Eco. Env. & Cons. 29 (May Suppl. Issue) : 2023; pp. (S9-S18)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i03s.003

A Comparative Study on Community Structure and Regeneration Status of Tree Species in Urban Forests of Delhi, India

Khushboo Randhawa* and Tuisem Shimrah

University School of Environment Management, Guru Gobind Singh Indraprastha University, New Delhi 110 078, India

(Received 8 November, 2022; Accepted 16 January, 2023)

ABSTRACT

'New Delhi' capital of India is under immense pressure to sustain increasing population and to cope up with urbanization. It has urban forests or ridges, which aids the Delhi's healthy lifestyle by balancing ecosystem. To assess the forest health the species composition, density, basal area, IVI, diversity indices, regeneration status of tree species were evaluated. Three sites namely Kamla Nehru Ridge (KR), Central Ridge (CR) and Southern Ridge (SR) were selected. A total of 51 tree species belonging to 21 families were reported. Species richness varied for trees (20-37), saplings (5-20) and seedlings (5-11). Densities ranged between (517-1043 Individuals/ha) for trees, saplings (133-470 Individuals/ha) and seedlings (53-273 Individuals/ha) respectively. Species diversity ranged between for trees (2.3-3.3), saplings (1.4-2.2) and seedlings (1.5-2.1). Total basal area varied from 4.87 to 22.94 m^2/ha (trees), 0.26 to 0.49 m^2/ha (saplings) and 0.17 to 0.02 m^2/ha (seedlings). Maximum species (20-70%) showed 'no' regeneration whereas, (30-50%) showed 'poor' regeneration and only *Acacia leucocephala* showed 'fair' regeneration in SR. It was observed that *Prosopis juliflora* was the dominant species in all three sites; it is an exotic species which hinders the understory growth. All over regeneration status of Delhi's urban forest was found 'poor', which is a matter of concern. For balance environment and for proper inflow of ecosystem services provided by urban forest to sustain healthy lifestyle in city, it is necessary to implement proper strategies for conservation and maintenance of these forests.

Key words: *Urban forest, Regeneration, Conservation, Diversity indices*

Introduction

The National Capital Region of Delhi is situated in a cusp formed by the tail end of the Aravalli Mountain Range which is 800 km long (elevation: 1700 meters). Delhi is divided into two main ecological zones, an extension of the Aravalli Hills and the Plains. Forests in the Delhi are known as Ridges. There are four main ridge forests namely: Kamla Nehru Ridge, Central Ridge, South-Central Ridge and Southern Ridge. During British rule massive afforestation drive was started, exotic species like *Prosopis juliflora* was introduced and this created extensive monocultures on the Ridge (Sinha, 2014). The Ridges are managed by different agencies like Delhi Development Authority (DDA), New Delhi Municipal Committee (NDMC), Municipal Corporation of Delhi(MCD), Forest Department, Central Public Works Department (CPWD) and Ministry of Defence. Ridges are notified as reserved forest of Delhi and represent its own distinct ecosystem (Meena *et al.*, 2016). The present study focuses on the tree species diversity, population structure and regeneration potential of tree species in the ridges of National Capital of India.

Delhi falls in urban area category and hold urban forests in the form of ridges and these ridges face greater threat of losing forest area and biodiversity to anthropogenic disturbances like urbanization. Urbanization is a process, which leads to significant shifts in land use such as croplands, forests, grasslands, and old fields give way to cities, roads, gardens, airports and industries (McDonnell and Pickett, 1990; Faeth *et al*., 2005). The urbanisation and development in the National capital such as road widening, garbage dumping, construction work and encroachment led to swallowing up large chunks of Ridge areas by the city (Sinha, 2014). The large and intact natural forests kept a close eye to conserve their biodiversity, similarly it is necessary to make equal efforts to preserve isolated small patches of forests available in urban areas (Khadanga and Jayakumar, 2018). Urban forest provides different services like regulating microclimate, recharge ground water level, carbon sequestration, prevent soil erosion, reduce noise pollution, generate oxygen, reduce atmospheric pollutants and mitigate urban heat island effects (Bolund and Hunhammar, 1999; Khadanga and Jayakumar, 2018). Major threat faced by urban forest is fragmentation i.e. convert large continuous forest patches into smaller patches, biodiversity loss, population shift and this affects the ecosystem integrity (Mikkelson, 1993; Pao and Upadhaya, 2017).

Community structure, composition and vegetation function are the most important ecological attributes of forests, which show variations in response to environmental as well as anthropogenic variables (Gairola *et al.,* 2012; Timilsina *et al.,* 2007). Forest health can be assessed by understanding community structure together with regeneration potential. Population structure is indicator of the forest health. Species distribution and abundance patterns influence the plant diversity of any site (Palit and Chanda, 2012). Different parameters like geography, topography, soil and climate influence the community structure, species diversity of the forest ecosystem (Ram *et al.,* 2004). Species diversity evaluates the stability and sustainability of the forest communities. In any Forest ecosystem, information on the species composition is essential for effective management practice in terms of economic value and regeneration potential (Wyatt-Smith, 1987) and this will lead to conservation of biological diversity (Verma *et al.,* 1999). If plant population structure of forest has stable distribution then that allows continuous regeneration (Gebeyehu *et al.*, 2019).

