VEGETATION INTER-RELATIONSHIP AND REGENERATION STATUS IN TROPICAL FOREST STANDS OF CENTRAL INDIA

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Abstract: The regeneration status of the vegetation reflects the health of forest ecosystem. In this context, the present study was done in order to assess the rarity or commonness of the species along with regeneration status and species inter-relationship in tropical forest ecosystem. The study site of present investigation includes Achanakmar-Amarkantak Biosphere Reserve. Four forests stand *viz.*, ddense, regenerating, medium and degraded forest having diverse vegetation attributes and representative of the region's vegetation were marked for the study. The permanent plot techniques were opted for enumeration through stratified random sampling method. The tropical forest studied reflects high rarity of the species in different sites under various stratified vegetation. Total 24 species distributed into 17 families were recorded in the study sites. The species commonness or high occurrence of the species is found to be negligible due dominance of species over the area. Regeneration status of different species showed drastic scenario in different forest stands. The good regeneration in different sites varied from 9.09-30.77% being lowest in degraded forest site and maximum in regenerated forest stand. The results revealed significant differences in species abundance, occurrence, regeneration status and inter-relationship in various forests stands. The screening of the species on the basis of abundance, regeneration status and positive or close inter-relationship between different species at site level can be utilized as effective tools for the scientific management, conservation and sustainable development of forest stands.

Keywords: Abundance, Inter-relationship, Rarity, Regeneration status, Vegetation stands

INTRODUCTION

The tropical forests are major natural resource having diverse variation in terms of floral and faunal biodiversity. These forests are subjected to alter due to various biotic and abiotic factors which accelerate the process of degradation of these landscapes throughout the world. In Indian context, these situations area more alarming due to population rise, urbanization, industrialization, resource dependency, land use change, changing climates, forest fragmentation and forest fire events (Kagezi et al. 2016;Yadav et al. 2017; Yadav and Jhariya, 2017; Jhariya and Yadav, 2018; Oraon et al. 2018; Jhariya et al. 2019).

The tropical forests are reported to have the diversity in vegetational life forms and great inherent self-recruitment ability to sustain these terrestrial ecosystems (Singh and Chaturvedi, 2017; Oraon and Jhariya, 2018). The natural forest stand development depends upon site condition, seed factors and regeneration status of the species under specific environmental conditions (Jhariya and Oraon, 2012). The renewal of forest is the natural events in which seedlings undergone through various processes towards establishing as a tree. The regeneration potential and its status is a detrimental for sustainable forestry towards management and conservation of these valuable forests resources.

The systematic and precise information on species status, abundance, occurrence, species inter-relationship in different vegetal layer at species and site level is insufficient and lacking. The depletion of species in a given area due to site specific disturbance causes improper natural recovery which declines the population dynamics in a stand and leads towards alterations in the ecosystems integrity (Singh et al. 2009; Singh and Chaturvedi, 2017; Jhariya et al. 2019). These problems of natural sustenance of vegetation need to be properly addressed and managed for healthy ecosystems. In this connection the present investigation deals with the species inter-relationship and regeneration status of different forest stands in a tropical ecosystem of Chhattisgarh, India.

MATERIALS AND METHODS

The present investigation was carried out at tropical forest of Chhattisgarh, India. The study site includes the Achanakmar-Amarkantak Biosphere Reserve. Four forests stand *viz.*, dense, medium, regenerating and degraded forest stand having diverse vegetation attributes and representative of the region's vegetation were marked for the study. The area situated at 22º 15' - 22º 58' N latitude and 81º 25' - 82º 5' E longitude. The study region reflects tropical climate with average temperature of $17.2^{o}C$ (January) to $31.8^{o}C$ (May). The total average annual precipitation is about 1400 mm. The laterite, black and alluvial soil are characteristic features of the entire region (Yadav, 2016, 2018, 2019). The forest

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are mostly tropical (i.e., dry tropical and moist deciduous) over the entire region (Champion and Seth, 1968).

The stratified random sampling was done within the 1 hectare permanent plot in various forests stands. The trees were measured within 10m × 10m sized quadrats and girth at breast height (GBH) of individuals was measured at species level. For measuring saplings and seedlings, a quadrat of 2m × 2m within 10m × 10m quadrats at the center point was laid. The GBH of trees and saplings were recorded at 1.37 m from ground level. The seedling was measured above 10 cm from the ground level. The field data were subjected to various analyses *viz.,* frequency, density, abundance, and importance value index (IVI) through standard methods (Curtis and McIntosh, 1950; Phillips, 1959).

The species rarity or commonness of the species was calculated as the frequency class of the species (Raunkiaer, 1934; Hewit and Kellman, 2002). As per frequency classes, the species were categorized as A, B, C, D, and E, where A represents rare (0–20%), B represents low frequency (20–40%), C represents intermediate frequency (40–60%), D represents moderately high frequency (60–80%), and E represents high frequency or common (80–100%). The regeneration potential of urban vegetation was determined as per the Khan et al. (1987). The statistical interpretation (multivariate analysis) was done through two-way dendrogram to assess the inter-relationship of the different tree species in various forests stand by using MINITAB presents version 15.0 statistical computer software (Kumar et al. 2017; Jhariya 2017).

