Density and Population Structure of Globally Vulnerable and Endangered Trees in Chennai Metropolitan City, India

M. Udayakumar^{1,*}, A. Selvam¹, T. Sekar²

¹Department of Plant Science, Manonmaniam Sundaranar University, Tirunelveli, Tamil Nadu, India

²PG and Research Department of Botany, Pachaiyappa's College, Chennai, Tamil Nadu, India

Received March 19, 2020; Revised April 13, 2020; Accepted April 27, 2020

Copyright©2020 by authors, all rights reserved. Authors agree that this article remains permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

Abstract A quantitative floristic study was conducted in Chennai metropolitan city (CMC), Tamil Nadu, India to estimate density and population structure of trees categorized as vulnerable and endangered by International Union for Conservation of Nature and Natural Resources (IUCN) red-list. A total of one hundred 1-ha (100 m × 100 m) square plots were randomly laid to estimate density and species richness of threatened trees in study area. All trees ≥ 10 cm girth at breast height (gbh) were recorded, and identified up to species level on the field with the aid of regional floras and checklists. Six different land uses were recognised. In total, 10426 trees belonging to 99 species, 36 families and 86 genera were recorded. Of six land use categories, riverbanks had highest tree density (150.08 ± 21.02 trees ha⁻¹) followed by parks (138.86 ± 29.08 trees ha⁻¹) and institutional areas (98.77 ± 4.48 trees ha⁻¹). In total, 1272 IUCN red-listed trees belonged to six families and eight genera were enumerated. Among land uses, educational institutions had largest number of threatened trees (374 individuals) followed by parks (327 individuals) and residential areas (228 individuals). We find Chennai's urban forests as home for seven vulnerable and three endangered tree species. This study reveals density and population structure of threatened trees growing in CMC, India.

Keywords Endangered Tree Species, South India, Threatened Species, Urban Forest, Vulnerable Tree Species

1. Introduction

Urban forests serve aesthetic, ecological, health, psychological and social functions [1]. They form a

considerable amount of nation's total tree cover [2]. In addition, urban forests provide habitat for plants and animals [3]. Frequently, the species richness of urban forests is greater than it is in rural areas [4-8]. Further, urban forests provide niches to endangered species [9]. Besides, urbanized areas also harbor a large number of threatened species [10-13]. Interestingly, even a small green space serves as a habitat for native flora and fauna [14]. Information on density and species richness of threatened species is one of the basic needs to assess conservation values of urban forests and trees [15]. Promoting and preserving biota within urban forests is believed to decelerate the uncontrollable biodiversity loss [2]. Baseline data such as density, diversity and species richness of plant and animal species are scarce for many Indian cities including Chennai. Information on these lines could aid in the preparation of conservation measures that protect and preserve species from damages. Only a limited number of studies have concentrated on urban biodiversity in Chennai Metropolitan City (CMC) [14, 16, 17]. Moreover, information on threatened trees of CMC is lacking. Thus, the present study was planned to fill this gap, and to assess density and species richness and population structure of globally vulnerable and endangered tree species in CMC.

2. Methods

2.1. Study Area

Chennai is one of the four metropolitan cities of the Indian sub-continent. The city is the capital of Tamil Nadu state and has 174 km² of geographical area. Climate of the city is tropical-humid. The mean maximum and minimum temperature and rainfall are 37 °C and 24 °C, and 1200 and

1300 mm, respectively [18]. The city serves as home for 6.4 million people [19]. The city has Bay of Bengal as its eastern border and Thiruvallur and Kanchipuram districts as its northern, southern and western boundaries.

2.2. Field Survey

The entire area of CMC is sub-gridded into hectares by using ArcGIS 9.3 tool. Among sub-grids 100 study plots (one ha each) were selected with random table for tree density enumeration. A total of one hundred 1-ha (100 m × 100 m) square plots were laid to reveal density of IUCN's

Red-listed trees in CMC (Figure 1). Study area comprises of residential areas, urban parks, educational institutions, roads, riverbanks and government offices (Table 1). All trees ≥ 10 cm girth at breast height were counted. All the encountered trees were identified to species level in the field with the help of available field guides, floras and checklists [14, 16, 20]. Voucher specimens were deposited at Pachaiyappa's College Herbarium, Chennai (PCHC). Status of threatened species was recorded with the help of IUCN Red List's website [21].

