the form of deposition in the crevices of rocks. *Tephrosia maxima* occur on exposed rocks and apparently behave as a lithophyte.

(g) *Wild plants of horticultural importance*

A large number of wild plants with beautiful flowers, foliage or interesting crown characters have great potentiality to be used as garden ornamentals. Some of them which occur in Chandaka and can be introduced as garden ornamentals are: *Crotalaria verrucosa*, *Crotalaria laburnifolia*, *Crotalaria spectabilis*, *Carissa spinarum*, *Pavetta indica*, *Gloriosa superba*, *Calycopteris floribunda*, *Dalbergia rubiginosa*, *Ichnocarpus frutescens*, *Sarcostemma acidum* etc.

4.2. Quantitative assessment of tree species

4.2.1. Species diversity and richness

A total number of 2108 individuals of tree species with e" 30 cm GBH were recorded from 79 sample quadrates (39.5 ha) of Chandaka-Domapada Sanctuary. They represent 113 species belonging to 83 genera under 36 families (Table-6). The family Fabaceae (including Papilionaceae,

Mimosaceae and Caesalpiniaceae) with 28 species was the most dominant taxon in terms of species content followed by Euphorbiaceae (10 species), Rubiaceae (10 species), Verbenaceae (8 species) and Moraceae (8 species). Eighteen (18) families were represented by single species only. The values of diversity indices such as Shannon-Weiner Index, Simpson Index and Evenness Index were calculated as 3.962, 0.03 and 0.83 respectively.

4.2.2. Importance Value Index (IVI)

The IVI depicts the sociological structure of a species in its totality in the community. Though the Tropical deciduous forests of Odisha state are dominated by the *Shorea robusta* (Sal), for Chandaka Damapada Sanctuary *Xylia xylocarpa* scored the highest IVI of 30.979 pointing at the dominance of the species in terms of density, basal area and frequency of occurrence (Table-7). The top 10 species and their contribution to density, basal area and IVI in studied area were *Xylia xylocarpa* (IVI=30.979), *Diospyros sylvatica* (IVI=14.164), *Aegle marmelos* (IVI=13.842), *Careya arborea* (IVI=11.606), *Strychnos potatorum* (IVI=11.351), *Tectona grandis* (IVI=11.033), *Strychnos nux-vomica* (IVI=11.000), *Lagestroemia parviflora* (IVI=10.681), *Holarrhena pubescens* (IVI=8.908) and *Cassia fistula* (IVI=7.556). Twenty-four species were represented by single individuals and are considered rare in the area.

4.2.3. Family composition

A total number of 2108 standing trees with e" 30 cm GBH were recorded from 79 sample quadrates (39.5 ha) of Chandaka- Domapada Sanctuary, which come under 113 species under 83 genera and 36 families. In terms of tree density, Mimosaceae with 7 species and maximum of 320 trees dominated the area followed by Strychnaceae (167 stems), Verbenaceae (151 stems), Ebenaceae (151 stems), Rutaceae (148 stems), Combretaceae (123 stems) and Lythraceae (110 stems). Mimosaceae scored the maximum FIV of 30.099 followed by Verbenaceae (FIV=19.881), Ebenaceae (FIV=19.695), Euphorbiaceae (FIV=17.791) and Strychnaceae (FIV=17.567).

4.2.4. Stand density, basal area and girth class distribution

A total of 2108 trees were enumerated from on the study sites of Chandaka-Dampara sanctuary and the total basal area (BA) was found to be 34.517 sq. m. The stand density was calculated as 222.211 stems/ ha. The stand density and basal area showed decreasing trend with increasing girth class in Chandaka (Table-8). The highest stem density of 618.83 stems/ ha and basal area of 8.613 sq.

m/ ha was recorded for lowest girth class of 30-60 cm GBH. The lowest stem density of 1.94 stems/ ha and basal area of 0.149 sq. m/ ha was calculated for trees of lowest girth class (91-120 cm).

The density, abundance and distribution of individual species are measurable indicators of plant diversity (Wattenberg and Breckle, 1995). The species richness of 113 tree species over 39.50 ha sampled area in three forest ranges of Chandaka- Damapada Sanctuary reflects a moderate level of diversity. The result of the study compared well with other large-scale inventories conducted in tropical forests both in India and elsewhere. For example, 63 species were recorded for 50 ha plot at Mudumalai Forest Reserve, India, to 272 species in the 60 ha area in southern Eastern Ghats (Arul Pragasan and Parthasarathy, 2010).