RESULTS AND DISCUSSION

Floristic status of vegetation

The family-wise distribution of the species across the sites was presented in Figure 1. A sum of 17 families includes 24 species were recorded over entire region of study sites. The distribution of species as per family reflected that the dominant family was Combretaceae (3 species) followed by Anacardeaceae, Caesalpiniaceae, Euphorbiaceae, Leguminaceae, Myrtaceae (2 species each). The families (11) having single species were Annonaceae, Bombicaceae, Burseraceae, Dipterocarpaceae, Ebnaceae, Lythraceae, Phyllanthaceae, Rhamnaceae, Samydaceae, Sapindaceae and Sapotaceae, respectively.

The present finding is supported by Rahman et al. (2010) they mentioned 22 species representing 17 families in the study sites. Total 12 species were reported by Gutierrez et al. (2004) during the investigation. Further they reported the disturbance regimes alter the stand scenario in term of species and plant family presence. Similarly, Pawar et al. (2014) reported the number of tree species in different sites ranged from 6-12.
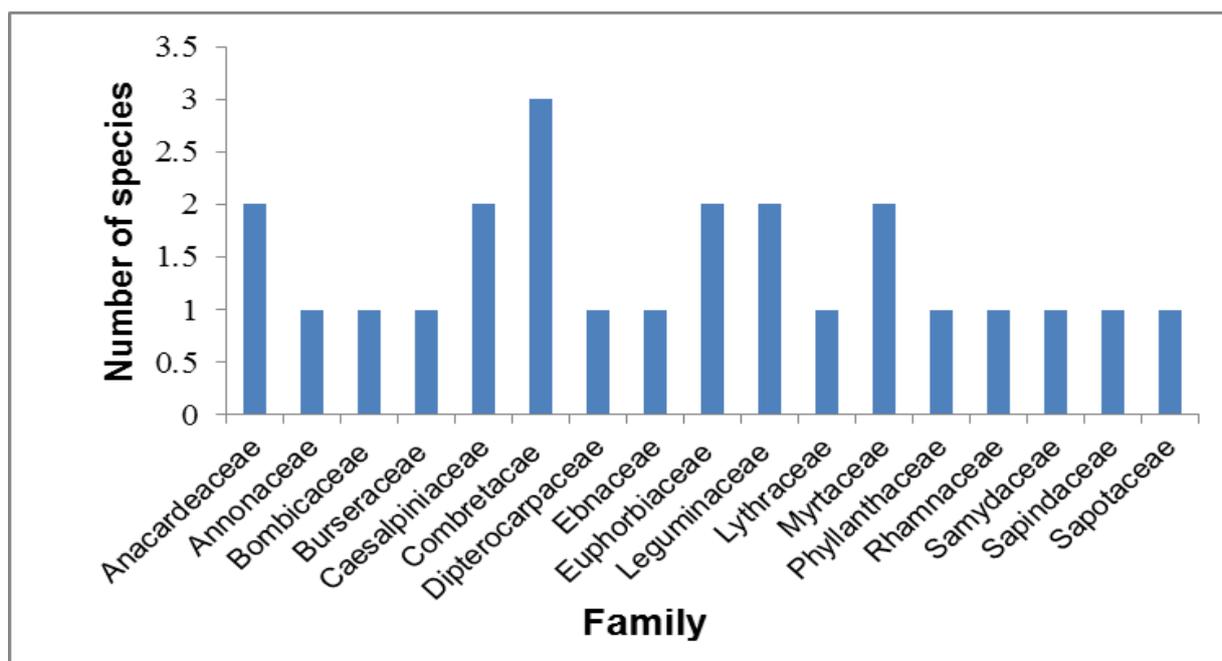

Figure 1. Family-wise distribution of species in the concerned study sites

Vegetation Abundance

The species occurrence and abundance of species under different vegetation stratum in various forest stand of tropical forest studied are given in Table 1 & Table 2.

Dense forest site reflected total 8 species under seedlings, out of which 5 species (62.5%) were rare in the studied site while remaining 37.5% (3 species) where showed low frequency class distribution. There is no species which reflects common, intermediate and moderately high frequency class in seedling

layer. Similar trend in sapling layer was recorded as 66.67% reflected rarity over that area while remaining showed low frequency class. The tree layer reflected 50% species were showed rarity over the area 37.50% species revealed low frequency class, 6.25% species reflected intermediate frequency and 6.25% species have common distribution over the area. At regenerated forest site total 5 seedling species were recorded, of which 40% species were rare, 40% species showed low frequency class and 20% species recorded intermediate frequency class. The sapling layer showed almost similar trends as in case of seedling. Tree layer revealed that 83.33% species showed rarity over the area while remaining 16.67% species were showed common occurrence. The medium forest site, in seedling stratum cent percent species showed rarity over the study site, whereas in case of saplings 66.67% species showed rarity while remaining species reported the low frequency in the medium forest site. In tree layer 66.67% reported rarity in the site, 22.22% species showed low frequency class and 11.11% reported under species commonness. At degraded forest site 3 out of 4 species showed rarity under the seedling layer, cent percent species reported rarity under sapling layer while in tree layer 4 out of 7 species showed rarity. In this site not a single species under seedling, sapling and trees were recorded under the category of moderately high to common in occurrence.

