RESEARCH ARTICLE

LOCAL ASSESSMENT OF URBAN TREE DIVERSITY

Vinay M. Raole*, Kusum G. Vegda and Rinku J. Desai

Department of Botany,Faculty of Science,
The Maharaja Sayajirao University of Baroda,Vadodara, 390002,
Email: vinaysar@rediffmail.com

Received-10.07.2017, Revised-24.07.2017

Abstract: This work provides an overview of tree diversity in the municipality of porbandar through an assessment of the road side tree flora in urban sectors of the city. An enumeration of roadside trees along major routes of porbandar city was examined. It is aimed to make available the knowledge required for supporting proactive action for plant documentation, diversity assessment and conservation. Biodiversity indices for individual roads and area were calculated and used to depict the biodiversity in the urbanized area. A total of 35 tree species belonging to 23 families were enumerated. Most of the trees were products of planted rather than wildling preservation at number of roads. Distribution pattern of tree species analysis depict the contiguous pattern except the Avicennia marina showed random distribution. The analysis was based on a tree census in which all tree species were counted and studied for various parameters. Sum total of indices of a city then compared with the major urban spaces in the saurashtra region resulted into species richness and evenness at regional level.

Keywords: Biodiversity, Roadside trees, Saurashtra region, Urban area

INTRODUCTION

Urbanization is a global phenomenon acting at large scale and land use changes is the driver of its impact (Vitousek *et al*., 1997). Municipal biodiversity is coming under pressure exerted cover due to construction and expansion of towns and cities. These developmental activities promote the loss of native species and their replacement by introduction of non-native species (Ku¨hn *et al*. 2004; Sukopp 2004; Stehlik *et al*. 2007). A higher number of tree diversity composition and structure may change, affecting food and shelter resources; which enhances number of associated inhabitant species such as understory plants and animals (Wunderle, 1997). As urbanization occurs, traditional activities are withdrawing and depicting the physical destruction causes biodiversity reduction and extinction of the sensitive plant elements (Andrieu *et al*, 2007). Avenues with more trees diversity are most beautiful pictorial locality in every city. Regardless of its anthropogenic importance, city roadside vegetation was neglected for number of years by biologist (McDonnel, 1997).

Today, cities are not only the most important habitat of humans but, they also host the great number of plant species. Developing cities are vital to humans as settlement and habitat. Plants are the foundation of all life on earth and trees means engineers and ecosystem components' (Jorgenson 2009). Plants always play a vital role in ecosystem development and stability. In present scenario, these landscapes are ever changing as well as provide number of species on roadsides. Tree diversity is an assemblage of various categories such as wild, cultivated, ornamental, shade giving, religious, and sacred. In India the knowledge of the tree diversity is inbuilt in society as in depth information about diversity, distribution and ecological status in surrounding area is known to common man. It is also well documented as 15,000 species of vascular plants has been reported from our nation. The wealth is not only in terms of the number of unique species documented just for their uses but, its use at urban and periurban area of any city (Hiremath and Taranath, 2011).

More infrastructural development is going on in past 50 years in human history. Consequently, impact study is well suited to reveal effect on tree variety in any urban landscape. Roadside tree diversity studies provide enormous opportunities for investigations for science and society (Forman and Deblinger, 2000). In developing countries, roads are continuously increasing at a fast rate because of urbanization and roadsides occupy a very broad area. However, very little literature is found describing roadside vegetation in urban areas of Gujarat in detail which is one of the biodiversity-rich and fast urbanizing states of tropical India. Importance of tree diversity can be seen from various phases as they are not restricted to forests but exist outside also having significant importance as they carry out a number of scientific and societal functions.