Figure 1. Map of Chennai metropolitan city wherein tree diversity study conducted

Table 1. Land use types and area covered to record threatened trees in study area

Land use type	Area covered (ha)
Educational institutions	19.532
Riverbanks	13.234
Parks	21.512
Road sides	16.112
Residential areas	20.511
Government offices	9.099
Total	100.000

2.3. Diversity Indices

The Shannon diversity (H) and equitability (E_H) indices were computed for all the sample plots together (total area = 100 ha) [22].

$$H = -\sum_{i=1}^S P_i \ln P_i$$

where H is known as Shannon diversity index; P_i termed as a fraction of the whole population made up of species i ; S recognized as numbers of species encountered; $\sum$ is the total number of species from 1 to S .

Shannon equitability index (E_H) computed by dividing H by H_{max} ($H_{max} = \ln S$). $E_H = H/H_{max} = H/\ln S$. Species richness of study area was calculated directly by

summing the number of species encountered in each 1-ha study plot. Similarly, tree density of study area also calculated directly by totaling the number of individuals recorded in each study plot.

3. Results and Discussion

3.1. Species, Genera and Family Richness

On the whole, during January to December, 2012 we recorded 10426 trees in 100 ha study area. Ninety nine tree species belonging to 36 families and 86 genera were recorded. The family Fabaceae represented with large number of species (22 species) followed by Arecaceae, Bignoniaceae and Moraceae (each 7 species), while 17 families represented by just single species' each in study area. Of 99 species, 43 species each recorded under not evaluated and least concern, 8 in vulnerable, 2 each in data deficient and endangered, and just one in near threatened categories of IUCN's Red List (Figure 2). Seven species namely, *Canthium dicoccum*, *Chloroxylon swietenia*, *Delonix regia*, *Khaya senegalensis*, *Pterocarpus marsupium*, *Saraca asoca* and *Swietenia macrophylla* were recorded as vulnerable in IUCN's Red List, while the remaining three species *Guaiaecum officinale*, *Pterocarpus santalinus* and *Swietenia mahagoni* were found as endangered (Table 2).

Figure 1. Proportion of trees categorized based on IUCN threat status

Table 2. Botanical name, family, density and IUCN categories of trees recorded in Chennai metropolitan city, India (NE: Not Evaluated, DD: Data Deficient, LC: Least concern, NT: Near Threatened, VU: Vulnerable, EN: Endangered)