The abundance of the species depends on the site condition, prevailing environmental factors as well as various natural and anthropogenic factors in a given localities. It is reported that in various ecosystems most of the species under different plant life forms showed more occurrence of species individually. The similar trend was also reflected during the present investigation that the most of the species showed rarity over the area under different forest stands (Raunkiaer, 1934; Hewit and Kellman, 2002; Kumar *et al.* 2017; Jhariya, 2017; Oraon and Jhariya, 2018).

Vegetational inter-relationship in different forest stand

Figure 2 shows the inter-relationship of tree species between various phytosociological parameter (density, IVI and basal area) of different species found in dense forest stands. It reflects variable pattern of clustering which revealed some species have smaller cluster while some distant clustering pattern. The smaller clustering between species and various parameters showed their positive inter-relationship and association between them. In dense forest stand the smaller clustering were framed between *Diospyros melanoxylon* and *Buchanania lanzan*, *Lannea grandis* and *Miliusa tomentosa*, *Lagerstroemia parviflora* and *Anogeissus latifolia*.
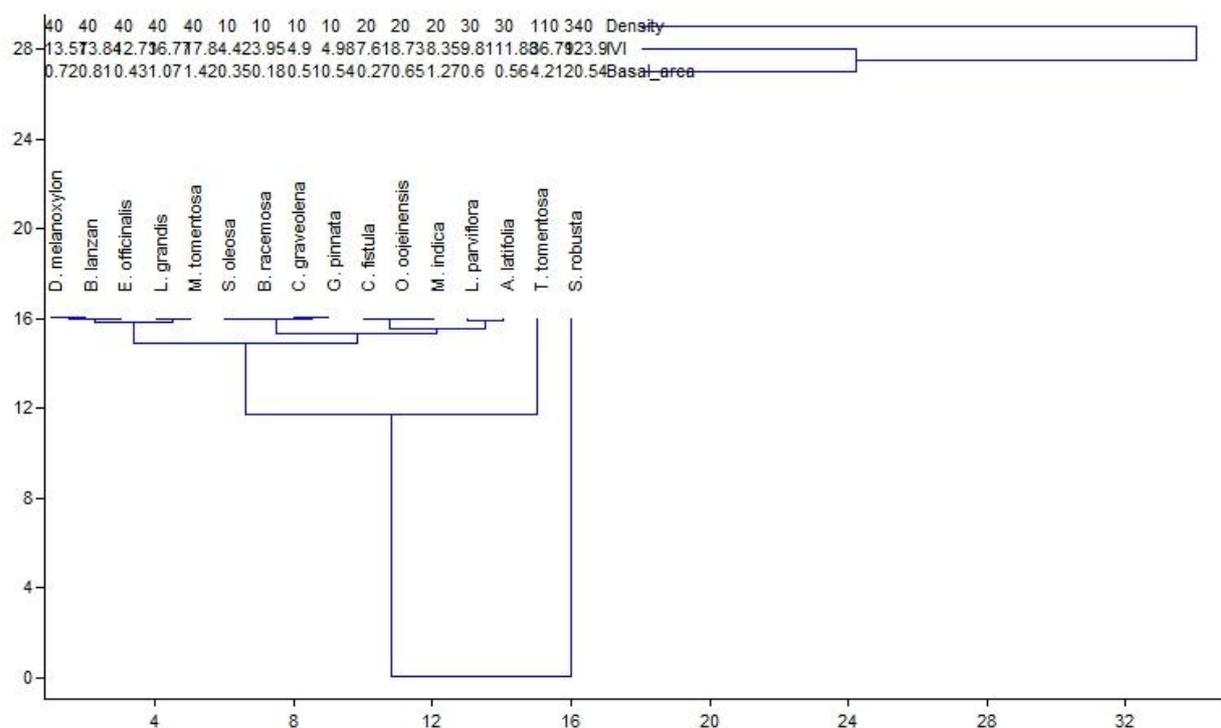

Figure 2 Clustering of various phytosociological parameter of tree layer of dense forest site

Table 1. Occurrence of the species as per the rarity and commonness scheme at tropical forest of Chhattisgarh

