02-Archana Meena 95-102

Article · June 2020

CITATIONS
0

READS
692

1 author:

Archana Meena
University of Rajasthan
6 PUBLICATIONS **180** CITATIONS

SEE PROFILE

Phytomorphology 66(3&4) 2016, 95-102

Structure, Composition and Diversity of Tree Strata of Semi-Arid Forest Community in Delhi, India

Archana Meena, M. Hanief, A. Bidalia and K.S. Rao
Natural Resource Management Lab, Department of Botany, University of Delhi, Delhi-110007, India

ABSTRACT

The present study investigated species composition, density, basal area, IVI (Importance Value Index), distribution pattern and diversity indices of trees in a semi-arid forest. Two sites, i.e., North Ridge Forest (NRF) and Central Ridge Forest (CRF) representing varied soil physical characters were selected for the study. The total tree density was 633 and 684 individuals ha^{-1} in NRF and CRF sites, respectively and the total basal area was 33.61 and 19.87 m^2 ha^{-1} in NRF and CRF sites, respectively. *Prosopis juliflora* (Sw.) DC was the most dominant tree species having highest density, basal area, frequency and IVI in both the forest sites. The Shannon-Weiner diversity index was higher for NRF (1.78) than CRF, whereas, the Simpson concentration of dominance was higher for CRF (0.52) than NRF. The distribution pattern analysis of the trees showed contiguous pattern for all the tree species except for *P. juliflora,* which showed random distribution at NRF. The present study provides significant baseline information for future studies on monitoring and sustaining biodiversity in these forests.

Key words: Dispersion pattern, diversity, invasion of exotic species, urbanization

Author for correspondence: Archana Meena, email: archanam417@gmail.com

Introduction

Vegetation ecology is the study of composition and sociological interaction of the species in a community (Mueller-Dombois & Ellenberg, 1974). The study provides information of species diversity, community organization, niche resource distribution, and turnover rate of species in an ecosystem (Mandal & Joshi, 2014). The study of quantification of forest vegetation is phytosociology (Braun-Blanquet, 1932), which aims to describe and classify the tree vegetation and predicts its future distribution pattern (Odum, 1971). In any ecological study of the forest, focusing on structure and function, the phytosociological analysis is a pre-requisite. Trees, being an important component of vegetation, require proper monitoring and management for maintaining species and habitat diversity (Turner, 1987; Attua & Pabi, 2013), which, in turn, are important aspects of forest dynamics that direct successional processes (Rennolls & Laumonier, 2000). The inventory of tree species will therefore be a useful tool in order to provide information on diversity of the forest and to maximize the conservation of biodiversity (Baraloto et al., 2013).

The Aravalli Mountain range are the oldest fold mountains and are approximately 692 km long extending from Gujarat through Rajasthan to Haryana and Delhi stretching in the south-west and north-west direction. It covers an area of 50,000 km^2 and protects the Indo-Gangetic Plains by acting as a barrier against the advancement of desert (Sinha, 2014). The northern end of the range, the Mewat Branch ends in Delhi as isolated hills and known as Delhi Ridge. The Delhi Ridge represents an ecosystem with its own distinct biodiversity and has been notified as reserved forest. The Flora of Delhi (Maheshwari, 1963) reported 478 tree species in Delhi. The vegetation of the ridge is semi-arid desert scrub characterized by more or less widely spaced stunted trees with patchy distribution (Maheshwari, 1963; Dakshini, 1966). The ridge is functioning as the Green lungs of the city and hence, proper and periodic monitoring of vegetation cover is essential to assess the environmental conditions in the ridge. The ridge is under the management of various government including the Forest Department and non-government organizations, which are working effectively towards the conservation and protection of the ridge. The National Green Tribunal (NGT) with its main focus to protect and conserve the green cover of Delhi has given further legal powers to the forest departments. Over the years, the ridge has shrunk and was limited

to few patches due to anthropogenic disturbances like urbanization, resource extraction, quarrying and encroachment (Sinha, 2014). Additionally, continuous urbanization leads to destruction and fragmentation of these forests and invasion of exotic species having serious impacts on the native tree species (Ouinsavi & Sokpon, 2010). The present study provides a significant baseline data for the conservation and management of existing flora and native tree species in these forests. The objective of the paper is to study the structure, composition and diversity of tree species in two forest sites of semi-arid forest of Delhi.