Regeneration is a natural process that leads to the growth of forest community.Natural regeneration is a central component for tropical forest ecosystem dynamics (Getachew *et al*., 2010) and is essential for preservation and maintenance of biodiversity (Rahman *et al.,* 2011). Pokhriyal *et al*. (2010) reported presences of sufficient number of seedlings, saplings and young trees in a given population indicate successful regeneration in the forest and the number of seedling of any species can be considered as the regeneration potential of that species (Negi and Nautiyal, 2005). The regeneration of plant species in the forest helps to maintain the population structure and diversity of the forest and strengthens the resilience against disturbances (Dyderski and Jagodzinski, 2020). This will ultimately lead to stability of that ecosystem. Ecosystem stability can be determined by understanding the growth status of a species (Kadavul and Parthasarathy, 2001; Deb and Sundriyal, 2011). The anthropogenic disturbances logging, grazing, land encroachment, gap formation, litter fall, etc. affects the growth status of the species in the forest (Malik *et al.,* 2016).

To determine the regeneration of any forest community, assessment of seedlings, saplings, and adult trees is necessary. Along with the understanding of environmental conditions largely decides the regeneration capacity of species and affects its existence in the community. It is important to understand the growth status of a species in the ecosystem and is one of the key parameter to determine ecosystem stability (Kadavul and Parthasarathy, 2001; Deb and Sundriyal, 2011).Natural regeneration can be affected by different disturbances like human interventions, forest fragmentation, litterfall, invasive species, etc. These disturbances create hindrance to the natural regeneration process of species, which leads to the undergrowth of the species and poor regeneration of the plant species. Successful regeneration of tree species might be considered to a function of three major components: (i) ability to initiate new seedlings, (ii) ability of seedlings and saplings to survive and (iii) ability of seedlings and saplings to grow (Good and Good 1972).

Materials and Methods

Study area

Delhi, the National Capital of India is located at the end of Aravalli Mountain range within N- 28^o12′ – 28^o53′longitudes and E- 76^o50′ – 77^o23′ latitudes (Fig. 1). The climatic condition is of semi-arid nature and receives about 66.6 cm annual rainfall of which nearly 80% is recorded from middle of June to the middle of September. The annual mean average temperature is 29^o C. The forest area in Delhi is known as 'Delhi Ridge' and it has four major Ridges: Kamla Nehru Ridge, Southern Ridge, Central Ridge and South- Central Ridge. These Ridges comprises of total area of 7,784 ha spreads over the entire city in different patches. The present study was conducted in three ridges namely: Kamla Nehru Ridge (KR) and Central Ridge (CR) and Southern Ridge (SR). According to Champion and Seth (1968) Ridge forest falls into 'Semi-Arid Open Scrub' category, as Ridge is dominated by thorny scrub vegetation. Ridges have rocky and undulating surface comprised of quartzite, arkosic grit with thin intercalations of micaceous schist (Sinha, 2014).

Method

To evaluate the tree diversity, community structure and regeneration potential of the study area, the field survey for data collection were conducted during 2019 – 2021 using stratified random sampling method. Extensive field surveys in all ridges were carried out during the study period. Those common tree species present were identified on the spot and for those tree species which could not identified in the field, specimens were collected and herbarium were prepared for future identification. Quadrat method was followed to record phyto-sociological parameters. To carry out the present study, 10m x 10m quadrats were randomly laid in the study area. There were 30 quadrats laid in CR and KR each, 60 quadrats in SR. Number of individuals present in each quadrat were counted, and girth at breast height (GBH) was measured. According to girth size, the individuals were group into 3 types: Adults (GBH) ≥30 cm), saplings (≥ 10 cm to <30 cm) and seedlings (<10 cm girth).

Phyto-sociological parameters such as basal area, frequency, density, importance value index (IVI) were determined by following Misra (1968). Shanon and Weiner (1963) index was followed to calculate species diversity and Simpson's index (Simpson, 1949) was followed to calculate dominance of the community and evenness index following Pielou (Pielou, 1966). The status of regeneration was calcu-

Table 1. Characteristics of the study sites.

Ridges or Forests	Area (ha)	Elevation (m)	Latitude (N)	Longitude (E)	Dominant tree species
Central Ridge	864	260	$28^0$37′25.38′′	$77^0$10′50.43′′	*P. juliflora*
Kamla Nehru Ridge	87	217	$28^0$40′04.54′′	$77^0$13′07.66′′	*P. juliflora*
South Ridge	6200	261	$28^0$29′38.64′′	$77^0$16′03.01′′	*P. juliflora*

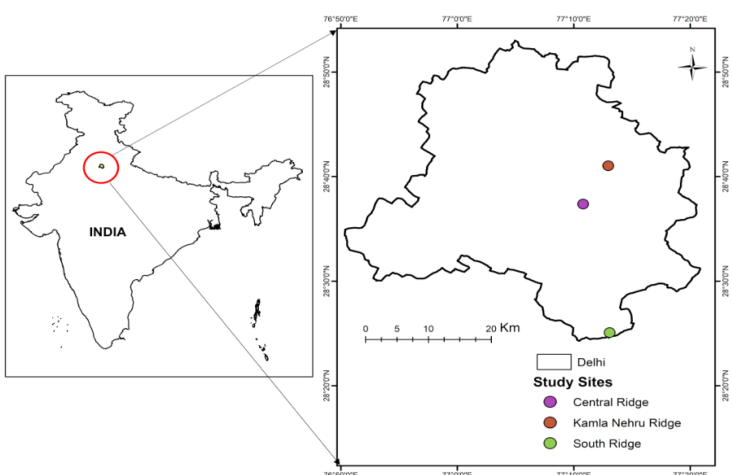

Fig. 1. An outline map of India showing Delhi and the locality of different forests studied.

lated by analysing population size of adults, saplings and seedlings as (followed from Khan *et al.* 1987; Khumbongmayum *et al.*, 2006; Shankar, 2001):

(a) 'good', if seedlings > or < saplings > adults;
(b) 'fair', if seedlings > or d" saplings d" adults;
(c) 'poor', if a species survives only in sapling stage but no seedlings;
(d) 'none', if it is absent both in saplings and/or seedlings but found only in adults stage;
(e) 'new', if a species has no adults, but only saplings and/or seedlings.