Species	Dense Forest Site			Regenerated Forest Site			Medium Forest Site			Degraded Forest Site		
	Seedlings	Saplings	Trees	Seedlings	Saplings	Trees	Seedlings	Saplings	Trees	Seedlings	Saplings	Trees
Anogeissus latifolia Wall. ex Bedd	10 (A)	0	30 (B)	0	0	10 (A)	0	0	10 (A)	0	0	10 (A)
Bauhinia racemosa Lam.	0	0	10 (A)	--	--	--	--	--	--	--	--	--
Bombax malabaricum Linn.	--	--	--	--	--	--	--	--	--	0	0	20 (A)
Buchanania lanzan Spreng,	10 (A)	0	30 (B)	0	0	10 (A)	--	--	--	0	0	30 (B)
Careya arborea Roxb.	--	--	--	--	--	--	0	0	20 (A)	--	--	--
Casearia graveolens	30 (B)	10 (A)	10 (A)	30 (B)	40 (B)	10 (A)	10 (A)	20 (A)	0	30 (B)	10 (A)	0
Cassia fistula Linn.	0	0	20 (A)	--	--	--	--	--	--	--	--	--
Cleistenthus collinus (Roxb) Benth & Hook.	--	--	--	0	0	10 (A)	--	--	--	--	--	--
Diospyros melanoxylon Roxb.	30 (B)	0	30 (B)	50 (C)	60 (C)	10 (A)	10 (A)	10 (A)	10 (A)	10 (A)	0	40 (B)
Emblica officinalis Gaerth,	0	0	30 (B)	--	--	--	--	--	--	--	--	--
Garuga pinnata Roxb.	0	0	10 (A)	--	--	--	--	--	--	--	--	--
Lagerstroemia parviflora Roxb.	0	0	20 (A)	--	--	--	10 (A)	0	10 (A)	--	--	--
Lannea grandis Engl.	0	0	40 (B)	0	0	20 (A)	0	0	10 (A)	--	--	--
Madhuca indica J.F. Gmel.	0	0	10 (A)	--	--	--	--	--	--	0	0	20 (A)
Mallotus philipensis	10 (A)	30 (B)	0	20 (A)	10 (A)	0	--	--	--	--	--	--
Miliusa tomentosa (Roxb.) J.Sinclair	0	20 (A)	40 (B)	--	--	--	--	--	--	--	--	--
Ougeinia oojeinensis (Roxb.) Hochr.	0	0	20 (A)	0	0	20 (A)	--	--	--	--	--	--
Pterocarpus marsupium Roxb	--	--	--	0	0	10 (A)	--	--	--	0	0	20 (A)
Schleichera oleosa (Lour) Oken.	0	0	10 (A)	--	--	--	--	--	--	--	--	--
Shorea robusta Gaertn F.	40 (B)	0	100 (E)	40 (B)	10 (A)	100 (E)	20 (A)	0	100 (E)	10 (A)	0	0
Syzygium cumini	10 (A)	0	0	0	0	10 (A)	10 (A)	40 (B)	10 (A)	0	20 (A)	0
Terminalia chebula Retz.	--	--	--	0	0	10 (A)	--	--	--	--	--	--
Terminalia tomentosa Wt & Ang.	10 (A)	0	50 (C)	10 (A)	0	90 (E)	0	0	30 (B)	0	0	50 (C)
Zizyphus xylopyra Willd	--	--	--	--	--	--	0	0	30 (B)	10 (A)	0	0

Table 2. Species distribution as per frequency class in a tropical forest of Chhattisgarh

Study site	Vegetation Layer	Class A (Rare)	Class B (Low)	Class C (Intermediate)	Class D (Moderately High)	Class E (Common)
Dense Forest Site	Seedling	5	3	0	0	0
	Sapling	2	1	0	0	0
	Tree	8	6	1	0	1
Regenerated Forest Site	Seedling	2	2	1	0	0
	Sapling	2	1	1	0	0
	Tree	10	0	0	0	2
Medium Forest Site	Seedling	5	0	0	0	0
	Sapling	2	1	0	0	0
	Tree	6	2	0	0	1
Degraded Forest Site	Seedling	3	1	0	0	0
	Sapling	2	0	0	0	0
	Tree	4	2	1	0	0