Ten years back UNPD predicted that by 2030 almost two third of the world population will inhabit in cities (Anonymous, 2007). As well as according CBD (2008), TEEB (2011) and UNHABITAT (2010) urbanization and urban landscapes are crucial ecosystems for the future cons ervation and management of the biodiversity as well as human health as it provides primary ecosystem services at local level and enhance the diversity at global level. And, it has already started moving towards urban and periurban area all over the world ((Andersson, 2006; Crane & Kinzig 2005). It plays a key role in maintaining the biodiversity and supports various components of an ecosystem and it can be a step

*Corresponding Author

towards conservation in a town (Jim and Chen, 2009).The urban biodiversity also enables its inhabitants to interact with nature, thereby enhancing appreciation and makes understand functions of green areas as a beneficiary to general people (Nagendra and Gopal, 2010). Yet, despite extensive evidences of the critical role played by street trees in city environments, urban planners and managers have often undervalued this role. It is a common practice that road-side trees are often sacrificed first, when infrastructural developments such as road widening take place, especially in fast growing cities. The welfare of mankind is affected not only by their density and diversity but also by their direct and indirect values, which are beyond estimation (Seth, 2004). To prepare more effective and long term management plan for roadside and street trees, it is essential to obtain data on tree census and various other aspects (Maco and McPherson, 2003).

Street tree management and planning occurs at various levels in different states of India. However, managing streets trees at the regional and state levels typically lack the comprehensive, detailed information of street tree inventory. Trees, being highly visible, have significant landscape value, both as an aesthetic and historic feature in the landscape and as a portrayal, intentional or not, of the values held by the local communities. An earlier preliminary report tells about vegetational aspects but, there is no authentic documentation, inventorization and systematic studies on the roadside tree diversity of the porbandar. The present investigation will provide the roadside variation of the urban area with an insight to the diversity, distribution, ecological status and biodiversity studies of the trees.

Investigation of the documentation of species diversity, abundance and distribution of street trees can be an important step towards biodiversity conservation within the urban setting. Different people think always differently for the urban trees and its valuation. Therefore, this study aims to address the shortfalls in site specific baseline information with regards to the distribution and description of the major plants occurring within the porbandar municipality through floristic documentation of roadside trees. Moreover, main objectives of the present study were to prepare data on tree distribution, species composition, diversity indices and identification of rare trees, if any. The collected information intended to sensitize decision makers to concerns and issues that can help develop place specific knowledge and strategies.

METHODOLOGY

The current study has been accomplished for the port city Porbandar, Saurashtra; of Gujarat state situated along the coast of the Arabian Sea. Porbandar is located at 21°37′48″N and 69°36′0″E. having elevation of 1M. Climate of Porbandar is quite pleasant except summers and included under hot semiarid category. The survey and documentation has been conducted at selected major streets of Porbandar City in year 2016-17 in different seasons. We have concentrated our data collection only on some important public roads managed by the local government. A total of 11 main roads were selected for this purpose with an aggregated 32 km distance ranged from 2.3 Km to a maximum of 6.4 km. The study area has been divided into 4 zones for understanding the variability on different parts of the city. A number of trees are wild while, a good number have been planted and managed by the Municipality. Direct tree census in the study area has been conducted and documented. Road side trees up to distance of 10m from the centre of the road were considered having individuals possessing minimum 10 cm DBH. Preliminary qualifying criteria included numbers, species, and ecological, economical, medicinal plus aesthetic value. Biodiversity assessment embraces not just the classical measures of richness, evenness, and species abundances distributions but also evaluations of occurrence, range size and vulnerability. Different biodiversity indices were used to calculate and understand the variability present therein. Various biodiversity indices taken in to account such as: Shannon-wiener index, Simpson index, Margalef´s index, Pielou's index, Menhinick's index, Inverse Simpson index, and Simpson measure of evenness.