Materials and Methods

Study area: The state Delhi, comprising National Capital Territory, lies between 28˚24'17" N and 28˚53'00"N latitudes and 76˚50'24"E and 77˚24'17"E longitudes and covers an area of 1,483 km^2. The recorded forest area of the state is 85 km^2, which constitutes 5.73% of its geographical area, with reserved and protected forests comprising 91.76% and 8.24% of total forest area, respectively. The climate of the area is semi-arid and dry except during monsoon season. The study area received a total annual rainfall of 720 mm with 87 % of the total rain was received during the monsoon season (July-September). The average maximum and minimum temperature was with 31 and 19˚C, respectively, during the study period. The forest type is tropical thorny (6B/C) (Champion & Seth, 1968).

Geomorphologically, the NCT of Delhi is grouped into three units i.e., rocky surface representing the linear ridges with rounded crest and isolated hillocks comprising of rocks of Delhi; older Alluvial Plain with gently undulating surface; and flood plains of Yamuna river. The Delhi supergroup comprises quartzite, gritty quartzite, and arkosic grit with thin intercalations of micaceous schist. The micaceous schist occasionally contains crystals of garnet, andalusite and staurolite. Delhi Ridge constitutes the northernmost extension of the Aravalli range and contains the remnants of Precambrian time. The soil type on ridge has been reported as sandy loam to loam (Chibbar, 1985). For the present study, two sites were selected (1) North Ridge Forest (NRF) and (2) Central Ridge Forest (CRF) (Fig. 1),

Sampling and Data analysis: Sampling of tree species was conducted during August-September (2012). For assessing the population of trees, a total of 15 and 25 quadrats of 10 × 10 m each were laid randomly in NRF and CRF sites, respectively. All the trees with the diameter ≥ 10 cm DBH (1.37 m above from the base) occurring in each plot was measured and identified to the species level. All the trees were considered as individuals as per Knight (1975) and individuals with DBH < 10 cm were recorded as seedling/saplings (Pande et al., 1988). The vegetation composition was evaluated by determining the frequency, density and abundance, using the standard methods suggested (Misra, 1968).

$$\text{Frequency} = \frac{\text{Total number of quadrats in which the species occured}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of one species}}{\text{Total number of quadrats studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals of one species}}{\text{Total number of quadrats in which the species occured}}$$

The IVI of trees was calculated as the sum of relative frequency, relative density and relative dominance (Curtis & McIntosh, 1950), calculated as follows.

$$\text{Relative frequency} = \frac{\text{Frequency of one species}}{\text{Frequency of all species}} \times$$

$$\text{Relative density (\%)} = \frac{\text{Density of one species}}{\text{Density of all species}} \times 100$$

$$\text{Relative dominance (\%)} = \frac{\text{Basal area of one species}}{\text{Basal area of all species}} \times 100$$

The basal area of each tree was calculated as the ratio of CBH^2 (squared circumference at breast height) to 4π (Misra, 1968). To study the distribution pattern of tree species in both the forest sites, the ratio of abundance to frequency (A/F) for different species was derived. On the basis of A/F ratio the distribution pattern was designed as regular (<0.025), random (0.025-0.050) and contiguous (> 0.050) (Whitford, 1949).

Diversity indices: The Shannon-Wiener diversity index (H) (Shannon & Weaver, 1963) was calculated as:

$$H = -\sum_{i=1}^{s} -pi \ln(pi)$$

where H is Shannon-Wiener diversity index, pi is the proportion of individuals of species i out of all the individuals, and S is the number of species.