Results and Discussion

Community structure and ecological status of studied urban forests or Ridges

The community structure of the present study sites were performed using quadrat method. The study site was composed of different tree species and the most dominated tree species is *Prosopis juliflora.* Different parameters like basal area, density, abundance, different indices, were measured to study thecommunity structure of all selected forests as listed in Table 2.

Family dominance

Overall, 51 species were recorded from 21 families in all three studied sites. Fabaceae was the dominant family in all three studied sites with 11 species in SR, 12 species in CR whereas 7 species in KR. However, in CR the presence of 37 tree species belonging to 18 families and in KR 26 tree species belonging to 15 families were recorded. Fabaceae was the dominant family followed by Moraceae with four tree species in both KR and CR. Whereas in SR, Fabaceaewas followed by Bignoniaceae, Combretaceae, Zygophyllaceae, Ulmaceae, Euphorbiaceae, Apocynaceae and Simaroubaceae with one tree species each.

Table 2. Phytosociological attributes of the studied forests.

Parameters	Central Ridge	Northern Ridge	Southern Ridge
Species richness			
Trees	37	26	20
Saplings	14	5	20
Seedlings	13	5	11
Shannon-Weaver index (H)			
Trees	3.3	2.27	2.34
Saplings	2.23	1.47	2.46
Seedlings	2.26	1.54	2.12
Density(Ind/ha)			
Trees	1043	520	517
Saplings	326	133	470
Seedlings	273	53	65
Total basal area(m^2/ha)			
Trees	22.94	13.96	4.87
Saplings	0.49	0.26	0.68
Seedlings	0.048	0.028	0.17
Pielouseveness index (J)			
Trees	0.91	0.83	0.79
Saplings	0.84	0.91	0.82
Seedlings	0.88	0.95	0.88
Simpsons Diversity index (D)			
Trees	0.95	0.89	0.87
Saplings	0.86	0.82	0.97
Seedlings	0.88	0.90	0.88
Margalef index (Species richness)			
Trees	6.26	4.95	3.11
Saplings	2.83	1.73	3.36
Seedlings	2.72	2.05	2.72
Dominant species(highest IVI)			
Trees	*Prosopisjuliflora*(63.82)	*Prosopisjuliflora*(58.77)	*Prosopisjuliflora*(48.69)
Saplings	*Leucaenaleucocephala*(43.8)	*Diospyroscordifolia(100)*	*Anogeissus pendula* (39.31)
Seedlings	*Haplophragmaheterophyllum*(44.64)	*Diospyroscordifolia(77.11)*	*Acacia leucocephala* (43.8)

Density and basal area

There was a distinct variation in density, basal area and IVI values among all three studied sites (Table 2). The overall tree density ranged between a maximum of 1043 Individuals per hectare (Ind/ha) in CR and minimum of 517 Ind/ha in SR, sapling density varied between a maximum of 470 Ind/ha in SR and minimum of 326Ind/ha in CR. Seedling density ranged varied between a maximum of 273Ind/ha in CR and minimum of 65Ind/ha in KR. The basal area of adult trees ranged between a maximum of 22.94 m^2/ha in CR and a minimum of 4.87 m^2/ha in SR. The basal area was higher in SR (0.68 m^2/ha) than CR (0.49 m^2/ha) and KR (0.26 m^2/ha) for sapling vegetation. For seedling basal area was highest in SR (0.17 m^2/ha) than other two sites CR (0.048 m^2/ha) and KR (0.028 m^2/ha). As IVI for, adult trees *Prosopis juliflora* was dominant species in all three sites; CR (63.82), KR (58.77) and SR (48.69). *Leucaena leucocephala* (43.8) in CR, *Diospyros cordifolia* (100) in KR and *Anogeissus pendula* (39.31) in SR were dominant species in sapling population. Whereas species like *Haplophragma adenophyllum* (44.64) in CR, *Diospyros cordifolia* (77.11) in KR and *Acacia nilotica*(43.8) were dominant in seedling population.

Species richness and diversity

In the study plots, different indices were calculated (Table 2), diversity of tree species calculated using Shannon-Weiner index (H’) showed that the highest diversity was in CR (3.3) and the lowest was in NR (2.27). The dominance of tree species in the study sites was calculated using dominance of Simpson’s value ranging from 0.95 in CR to 0.87 in SR. Evennessindex was highest in CR (0.91) and lowest in SR (0.79). Margalef index was highest in CR (6.26) and lowest in SR (3.11).

Distribution pattern (A/F ratio)

Maximum species about 81-100% showed contagious distribution, followed by random distribution (7-19%) and no species showed regular distribution. Saplings (100%) of SR and KR showed the highest percentage of contagious distribution, and adult trees in SR. Seedlings in CR and KR showed 100% contagious distribution.

