Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231-6345 (Online)
An Online International Journal Available at http://www.cibtech.org/jls.htm
2012 Vol. 2 (2) April-June, pp.355-364/Joshi
Research Article

VEGETATION STRUCTURE, FLORISTIC COMPOSITION AND SOIL NUTRIENT STATUS IN THREE SITES OF TROPICAL DRY DECIDUOUS FOREST OF WEST BENGAL, INDIA

***Hema Gupta Joshi**
Department of Botany, Visva-Bharati, Santiniketan 731235, West Bengal, India
**Author for Correspondence*

ABSTRACT
The present work reports some preliminary observations on the vegetation structure, composition and soil nutrient status in three sites of tropical dry deciduous forest of West Bengal ((23°40'54.4"N latitude to 87°40'20.2"E, 23°35'52.3"N latitude to 87°25'42.2"E and 24°04'17.7"N latitude to 87°40'56.4"E). Total 77 woody individuals (≥ 1cm DBH) of six tree species belonging to 6 families were enumerated in the three sites covering an area of 0.06 ha. Ground vegetation consisted of 3 species of shrubs, 12 of herbs, 5 of climbers and 11 species saplings. The tree density varied from 500 - 1700 stems ha^{-1} and basal area ranged from 7.66 – 19.55 m^2 ha^{-1}. Shannon-Wiener Index (H′) ranged from 0 - 1.28 while Simpson's index (Cd) ranged from 0.51 – 1. A greater number of tree species fell in 10-15 cm dbh followed by 5-10 cm diameter class.

Key Words: *Dry Deciduous Forest, Lateritic Zone, Tree Diversity, Vegetation Structure*

INTRODUCTION
Tropical and subtropical forests harbor maximum diversity of plant species on the earth (WCMC, 1992). The tropical dry forests occupy 38% of the total forest area in India (Dixit, 1997). Tropical dry forests have been recognized as comprising some of the most endangered and economically important species in the tropics (Hoekstra *et al*., 2005).

These forests are disappearing at alarming rates owing to deforestation for extraction of timber and other forest produce (Murphy and Lugo, 1986b; Hare *et al*., 1997; Raghubanshi and Tripathi, 2009). Further, Murphy and Lugo (1986b) argued that the seasonally dry deciduous forests are the most disturbed and least protected ecosystems on earth.

As about 42% of the world forests are dry forests, successful conservation of these tropical forests will ultimately depend on understanding their ecosystems (Hartshorn, 1983; Gentry, 1990). Study on species diversity, distribution pattern and vegetation structure of tropical forests is ecologically significant besides its usefulness in forest management.

Lateritic zone in West Bengal, comprising of Purulia district and western portions of Birbhum, Burdwan, Midnapore and Bankura districts, harbour floristically important Northern Tropical Dry Deciduous forests (Champion and Seth, 1968). Many of the plants have immense medicinal properties while some are traditionally used as dye yielding plants. The minor forest products of the region include lac, sal seeds and leaves, mohua flowers, fibres and flosses, grasses, barks, gums and resins (Mukherjee, 1995).

Lateritic soils are characterised by acidic pH, low NPK content and high iron as reported by many studies (Raychaudhuri and Mukherjee, 1942; Raychaudhuri, 1950, 1964, 1980; Choudhury, 1973; Ojha and Chattopadhyay, 1976; Chakraborty *et al*., 2002). Most of the earlier studies in this zone concentrated on floristic and ethnobotanical aspects (Rahaman and Mandal, 1999; Rahaman *et al*., 2000, 2008; Bhattacharya and Mukherjee, 2006; Bouri and Bhattacharya, 2011).

Bhattacharyaa *et al*., (2003) tried to reconstruct modern vegetation changes in lateritic zone using pollen analysis. Baring these, no quantitative analysis of forest structure has been reported. Therefore in this pilot study covering a few sites only, an attempt has been made to analyze the vegetation structure, composition and diversity of dry deciduous forests in this lateritic zone.