RESULT

The ten most common species are largely deciduous, with only three evergreen species, of which 6 are native to Porbandar. They are largely ornamental and some economical. *Polyalthia longifolia* (mast tree) with its graceful drooping foliage is commonly planted at the roadside to provide a natural barrier that screens out the congested, noisy and dusty urban periphery. *Delonix regia* and *Tecoma stans* are an introduced ornamental flowering which has also become popular in the city in recent decades. Both these species grow quickly, and are preferred for this reason as well. There are a few large shade-providing canopy trees; *Peltophorum pterocarpum* (copper pod), and *Terminalia catapa.* These species, along with the other common tree species with narrow to medium canopies—*Millingtonia hortensis* (Indian cork), *Tabebuia aurea* (golden bell), and *Spathodea campanulata* (Africal tulip), have been planted in the city because of their strikingly beautiful flowers. *Prosopis juliflora*, Azadirachta *indica, Ficus religiosa and Pongamia pinnata* are indigenous species commonly found and can also used for firewood, timber, and biofuel and has become an increasingly popular species of choice for Porbandar city in recent years.

The total number of recorded trees was 19,288 and 37 species belonging to different genera. Among these 35 species *Prosopis juliflora*, Azadirachta *indica, Ficus religiosa, Delonix regia, Ficus benghalensis, Polyalthia longifolia, Peltophoram pterocarpum* and *Pongamia pinnata* are the most frequently observed trees in the city. On different roads, the tree composition exhibit different numbers and distinct composition in all 4 zones. By and large, 8326 trees are noticed in the South zone which dominates the race followed by East zone 2242 trees as well as West zone 3492 trees and North with just 1137 trees. When we consider the tree diversity ladder including the diversity indices the picture is becoming quite clear and presented (table 1).

Tree species diversity ladder

The aim of the study is to identify the city with richness of tree species diversity. For that purpose we have used Simpson's Diversity formula.

The total number of tree encountered in north zone is 1744 of 21 different genera and species. The zone is dominanated by *Prosopis juliflora* and *Cocos nucifera*; first one is wild and other is wild plus economical. The various plant species which are present in the area, *Tecoma Stans, Prosopis cineraria, Pithecellobium dulce, Ziziphus Nummularia, Moringa oleifera etc*. along with the other taxa.

The East zone number of species is similar to earlier zone i.e. 21 and total number of tree individuals is 2242. This zone portrays species richness because of the variety of plants which are present there. Such as *Peltophorum pterocarpum,, Acacia nilotica, Senna auriculata, Ziziphus trinerva, Ficus religiosa, F. golerata, and Prosopis juliflora* etc. All the plants are playing vital role and share equal responsibility for the road side environment.

Next in line is west zone 3492 and 41 are the total numbers of trees as well as number of species respectively. It shows that the variety of species and the numbers are more or less equally distributed among the species. This zone is not only rich in economical trees viz., *Azadirachta indica, Ailanthus excelsa, Senna auriculata, Ficus benghalensis* and *cocas nucifera* but, also with other important taxa occupying almost of all the area.

The South zone of municipality is having the highest number of tree individuals with the total number of tree are 8326 but number of species are only 17. The zone is mostly coastal one covered by halophytic plant *Avicinea marina*. Other co dominant common plants with large numbers are *Prosopis juliflora*, *Delonix regia* and *Azadirachta indica.* The zone looks almost green covered vegetation compared to all three zones due to more diverse vegetation. The highest number of plants in this zone includes *Cassuarina equisetifolia, Prosopis juliflora, Cocos nucifera* and *Ziziphus nummularia.*

The calculated values for 4 zones depict the clear cut differences in terms of various indices The calculated values for different indices are given in table 3 and it is also represented graphically for better understanding. For north zone Shannon -wiener index depict greater diversity in the area which is somewhat good. Simpson evenness and Pileous evenness index tells about the evenly distribution. The values of Margalef's index for north zone are almost nearer to the west zone explaining similar species richness in both zones. The value of Inverse Simpson index in north zone is quite less due to *Thevetia peruviana, Psidium guajava, Annona squamosa,* and *Tecoma Stans.* Although, the 2 species of *Prosopis* were higher in number in other zones in the north zone it was recorded at only at few places.