The Simpson concentration of dominance (Simpson, 1949) index was calculated as follows:

$$D = \sum_{n=1}^{s} (pi)^2$$

where, D is the Simpson concentration of dominance index; and pi is the proportion of individuals of species i out of all the individuals and S is the number of species

Species richness was determined by Margalef index (Margalef, 1968) as follows:

$$d = \frac{S}{\ln N} d = \frac{S}{\ln N}$$

where d is the Margalef index of species richness; S is the total number of species and N is the total number of individuals

Results

A total of 18 tree species belonging to eight families were present in the two forest sites; sixteen of them were found in NRF and only nine in CRF (Table. 1). Only seven species were common to both the sites. The Shannon-Weiner diversity index (H) was higher in NRF (1.78) as compared to CRF (1.17) site, whereas the Simpson concentration of dominance (D) was higher in CRF (0.52) as compared to NRF (0.42) site. *P. juliflora* was found to be the dominant tree species in both the sites with the highest density (360 and 460 individuals ha^{-1} in NRF and CRF sites, respectively), total basal area (18.07 and 11.25 m^2 ha^{-1} in NRF and CRF sites, respectively) and IVI (190.93 and 213.23 in NRF and CRF site, respectively). This is followed by *Pongamia pinnata* (L.) Pierre, *Azadirachta indica* Juss., *Acacia leucophloea* (Roxb.) Willd. and *Salvadora oleoides* Decne in NRF and CRF sites (Tables 2, 3). The frequency of *P. juliflora* was highest, at 84% and 100% in the NRF and CRF sites, respectively. The ratio of abundance to frequency (A/F) ranged from 0.04 to 0.45 and 0.06 to 1.50 in NRF and CRF site, respectively. The total tree density was estimated as 633 and 684 individuals ha^{-1} in the NRF and CRF sites, respectively. The total basal area for both the