MATERIAL AND METHODS

Study area

The study was conducted in three sites during August 2010 to September 2010. Total six quadrats of 10m x 10m size were laid in three sites. Two quadrats were laid in 11miles, Panagarh Range, Burdwan division (23°40'54.4"N latitude, 87°40'20.2"E longitude), one in Garhjangal, Durgapur Range, Burdwan division (23°35'52.3"N latitude, 87°25'42.2"E longitude) and three in Gonpur, Birbhum division (24°04'17.7"N latitude, 87°40'56.4"E longitude). At all these sites a similar pattern of temperature and rainfall prevails throughout the year. Hot and humid climate dominate with a short duration of winter (December-January). Rainfall continues from June to September. In each quadrat, all the trees (plants > 1cm dbh) were identified and their number and diameter at breast height (dbh at 1.3m from the ground) were recorded. The shrubs, climbers and saplings were sampled through two 5m x 5m quadrats and herbs were sampled by laying four 1m x 1m quadrats nested within 10 m x 10m quadrat for trees. Voucher specimens of species were collected and their identities confirmed by the Taxonomists of the Department of Botany, Visva-Bharati consulting regional floras (Prain, 1903; Guha Bakshi, 1984; Sanyal, 1994).

Data Analysis

To determine the vegetation structure, analytical characters such as frequency, density, basal area and importance value index (IVI) were computed for each species in each site. Importance value index was calculated by summing up relative frequency, relative density and relative dominance values. A species area curve was plotted using the new species encountered in each of the subsequent 10m x 10m quadrats measured in terms of hectare. Density distribution was studied by determining the number of individuals in different size classes starting from 0 – 5 cm to 20 – 25 cm. Diversity indices reflect the manner in which abundance is distributed among the different species constituting the community. Species diversity index (H′) was determined for each site from the Shannon-Wiener's information function (Shannon and Weaver, 1963).

$H' = -\sum p_i \log_2 p_i$

Where, pi = ni/N, which denotes the importance probability of each species in a population; ni = number of individuals for species "i", N= total number of individuals of all the species. Concentration of dominance (Cd), known as Simpson's index was measured according to Simpson (1949).

$Cd = \sum p_i^2$

Soil Analysis

Three soil samples were collected from each site from a rooting depth of 15 cm in polythene bags and brought to the laboratory. The soil samples were air-dried, crushed using a pestle and mortar and then passed through a 10-mesh (2 mm) screen for analysis. Standard methodology as described by Jackson (1978) was followed for estimating pH, electrical conductivity, organic carbon, available nitrogen and phosphorus. Organic carbon was estimated by the wet digestion method (Walkley and Black, 1934). Potassium Permanganate Oxidation method (Subbiah and Asiza, 1956) has been employed for available nitrogen estimation. Olsen's Bicarbonate Extraction method (Olsen *et al*., 1954) was employed for estimation of available phosphorus.

RESULTS AND DISCUSSION

Floristic composition

Total 77 woody individuals (≥ 1cm dbh) of six tree species were enumerated in the three sites covering an area of 0.06 ha (Table 1). *Shorea robusta* dominated in all three sites with density per quadrat ranging from 5 to 12 individuals. 11 Miles has a monospecific forest of *Shorea robusta* with highest IVI of 300. In Garhjangal, *Shorea robusta* had highest IVI (257.5) followed by *Buchanania lanzan* (113.9). In Gonpur also, *Shorea robusta* scored the highest IVI (178.4) followed by *Madhuca indica* (68). Structurally and floristically the tropical dry forests are less complex than the wet forests, comprising about half or less of the tree species of wet forests (Murphy and Lugo, 1986b). In this regard the species richness of the present study (6 species in 0.06 ha for individuals ≥1 cm) is low.

Table 1: Phytosociological characteristics of tree species in the three sites

SN	Species	Family	Total No. of Individuals	Density (N quad^{-1})	Density (N ha^{-1})	Frequency (%)	Basal area (m^2 ha^{-1})	IVI (%)
11 Miles								
1	***Shorea robusta*** **Gaertn.f.**	**Dipterocarpaceae**	10	5	500	100	7.66	300
Garhjangal								
1	***Acacia catechu*** **Willd.**	**Mimosaceae**	1	1	100	100	0.29	108.6
2	***Buchanania lanzan*** **Spreng**	**Anacardiaceae**	1	1	100	100	1.69	120
3	***Holarrhena antidysentrica*** **L.**	**Apocynaceae**	2	2	200	100	0.18	114
4	***Shorea robusta*** **Gaertn.f.**	**Dipterocarpaceae**	12	12	1200	100	10.1	257.5
Gonpur								
1	***Buchanania lanzan*** **Spreng**	**Anacardiaceae**	4	1.33	133.33	66.67	0.58	35.8
2	***Madhuca indica*** **J.F. Gmel.**	**Sapotaceae**	12	4	400	66.67	3.8	68
3	***Pterocarpus marsupium*** **Roxb.**	**Papilionaceae**	1	0.33	33.33	33.33	0.66	17.8
4	***Shorea robusta*** **Gaertn.f.**	**Dipterocarpaceae**	34	11.33	1133.33	100	14.5	178.4