There is a linear relationship between the Margalef's index and species richness. Such correlation is recorded in west, south, and east zone. The indices calculated are highly sensitive and generally compensate the sampling done at the time of observations. This can be noticed before calculation of the indices and evenness on the road and area i.e. zones in the city. Biodiversity assessment embraces not just classical measures of biodiversity indices but they also explain the functional traits and diversity. The calculated numbers are also suggests that there cannot be single index that will suit all the need of understanding. Therefore cluster of measures gives the guideline about how the ecosystem at local functions as well as throw the light on the practical concerns about link between diversity and ecosystem services (Magurran and McGill, 2011). Our results are in concurrence with earlier reports, suggesting that urbanization may be contributing to enhanced global diversity in both abundance and species richness at local land-uses.

DISCUSSION

Tree species identified were denoted as "native" or "non-native" based on whether the natural range of the species is found in the zone. Out of the total tree species present near selected roads, 25 species (70%) are indigenous and 10 exotic species (30%). These trees may be successful in adapting local environment therefore, grow successfully in such habitat and provide shelter and forage to native fauna to enrich the ecology of the study area. The analysis of the tree flora of the study area showed that the *Prosopis juliflora* is the most represented and *Cicca acida, Cordia gharaf, Ficus glomerata, Ficus elastica,* and *Tecoma stance* are least represented in different zones. These micro variations that would exist between the zones of the study area are due to natural and planted tree species. From a functional point of view, roadside trees are biased towards shading and ecosystem services such as pollution removal, temperature mitigation and noise reduction. Moreover, in the scope of this study, we tested the

role that vegetation indices will be helpful in the evaluation of plant diversity.

For better understanding of the diversity and composition of trees from the saurashtra region we have tried to compare with other main cities. In comparison to other cities such as Jamnagar, Junagarh and Rajkot of Saurashtra, the highest number of *Prosopis juliflora* (5,179) are observed in the present study as in Junagarh the number is so poor (165) and in Rajkot (623) only. Whereas, in Jamnagar it is comparatively good (2184) and well spread over the city limits which is also situated near sea coast. Second number is *Cassuarina equisetifolia*. (3251) in the Porbandar city against other cities Rajkot, Junagarh and Jamnagar where the number of this species is comparatively low as, 315, 710 and 908 respectively. But, the smallest number of plant species in Porbandar city in compare to these three mahanagarpalikas is *Polyalthia longifolia (491)* and *Azadirachta indica (1*,223). The plant which quite less (50) in number is recorded from all four cities is *Pongamia pinnata* only (table 2).

Investigation of the species diversity, abundance and distribution of street trees can be an important step towards biodiversity conservation within the urban setting (Jim and Chen, 2009). A recent study in Bangalore, India, suggested that data on tree distribution including species composition, size and age structure, and spatial inventories are essential to allow for more effective management of street trees and the biodiversity they represent (Nagendra and Gopal, 2010).

Urbanization may be contributing to enhance the global diversity of plant diversity in both abundance and species richness. Simply encouraging the preservation and restoration of biodiversity in urban habitats is insufficient. Although a significant part of urban species richness is based on common native and alien species (Kühn & Klotz 2006), there are also urban habitats where rare species can persist (e.g. Brandes 1993). The predominance of exotic species is a matter of concern. Urban and periurban area of city are known to consist of a mix of introduced and native species (McKinney 2008; Garcillán et al. 2009). As just noted, biodiversity in many urban areas is often already quite high, in terms of species richness, beta and alpha diversity. These landscape values are therefore highly variable and context dependent. Thus, trees may be regarded as highly desirable in one location and a menace in another. Two basic factors enhance non-native species richness owing to transportation and habitat by humans for ornamental plants and aesthetics (1) increasing importation of non-native individuals and (2) favorable habitat for the establishment of non-native species (Mack and Lonsdale, 2001). The preservation of indigenous species in urban habitats is important for more than retaining the biological distinctiveness of urban areas. For conservation goals, it is also important as a way of educating the large numbers of people who inhabit cities about local indigenous biodiversity. Educating the urban public could be the most important method of promoting effective conservation of native species (Kendle and Forbes, 1997; Miller and Hobbs, 2002).