Regeneration status

The regeneration status of individual tree species shown in (Table 4). As for CR, the population struc-

Table 3. Abundance, important value index (IVI), and basal area of the 10 most important species in three study sites.

Tree Species	CR			Tree Species	NR			Tree Species	SR		
	A	BA	IVI		A	BA	IVI		A	BA	IVI
Prosopis juliflora	2	0.08	63.82	*Prosopis juliflora*	1	0.08	58.77	*Prosopis juliflora*	3	0.02	48.69
Ficus religiosa	1	0.49	16.62	*Ficus religiosa*	1	0.42	23.67	*Pongamia pinnata*	4	0.01	30.46
Cassia fistula	1	0.03	16.45	*Pithecellobium dulce*	2	0.03	16.13	*Acacia leucocephala*	2	0.02	24.88
Diospyros cordifolia	1	0.21	16.14	*Pongamia pinnata*	1	0.04	16.02	*Anogeissus pendula*	4	0.02	21.24
Haplophragma adenophyllum	2	0.04	15.75	*Kigelia africana*	1	0.34	15.66	*Butea monosperma*	2	0.01	20.76
Terminalia catappa	2	0.44	14.35	*Albizia lebbeck*	1	0.19	15.27	*Balanites aegyptica*	4	0.02	17.96
Pongamia pinnata	2	0.04	13.96	*Azadirachta indica*	1	0.17	14.37	*Alianthus excelsa*	1	0.07	17.87
Bombax ceiba	1	0.30	12.33	*Diospyros cordifolia*	1	0.03	14.21	*Pithecellobium dulce*	3	0.04	15.72
Holoptelea integrifolia	1	0.06	11.85	*Ehretia laevis*	1	0.01	13.92	*Bauhinia racemosa*	1	0.05	14.04
Ehretia laevis	1	0.02	11.21	*Eucalyptus camaldulensis*	2	0.12	13.35	*Dalbergia sisso*	2	0.01	13.75

A= Abundance; BA= Basal Area; IVI= Importance Value Index; CR= Central Ridge; NR= North Ridge; SR= South Ridge ture of CR showed presence 58.07% adult trees, followed by 23.3% saplings and 18.55% seedlings (Figure 2). About 56.75% species showed "no" regeneration and 43.24% showed "poor" regeneration, whereas no species showed good or fair regeneration status (Figure 3). In KR, about 80.41% individuals were present in adult stage, followed 18.55% saplings and 9.79% seedlings. 73.07% species showed "no" regeneration and 26.92% showed "poor" regeneration, no species found showing good or fair regeneration. In SR, 3.7% species showed "fair" regeneration status, 48.14% species showed "poor" regeneration and 18.51% species showed "no" regeneration, whereas 29.62% species were "new" to the SR namely *Carissa spinarum, Cassia javanica, Dichrostachys cineraria, Leucaena leucocephala, and Ziziphus mauritiana* found only in sapling/seedling stage.

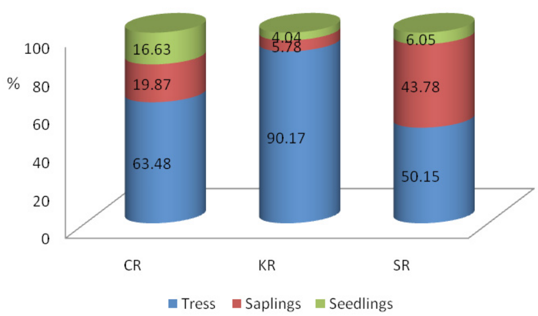

Fig. 2. Percentage of seedlings, saplings and trees in the studied forests; CR= Central Ridge; KR= Kamla Nehru Ridge; SR= South Ridge.

To conserve the natural areas, it is evident to gather information on species composition and diversity status of the areas. Many factors like rainfall, soil, altitude, climate and anthropogenic disturbances affect the community structure. For wise management practice in forest, it is necessary to obtain the knowledge about all the above-mentioned factors and floristic composition. Quantitative analysis of population structure and regeneration potential of forest recorded in this study can be used for management strategies of the forest. The values recorded for different indices and regeneration status is comparable to those studies earlier reported from different forests.

Diversity of the area gives baseline information about distribution of individuals among species. Diversification among different communities can be regulated by long-term factors such as community stability and evolutionary time as heterogeneity of both microclimate and macroclimate (Verma *et al.* 2004). The diversity (H) values for tree species ranged from 2.27 (NR) to 3.3 (CR). These reported values are comparable to those values reported for ecosystems of India's forest (0.00-4.21) (Singh *et al.* 1984; Bisht and Sharma 1984), Raturi 2012 (0.78-3.45), Kothandaraman *et al.* 2017 for deciduous forests (2.01-2.30). The Simpson dominance index (D) values ranged from 0.87 (SR) to 0.95 (CR). These values are more or less comparable to the values reported in earlier studies. Kothandaraman *et al.* 2017 had observed the range values of D for certain deciduous forest from (0.13-0.97), Meena *et al.* 2016 (0.42-0.52) for Delhi Ridge which is less than the reported values in this study. The increased values of index suggests the protective boundaries installations, which reduces the grazing, and contribute to high diversity index values. Among study areas SR shows lowest Dvalues which is due to more anthropogenic disturbances like over-grazing, forest fragmentation within forest-protected area.