Table 2: Population size and tree diversity at the three sites

Parameter	11 Miles	Garhjangal	Gonpur
Number of families	1	4	4
Number of species	1	4	4
Tree density (no ha^{-1})	500	1600	1700
Total basal area (m^2 ha^{-1})	7.66	12.25	19.55
Shannon's index (H′)	0	1.19	1.28
Simpson's index (Cd)	1	0.59	0.51

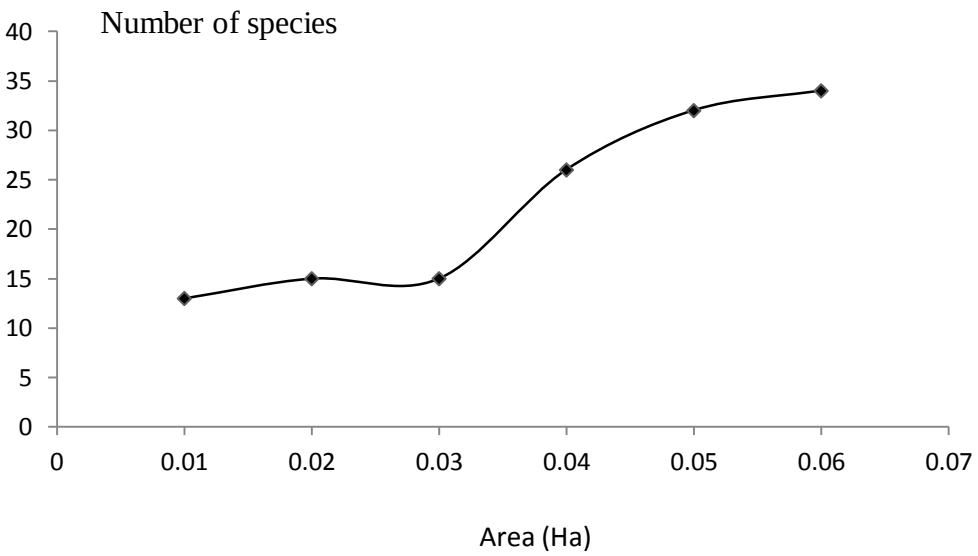

Figure 1: Species area curve for the forest sampled

However, it may be due to the area sampled being very small. The species area curve (Figure 1) shows an increase in number of species with the area sampled and more samples are required to obtain an asymptote and thus determine the biodiversity of this zone. Similar studies in other tropical dry deciduous forests covering 1 – 2 ha area have reported considerably high number of species – 57 species in the dry deciduous forests of Eastern Ghats (Sahu *et al*., 2012), 93 species in Rajasthan (Kumar *et al*., 2010), 46-133 species in Karnataka (Sukumar *et al*., 1992; Murali *et al*., 2003; Krishnamurthy *et al*., 2010), 50 species in Puerto Rico (Murphy and Lugo, 1986a).

Vegetation structure and Tree species diversity

Table 2 shows the average tree density, total basal area and diversity indices of the three sites. Average tree density is low in 11 Miles (500 N ha^{-1}) as compared to Garhjangal (1600 N ha^{-1}) and Gonpur (1700 N ha^{-1}). Similar trend was observed for total basal area with 7.66 m^2ha^{-1} in 11 Miles, 12.25 m^2ha^{-1} in Garhjangal and 19.55 m^2ha^{-1} in Gonpur. The basal area values are similar to those reported for dry deciduous forests of western India (5.9 to 19.31m^2ha^{-1}) and comparable with the ranges reported for dry forests of the world, 17 to 40 m^2ha^{-1} (Murphy and Lugo, 1986b).