The stand density of 222.211 stems/ ha now reported for Chandaka is much lower than reported for other tropical forests of Indian subcontinent such as 516.23 stems ha⁻¹ for Nayagarh Forest Division (Sahoo & Panda, 2015; Sahoo et al., 2017), 352 stems ha⁻¹ in northern Eastern Ghats (Panda et al., 2013); 443 stems ha⁻¹ in Malyagiri hills of Odisha (Sahu et al., 2012); 298 stems ha⁻¹ at Mudumalai Forest Reserve, India and 689 stems ha⁻¹ at Sinharaja, Sri Lanka (Condit, 2000). Density of trees (30 cm GBH and above) in tropical forests ranges between 245 and 859 (Ashton 1964; Campbell et al., 1992; Richards, 1996) but the mean stand density of trees now reported for Chandaka Damapada Sanctuary (222.211 stems ha⁻¹) is less than the reported range for tropical forests of India.

The species diversity depends on the adaptation of species which increases with the stability of community and Shannon's Index (H') is generally higher for tropical forests (Knight, 1975). In Indian forests, the value is reported to vary in the range of 0.83 to 4.0 (Singh et al., 1984). In the present study, Shannon's Index of diversity of tree species was found to be 3.962, which is within the reported range for the forests of Indian sub-continent (Ayyapan and Parthasarathy, 1999; Pandey, 2003; Panda et al., 2013). Comparison of diversity indices is very difficult because of the difference in the area sampled and lack of uniform plot dimensions. However, the index now determined is lower than the value reported for Northern Andhra Pradesh (Reddy et al., 2011), Niyamgiri hills, Odisha (Dash et al., 2009).

In most of the studies relating to vegetation composition and site quality of forests, basal area acts as an important attribute (Mani and Parthasarathy, 2005; Parthasarathy and Karthikeyan, 1997; Srinivas and Parthasarathy, 2000). The stand basal area recorded in the present study was calculated as 11.20 m² ha⁻¹, which is

comparable to the value of 10.47 m² ha⁻¹ reported for southern Eastern GHat region (Panda et al., 2013) but lower than that known for Nayagarh Forest Division, which is 16.90 m² ha⁻¹ (Sahoo et al., 2017).

The diameter distribution reflects the disturbance effect within the forests (Denslow, 1995; Hett and Loucks, 1976) and helpful in detecting trends in regeneration patterns (Poorter et al., 1996). The low basal area values in all the sample plots in the present study revealed the extent of forest disturbance with poor representation of trees in higher girth class. Tree density decreased with increasing size class of trees indicates how well the growing forest is utilizing site resources. A few small-to-medium sized trees per hectare may imply that land is not being fully utilized by the tree crop (Hitimana et al., 2004). Quantitative floristic data from the present study will provide base-line information on distribution, richness and relative abundance of taxa for formulating management and conservation actions for Chandaka Damapada Sanctuary in general and other protected areas, in particular.

Acknowledgements

The authors are grateful to the Divisional Forest Officer, Chandaka Wildlife Division, Bhubaneswar for financial assistance to carry out this work and to the Chief Executive, RPRC, Bhubaneswar for providing facilities.

References

- Arul Pragasan, A. & Parthasarathy, N. (2010). Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. *Flora* 205(11):728–737.
- Ashton, P. S. (1964) Ecological studies in the mixed Dipterocarp forests of Brunei State (Oxford Forestry Memoirs 25). Clarendon Press, Oxford, p 74
- Ayyappan, N. & Parthasarathy, N. (1999). Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. *Biodivers. Conserv.* 8:1533–1554.
- Behera, K. K., Sahoo, S. & Patra, S. (2008). Floristic and medicinal uses of some plants of Chandaka denuded forest patches of Bhubaneswar, Orissa, India. *Ethnobot Leaflets* 12: 1043-1053.
- Bridson, D. & Forman, L. L. (1998). *The Herbarium Handbook* (3rd Edn), Royal Botanic Gardens, Kew, UK.
- Campbell, D. G. (1994). Scale and pattern of community structure in Amazonian rainforests. In: Edwards PJ, May RM, Web NR (eds) *Larger scale ecology and conservation biology*. Blackwell, Oxford, pp 179–194.
- Condit, R. (2000). Spatial patterns in the distribution of tropical tree species. *Science* 288:1414–1418.