Botanical name	Family	Density	IUCN category
1. <i>Acacia auriculiformis</i> A.Cunn. ex Benth.	Fabaceae	15	LC
2. <i>Adenanthera pavonina</i> L.	Fabaceae	65	LC
3. <i>Alangium salviifolium</i> (L.f.) Wangerin.	Cornaceae	5	LC
4. <i>Albizia saman</i> (Jacq.) F.Muell.	Fabaceae	430	NE
5. <i>Albizia lebbek</i> (L.) Benth.	Fabaceae	27	NE
6. <i>Alstonia scholaris</i> (L.) R. Br.	Apocynaceae	17	LC
7. <i>Annona squamosa</i> L.	Annonaceae	15	LC
8. <i>Artocarpus heterophyllus</i> Lam.	Moraceae	31	NE
9. <i>Azadirachta indica</i> A. Juss.	Meliaceae	215	LC
10. <i>Bauhinia racemosa</i> Lam.	Fabaceae	27	NE
11. <i>Bixa orellana</i> L.	Bixaceae	5	LC
12. <i>Bombax ceiba</i> L.	Bombacaceae	23	NE
13. <i>Borassus flabellifer</i> L.	Arecaceae	27	NE
14. <i>Butea monosperma</i> (Lam.) Taub.	Fabaceae	7	NE
15. <i>Caesalpinia coriaria</i> (Jacq.) Willd.	Fabaceae	35	NE
16. <i>Caesalpinia pulcherrima</i> (L.) Sw.	Fabaceae	37	LC
17. <i>Callistemon citrinus</i> (Curtis) Stapf.	Myrtaceae	10	NE
18. <i>Calophyllum inophyllum</i> L.	Clusiaceae	13	LC
19. <i>Canthium dicoccum</i> (Gaertn.) Merr.	Rubiaceae	52	VU
20. <i>Carica papaya</i> L.	Caricaceae	52	DD
21. <i>Caryota urens</i> L.	Arecaceae	13	LC
22. <i>Cassia fistula</i> L.	Fabaceae	57	LC
23. <i>Cassia roxburghii</i> DC.	Fabaceae	62	NE
24. <i>Cassia siamea</i> Lam.	Fabaceae	27	LC
25. <i>Casuarina equisetifolia</i> L.	Casuarinaceae	65	LC
26. <i>Chloroxylon swietenia</i> DC.	Rutaceae	6	VU
27. <i>Chrysalidocarpus lutescens</i> H.Wendl.	Arecaceae	75	NT
28. <i>Cocos nucifera</i> L.	Arecaceae	765	LC
29. <i>Cordia obliqua</i> Willd.	Boraginaceae	198	NE
30. <i>Cordia sebestena</i> L.	Boraginaceae	76	LC
31. <i>Couroupita guianensis</i> Aubl.	Lecythidaceae	5	LC
32. <i>Crateva magna</i> (Lour.) DC.	Capparidaceae	5	LC
33. <i>Crescentia cujete</i> L.	Bignoniaceae	5	LC
34. <i>Dalbergia coromandeliana</i> Prain	Papilionaceae	2	NE
35. <i>Delonix regia</i> (Bojer ex Hook.) Raf.	Fabaceae	1002	VU
36. <i>Diospyros peregrina</i> Gurke	Ebenaceae	3	NE
37. <i>Erythrina variegata</i> L.	Fabaceae	15	LC
38. <i>Eucalyptus globulus</i> Labill.	Myrtaceae	51	LC
39. <i>Ficus benghalensis</i> L.	Moraceae	15	NE
40. <i>Ficus elastica</i> Roxb.	Moraceae	5	NE
41. <i>Ficus racemosa</i> L.	Moraceae	21	LC
42. <i>Ficus religiosa</i> L.	Moraceae	33	NE
43. <i>Ficus tomentosa</i> L.	Moraceae	3	NE
44. <i>Glicidia sepium</i> (Jacq.) Kunth	Fabaceae	47	LC
45. <i>Gmelina arborea</i> Roxb.	Verbenaceae	51	LC
46. <i>Guaiacum officinale</i> L.	Zygophyllaceae	9	EN
47. <i>Guazuma ulmifolia</i> Lam.	Sterculiaceae	297	LC
48. <i>Hibiscus tiliaceus</i> L.	Malvaceae	32	LC
49. <i>Ixora pavetta</i> Andrews	Rubiaceae	15	NE