Table 3. Regeneration status of species at tropical forest of Chhattisgarh

Species	Dense Forest Site				Regenerated Forest Site				Medium Forest Site				Degraded Forest Site			
	Seedlings	Saplings	Trees	Regeneration Status	Seedlings	Saplings	Trees	Regeneration Status	Seedlings	Saplings	Trees	Regeneration Status	Seedlings	Saplings	Trees	Regeneration Status
Anogeissus latifolia Wall. ex Bedd	2500	0	30	FR	0	0	10	NR	0	0	10	NR	0	0	10	NR
Bauhinia racemosa Lam.	0	0	10	NR	--	--	--	--	--	--	--	--	--	--	--	--
Bombax malabaricum Linn.	--	--	--	--	--	--	--	--	--	--	--	--	0	0	20	NR
Buchanania lanzan Spreng,	5000	0	40	FR	0	0	10	NR	--	--	--	--	0	0	40	NR
Careya arborea Roxb.	--	--	--	--	--	--	--	--	0	0	20	NR	--	--	--	--
Casearia graveolens	7500	2500	10	GR	10000	12500	10	GR	10000	7500	0	GR	17500	2500	0	GR
Cassia fistula Linn.	0	0	20	NR	--	--	--	--	--	--	--	--	--	--	--	--
Cleistenthus collinus (Roxb) Benth & Hook.	--	--	--	--	0	0	10	NR	--	--	--	--	--	--	--	--
Diospyros melanoxylon Roxb.	10000	0	40	FR	27500	15000	10	GR	2500	2500	10	GR	2500	0	70	FR
Emblica officinalis Gaerth,	0	0	40	NR	--	--	--	--	--	--	--	--	--	--	--	--
Garuga pinnata Roxb.	0	0	10	NR	--	--	--	--	--	--	--	--	--	--	--	--
Lagerstroemia parviflora Roxb.	0	0	30	NR	--	--	--	--	2500	0	10	FR	--	--	--	--
Lannea grandis Engl.	0	0	40	NR	0	0	20	NR	0	0	10	NR	--	--	--	--
Madhuca indica J.F. Gmel.	0	0	20	NR	--	--	--	--	--	--	--		0	0	50	NR
Mallotus philipensis	2500	20000	0	GR	10000	5000	0	GR	--	--	--	--	--	--	--	--
Miliusa tomentosa (Roxb.) J.Sinclair	0	5000	40	PR	--	--	--	--	--	--	--	--	--	--	--	--
Ougeinia oojeinensis (Roxb.) Hochr.	0	0	20	NR	0	0	40	NR	--	--	--	--	--	--	--	--
Pterocarpus marsupium Roxb	--	--	--	--	0	0	10	NR	--	--	--	--	0	0	20	NR
Schleichera oleosa (Lour) Oken.	0	0	10	NR	--	--	--	--	--	--	--	--	--	--	--	--
Shorea robusta Gaertn F.	32500	0	340	FR	40000	2500	500	GR	15000	0	470	FR	2500	0	0	FR
Syzygium cumini	5000	0	0	FR	0	0	10	NR	2500	10000	10	GR	0	5000	0	PR
Terminalia chebula Retz.	--	--	--	--	0	0	10	NR	--	--	--	--	--	--	--	--
Terminalia tomentosa Wt & Ang.	2500	0	110	FR	5000	0	120	FR	0	0	40	NR	0	0	50	NR
Zizyphus xylopyra Willd	--	--	--	--	--	--	--	--	0	0	30	NR	2500	0	0	FR

Table 4. Regeneration categorization of species (%) in different sites in tropical forest of Chhattisgarh

Status	Dense Forest Site	Regenerated Forest Site	Medium Forest Site	Degraded Forest Site
Good Regeneration	11.11	30.77	30.0	9.09
Fair Regeneration	33.33	7.69	20.0	27.27
Poor Regeneration	5.56	0.0	0.0	9.09
Not Regenerating	50.0	61.54	50.0	54.55
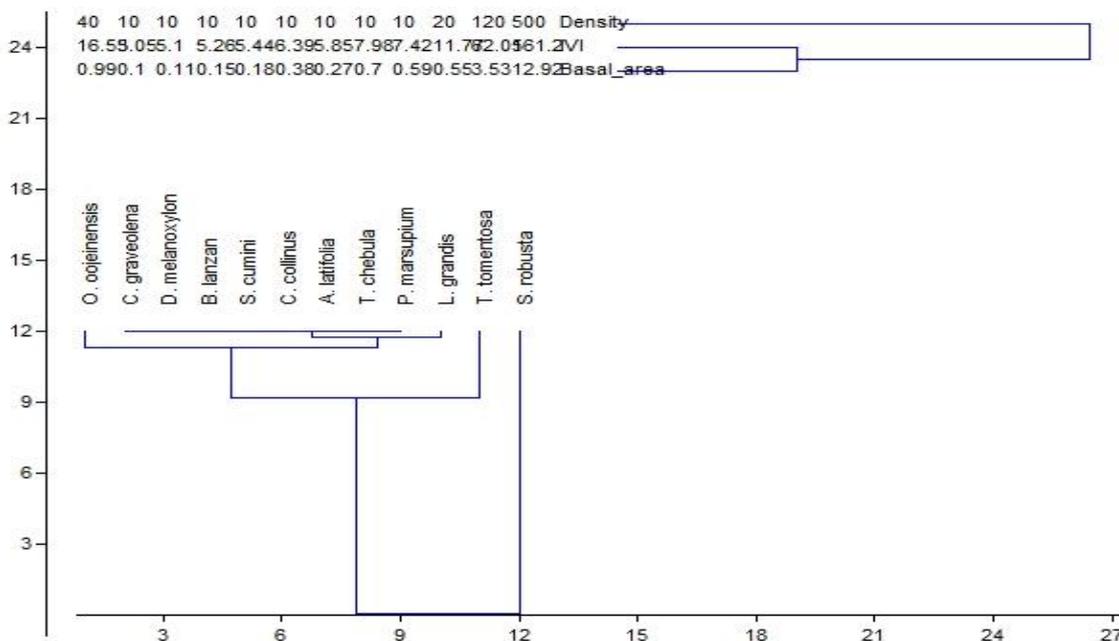
Figure 3 Clustering of various phytosociological parameter of tree layer of regenerated forest site