As a result, city has to manage good quality environment means living in a carefully managed and maintained that milieu. If the city environment declines, the environment of its surroundings will also decline. Beyond species richness, species frequency or rarity is a further aspect of biodiversity. Measures of species richness treat rare and common species equally. However, for conservation purposes, rare species are normally valued higher than common species. Therefore, it is important to consider species rarity in addition to species richness, especially in terms of species conservation.

Table 1. Main trees of Porbandar Nagarpalika:

Sr no	Name	Scientific name	No. of plants
1	Pilli vasant	***Tecoma stans* (L.) Juss.**	**30**
2	Aawal	***Senna auriculata (* L.) Roxb.**	**324**
3	Sharu	***Casuarina equisetifolia* L.**	**3251**
4	Pipalo	***Ficus religiosa* L.**	**729**
5	Goras aamli	***Pithecellobium dulce* (Roxb.) Benth.**	**139**
6	Aso palav/pendula	***Polyalthia longifolia* (Sonn.) Hook.f. & Thomson**	**491**
7	Neem/limdo	***Azadirachta indica* L.**	**1223**
8	Gulmohar	***Delonix regia* (Bojer) Raf.**	**535**
9	Vadlo/vad	***Ficus benghalensis* L.**	**850**
10	Pilli Karen	***Thevetia peruviana(* Pers.*)* K. Schum.**	**306**
11	Paras pipalo	***Thespecia populnea* (L.) Sol. ex Correa**	**144**
12	Kanji	***Holoptelea integrefolia* Planch.**	**152**