Table 2 Continued

50. <i>Khaya senegalensis</i> (Desv.) A.Juss.	Meliaceae	11	VU
51. <i>Kigelia africana</i> (Lam.) Benth.	Bignoniaceae	105	LC
52. <i>Lannea coromandelica</i> (Houtt.) Merr.	Anacardiaceae	205	NE
53. <i>Lawsonia inermis</i> L.	Lythraceae	18	NE
54. <i>Leucaena latisiliqua</i> (L.) Gillis & Stearn	Fabaceae	787	NE
55. <i>Limonia acidissima</i> L.	Rutaceae	27	NE
56. <i>Livistona chinensis</i> R.Br.	Arecaceae	15	NE
57. <i>Madhuca longifolia</i> (J. König ex L.) J.F. Macbr.	Sapotaceae	65	NE
58. <i>Mangifera indica</i> L.	Anacardiaceae	55	DD
59. <i>Markhamia stipulata</i> Seem.	Bignoniaceae	19	LC
60. <i>Millingtonia hortensis</i> L.f.	Bignoniaceae	112	NE
61. <i>Mimusops elengi</i> L.	Sapotaceae	139	LC
62. <i>Morinda coreia</i> Buch. -Ham.	Rubiaceae	187	NE
63. <i>Moringa oleifera</i> Lam.	Moringaceae	22	NE
64. <i>Nerium oleander</i> L.	Apocynaceae	85	LC
65. <i>Nyctanthes arbor-tristis</i> L.	Oleaceae	56	NE
66. <i>Ochna serrata</i> L.	Ochnaceae	11	NE
67. <i>Peltophorum pterocarpum</i> (DC.) Baker ex. K.Heyne	Fabaceae	532	NE
68. <i>Phoenix sylvestris</i> (L.) Roxb.	Arecaceae	10	NE
69. <i>Phyllanthus acidus</i> (L.) Skeels	Euphorbiaceae	55	NE
70. <i>Phyllanthus emblica</i> L.	Euphorbiaceae	35	NE
71. <i>Pisonia alba</i> Span.	Nyctaginaceae	27	NE
72. <i>Pithecellobium dulce</i> (Roxb.) Benth.	Fabaceae	15	LC
73. <i>Polyalthia longifolia</i> (Sonn.) Thwaites	Annonaceae	1150	NE
74. <i>Pongamia pinnata</i> (L.) Merr.	Fabaceae	513	LC
75. <i>Premna latifolia</i> Roxb.	Verbenaceae	5	NE
76. <i>Prosopis juliflora</i> (Sw.) DC.	Fabaceae	612	NE
77. <i>Psidium guajava</i> L.	Myrtaceae	32	LC
78. <i>Pterocarpus marsupium</i> Roxb.	Fabaceae	20	VU
79. <i>Pterocarpus santalinus</i> L.f.	Fabaceae	10	EN
80. <i>Pterospermum canescens</i> Roxb.	Sterculiaceae	2	NE
81. <i>Punica granatum</i> L.	Lythraceae	15	LC
82. <i>Roystonea regia</i> (Kunth.) O.F.Cook.	Arecaceae	32	NE
83. <i>Saraca asoca</i> (Roxb.) De Wilde	Caesalpiniaceae	55	VU
84. <i>Spathodea campanulata</i> P.Beauv.	Bignoniaceae	184	LC
85. <i>Sterculia foetida</i> L.	Sterculiaceae	112	NE
86. <i>Streblus asper</i> Lour.	Moraceae	15	LC
87. <i>Swietenia macrophylla</i> King.	Meliaceae	55	VU
88. <i>Swietenia mahagoni</i> L.	Meliaceae	52	VU
89. <i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	97	LC
90. <i>Tabebuia rosea</i> DC.	Bignoniaceae	165	LC
91. <i>Tamarindus indica</i> L.	Fabaceae	65	LC
92. <i>Tecoma stans</i> (L.) Kunth.	Bignoniaceae	97	NE
93. <i>Terminalia arjuna</i> Wight & Arn.	Combretaceae	13	NE
94. <i>Terminalia bellirica</i> (Gaertn.) Roxb.	Combretaceae	11	NE
95. <i>Terminalia catappa</i> L.	Combretaceae	106	LC
96. <i>Thespesia populnea</i> (L.) Sol. ex Corrêa	Malvaceae	56	LC
97. <i>Vitex altissima</i> L. f.	Verbenaceae	1	LC
98. <i>Wrightia tinctoria</i> R. Br.	Apocynaceae	112	LC
99. <i>Ziziphus mauritiana</i> Lam.	Rhamnaceae	178	LC
	Total	10426	

3.2. Density

Density of trees (≥ 10 cm gbh) varied considerably across land use categories. The riverbanks recorded highest tree density (150.08 ± 21.02 trees ha^{-1}) followed by parks (138.86 ± 29.08 trees ha^{-1}) and educational institutions (98.77 ± 4.48 trees ha^{-1}), while roadsides had the least tree density (61.69 ± 6.72 trees ha^{-1}) in CMC (Table 3).

The mean tree density of study area was 104.26 ± 36.13 trees ha^{-1} . The average tree density ha^{-1} recorded is more or less equal to urban forests of Oakland, USA (111.9 trees ha^{-1}), while it is lesser than urban forests of ten USA cities (147 trees ha^{-1}) [23], Miami-Dade county (235 trees ha^{-1}) [24], urban forests of New Delhi, India (228 trees ha^{-1}) [25] and Nagoya, Japan (2852 trees ha^{-1}) [26]. However, the mean tree density ha^{-1} found in this study is higher than that of what has been reported for urban forests (45.6 trees ha^{-1}) [27] and parks (47.5 trees ha^{-1}) of Bangalore, India [28]; Sacramento, USA (73 trees ha^{-1}) [29]; and Beijing, China (79 trees ha^{-1}) [30].