Figure 3 showed various clumpy clustering between various species, while the *Shorea robusta* revealed distant position among all the species recorded in regenerated forests stand. The cluster analysis for various phytosociological parameters in medium forest stand (Figure 4) revealed similar trend in case of the *Shorea robusta* while the small clustering were framed between *Terminalia tomentosa* and *Zizyphus xylopyra*.
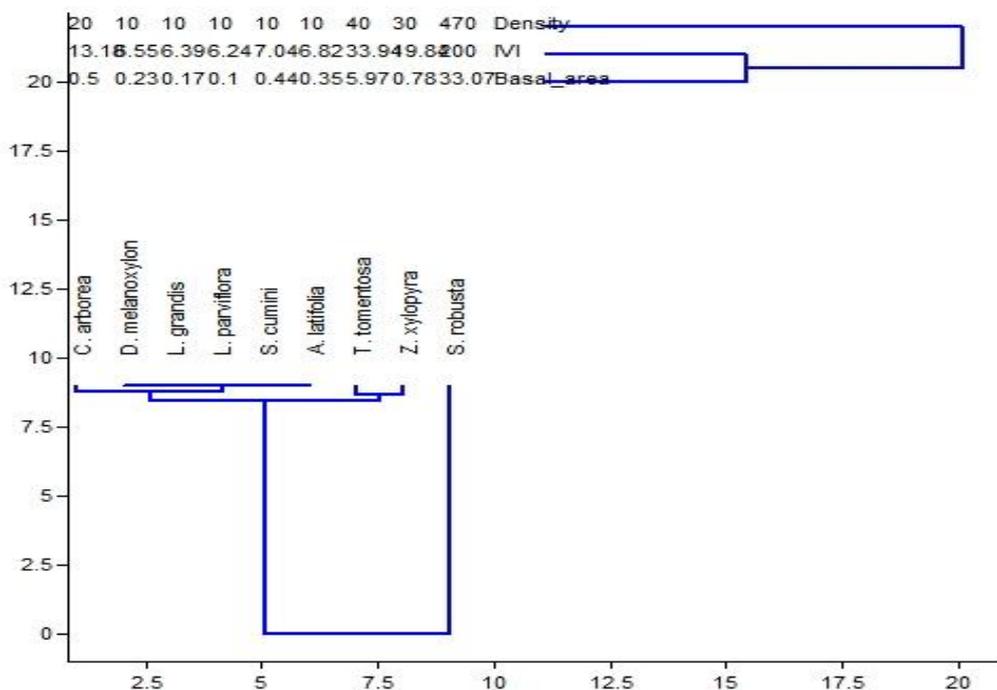

Figure 4 Clustering of various phytosociological parameter of tree layer of medium forest site
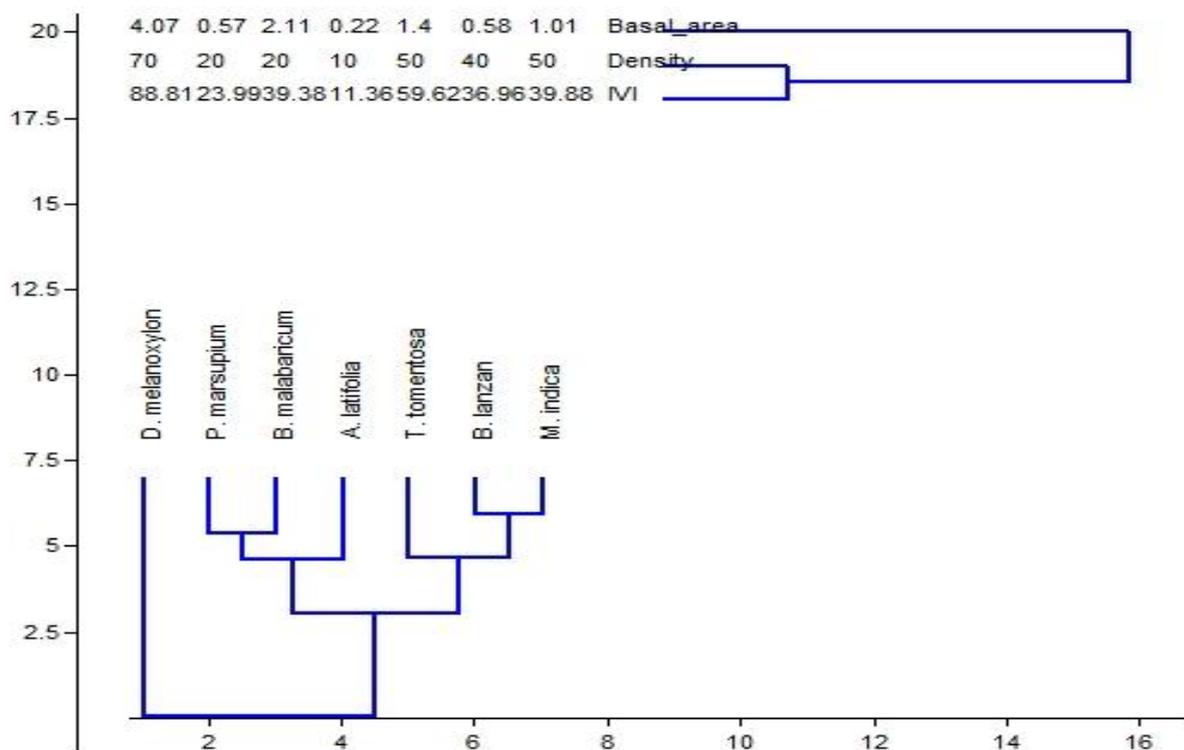
Figure 5 Clustering of various phytosociological parameter of tree layer of degraded forest site

Figure 5 showed small clustering between *Pterocarpus marsupium* and *Bombax malabaricum*, *Buchanania lanzan* and *Madhuca indica*, whereas *Diospyros melanoxylon* reflected distant position among all the species.