According to Zobel *et al.* 1976 the general case in established forest is that Shannon diversity index (H') and concentration of dominance (Cd) values are inversely related to each other. The Pielous eveness index (J) value, reported for tree species from 0.79 (SR) to 0.91 (CR). These values are comparable to the values reported by Kaushal *et al.*, 2021 (0.57-0.86) for Central Himalayan forest. Margalef index values ranged from 3.11 (SR) to 6.26 (CR), this indicated that SR to be least species rich. These values are comparable to the earlier reported values by Kaushal *et al.*, 2021 (0.57-3.67) for Central Himalayan forest. According to Huang *et al.* 2003 forest structure and species composition significantly influenced species diversity. For useful management

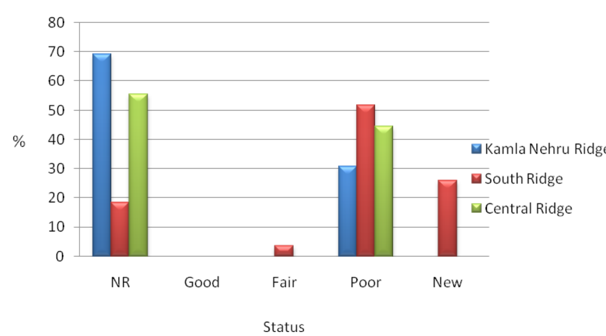

Fig. 3. Regeneration status (%) of different forests in the three ridge tops; CR= Central Ridge; KR= Kamla Nehru Ridge; SR= South Ridge.

measures in these forest, it is important to have a good database of patterns of tree diversity and their distribution (Naidu *et al.*, 2016).

In this study reported basal area (m^2/ha) values ranged from 4.87 m^2/ha (SR) to 22.94 m^2/ha (CR). These values are similar to the values reported by Meena *et al.* 2016 (19.87-33.61m^2/ha), Bhat 2012 (2.91-37.96 m^2/ha). These values are comparable to the basal area values reported from other studies include 7-23m^2/ha (Jha and Singh, 1990) from dry forest community in India. These values are less comparable to the values reported 47-49.5m^2/ha (Jaffre and Veillon, 1990). Different factors like altitude, species composition, age of trees, and extent of disturbances and successional strategies of the stand cause the difference in basal area values of tree layers among the study plots (Naidu *et al.*, 2016). The reproductive status of population can be determined by the ratio of various age groups present in the population and this also indicates the future course (Odum, 1971). The density values reported for trees ranged from 520 Ind/ha (KR) to 1043Ind/ha (CR). These values are comparable to the values reported by Meena *et al.*, 2016 (633Ind/ha -684Ind/ha,) in Delhi Ridge, Sahu *et al.*, 2010 (565-671Ind/ha) in Eastern Ghats, Campbell *et al.*, 1992 (420-777 Ind/ha) in Brazil. In this study, sapling density ranged from 133Ind/ha (KR) to 470 Ind/ha SR, whereas seedling density ranged from 53Ind/ha (KR) to 273Ind/ha (CR). These values more or less comparable for saplings values earlier reported studies, Bhatt 2012 for sapling ranging (160-330 Ind/ha) and for seedling density ranging (155-695 Ind/ha) from Garhwal Himalaya. Singh *et al.*, 2016 for sapling ranging (167-1296 Ind/ha). But for seedling reported values in present study is less comparable to earlier reported values from ranging (1376-9600 Ind/ha) from Garhwal Himalaya, Balemlay *et al.*, 2021 (770 Ind/ha) from Southwest Ethiopia.

This study shows the presences of adult trees are greater than the presence of Saplings and seedlings. Based on this study, 22 tree species reported was not present in both seedlings and saplings stage. These species were *Acacia catechu*, *Aegle marmelos*, *Albizialebbeck*, *Ailanthus excelsa*, *Alstonia scholaris*, *Azadirachta indica*, *Butea monosperma*, *Callistemon viminalis*, *Clerodendrum phlomidis*, *Delonix regia*, *Eucalyptus camaldulensis*, *Ficus virens*, *Kigelia africana*, *Mangifera indica*, *Melia azadarach*, *Neolamarckia cadamba*, *Bauhinia racemosa*, *Polyalthia lonifolia*, *Syzgium cumini*, *Tectona grandis*, *Terminalia catappa and Ziziphus mauritiana.* The possible factors which affects the lower count of seedlings and saplings maybe due to over grazing, seed predation, species specificity, moisture stress or might have other alternative adaptation for propagation and reproduction rather than seed germination (Balemlay *et al.*, 2021). This result indicates that many species are under

Table 4. Regeneration status of tree species in all three studied forests.

RS	Tree Species CR	KR	SR
No	*A.catechu, A. marmelos, A. lebbeck, A. scholaris, A. indica, B. ceiba B. monosperma, C. viminalis, D.regia F. religosa, F. virens, E. camalduensis, K. africana, N. cadamba, P. dulce, P. lonifolia. P. pinnata, S. cumini, T. grandis, T. catappa, Z. mauritiana*	*A. leucocephala, A. marmelos, A.lebbeck,A.indica, B.ceiba, B.monosperma, C.phlomidis, D. sisso, F. religosa, F. virens, H. integrifolia, K. africana, M. indica, M. azedarach, P. dulce,P.lonifolia, P. pinnata, S. cumini*	*A. catechu, A.excelsa, J. curcas, B. monosperma, B. purpurea,*
Poor	*C.fistula, C.adansonii, D.sisso,D.cineraria, D. cordifolia, D. roxburgii, E. laevis, H. heterophyllum, H. integrifolia, L. leucocephala, M. alba, P. juliflora, T. indica, T. peruviana, W. tinctoria*	*D. cordifolia, D.roxburghii, E. laevis, E.camaldulensis, F. racemosa, M. alba, P. juliflora, T. peruviana*	*A. nilotica, A. pendula A. senegal, B. roxiburgii, C. fistula, D. sisso, D. cordifolia, H. heterophyllum, H. integrifolia, P. dulce, P. pinnata, P. juliflora, P. cineria W. tinctoria*
Fair	-	-	*A. leucocephala*
Good	-	-	-
New	-	-	