Shannon-Wiener Index (H′) ranged from 0-1.28 while Simpson's index (Cd) ranged from 0.51-1 in the three sites. The value of Shannon's diversity index is 0 in the monospecific site 11 Miles and Simpson's concentration of dominance is maximum, 1. Garhjangal and Gonpur had low values of Shannon's index than reported in other similar forests, and Simpson's index is within the reported range for tropical forests. Diversity (H′) range of 0.83 – 4.1 has been reported by earlier workers for Sal forests (Singh *et al*., 1985; Rasingam and Parthasarathy, 2009; Shukla, 2009; Tripathi and Singh, 2009; Krishnamurthy *et al*., 2010; Sahu *et al*., 2012). The concentration of dominance (Simpson's index) in the present study sites are within the reported range (0.10 – 1) for tropical dry forests by other workers (Visalakshi, 1995; Kumar *et al*., 2010; Sahu *et al*., 2012).

The shrub layer had 76 individuals belonging to three species in 11 Miles (Table 3). This layer also had 55 saplings (< 1cm dbh) falling under seven species and four climbers having 35 individuals. Three herbs with 54 individuals composed the ground flora. Garhjangal had a single shrub species, 17 saplings of *Hollarhena* and two climbers with nine individuals. Five herbs with 55 individuals constituted the ground vegetation. Gonpur had three shrubs with nine individuals and four climbers with 37 individuals in the shrub layer. This layer also had 81 saplings belonging to seven tree species. The ground flora was rich with 259 individuals belonging to 12 herb species.

Table 3: Phytosociological characteristics of shrub layer and ground layer in the three sites

S.No.	Species	Family	Total No. of Individuals	Density (N quad^{-1})	Density (N ha^{-1})	Frequency (%)
11 Miles						
Shrubs						
1	*Carissa spinarum* L.	Apocynaceae	23	11.5	4600	100
2	*Phoenix acaulis* Roxb.	Arecaceae	45	22.5	9000	100
3	*Zizyphus oenoplia* (L.) Mill.	Rhamnaceae	8	4	1600	50
Saplings						
1	*Acacia catechu* Willd.	Mimosaceae	1	0.5	200	50
2	*Buchanania lanzan* Spreng	Anacardiaceae	17	8.5	3400	100
3	*Dillenia pentagyna* Roxb.	Dilleniaceae	1	0.5	200	50
4	*Holarrhena antidysentrica* L.	Apocynaceae	22	11	4400	100
5	*Madhuca indica* J.F. Gmel.	Sapotaceae	2	1	400	50
6	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	2	1	400	50
7	*Semecarpus anacardium* L.f.	Anacardiaceae	10	5	2000	100
Climbers						
1	*Asparagus racemosus* Willd.	Asparagaceae	15	7.5	3000	100
2	*Dioscorea alata* L.	Dioscoreaceae	1	0.5	200	50
3	*Hemidesmus indicus* (L.) R. Br.	Asclepiadaceae	8	4	1600	100
4	*Smilax macrophylla* Roxb. non Willd.	Smilacaceae	11	5.5	2200	100
Herbs						
1	*Phaseolus* sp	Papilionaceae	13	2.17	21666.67	66.67
2	*Lindernia parviflora* (Roxb.) Haines	Scrophulariaceae	21	3.5	35000	100
3	*Oldenlandia corymbosa* (L.) Lam.	Rubiaceae	20	3.33	33333.34	83.33
Garhjangal						
Shrubs						
1	*Zizyphus oenoplia* (L.) Mill.	Rhamnaceae	1	1	400	100
Saplings						
1	*Holarrhena antidysentrica* L.	Apocynaceae	17	17	6800	100
Climbers						
1	*Asparagus racemosus* Willd.	Asparagaceae	1	1	400	100
2	*Smilax macrophylla* Roxb. non Willd.	Smilacaceae	8	8	3200	100