Clustering of various phytosociological parameters of tree layer in different forest stands showed significant level of variation among them. Similarly, Eni et al. (2012) mentioned utility of such analysis for establishing the inter-relationship of forest vegetation in Nigeria. Further such analysis work as fact finding tools and reduces the data complexity to find out the key species, parameters or attributes which have significant contribution and inter-relationship between them (Kumar et al. 2017; Jhariya, 2017).

Vegetation regeneration status

The regeneration of species and its overall scenario in different forest stands under tropical condition is reported in Table 3 & 4. In dense forest site 6 species showed fair regeneration 2 species good regeneration, 1 species poor regeneration and 9 species not regenerating. At regenerated forest stand 1 species reflected fair regeneration, 4 species good regeneration and 8 species were not regenerating. In case of medium forest stands 2 species showed fair regeneration, 3 species good regeneration and 5 species were not regenerating. Degraded forest stands showed 3 species under fair regeneration, 1 species each in good regeneration and poor regeneration as well as 6 species under not regenerating condition. The regeneration scenario revealed that the regenerated forest have highest regeneration potential (30.77%) followed by medium forest stand (30.0%),

dense forest stand (11.11%) and least at degraded forest stands (9.09%). It evident from the study that in all the forest stands nearly half or more than half of the species were not regenerating.

Regeneration of various species in a given forest stands is crucial factors determining the future stand development, stand stocking and quality, and health of the sustained forest in terms of stand volume, biomass and productivity (Pawar et al. 2012; Jhariya, 2014). The transformation rate of species into different vegetal layers viz., seedlings into saplings, and saplings into trees are drastically reduced in different forests stands as confirmed by the more than half of the species are not regenerating under specific environmental conditions. Similar trend were also mentioned by various workers under similar types of forest stands (Good and Good, 1972; Pawar et al. 2012; Jhariya and Oraon, 2012; Oraon and Jhariya, 2018).

CONCLUSION

Enormous diversity of vegetation in different forest stands were recorded in terms of species and family distributed over the area. The degraded forest revealed lesser diversity and abundance of species, family, density, basal area and regeneration status in relation to other forests stand. Moreover, the pooled data reflected that nearly 65.38% species were rare in occurrence followed by 24.36% species have low occurrence, 5.13% species each showed intermediate and commonness over the area while moderately high frequency class reflects no presence of an species

across the sites under different vegetal layers. This therefore, highlights the conservation priority of the rare species otherwise it may be collapsed due to improper regeneration and other ecological constraints. Besides this the species having good regeneration (*Casearia graveolens*, *Diospyros melanoxylon*, *Mallotus philipensis*, *Shorea robusta* and *Syzygium cumini*) can be selected for the further reforestation and afforestation plans due to its greater adaptability and wider ecological amplitude which accelerate the sustainable development these forest stands.

REFERENCES

Champion, H.G. and Seth, S.K. (1968). A Revised Survey of the Forest Types of India. Government of India Publications, New Delhi, 404p.

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

Eni, D.D., Iwara, A.I. and Offiong, R.A. (2012). Analysis of soil vegetation interrelationship in a south-southern secondary forest of Nigeria. *International Journal of Forestry Research*, 2012, pp. 1–8. Doi:10.1155/2012/469326.

Good, N.F. and Good, R.E. (1972). Population dynamics of tree seedlings and saplings in mature Eastern hardwood forest. *Bull Torrey Bot. Club*, 99.

Gutierrez, A.G., Armesto, J.J. and Aravena, J.C. (2004). Disturbance and regeneration dynamics of an old-growth North Patagonian rain forest in Chiloé Island, Chile. *Journal of Ecology*, 92:598-608.

Hewit, N. and Kellman, M. (2002). True seed dispersal among forest fragments: dispersal ability and biogeographical controls. *Journal of Biogeography*, 29(3):351–363.

Jhariya, M.K. and Oraon, P.R. (2012). Regeneration Status and Species Diversity along the Fire Gradients in Tropical Deciduous Forest of Chhattisgarh. *Journal of Plant Development Sciences*, 4(1):49-54.

Jhariya, M.K. (2014). Effect of forest fire on microbial biomass, storage and sequestration of carbon in a tropical deciduous forest of Chhattisgarh. Ph.D. Thesis, I.G.K.V., Raipur (C.G.), pp. 259.

Jhariya, M.K. (2017). Vegetation ecology and carbon sequestration potential of shrubs in tropics of Chhattisgarh, India. *Environmental Monitoring and Assessment*, 189(10):1-15. Doi: 10.1007/s10661-017-6246-2.