B. cebia, C. spinarum, C. javanica, D.cineraria, F.religosa, L.leucocephala, Z. mauritiana (all these species will be under No regeneration column of SR

RS= Regeneration status; CR= Central Ridge; KR= Kamla Nehru Ridge; SR= South Ridge.

threat of local extinction and for conservation priority should be given to such stressed species. Dalling *et al.*, 1998 stated that if any forest area characterized by presence of adults only and show absence or lower count of seedlings and saplings, these species are prone for local extinction. Only one specie i.e. *A. leucocephala* in SR shows "Fair" regeneration, as its presence only reported in SR and no individuals were reported in KR and NR. Whereas 7 Species reported in SR were "new" to the area, as only present in sapling or seedling stage. These species might be introduced to the area by dropping of the birds and animals. These species seeds germinate after getting favourable conditions and transforms into seedlings and saplings stage and struggling for establishment, in future may form sub canopy of the forest (Malik and Bhatt, 2016).

The regeneration status of all three sites shows that CR has greater density of trees, saplings and seedlings as compares to other KR and SR. Many possible reasons for this maybe proper installation of boundaries around CR, limited access to human disturbances, low grazing, fulfilling water supply, proper management practice and care practices follows by authorities. But as whole, results shows that all three sites CR, KR and SR are highly disturbed and in poor health. The reasons for this might be because of water scarcity, over grazing, land encroachment, forest fragmentation, urbanization, invasive species dominance, human disturbances, lack of knowledge about native species. Other reasons for "no" or "poor" regeneration are tree species having poor biotic potential which can affects fruiting or seed germination or transformation of seedling to sapling stage (Sarkar and Devi, 2014). Many disturbances like uncontrolled grazing, removal of young seedlings and saplings and soil loss due to trampling can drastically affects regeneration of forests (Saberwal, 1996).

Conclusion

For conservation and management of the forest, it is important to assess population community structure and regeneration status of the forest. In this study, it was observed that among all three selected sites the CR is more diverse in terms of diversity than other two. Seedlings and saplings population were more in CR as compare to KR and SR. But as whole the population of adult trees was highest followed by saplings and seedlings. Despite all the efforts made by forest department the overall regeneration status is"poor" among all three selected ridges or forests. And the species reported and showing "new" to the area may survive, if conditions remain favourable and control on anthropogenic disturbances. Therefore, it is necessary to implement a systematic plan for conservation and sustainable utilization of forest. It is necessary for all the departments to work with common goals and objectives. Conserving and managing biodiversity of urban forest leads to preserving biological integr0ity of native remnant forests. Awareness program must be initiated to involve citizens to understand and participates in urban forest management practices. Proper guidelines should be released about specific local flora species to plant, to avoid plantation of invasive or exotic species.

Acknowledgements

The authors are thankful to the Science and Engineering Research Board (SERB), a statutory body of Department of Science, Government of India, New Delhi, India, for providing financial support to carry out this research work (Project No. SERB/EEQ/ 2017/000181). The authors are highly thankful to the University School of Environment Management, GGSIPU, New Delhi, India to provide laboratory and library facilities. We are grateful to the Forest Department of Delhi to allow us to conduct the extensive research work.

References

Balemlay, S. and Siraj, M. 2021. Population Structure and Regeneration Status of Woody Species in Kenech Forest, Southwest Ethiopia. *International Journal of Forestry Research.*

Bolund, P. and Hunhammar, S. 1999. Ecosystem services in urban areas. *Ecological economics*. 29(2): 293-301.

Campbell, D.G., Stone, J.L. and Rosas Jr, A.R.I.T.O. 1992. A comparison of the phytosociology and dynamics of three floodplain (Várzea) forests of known ages, Rio Juruá, western Brazilian Amazon. *Botanical journal of the Linnean Society.* 108(3) : 213-237.

Champion, H.G. and Seth, S.K. 1968. *A revised survey of the forest types of India*. Manager of publications.

Chauhan, S., Yadav, G. and Babu, S. 2022. Ecological Networks in Urban Forest Fragments Reveal Species Associations between Native and Invasive Plant Communities. *Plants.* 11(4) : 541.

Clark, J.R., Matheny, N.P., Cross, G. and Wake, V. 1997. A model of urban forest sustainability. *Journal of Arboriculture.* 23 : 17-30.

Clark, J.S., Beckage, B., Camill, P., Cleveland, B., Hille Ris Lambers, J., Lichter, J., McLachlan, J., Mohan, J. and Wyckoff, P. 1999. Interpreting recruitment limitation in forests. *American Journal of Botany.* 86(1): 1-16.

Dalling, J.W., Hubbell, S.P. and Silvera, K. 1998. Seed dispersal, seedling establishment and gap partitioning among tropical pioneer trees. *Journal of Ecology.* 86(4): 674-689.

Deb, P. and Sundriyal, R.C. 2011. Vegetation dynamics of an old-growth lowland tropical rainforest in North-east India: species composition and stand heterogeneity. *International Journal of Biodiversity and Conservation.* 3(9) : 405-430.