- Curtis, J. T., McIntosh, R. P. (1951). The interrelation of certain analytic and synthetic phytosociological characters. *Ecology* 31:434–455.
- Dash, P. K., Mohapatra, P. P. & Rao, Y. G. (2009). Diversity and distribution of tree species in Niyamgiri hill ranges, Orissa, India. *Indian For.* 35(4): 927–94.
- Denslow, J. S. (1995). Disturbance and diversity in tropical rain forests: the density effect. *Ecol. Appl.* 5:962–968.
- Gamble, J. S. & Fischer, C. E. C. (1915–1935). *Flora of Presidency of Madras*, Vol. 1–3. Adlard & Son, London.
- Haines, H. H. (1921–1925). *The Botany of Bihar and Odisha*, 6 parts. Adlard & Sons, London.
- Hett, J. M. & Loucks, O. L. (1976). Age structure models of balsam fir and eastern hemlock. *J. Ecol.* 64:1029–1044.
- Hitimana, J., Kiyiapi, J. L. & Njunge, J. T. (2004). Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon moist lower montane forest, Western Kenya. *For. Ecol. Manag.* 194:269–291.
- Jain, S. K. & Rao, R. R. (1977). *A Handbook of Field and Herbarium Methods*, Today and Tomorrow's Printers and Publishers, New Delhi.
- Knight, D. H. A. (1975). Phytosociological analysis of species rich tropical forest on Barro Colorado Island, Panama. *Ecol. Monogr.* 45:259–284.
- Magurran, A. E. (1988). *Ecological diversity and its measurement*. Princeton University Press, Princeton, pp. 192.
- Mani, S. & Parthasarathy, N. (2005). Biodiversity assessment of trees in five inland tropical dry evergreen forests of peninsular India. *Syst. Biodivers.* 3(1):1–12.
- Mooney, H. F. (1950). *Supplement to the Botany of Bihar and Odisha*. Catholic Press, Ranchi, pp. 294.
- Panda, P. C., Mahapatra, A. K., Acharya, P. K. & Debata, A. K. (2013). Plant diversity in tropical deciduous forests of Eastern Ghats, India: a landscape level assessment. *Int. J. Biodivers. Conserv.* 5(10):625–639.
- Pandey, S. K. & Shukla, R. P. (2003). Plant diversity in managed Sal (*Shorea robusta* Gaertn.) forests of Gorakhpur, India: species composition, regeneration and conservation. *Biodivers. Conserv.* 12:2295–2319.
- Parthasarathy, N. & Karthikeyan, R. (1997). Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandel Coast, South India. *Biodivers. Conserv.* 6:1063–1083.
- Poorter, L., Bongers, F., van Rompaey, R. S. A. R. & de Klerk, M. (1996). Regeneration of canopy tree species at five sites in West African moist forest. *For. Ecol. Manag.* 84:61–69.
- Reddy, C. S., Prachi, U., Murthy, M. S. R. & Sudhakar, S. (2008a). Quantitative structure and composition of tropical forests of Mudumalai Wildlife Sanctuary, Western Ghats, India. *Taiwania* 53(2):150–156.
- Richards, P. W. (1996). *The tropical rain forest: an ecological study*, 2nd edn. Cambridge University Press, Cambridge, pp. 575.
- Sahoo, T. & Panda, P. C. (2015). Comparative assessment of structure, composition and diversity of tree species of tropical moist deciduous forests in three forest ranges of Nayagarh Forest Division, Odisha, India. *Plant Sci Res* 37 (1 & 2): 39–48.
- Sahoo, T., Panda, P. C. & Acharya, L. (2017). Structure, composition and diversity of tree species in tropical moist deciduous forests of Eastern India: a case study of Nayagarh Forest Division, Odisha. *J. For. Res.* 28 (6): 1219–1230.
- Sahu, S. C., Dhal, N. K. & Mohanty, R. C. (2012). Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India. *Tropical Ecology* 53 (2): 163–168.
- Saxena, H. O. & Brahmam, M. (1994–1996). *Flora of Odisha*, Vol. 1–4. Odisha Forest Development Corporation Ltd. and Regional Research Laboratory, Bhubaneswar, p 2918
- Singh, J. S., Singh, S. P., Saxena, A. K. & Rawat, Y. S. (1984). India's Silent valley and its threatened rain forest ecosystem. *Environ. Conserv.* 11:223–233.
- Srinivas, V. & Parthasarathy, N. (2000). Comparative analysis of tree diversity and dispersion in the tropical lowland evergreen forest of Agumbe, Central Western Ghats, India. *Trop. Biodivers.* 7:45–60.
- Wattenberg, I. & Breckle, S. (1995). Tree species diversity of a premontane rain forest in the Cordillera de Tilaren, Costa Rica. *Biotropica* 1:21–30.