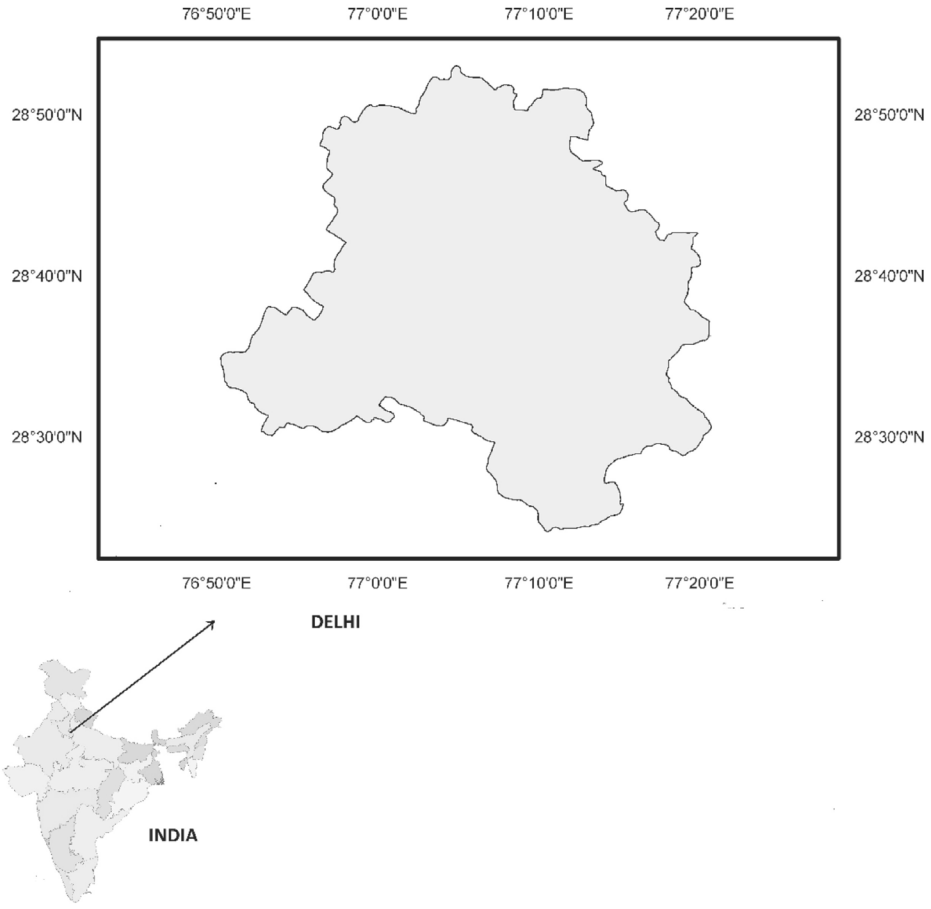

Fig. 1: Map of the study area

Table 1. Tree stand structure and diversity indices of a semi-arid forest, Delhi

Variable	North Ridge Forest	Central Ridge Forest
Area	87	864
No. of families	8	4
No. of species	16	9
Total density (individuals ha^{-1})	633	684
Total basal area (m^2 ha^{-1})	33.61	19.87
Species Richness	2.33	1.33
Shannon-Wiener	1.78	1.17
Simpson	0.42	0.52

Table 2. Phytosociological analysis of trees of the North Ridge Forest (NRF) site

Tree species	Family	F (%)	TD (individuals ha^{-1})	A	A/F	TBA (m^2 ha^{-1})	IVI
***Acacia leucophloea* (Roxb.) Willd.**	Fabaceae	13.33	33	2.50	0.19	2.69	11.77
***A. modesta* Wall.**	Fabaceae	6.67	7	1	0.15	0.03	3.74
***Albizia lebbeck* (L.) Bent.**	Fabaceae	6.67	7	1	0.15	1.88	3.93
***Azadirachta indica* Juss.**	Meliaceae	20	33	1.67	0.08	2.86	14.48
***Bauhinia purpurea* L.**	Fabaceae	6.67	13	2	0.30	0.09	4.70
***Butea monosperma* (Lam.) Taub.**	Fabaceae	6.67	7	1	0.15	0.10	3.75
***Cassia fistula* L.**	Fabaceae	13.33	27	2	0.15	1.01	9.93
***Cordia dichotoma* G. Forst.**	Boraginaceae	6.67	13	2	0.30	0.47	4.77
***Crateva religiosa* Forst.f.**	Capparaceae	6.67	13	2	0.30	0.07	4.70
***Ficus racemosa* L.**	Moraceae	6.67	13	2	0.30	0.19	4.72
***Holoptelea integrifolia* Planch.**	Ulmaceae	13.33	27	2	0.15	0.52	9.73
***Pithecellobium dulce* (Roxb.) Benth.**	Fabaceae	6.67	7	1	0.15	0.20	3.76
***Pongamia pinnata* (L.) Pierre**	Fabaceae	26.67	33	1.25	0.05	1.01	16.22
***Prosopis juliflora* (Sw.) DC**	Fabaceae	100	360	3.60	0.04	18.07	190.93
***Salvadora oleoides* Decne.**	Salvadoraceae	6.67	20	3	0.45	0.49	5.93
***Syzygium cumini* (L.) Skeels.**	Myrtaceae	6.67	20	3	0.45	3.93	6.93

F = Frequency; TD = Tree density; A = Abundance; A/F = Abundance to frequency ratio; TBA = Total basal area; IVI = Importance Value Index.

forest sites was estimated to be 33.61 and 19.87 m^2 ha^{-1}, for NRF and CRF sites, respectively.

Discussion

The structure, function and composition of a forest are controlled by factors like soil conditions, topography, climate and natural or anthropogenic disturbances (Mandal & Joshi, 2014). The tree density (658 individuals ha^{-1}) is lower than that of the dry deciduous forests of Rajasthan (917-1368 stems ha^{-1}, Sultana et al., 2014), but is higher than that of the dry tropical forests of Vindhyan hills (35-419 stems ha^{-1}, Sagar et al., 2003). This could be due to the high density of individuals with small diameters (Krishnamurthy et al., 2010).