Herbs						
1	*Phaseolus* sp	Papilionaceae	7	1.67	11666.67	50
2	*Lindernia parviflora* (Roxb.) Haines	Scrophulariaceae	2	0.33	3333.33	16.67
3	*Oldenlandia corymbosa* (L.) Lam.	Rubiaceae	13	2.17	21666.67	66.67
4	*Fimbristylis* sp	Cyperaceae	21	3.5	35000	100
5	*Rungia pectinata* Nees	Acanthaceae	12	2	20000	50
Gonpur						
Shrubs						
1	*Carissa spinarum* L.	Apocynaceae	5	1.67	166.67	66.67
2	*Phoenix acaulis* Roxb.	Arecaceae	2	0.67	66.67	33.33
3	*Zizyphus oenoplia* (L.) Mill.	Rhamnaceae	2	0.67	66.67	33.33
Saplings						
1	*Holarrhena antidysentrica* L.	Apocynaceae	8	2.67	266.67	33.33
2	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	1	0.33	33.33	33.33
3	*Madhuca indica* J.F. Gmel.	Sapotaceae	28	9.33	933.33	33.33
4	*Semecarpus anacardium* L.f.	Anacardiaceae	2	0.67	66.67	33.33
5	*Shorea robusta* Gaertn. f.	Dipterocarpaceae	24	8	800	100
6	*Syzygium cumini* (L.) Skeels	Myrtaceae	2	0.67	66.67	33.33
7	*Vangueria spinosa* (Roxb. ex Link) Roxb.	Rubiaceae	6	2	200	33.33
Climbers						
1	*Cissus adnata* Roxb.	Vitaceae	6	2	200	33.33
2	*Dioscorea alata* L.	Dioscoreaceae	15	5	500	66.67
3	*Hemidesmus indicus* (L.) R. Br.	Asclepiadaceae	13	4.33	433.33	100
4	*Smilax macrophylla* Roxb. non Willd.	Smilacaceae	3	1	100	66.67
Herbs						
1	*Borreria articularis* (L. f.) F.N. Will.	Rubiaceae	7	1.16	11666.67	50
2	*Curculigo orchioides* Gaertn.	Hypoxideae	19	3.16	31666.67	100
3	*Cynotis tuberosa* (Roxb.) Schult. f.	Commelinaceae	50	8.33	83333.33	33.33
4	*Desmodium gangeticum* (L.) DC.	Papilionaceae	6	1	10000	33.33
5	*Fimbristylis* sp	Cyperaceae	46	7.67	76666.67	66.67

6	*Kirganalia reticulata* (Poir.) Baill.	Euphorbiaceae	1	0.16	1666.67	16.67
7	*Lindernia parviflora* (Roxb.) Haines	Scrophulariaceae	91	15.16	151666.67	83.33
8	*Oldenlandia corymbosa* (L.) Lam.	Rubiaceae	13	2.16	21666.67	33.33
9	*Phaseolus* sp	Papilionaceae	8	1.33	13333.33	50
10	*Phyllanthus fraternus* GL Webster	Euphorbiaceae	15	2.5	25000	50
11	*Rungia pectinata* Nees	Acanthaceae	2	0.33	3333.33	16.67
12	*Vernonia cinerea* L.	Asteraceae	1	0.16	1666.67	16.67

Density distribution pattern

The distribution of trees in different density classes reveals a typical reverse J shaped distribution with dominance by small sized trees in all the three sites (Fig. 2). The maximum diameter recorded was 22.9 cm (for *Shorea robusta*). Only 9 out of total 77 trees exceeded 15cm diameter. The most preferred diameter class was 10-15 cm in 11 Miles (26 stems) and Garhjangal (9 stems) and 5-10 cm in Gonpur (8 stems). Mean tree density of 276 – 980 stems ha^{-1} has been reported in other tropical dry forests with preferred diameter classes ranging from 20 – 50 cm and above (Sahu *et al*., 2007, 2012; Bhadra *et al*., 2010; Krishnamurthy *et al*., 2010; Kumar *et al*., 2010). In the present study, the density ranged from 500-1700 stems ha^{-1} in the diameter classes 5 – 15 cm. Such a higher density of small sized individuals can be attributed to the open canopy and lower age of the trees. This is also clear from the reverse J-shaped diameter density distribution of trees indicating a regenerating forest with an evolving or expanding population. Presence of a large number of saplings of 11 species also indicates the same. Similar reverse J-shaped distribution has been reported in other tropical dry forests (Krishnamurthy *et al*., 2010; Sahu *et al*., 2012). Density is the most discriminating factor for early development of trees – a young stand matures by decreasing the number of individuals (Yoda, 1963). In some other tropical deciduous forests, A-shaped curve of tree density distribution suggested medium age of the forests (Vishalakshi, 1995; Parthasarthy and Sethi, 1997; Ayyappan and Parthasarathy, 1999; Kumar *et al*., 2010).