Debnath, P., Sudin, P. and Soma, C. 2012. Diversity and richness of plants in Darjeeling Himalaya with an eye on Gaddikhana Forest beat, Senchal east zone forest range, Darjeeling. *Indian Journal of Forestry.* 35(1) : 39-44.

Dyderski, M.K. and Jagodziñski, A.M. 2020. Impact of invasive tree species on natural regeneration species composition, diversity, and density. *Forests.* 11(4) : 456.

Faeth, S.H., Warren, P.S., Shochat, E. and Marussich, W.A., 2005. Trophic dynamics in urban communities. *BioScience*. 55(5) : 399-407.

Fayiah, M., Singh, S., Mengesha, Z. and Chen, B. 2018. Regeneration status and species diversity of a mix dry deciduous forest: a case of Barah forest, Jabalpur, Madhya Pradesh, India. *Indian Journal of Tropical Biodiversity.* 26(1) : 17-29.

Gairola, S., Sharma, C.M., Ghildiyal, S.K. and Suyal, S. 2012. Regeneration dynamics of dominant tree species along an altitudinal gradient in moist temperate valley slopes of the Garhwal Himalaya. *Journal of Forestry Research.* 23(1) : 53-63.

Gebeyehu, G., Soromessa, T., Bekele, T. and Teketay, D. 2019. Species composition, stand structure, and regeneration status of tree species in dry Afromontane forests of Awi Zone, northwestern Ethiopia. *Ecosystem Health and Sustainability*. 5(1): 199-215.

Getachew, T., Demel, T., Masresha, F. and Erwin, B. 2010. Regeneration of seven indigenous tree species in a dry Afromontane forest, Southern Ethiopia. *Flora.* 205: 135-143.

Good, N.F. and Good, R.E. 1972. Population dynamics of tree seedlings and saplings in a mature eastern hardwood forest. *Bulletin of the Torrey Botanical Club.* 172-178.

Iqbal, K., Pala, N.A., Bhat, J.A. and Negi, A.K. 2012. Regeneration status of trees around Khoh river in Garhwal Himalaya. *Indian Journal of Forestry*. 35(4): 471-476.

Jaffré, T. and Veillon, J.M. 1991. *Etude floristiqueetstructurale de deuxforêtsdenseshumides sur rochesultrabasiquesen Nouvelle-Calédonie*. Muséum National d'Histoire Naturelle.

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

Kadavul, K. and Parthasarathy, N. 2001. Population analysis of Alphonseasclerocarpa Thw.(Annonaceae) in the Kalrayan hills of Eastern Ghats, India. *International Journal of Ecology and Environmental Science.* 27(1): 51-54.

Kaur, M., Joshi, P., Sarma, K. and Das, S.K. 2020. Assessment of plant community structure in Tal Chhapar Wildlife Sanctuary, Rajasthan, India. *Species.* 21 :126-139.

Kaushal, S., Siwach, A. and Baishya, R. 2021. Diversity, regeneration, and anthropogenic disturbance in major Indian Central Himalayan forest types: implications for conservation. *Biodiversity and Conservation.* 30(8) : 2451-2480.

Khadanga, S.S. and Jayakumar, S. 2018. Tree diversity and carbon sequestration potential of an urban Forest patch of Pondicherry, India. *Journal of Tree Sciences*, 37(1): 58-71.

Khan, M.L., Rai, J.P.N. and Tripathi, R.S. 1987. Population structure of some tree species in disturbed and protected subtropical forests of north-east India. *Acta Oecol. (Oecol. Appl.).* 8(3) : 247-255.

Khumbongmayum, A.D., Khan, M.L. and Tripathi, R.S. 2006. Biodiversity conservation in sacred groves of Manipur, northeast India: population structure and regeneration status of woody species. In: *Human Exploitation and Biodiversity Conservation* (pp. 99-116).

Kothandaraman, S. and Sundarapandian, S. 2017. Structure of plant community in tropical deciduous forests of Kanyakumari Wildlife Sanctuary, India. *Biodiversitas Journal of Biological Diversity.* 18(1).

Kujur, E., Jhariya, M.K., Yadav, D.K. and Banerjee, A., 2022. Phytosociological attributes and regeneration potential of riparian vegetation in Northern Chhattisgarh, India. *Environment, Development and Sustainability.* 24(2) : 2861-2886.

Maheshwari, J.K. 1966. Illustrations to the Flora of Delhi.

Malik, Z.A. and Bhatt, A.B. 2016. Regeneration status of tree species and survival of their seedlings in Kedarnath Wildlife Sanctuary and its adjoining areas in Western Himalaya, India. *Tropical Ecology.* 57(4) : 677-690.

McDonnell, M.J. and Pickett, S.T. 1990. Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. *Ecology*. 71(4): 1232-1237.

Meena, A., Hanief, M., Bidalia, A., Dinakaran, J. and Rao, K.S. 2016. Structure, composition and diversity of tree strata of semi-arid forest community in Delhi, India. *Phytomorphology.* 66(3-4) : 95-102.

Mikkelson, G.M. 1993. How do food webs fall apart? A study of changes in trophic structure during relaxation on habitat fragments. *Oikos*. 539-547.

Misra, R. 1968. *Ecology workbook*. Scientific publishers.

Naidu, M.T. and 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(3) : 328-334.