The mean basal area (26.74 m^2 ha^{-1}) recorded in the study is within the range reported in studies for dry forests (3-32.73 m^2 ha^{-1}; Krishnamurthy et al., 2010; Sultana et al., 2014) but was higher than range reported for various forests of India (1.31-13.78 m^2 ha^{-1}, Jha & Singh, 1990); tropical dry forests in Vindhyan hills (1.30-13.78 m^2 ha^{-1}, Sagar et al., 2003; Sagar & Singh, 2006) and Eastern Ghats (15.20 m^2 ha^{-1}, Sahu et al., 2016). Within the forest sites the total basal area was lower in CRF as compared to NRF which could be due to smaller number of individuals in larger diameter classes as also observed in other studies (Gonzalez & Zak, 1996).

In the present study, *P. juliflora* was found to be the most dominant tree species contributing 40 and 50% of the total frequency, 31 and 29% of the total abundance, 57 and 68 % of the total tree density, 53 and 56% of the total basal area and 64 and 71% of the total IVI in NRF and CRF site, respectively. This indicates that the bulk of space and resources are being utilized by this species in these forests. The A/F ratio showed a contiguous distribution pattern for all the species in both sites except for *P. juliflora*, which was randomly distributed in the NRF site. Contiguous distribution pattern has been reported in tropical (Pande et al, 1988; Shanmughavel, 1994) and temperate forest (Kershaw, 1973; Gairola et al., 2011) and tropical dry deciduous forest (Sultana et al., 2014). The contiguous distribution is considered as the most common pattern of distribution in nature (Odum, 1971) and is due to slight but significant variations in the ambient environmental conditions or due to natural or anthropogenic disturbances causes large gap formation (Goparaju & Jha, 2009). Contrary to this, random distributions occur in more uniform environmental condition (Odum, 1971). The random distribution of *P. juliflora* could be due to its wide ecological amplitude and ability to survive in extreme conditions. The distribution pattern is therefore considered as an important ecological factor as it controls the dispersal of species at any given site (Hubbell et al., 1999). In order to compare the diversity and abundance of species, biodiversity indices are generated**.** Higher the values of biodiversity indices greater will be the species richness, diversity and abundance (Adekunle et al., 2013). In the present study, the Shannon-Wiener

Table 3. Phytosociological analysis of trees of the Central Ridge Forest (CRF) site

Tree species	Family	F (%)	TD (individuals ha^{-1}`)	A	A/F	TBA (m^2 ha^{-1})	IVI
***Acacia leucophloea* (Roxb.) Willd.**	Fabaceae	20	24	1.20	0.06	1.73	16.16
***A. nilotica* (L.) Delile**	Fabaceae	12	16	1.33	0.11	1.32	12.29
***Azadirachta indica* Juss.**	Meliaceae	12	16	1.33	0.11	1.32	9.86
***Butea monosperma* (Lam.) Taub.**	Fabaceae	4	24	6	1.50	0.56	6.13
***Cassia fistula* L.**	Fabaceae	8	8	1	0.13	0.11	5.95
***Ficus drupacea* Thunb.**	Moraceae	4	8	2	0.50	0.34	3.60
***Pongamia pinnata* (L.) Pierre**	Fabaceae	16	44	2.75	0.17	1.14	16.86
***Prosopis juliflora* (Sw.) DC**	Fabaceae	84	468	5.57	0.07	11.25	213.23
***Salvadora oleoides* Decne.**	Salvadoraceae	12	48	4	0.33	2.04	15.92

F = Frequency; TD = Tree density; A = Abundance; A/F = Abundance to frequency ratio; TBA = Total basal area; IVI = Importance Value Index.