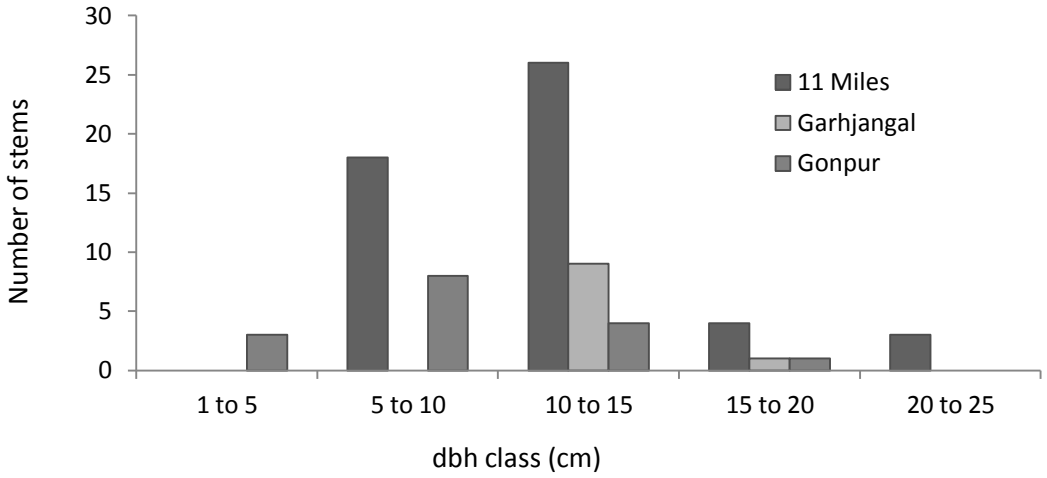

Figure 2: Density distribution patterns in the three sites.

Soil

Table 4 shows the mean values of soil physicochemical parameters in the three sites. Soils had low pH ranging from 4.3 to 4.94. The soils are poor in NPK nutrients as indicated by low values of nitrates, phosphates and potassium. There is little variation in NPK values in the three sites.

Table 4: Mean values of soil physicochemical parameters in the three sites.

Soil parameter	11 Miles	Garhjangal	Gonpur
pH	4.94	4.89	4.3
K^+ (ppm)	179	182	178.2
$NO3^-$ (ppm)	9	9.02	9.09
$PO4^{-3}$ (ppm)	10	10	10
Organic C (%)	0.21	0.21	0.62
Electrical conductivity (µS)	102.32	88.93	188.66

The organic carbon was higher in Gonpur (0.62%) than the other two sites (0.21%). Comparatively high values of organic carbon (2.23 – 2.81%) have been reported in the dry deciduous forest of western India (Kumar *et al*., 2010). Many earlier studies report the laterite soils to be poor in available nutrients of phosphorus, potassium and calcium. The nitrogen content generally varies from 0.03 to 0.06%. The pH ranges from 4.8 to 5.5 and base exchange capacity is low (Raychaudhuri and Mukherjee, 1942; Raychaudhuri, 1950, 1964, 1980; Choudhury, 1973; Ojha and Chattopadhyay, 1976; Chakraborty *et al*., 2002).

The present study on limited sites in these forests is very preliminary and subsequent sampling and monitoring will provide additional data on forest composition and diversity changes, which will be useful in forest management and conservation efforts.

ACKNOWLEDGEMENTS

The author is sincerely thankful to Professors S. Ray and S.K. Sen, UGC-DRS Program Co-ordinators, Depatrment of Botany, Visva-Bharati for providing necessary facility to accomplish the present work. The help received by Dr. C.H. Rahman and Dr. Subrata Mondal in species identification and other faculty members of the Department of Botany is duly acknowledged.

REFERENCES

Ayyappan N and Parthasarthy N (1999). Biodiversity inventory of trees in a large scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalai, Western Ghats, India. *Biodiversity and Conservation* **8**(11) 1533-1554.