In total, institutional areas support highest number of threatened trees (374 trees) followed by parks (327 trees) and residential areas (228 trees), while riverbanks had just 15 trees in 13.234 hectare area. Total number of each threatened species varied across land uses. For example,

Delonix regia represented with 282 individuals in parks while riverbanks had just 15 individuals (Table 4). Of 10 threatened species, nine (except *Delonix regia*) represented by large number of individuals in institutional areas, whereas *D. regia* represented abundantly in residential areas than the other land uses. Similarly, institutional areas had all the 10 threatened species, while riverbanks had just single threatened species.

Generally, stakeholders of institutional areas have awareness on importance of biodiversity and threatened species. In addition, academic institutions have protected environment than the other land use categories and hence harbors all the 10 threatened species. Metropolitan authorities protect urban parks and trees on roadsides from anthropogenic damages. Local people grow trees not only for shade but also to enhance the aesthetic values of buildings and living places. Riverbanks of Cooum and Adyar are highly polluted by unhealthy human activities as is evident from the presence of invasive alien species on riverbanks [31]. Two tropical American species (*Prosopis juliflora* - Fabaceae and *Muntingia calabura* - Muntingiaceae) dominate riverbanks in CMC. Thus, only 15 threatened trees are occurring in 13.234 ha area of riverbanks.

Table 3. The mean (no. ha^{-1}) and total number of trees documented in study area

Site	Density of all trees (no. ha^{-1}) mean $\pm$ S.D.	Total no. of trees	Number of threatened trees in study area*
Educational institutions	98.77 ± 4.48	2173	374
Riverbanks	150.08 ± 21.02	1951	15
Parks	138.86 ± 29.08	3055	327
Roadsides	61.69 ± 6.72	987	165
Residential areas	70.05 ± 5.30	1471	228
Government offices	87.67 ± 5.61	789	163
	Mean $\pm$ S.D. = 104.26 ± 36.13	10426	1272

*Threatened trees include both vulnerable and endangered tree species

Table 4. Number of threatened trees encountered in different land use categories in Chennai metropolitan city, India

Species	Number of threatened trees					
	Institutions	Riverbanks	Parks	Roadsides	Residential areas	Government offices
<i>Delonix regia</i>	231	15	282	152	188	134
<i>Saraca asoca</i>	25	-	12	5	6	7
<i>Swietenia macrophylla</i>	28	-	6	2	12	7
<i>Swietenia mahagoni</i>	21	-	9	2	15	5
<i>Canthium dicoccum</i>	40	-	12	-	-	-
<i>Pterocarpus marsupium</i>	11	-	3	-	4	2
<i>Khaya senegalensis</i>	6	-	-	1	2	2
<i>Pterocarpus santalinus</i>	4	-	3	1	-	2
<i>Guaiacum officinale</i>	6	-	-	1	-	2
<i>Chloroxylon swietenia</i>	2	-	-	1	1	2
	374	15	327	165	228	163

3.3. Diversity

Shannon diversity index (H) recorded in study area ($H = 3.6$) is very well within the range compared with those of urban forests in the USA (mean = 2.7; range = 2.1-3.9) [32]. However, the present study area had a little higher Shannon index value compared to urban forests of Bangalore Metropolitan City ($H = 2.68$) [26, 27] and Miami-Dade County of USA ($H = 0.58$) [24]. Similarly, Shannon equitability index ($E_H = 0.78$) computed for study area is also higher than in Miami-Dade County of USA ($E_H = 0.6$). The top ten species constituted 60.29% of tree community in study area; remaining 89 species together formed only 39.71% tree community. The unequal contribution of species to tree community in study area produced less evenness.

3.4. Density and Diversity of Threatened Species

A total of 1272 threatened tree individuals belonging to six families and seven genera were recorded in 100 ha study area. Density and frequency of threatened species varied considerably in study area. Among 10426 trees, 1272 were found in threatened categories of IUCN's Red List - 2012. Of 1272 trees 74 belonged to endangered category of Red List, remaining 1198 individuals fell under vulnerable category. Of seven vulnerable species, *Delonix regia* had highest number of individuals (1002 trees) in study area followed by *Saraca asoca* and *Swietenia*

macrophylla (each 55 individuals), while *Chloroxylon swietenia* represented with just six individuals (Table 5). Of 100 study plots, vulnerable tree species *Delonix regia* recorded in 97 plots, *Saraca asoca* found in 49 plots, *Swietenia macrophylla* encountered in 42 plots. The endangered species *Swietenia mahagoni* recorded in 47 plots, while *Chloroxylon swietenia* found in just five study plots (Table 5).