diversity index (H) in both the sites were within the range reported for ecosystems of India's forest (0.00-4.21) (Singh et al., 1984; Bisht & Sharma, 1987; Pande, 1999; Sundarapandian &Swamy, 2000; Sahu et al., 2012; Naidu & Kumar, 2016). The Simpson concentration of dominance index (D) is within the range reported in earlier studies (0.21-1.34) (Knight, 1975; Visalakshi, 1995; Lalfakawma et al., 2009). The relatively wet conditions (soil moisture; 4.40%) helped the establishment of a higher number of species in NRF as compared to CRF with low moisture (3.09%). Management interventions such as protective boundary, reduced grazing by wild herbivores such as Neelgai in NRF are also other major contributing factors for high species diversity as compared to CRF. The ability of *P. juliflora* to adapt in low moisture conditions (de Souza Nascimento et al., 2014), higher density of *P. juliflora* in CRF as compared to NRF and its non-palatability provided additional opportunity to establish itself in larger numbers in CRF even though there is increased herbivore pressure (Sinha, 2014).

Monospecific stands of exotic species like *P. juliflora* are of concern, as this species is able to grow and spread rapidly in poor soil due its wide ecological amplitude (de Souza Nascimento et al., 2014). Being an invasive species it has superior competitive ability and can displace the native species by influencing their growth and seed germination (Inderjit et al., 2008). Hence, it is considered a potential threat to indigenous species and requires a strict check on its distribution (Robinson, 2003; Sultana et al., 2014) and special attention while framing conservation and management policies. The total eradication of the species is however difficult and ecologically risky as it has established well in these forests. Hence, future plans focusing on sustainable control on the growth and regeneration of the *P. julifora* and land use management strategies like using open patches for plantation of native or indigenous plant species will be helpful (Sinha, 2014). Although, the entire ridge has been notified as reserved forest, continued habitat destruction due to felling of trees, grazing, excavation and other activities is taking place. Therefore, systematic management plan is required for the effective conservation of Delhi Ridge. The present phytosociological analysis of the semi-arid forest of Delhi provides data for researchers and policy makers on forest inventory and its effects on future conservation strategies.

Conclusion

Tree species in a forest ecosystem influences its structure and composition. The data of phytosociological parameters, distribution pattern and diversity of tree species in a forest is useful for forest managers, researchers and scientists for framing effective management policies for forest conservation. Although the Delhi Ridge forest is notified as reserved forest over the years destruction for the purpose of construction and expansion leads to loss of indigenous trees. The high contribution of *P. juliflora* to the total tree density, basal area, frequency and IVI of both the sites indicates its dominance and potential threat to biodiversity in these forests. The study is limited to a small area; however, studies on a larger scale are required to determine suitable conservation and management strategies for the enhancement of biodiversity of the forests.

Acknowledgements

Archana Meena thanks Council of Scientific and Industrial Research (CSIR), M. Hanief and A. Bidalia thank University Grants Commission (UGC) for funding. We thank University of Delhi for providing Research and Development Grant. We are also grateful to the Forest Department of Delhi for their support during study.

References

Adekunle, V.A.J, Olagoke, A.O. & Abilene, S.O. 2013. Tree species diversity and structure of a Nigerian strict nature reserve. Tropical Ecology, 54: 275-289.

Attua, E.M. & Pabi, O. 2013. Tree species composition, richness and diversity in the northern forest-savanna ecotone of Ghana. Journal of Applied Biosciences, 69: 5437-5448.

Baraloto, C., Molto, Q., Rabaud, S., Hérault, B., Valencia, R., Blanc, L., Fine, P.V.A. & Thompson, J. 2013. Rapid simultaneous estimation of above ground biomass and tree diversity across Neotropical forests: a comparison of field inventory methods. Biotropica, 45: 288-298.

Bisht, A.P.S. & Sharma, S.C. 1987. Disturbance regimes in sal (*Shorea robusta*) forests of Dehra Dun Forest Division. International Journal of Ecology and Environmental Science, 13: 87-94.