Bhadra AK, Dhal NK, Rout NC and Reddy VR (2010). Phytosociology of the tree community of Gandhamardan hill ranges. *The Indian Forester* **136**(5) 610-620.

Bhattacharya A and Mukherjee A (2006). A preliminary forest survey in Garhjangal: Durgapur, West Bengal. *Indian Journal of Applied and Pure Biology* **21**(2) 293-298.

Bhattacharya K, Yousuf S and Gupta Bhattacharya S (2003). Pollen analysis in reconstructing modern vegetation changes in lateritic zones of West Bengal. In: *Late Quaternary Environment Change: Emerging Issues* (Ed. Anupama K and Achyuthan H), French Institute, Pondicherry 157-160.

Bouri T and Mukherjee A (2011). Biological spectrum of Bankati forest areas in Burdwan district, West Bengal. *Indian Journal of Science and Research* **2**(4) 57-60.

Chakraborty T, Ghosh GK and Laha P (2002). Fertility status and phosphorus fractionations in lateritic soils under different agro-ecosystems of West Bengal. *Journal of Agricultural Sciences* **72**(1) 42-44.
Choudhury RN (1973). Laterites of West Bengal. *Geographical review of India* **35**(1) 61-72.
Champion HS and Seth SK (1968). *A revised survey of forest types of India*. Delhi Manager of Publication, Delhi, Dehradun.
Dixit AM (1997). Ecological evaluation of dry tropical forest vegetation: An approach to environmental impact assessment. *Tropical Ecology* **38**(1) 87-100.
Gentry AH (1990). Floristic similarities and differences between Central America and upper and central Amazonia. In: *Four Neo Tropical Rainforests* (Ed. Gentry AH), Yale University Press, New Haven, CT. 141-160.
Guha Bkshi DN (1990). *Flora of Murshidabad District, West Bengal, India*. Scientific Publishers, Jodhpur, India.
Hare MA, Lantagne DO, Murphy PG and Chero H (1997). Structure and tree species composition in a subtropical dry forest in the Dominican Republic: Comparision with a dry forest in Puerto Rico. *Tropical Ecology* **38**(1) 1-17.
Hartshorn G (1983). Plants: introduction. In: *Costa Rican Natural History* (Ed. Jangen DH), University of Chicago Press, Chicago 118-157.
Hoekstra JM, Boucher TM, Ricketts TH and Roberts C (2005). Confronting a biome crisis: global disparities of habitat loss and protection. *Ecology Letters* **8**(1) 23-29.
Jackson ML (1973). *Soil Chemical Analysis.* Prentice Hall of India Private Limited, New Delhi.
Krishnamurthy YL, Prakasha HM, Nanda A, Krishnappa M, Dattaraja HS and Suresh HS (2010). Vegetation structure and floristic composition of a tropical dry deciduous forest in Bhadra Wildlife Sanctuary, Karnataka, India. *Tropical Ecology* **51**(2) 235-246.
Kumar JIN, Kumar RN, Bhoi RK and Sajish PR (2010). Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. *Tropical Ecology* **51**(2) 273-279.
Mukherjee AR (1995). *Forest resources conservation and regeneration – A study of West Bengal plateau*. Concept Publishing Company, New Delhi.
Murali KS, Kavitha A and Harish RP (2003). Spatial patterns of trees and shrub species diversity in Savandurga State Forest, Karnataka. *Current Science* **84**(6) 808-813.
Murphy PG and Lugo AE (1986a). Structure and biomass of subtropical dry forest in Puerto Rico. *Biotropica* **18**(2) 89-96.
Murphy PG and Lugo AE (1986b). Ecology of tropical dry forests. *Annual Review of Ecology and Systematics* **17** 67-88.
Ojha JK and Chattopadhyay NC (1976). Phosphate potential studies of five lateritic soils of West Bengal. *Indian Agriculturist* **20**(4) 241-244.
Olsen SR, Cole CV, Watanabe FS and Dean LA (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *U.S. Department of Agriculture Circular* **939**.
Parthasarthy N and Sethi P (1997). Tree and Liana species diversity and population structure in a tropical dry evergreen forest in south India. *Tropical Ecology* **38**(1) 19-30.
Prain D (1903). *Bengal Plants*. Calcutta, West Bengal.
Raghubanshi AS and Tripathi A (2009). Effect of disturbance, habitat fragmentation and alien invasive plants on floral diversity in dry tropical forest of Vindhyan Highlands: a review. *Tropical Ecology* **50**(1) 57-69.
Rahaman CH and Mandal S (1999). New records of some exotic plant species from Birbhum district, West Bengal. *Indian Journal of Applied and Pure Biology* **14**(2) 150-156.
Rahaman CH, Ghosh A and Mandal S (2008). Studies on ethnomedicinal uses of plants by the tribals of Birbhum district, West Bengal. *Indian Journal of Environment and Ecoplanning* **15**(1-2) 71-78.