Negi, C.S. and Nautiyal, S. 2005. Phyto-sociological studies of a traditional reserve forest-Thal Ke Dhar, Pithoragarh, Central Himalayas (India). *Indian Forester*. 131(4): 519.

Odum, E.P. and Barrett, G.W. 1971. *Fundamentals of Ecology* (Vol. 3, p. 5). Philadelphia: Saunders.

Pala, N.A., Negi, A.K., Gokhale, Y., Bhat, J.A. and Todaria, N.P. 2012. Diversity and regeneration status of Sarkot Van Panchyat in Garhwal Himalaya, India. *Journal of Forestry Research*. 23 : 399-404.

Pao, N.T. and Upadhaya, K. 2017. Effect of fragmentation and anthropogenic disturbances on floristic composition and structure of subtropical broad leaved humid forest in Meghalaya, Northeast India. *Appl. Ecol. Environ. Res.* 15 : 385-407.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical biology*. 13 : 131-144.

Pokhriyal, P., Uniyal, P., Chauhan, D.S. and Todaria, N.P., 2010. Regeneration status of tree species in forest of Phakot and Pathri Rao watersheds in Garhwal Himalaya. *Current Science*. 171-175.

Pratap, C., Ra, P., Ajay, K.M., Pradosh, K.A. and Akhil, K.D. 2013. Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. *International Journal of Biodiversity and Conservation.* 5(10) : 625-639.

Rahman, M.H., Khan, M.A.S.A., Roy, B. and Fardusi, M.J. 2011. Assessment of natural regeneration status and diversity of tree species in the biodiversity conservation areas of Northeastern Bangladesh. *Journal of Forestry Research*. 22: 551-559.

Ram, J., Kumar, A. and Bhatt, J., 2004. Plant diversity in six forest types of Uttaranchal, Central Himalaya, India. *Current Science*. pp. 975-978.

Raturi, G.P. 2012. Forest community structure along an altitudinal gradient of district Rudraprayag of Garhwal Himalaya, India. *Ecologia.* 2(3) : 76-84.

Rawat, D.S., Dash, S.S., Sinha, B.K., Kumar, V., Banerjee, A. and Singh, P. 2018. Community structure and regeneration status of tree species in Eastern Himalaya: A case study from Neora Valley National Park, West Bengal, India. *Taiwania. 63*(1).

Saberwal, V.K. 1996. Pastoral politics: Gaddi grazing, degradation, and biodiversity conservation in Himachal Pradesh, India. *Conservation Biology.* 10(3) : 741-749.

Sahu, S.C., Dhal, N.K. and Mohanty, R.C. 2010. Commercialization of few wild medicinal plants from Deogarh district, Orissa, India. *E-planet.* 8: 14-16.

Sarkar, M. and Devi, A. 2014. Assessment of diversity, population structure and regeneration status of tree species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India. *Tropical Plant Research.* 1(2): 26-36.

Saxena, A.K., Singh, S.P. and Singh, J.S. 1984. Population structure of forests of Kumaun Himalaya: implications for management. *Journal of Environmental Management*. 19(4) : 307-324.

Shankar, U. 2001. A case of high tree diversity in a sal (Shorea robusta)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Current Science*. pp. 776-786.

Shannon, C.E. and Wiener, W. 1963. *The Mathematical Theory of Communities.* University of Illinois press, Urbana, 117.

Simpson, E.H. 1949. Measurement of diversity. *Nature.* 163(4148) : 688-688.

Singh, J. S. and Singh, S. P. 1984. *An integrated ecological study of eastern Kumaun Himalaya with emphasis on natural resources*; (Kumaun University, Naini Tal: Final Report (HCS/DST/187/76)) vols 1–3

Singh, J.S. 1992. Man and forest interactions in Central Himalaya. *Himalayan environment and development: Problems and perspectives*.

Singh, S., Malik, Z.A. and Sharma, C.M. 2016. Tree species richness, diversity, and regeneration status in different oak (Quercus spp.) dominated forests of Garhwal Himalaya, India. *Journal of Asia-Pacific Biodiversity.* 9(3) : 293-300.

Sinha, G.N. 2014. An introduction to the Delhi Ridge. *Department of Forests and Wildlife, Govt. of NCT of Delhi, New Delhi, India, p Xxiv*, 154.

Timilsina, N., Ross, M.S. and Heinen, J.T. 2007. A community analysis of sal (Shorearobusta) forests in the western Terai of Nepal. *Forest Ecology and Management.* 241(1-3) : 223-234.

Uniyal, P., Pokhriyal, P., Dasgupta, S., Bhatt, D. and Todaria, N.P. 2010. Plant diversity in two forest types along the disturbance gradient in Dewalgarh Watershed, Garhwal Himalaya. *Current Science.* 938-943.

Verma, R.K., Kapoor, K.S., Subramani, S.P. and Rawat, R.S. 2004. Evaluation of plant diversity and soil quality under plantation raised in surface mined areas. *Indian Journal of Forestry.* 27(2) : 227-233.

Whittaker, R.H. 1965. Dominance and Diversity in Land Plant Communities: Numerical relations of species express the importance of competition in community function and evolution. *Science.* 147(3655) : 250-260.

Wyatt-Smith, J. 1987. Thb Management of Tropical Moist Forest for the Sustained Production of Timber: Some Issues.

Zobel, D.B., McKee, A., Hawk, G.M. and Dyrness, C.T. 1976. Relationships of environment to composition, structure, and diversity of forest communities of the central western Cascades of Oregon. *Ecological Monographs.* 46(2) : 135-156.