Braun-Blanquet, J. 1932. Plant Sociology. The study of plant communities. Conard, H.S. & Fuller, G.D. (eds.) McGraw-Hill Book Co, New York, 439 pp.

Champion, H.G. & Seth, S.K. 1968. A Revised Survey of The Forest Types of India. Government of India Publications, New Delhi, India, 404 pp.

Chibbar, R.K. 1985. Soils of Delhi and their management, In: Soils of India and Their Management.Biswas, B.C.,Yadav, D.S. & Maheshwari, S. (eds.) Fertiliser Association of India,

New Delhi, India, 72-86 pp.

Curtis, J.T. & McIntosh, R.P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology, 31: 434-455.

Dakshini, K.M.M. 1966. Vegetation of Delhi state: Mehrauli region. I. Analysis of Pattern. Proceedings of the National Institute of Sciences in India, 34B: 127-133.

de Souza Nascimento, C.E., Tabarelli, M., da Silva, C.A.S., Leal, I.R., de Souza Tavares, W., Serrãno, J.E. & Zanuncio, J.C. 2014. The introduced tree *Prosopis juliflora* is a serious threat to native species of the Brazilian Caatinga vegetation. Science of Total Environment, 481: 108-11

Goparaju, L. & Jha, C.S. 2009. Spatial dynamics of species diversity in fragmented plant communities of a Vindhyan dry tropical forest in India. Tropical Ecology, 51: 55-65.

Gairola, S., Sharma, C.M., Suyal, S. & Ghildiyal, S.K. 2011. Composition and diversity of five major forest types in moist temperate climate of the western Himalayas. Forestry Studies in China, 13: 139-153.

Gonzalez, O.J. & Zak, D.R. 1996. Tropical dry forest of St. Lucia, West Indies. Biotropica, 28: 618-626.

Hubbell, S.P., Foster, R.B., O'Brien, S.T., Harms, K.E., Wechsler, B., Wright, S.J. & de Lao, S.L. 1999. Light gap disturbance, recruitment limitation and tree diversity in a Neotropical forest. Science, 283: 554-557.

Inderjit, Seastedt, T.R., Callaway, R.M., Pollock, J.L. & Kaur, J. 2008. Allelopathy and plant invasions: traditional, congeneric, and biogeographical approaches. Biological Invasion 10: 875-90.

Jha, C.S. & Singh, J.S. 1990. Composition and dynamics of dry tropical forest in relation to soil texture. Journal of Vegetation Science, 1: 609-614.

Kershaw, K.A. 1973. Quantitative and Dynamic Plant Ecology. 2nd edn. ELBS and Edward Arnold (Publ.) Ltd., London, 308 pp.

Knight, D.H. 1975. A phytosociological analysis of species-rich tropical forest on Barro Colorado Island, Panama. Ecological Monographs, 45: 259-284.

Krishnamurthy, Y.L., Prakasha, H.M., Nanda, A. & Krishnappa, M. 2010. Vegetation structure and floristic composition of a tropical dry deciduous forest in Bhadra Wildlife Sanctuary, Karnataka, India. Tropical Ecology, 51: 235-246.

Lalfakawma, Sahoo, U.K., Roy, S., Vanlalhriatpuia, K. & Vanalalhluna, P.C. 2009. Community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of North-East India. Applied Ecology and Environmental Research, 7: 303-318.

Maheshwari, J.K. 1963. The Flora of Delhi. New Delhi: Council of Scientific and Industrial Research, India, 447 pp.

Mandal, G. & Joshi, S.P. 2014. Analysis of vegetation dynamics and phytodiversity from three dry deciduous forests of Doon Valley, Western Himalaya, India. Journal of Asia-Pacific Biodiversity, 7: 292-304.

Margalef, R. 1968. Perspectives in Ecological Theory. University of Chicago Press, Chicago, 111 pp.

Misra, R. 1968. Ecology Work Book. Calcutta, Oxford and IBH Publishing Company, New Delhi, India, 242 pp.