Rahaman CH, Mondal S and Mandal S (2000). Study of host ranges of some phanerogamic parasites of Birbhum district, West Bengal. *Asian Journal of Microbiology, Biotechnology and Environmental Science* **2**(3-4) 141-144.

Rasingam L and Parthasarthy N (2009). Tree species diversity and population structure across major forest formations and disturbance categories in Little Andaman Island, India. *Tropical Ecology* **50**(1) 89-102.

Raychaudhury SP (1950). Red and Lateritic soils of India. *4rth International Congress in Soil Science (Amsterdam) Transactions* **3** 128-131.

Raychaudhury SP (1964). Phosphorus and Potassium status of Indian soils. Indian Council of Agricultural Research Bulletin **36** 43.

Raychaudhury SP (1980). The occurrence, distribution, classification and management of laterite and lateritic soil. *Cah. ORSTOM, series Pedology* **18**(3-4) 249-252.

Raychaudhury SP and Mukherjee KC (1942). Studies in Indian Red soils: 6, Determination of mineralogical composition. *Indian Journal of Agricultural Science* **21**(2) 323-335.

Sahu SC, Dhal NK and Mohanty RC (2012). Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malygiri hill ranges, Eastern India. *Tropical Ecology* **53**(2) 163-168.

Sahu SC, Dhal NK, Reddy CS, Pattanaik C and Brahmam M (2007). Phytosociological study of tropical dry deciduous forest of Boudh district, Orissa, India. *Research Journal of Forestry* **1** 66-72.

Sanyal MN (1994). *Flora of Bankura District*. Bishen Singh Mahindra Pal Singh, Dehradun, pp. 555.

Shannon CE and Wiener W (1963). *The mathematical theory of communication*. Urban University press, Illinois.

Shukla RP (2009). Patterns of plant species diversity across Terai landscape in north-eastern Uttar-Pradesh, India. *Tropical Ecology* **50**(1) 111-123.

Simpson EH (1949). Measurement of diversity. *Nature* **163** 688.

Singh JS, Singh SP, Saxena AK and Rawat YS (1985). The forest vegetation of Silent Valley in India. In: *Tropical Rain Forest: The Leeds Symposium* (eds. Chadwick AC and Sutton SL), Leeds Philosophical and Literary Society, Leeds, U.K. 25-52.

Subbiah BV and Asiza GL (1956). A rapid procedure for the estimation of available nitrogen in soils. *Current Science* 25(8) 259-261.

Sukumar R, Dattaraja HS, Suresh HS, Radhakrishna R, Nirmala SV and Joshi NV (1992). Long-term monitoring of vegetation in a tropical deciduous forest in Mudumalai, southern India. *Current Science* 62(9) 608-610.

Tripathi KP and Singh B (2009). Species diversity and vegetation structure across various strata in natural and plantation forests in Katerniaghat Wildlife Sanctuary, North India. *Tropical Ecology* **50**(1) 191-200.

Visalakshi N (1995). Vegetation analysis of two tropical dry evergreen forests in southern India. *Tropical Ecology* **36**(1) 117-127.

Walkley A and Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* 34 54-56.

World Conservation Monitoring Centre (WCMC) (1992). *Global Biodiversity: Status of the Earths Living Resources*. Chapman and Hall, London.

Yoda KK, Ogawa TH and Hozumi K (1963). Self thinning in overcrowded pure stands under cultivated and natural conditions. *Journal of the Institute of Polytechniques*, Osaka City University, Series D **14** 107-129.