Earlier, urban forests have been recognised as habitats for endangered species. Urban green areas of Sweden harbor endangered tree species [3]. The thickly populated Stockholm County had two-thirds of red-listed species [33]. Gustaffson [34] found red-listed species such as *Dryopteris cristata* and *Buxbaumia viridis* in urban forests of Stockholm. Similarly, the highly populated Cook County of Chicago metropolitan area is recognised as a home for 130 endangered plant species [35].

The local people and foresters favour *Delonix regia* (Royal Poinciana) for its beautiful flowers, fruits and fast growth. These days, the urban forest division of Tamil Nadu forest department distributes evergreen tree species such as *Saraca asoca*, *Swietenia macrophylla*, *Pterocarpus marsupium* and *Khaya senegalensis* to enhance green cover in Chennai city. *Chloroxylon swietenia*, *Canthium dicroccum* and *Pterocarpus santalinus* are representing the local forest type i.e., tropical dry evergreen forest [14, 16, 36].

Table 5. Threatened category, density and frequency of trees recorded in study area

Species	Family	Threatened category (IUCN Red List – 2012)	Density	Frequency
<i>Canthium dicroccum</i>	Rubiaceae	Vulnerable	52	19
<i>Chloroxylon swietenia</i>	Rutaceae	Vulnerable	6	5
<i>Delonix regia</i>	Caesalpiniaceae	Vulnerable	1002	97
<i>Guaiacum officinale</i>	Zygophyllaceae	Endangered	9	9
<i>Khaya senegalensis</i>	Meliaceae	Vulnerable	11	10
<i>Pterocarpus marsupium</i>	Fabaceae	Vulnerable	20	15
<i>Pterocarpus santalinus</i>	Fabaceae	Endangered	10	8
<i>Saraca asoca</i>	Caesalpiniaceae	Vulnerable	55	49
<i>Swietenia mahagoni</i>	Meliaceae	Endangered	52	47
<i>Swietenia macrophylla</i>	Meliaceae	Vulnerable	55	42
		Total	1272	-

3.5. Population Structure

In total, tree community of the study area showed a typical expanding population structure. The smallest girth class had the highest number of individuals, while the largest girth class had the least number of trees (**Figure 3**). However, the population structure of threatened species varied considerably. Among 10 threatened species, four species namely, *Canthium dicoccum*, *Delonix regia*, *Saraca asoca* and *Swietenia macrophylla* showed expanding population structure (Figure 4). The remaining six species had disturbed population structure in study area (Figure 5). For example, the indigenous species

Chloroxylon swietenia had just three individuals each in 90.1-120 and 120.1-150 cm gbh. To ensure continuous presence of species in a community, the species should possess considerable number of individuals in all the girth classes. If a species' does not possess viable population then gradually it would lose its place from the community [37, 38]. Planting saplings of threatened species in appropriate places could improve the population structure of trees thereby urban forest of Chennai could serve as a habitat for more number of vulnerable and endangered tree species in the near future.

Figure 3. Stand structure of trees based on girth class frequency in study area.

Figure 4. Population structure of *Delonix regia* based on girth class frequency in study area

Figure 5. Population structure of threatened species based on girth class frequency in Chennai metropolitan city, India

4. Conclusions

We find Chennai's urban forest as home for 10 IUCN's red-listed tree species. Present study recorded density and population structure of threatened trees in 100 ha area of CMC. Further, studies with larger study areas are essential to record the total density and species richness of threatened trees in the entire area of CMC. The Government should provide financial support to researchers to document the essential baseline data on threatened species. In addition, as mentioned in earlier literatures [39-42] dissemination of information about threatened species is essential to preserve the precious natural resource in human dominated CMC, India.

Acknowledgements

The first author MU thank the Science and Engineering Research Board for providing fellowship under Young Scientist Scheme (File No. YSS/2015/002008 dt. 31.05.2016).