Jhariya, M.K. and Yadav, D.K. (2018). Biomass and carbon storage pattern in natural and plantation forest ecosystem of Chhattisgarh, India. *Journal of Forest and Environmental Science,* 34(1):1-11. DOI: 10.7747/JFES.2018.34.1.1.

Jhariya, M.K., Banerjee, A., Meena, R.S. and Yadav, D.K. (2019). Sustainable Agriculture, Forest and Environmental Management. Springer Nature Singapore Pte Ltd., 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore**.** eISBN: 978-981-13-6830-1, Hardcover ISBN: 978-981-13-6829-5.   DOI: 10.1007/978-981-13-6830-1. Pp. 605.

Kagezi, G.H., Kaib, M., Nyeko, P., Bakuneeta, C., Schädler, M., Stadler, J. and Brandl, R. (2016). Impacts of land-use intensification on litter decomposition in western Kenya. *Web Ecol.*, 16:51-58.

Khan, M.L., Rai, J.P.N. and Tripathi, R.S. (1987). Population structure of some tree species in disturbed and protected sub-tropical forests of north-east India. *Acta Oecologia*, 8:247-255.

Kumar, A., Jhariya, M.K., Yadav, D.K. and Banerjee, A. (2017). Vegetation Dynamics in Bishrampur Collieries of Northern Chhattisgarh, India: Eco-restoration and Management Perspectives. *Environmental Monitoring and Assessment,* 189(8):371. Doi: 10.1007/s10661-017-6086-0.

Oraon, P.R. and Jhariya, M.K. (2018). Regeneration and Species Status in Bhoramdeo Wildlife Sanctuary of Chhattisgarh, India under Different Anthropogenic Disturbance Regimes. *Bulletin of Environment, Pharmacology and Life Sciences,* 7(5):30-36.

Oraon, P.R., Singh, L. and Jhariya, M.K. (2018). Forest floor biomass, litterfall and physico-chemical properties of soil along the anthropogenic disturbance regimes in tropics of Chhattisgarh, India. *Journal of Forest and Environmental Science,* 34(5):359-375. https://doi.org/10.7747/JFES.2018.34.5.359.

Pawar, G.V., Singh, L., Jhariya, M.K. and Sahu, K.P. (2012). Regeneration status in relation to anthropogenic disturbance in tropical deciduous forest of Chhattisgarh. *The Ecoscan*, (Special Issue) 1:281-285.

Pawar, G.V., Singh, L., Jhariya, M.K. and Sahu, K.P. (2014). Effect of anthropogenic disturbances on biomass and carbon storage potential of a dry tropical forest in India. *Journal of Natural and Applied Science*, 6(2):383-392.

Phillips, EA. (1959). Methods of Vegetation Study. Henry Holt and Co., London. pp. 105.

Rahman, H., Khan, M.A.S.A., Fardusi, M.J. and Roy, B. (2010). Status, distribution and diversity of invasive forest undergrowth species in the tropics: a study from northeastern Bangladesh. *Journal of Forest Science*, 26(3):149–159.

Raunkiaer, C. (1934). The Life Form of Plants and Statistical Plant Geography. *Claredon Press,* ISBN 9978–40–943-2, Oxford.

Singh, L., Yadav, D. K., Pagare, P., Lekha, G. and Thakur, B. S. (2009). Impact of land use changes on species structure, biomass and carbon storage in tropical deciduous forest and converted forest. *International Journal of Ecology and Environmental Sciences*, 35(1):113–119.

Singh, J.S. and Chaturvedi, R.K. (2017). Tropical Dry Deciduous Forest: Research Trends and Emerging Features. Springer, Pp. 1-238. ISBN

978-981-10-7259-8 ISBN 978-981-10-7260-4 (eBook), https://doi.org/10.1007/978-981-10-7260-4.

Yadav, D.K. (2016). Species structure and diversity in Achanakmar-Amarkantak Biosphere reserve, Central India. *Journal of Applied and Natural Science*, 8(3): 1241-1248.

Yadav, D.K. and Jhariya, M.K. (2017). Tree community structure, regeneration and patterns of diversity in natural and plantation forest ecosystem. *Res. Environ. Life Sci.,* 10(4):383-389.

Yadav, D.K., Ghosh, L. and Jhariya, M.K. (2017). Forest Fragmentation and Stand Structure in Tropics: Stand Structure, Diversity and Biomass. Lap Lambert Academic Publishing. Heinrich-Bocking-Str. 6-8, 66121, Saarbrucken, Germany. Pp. 116. ISBN: 978-3-330-05287-1.

Yadav, D.K. (2018). Litterfall Pattern and Forest Floor Biomass in Achanakmar-Amarkantak Biosphere Reserve, India. *Bulletin of Environment, Pharmacology and Life Sciences,* 7(6):45-52.

Yadav, D.K. (2019). Fine root biomass and soil physico-chemical properties in Achanakmar-Amarkantak biosphere reserve. *Journal of Plant Development Sciences*, 11(2):79-83.