Mueller-Dombois, D. & Ellenberg, H. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York, 547 pp.

Naidu, M.T. & Kumar, O.A. 2016. Tree diversity, stand structure, and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. Journal of Asia-Pacific Biodiversity, 9: 328-334.

Odum, E.P. 1971. Fundamentals of Ecology. 3rd edn. W.B. Saunders and Co., Philadelphia, PA, 360pp.

Ouinsavi, C. & Sokpon, N. 2010. Morphological variation and ecological structure of Iroko (*Milicia excelsa* Welw. C.C. Berg) populations across different biogeographical zones in Benin. International Journal of Forestry Research, 2010: 1-10.

Pande, P.K., Bisht, A.P.S. & Sharma, S.C. 1988. Comparative vegetation analysis of some plantation ecosystems. Indian Forester, 114: 379-388.

Pande, P.K. 1999. Comparative vegetation analysis of Sal (*Shorea robusta*): regeneration in relation to their disturbance magnitude in some Sal forests. Tropical Ecology, 40: 51-61.

Rennolls, K. & Laumonier, Y. 2000. Species diversity structure analysis at two sites in the tropical rain forest of Sumatra. Journal of Tropical Ecology, 16: 253-270.

Robinson, M.D. 2003. The importance of native trees in sustaining biodiversity in arid lands. In: Conserving Biodiversity in Arid Regions. Best Practices in Developing Nations. Lemons, J., Victor, R. & Schaffer, D. (eds.) Kluwer Academic Publishers, Boston. 395-412 pp.

Sagar, R., Raghubanshi, A.S. & Singh, J.S. 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. Forest Ecology and Management, 186: 61-71.

Sagar, R. & Singh, J.S. 2006. Tree density, basal area and species diversity in a disturbed dry tropical forest of northern India: implications for conservation. Environmental Conservation, 33: 256-262.

Sahu, S.C., Dhal, N.K. & Mohanty, R.C. 2012. Tree species diversity and soil nutrient status in a tropical sacred forest ecosystem on Niyamgiri hill range, Eastern Ghats, India. Tropical Ecology, 53: 163-168.

Sahu, S.C., Suresh, H.S. & Ravindranath, N.H. 2016. Forest structure, composition and above ground biomass of tree community in a Tropical Dry Forests of Eastern Ghats, India. Notulae Scientia Biologicae, 8: 125-133.

Shannon, C.E. & Weaver, W. 1963. The Mathematical Theory of Communication. University of Illinois Press, Urbana, USA, 117 pp.

Shanmughavel, P. 1994. Phytosociological studies of Dimbam Hill, Sathyamangalam Forest Division, Tamil Nadu, India. Van Vigyan, 32: 80-85.

Simpson, E.H. 1949. Measurement of diversity. Nature, 163: 688.

Sinha, G.N. 2014. An Introduction to the Delhi Ridge. Department of Forests & Wildlife, Govt. of NCT of Delhi, New Delhi, India, xxiv + 154 pp.

Singh, J.S., Singh, S.P., Saxena, A.K. & Rawat, Y.S. 1984. The forest vegetation of Silent Valley, India. In: Tropical Rain Forest: the Leeds Symposium. Chadwick, A.C. (ed.). Literary Society, Leeds, U.K. Central Museum, 25-52 pp.

Sultana, A., Hussain, M.H. & Rathore, D.K. 2014. Diversity of tree vegetation of Rajasthan, India. Tropical Ecology, 55: 403-410.

Sundarapandian, S.M. & Swamy, P.S. 2000. Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, South India. Journal of Tropical Forest Science, 12: 104-123.

Turner, M.G. 1987. Landscape Heterogeneity and Disturbance. Springer-Verlag, New York, 240pp.

Visalakshi, N. 1995. Vegetation analysis of two tropical dry evergreen forests in southern India. Tropical Ecology, 36: 117-127.

Whitford, P.B. 1949. Distribution of woodland plants in relation to succession and clonal growth. Ecology, 30: 199-288.