REFERENCES

- [1] C.D. Ward, C. M. Parker, C. M. Shackleton. The use and appreciation of botanical gardens as urban green spaces in South Africa. *Urban Forestry & Urban Greening*, 9(1): 49-55, 2010.
- [2] A.A. Alvey. Promoting and preserving biodiversity in the urban forest. *Urban Forestry & Urban Greening*, 5(4): 195-201, 2006.
- [3] W.M. Kaerkes. Zur ökologischen Bedeutung urbaner Freiflächen: dargestellt an Beispielen aus dem mittleren Ruhrgebiet. *Geograph. Inst., Ruhr-Univ. Bochum*, 1987.
- [4] A. Balmford, J. L. Moore, T. Brooks, N. Burgess, L. A. Hansen, P. Williams, C. Rahbek. Conservation conflicts across Africa. *Science*, 291(5513): 2616-2619, 2001.
- [5] C. Jim, H. Liu. Species diversity of three major urban forest types in Guangzhou City, China. *Forest Ecology and Management*, 146(1): 99-114, 2001.
- [6] J. Cornelis, M. Hermy M. Biodiversity relationships in urban and suburban parks in Flanders. *Landscape and Urban Planning*, 69(4): 385-401, 2004.
- [7] I. Kühn, R. Brandl, S. Klotz. The flora of German cities is naturally species rich. *Evolutionary ecology research*, 6(5): 749-764, 2004.
- [8] H. Sukopp, R. Wittig. In: H. Sukopp, R. Wittig (eds.). *Stadtökologie*. Gustav Fischer Verlag, Stuttgart, 402 pp. 1993.
- [9] R. Witting. *Siedlungsvegetation*, Verlag Eugen Ulmer, Stuttgart, 252 pp, 2002.
- [10] R. A. Shepherd. A review of plant communities of derelict land in the city of Nottingham, England and their value for nature conservation. *Memorabilia Zoologica*, (49), 1994.
- [11] B. C. Eversham, D. B. Roy, M.G. Telfer. Urban, industrial and other manmade sites as analogues of natural habitats for Carabidae. In: *Annales Zoologici Fennici*, Finnish Zoological and Botanical Publishing Board, p. 149-156, 1996.
- [12] C. S. Holling, G. K. Meffe. Command and control and the pathology of natural resource management. *Conservation biology*, 10(2): 328-337, 1996.
- [13] N. S. Sodhi, T. M. Lee, L. P. Koh, D. M. Prawiradilaga. Long - Term Avifaunal Impoverishment in an Isolated Tropical Woodlot. *Conservation Biology*, 20(3): 772-779, 2006.

- [14] U. Muthulingam, S. Thangavel. Density, diversity and richness of woody plants in urban green spaces: A case study in Chennai metropolitan city. *Urban Forestry & Urban Greening*, 11(4): 450-459, 2012.
- [15] B. Thaiutsa, L. Puangchit, R. Kjelgren, W. Arunpraparut. Urban green space, street tree and heritage large tree assessment in Bangkok, Thailand. *Urban Forestry & Urban Greening*, 7(3): 219-229, 2008.
- [16] M. Udayakumar, M. Ayyanar, T. Sekar. Angiosperms, Pachaiyappa's College, Chennai, Tamil Nadu, India. *Check List*, 7(1): 37-48, 2011.
- [17] P. Nehru, G. Gnanasekaran, N. M. Karthick, D. Narasimhan. Angiosperms of Nanmangalam Reserve Forest, an urban forest in Metropolitan Chennai, India. *Check List*, 8(1): 057-076, 2012.
- [18] Climate and Weather of Chennai Metropolitan [<http://www.chennaiidistrict/tn.nic.in>].
- [19] Master plan-II for Chennai Metropolitan Area-2026, [<http://www.cmdachennai.gov.in>].
- [20] J. Gamble, C. E. C. Fischer. *Flora of the Presidency of Madras*. Vols I-III, Adlard & Co, London, 1915-1935.
- [21] IUCN: Red List of Threatened Species, Version 2012.1.
- [22] A. E. Magurran. *Ecological Diversity and its Measurement*, Princeton University Press. New Jersey, 1988.
- [23] D. J. Nowak, D. E. Crane. Carbon storage and sequestration by urban trees in the USA. *Environmental pollution*, 116(3): 381-389, 2002.
- [24] M. Zhao, F. J. Escobedo, C. Staudhammer. Spatial patterns of a subtropical, coastal urban forest: Implications for land tenure, hurricanes, and invasives. *Urban Forestry & Urban Greening*, 9(3): 205-214, 2010.
- [25] N. Khera, V. Mehta, B. Sabata. Interrelationship of birds and habitat features in urban greenspaces in Delhi, India. *Urban Forestry & Urban Greening*, 8(3): 187-196, 2009.
- [26] M. Awal, T. Ohta, K. Matsumoto, T. Toba, K. Daikoku, S. Hattori, T. Hiyama, H. Park. Comparing the carbon sequestration capacity of temperate deciduous forests between urban and rural landscapes in central Japan. *Urban Forestry & Urban Greening*, 9(3): 261-270, 2010.
- [27] H. Nagendra, D. Gopal. Street trees in Bangalore: Density, diversity, composition and distribution. *Urban Forestry & Urban Greening*, 9(2): 129-137, 2010.
- [28] H. Nagendra, D. Gopal. Tree diversity, distribution, history and change in urban parks: studies in Bangalore, India. *Urban Ecosystems*, 14(2): 211-223, 2011.
- [29] R. A. Birdsey, L. S. Heath. Carbon changes in U.S. forests. In: *Productivity of America's Forests and Climate Change*, General Technical Report RM-GTR-271, USA. Edited by L. A. Joyce, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 56-70, 1995.
- [30] J. Yang, J. McBride, J. Zhou, Z. Sun. The urban forest in Beijing and its role in air pollution reduction. *Urban Forestry & Urban Greening*, 3(2): 65-78, 2005.
- [31] P. V. Mayuranathan. The flowering plants of Madras city and its immediate neighbourhood, In: *Bulletin of the Madras government museum*. Madras Government Press, Madras, India, 1929.
- [32] E. G. McPherson, D. Nowak, G. Heisler, S. Grimmond, C. Souch, R. Grant, R. Rowntree. Quantifying urban forest structure, function, and value: The Chicago Urban Forest Climate Project. *Urban ecosystems*, 1(1): 49-61, 1997.
- [33] L. Gustafsson. Presence and abundance of red - listed plant species in Swedish forests. *Conservation Biology*, 16(2): 377-388, 2002.
- [34] J. Colding, T. Elmqvist, J. Lundberg, K. Ahrné, E. Andersson, S. Barthel, S. Borgström, A. Duit, H. Ernstsson, M. Tengö. *The Stockholm Urban Assessment (SUA-Sweden). Millennium Ecosystem Assessment Sub-Global Summary Report*, Stockholm. 2003.
- [35] W. L. Howenstine. Urban forests as part of the whole ecosystem. In: *6th National Urban Forestry Conference*, Washington, DC, American Forests, pp. 118-120, 1993.
- [36] M. Udayakumar, N. Parthasarathy. Angiosperms, tropical dry evergreen forests of southern Coromandel coast, India. *Check List*, 6(3): 368-381, 2010.
- [37] D. H. Janzen. *Guanacaste National Park: tropical ecological and cultural restoration* (No. AS 50907). Fundacion Tinkes, New York (EUA) FPN, San Jose (Costa Rica), 1986.
- [38] P. J. Donoso, R. D. Nyland. Seedling density according to structure, dominance and understory cover in old-growth forest stands of the evergreen forest type in the coastal range of Chile. *Revista Chilena de Historia Natural*, 78(1): 51-63, 2005.
- [39] T. Kendle, F. Stephen. *Urban Nature Conservation: landscape management in the urban countryside*, Taylor & Francis, 1997.
- [40] P. Clergeau, J. Jokimäki, J. P. L. Savard. Are urban bird communities influenced by the bird diversity of adjacent landscapes? *Journal of Applied Ecology*, 38(5): 1122-1134, 2001.
- [41] S. R. Mehmood, D. Zhang. A roll call analysis of the Endangered Species Act amendments. *American Journal of Agricultural Economics*, 83(3): 501-512, 2001.
- [42] J.R. Miller, R. J. Hobbs. Conservation where people live and work. *Conservation biology*, 16(2): 330-337, 2002.