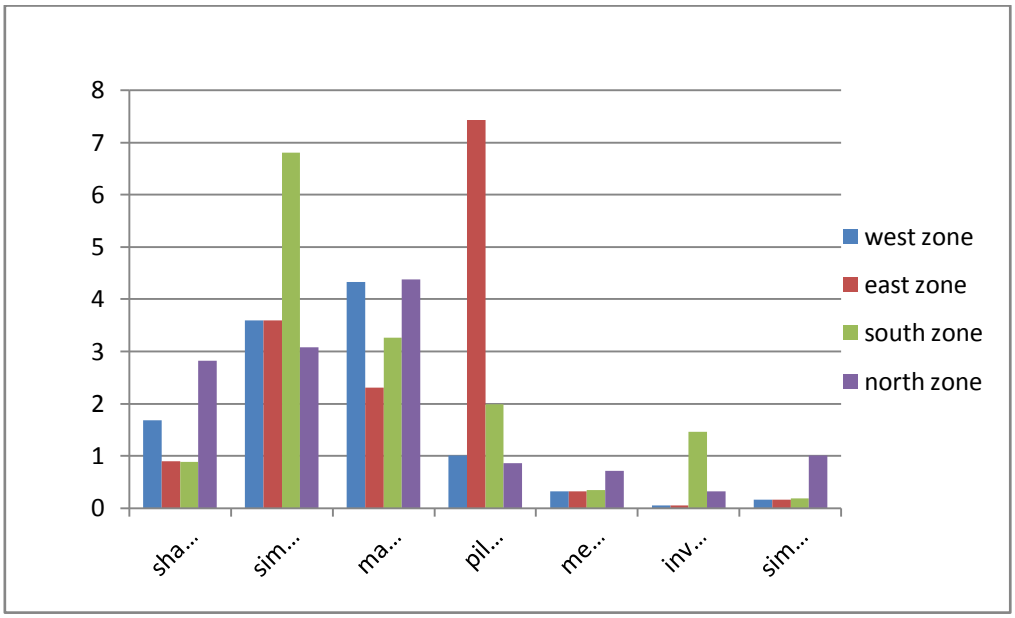
13	Nariyeli	***Cocus nucifera* L.**	**1276**
14	Sargavo	***Moringa oleifera* Lam.**	**276**
15	Lal Karen	***Nerium oleander* L.**	**94**
16	Gando bawal	***Prosopis juliflora* (Sw.) DC.**	**5179**
17	Badam	***Terminalia cattapa* L.**	**140**
18	Aamli	***Tamarindus indica* L.**	**103**
19	Khata amla	***Phyllanthus acidus (*L.*)* Skeels/ *Cicca acida (*L.*)* Merr.**	**18**
20	Tiwar	***Avicenia marina* (Forssk.) Vierh.**	**2530**
21	Gundi	***Cordial gharaf* Ascherson / *Cordia sinensis* Lam.**	**13**
22	Boradi	***Ziziphus nummularia (*Burm. f.*)* Wight & Walk.-Arn.**	**419**
23	Khijado	***Prosopis cineraria* (L.) Druce**	**43**
24	Peltophorum	***Peltophorum pterocarpum* (DC.) K. Heyne**	**257**
24	Karanj	***Pongamia pinnata(*L.*)* Pierre**	**57**
26	Desi bawal	***Acacia nilotica* (L.) Del.*ssp. indica* (Benth.) Brenan**	**124**
27	Arduso	***Ailanthus excels* Roxb.**	**226**
28	Divelo	***Riccinus communis* L.**	**57**
29	Jamphal	***Psidium gaujava* L.**	**61**
30	Chickoo	***Manilkara zapota* (L.) P.Royen**	**156**
31	Pipalo	***Ficus religiosa* L.**	**38**
32	Buch	***Millingtonia hortensis* L. fil.**	**18**
33	Tabebua	***Tabebuia aurea (*Manso*)* Benth. & Hook. fil. ex S. Moore**	**14**
34	Pichkari	***Spathodea campanulata* Beauv.**	**09**
35	Rubber	***Ficus elastica* L.**	**06**
			19,288

Table 2. Comparison of population of some major species with different Municipal Corporation:

Sr. no.	Name	Rajkot	Jamnagar	Junagadh	Porbandar
1	Neem	23,547	6,838	5,321	1,223
2	Aso palav	15,821	1,792	11,917	491
3	Gando bawal	1,293	2,184	165	5,179
4	Desi bawal	623	1,378	319	124
5	Peltoforum	6976	809	1637	257
6	Gulmohar	6,338	894	1,610	535
7	Kanji	662	110	52	152
8	Sharu	315	908	710	3251
9	Badam	941	962	458	140
10	Pipalo	2,411	357	703	729
11	Karanj	46	93	68	47
12	**Other plants**	24,264	47,242	1,176	7,075

Table 3. Calculated biodiversity indices for four different zones of Porbandar and its graphical representation

Biodiversity indices	West zone	East zone	South zone	North zone
Shannon-wiener index	1.68	0.90	0.88	**2.82**
Simpson index	0.27	0.045	0.147	**0.324**
Margalef´s index	4.33	2.30	3.76	**4.37**
Pielou's evenness index	1.002	**7.42**	1.98	0.86
Menhinick's index	0.32	0.32	0.34	**0.71**
Inverse Simpson index	0.045	0.045	0.146	**0.32**
Simpson measure of evenness	0.161	0.161	0.18	1



CONCLUSION

Urbanization alters the physicochemical environment, introduces non-native species and causes ecosystem characteristics to converge. It has been speculated that these alterations contribute to loss of regional and global biodiversity. But, so far most urban studies have assessed macro-organisms and reported mixed evidence for biodiversity loss. We studied four zones of the Porbandar city to assess the global convergence of urban roadside avenue tree communities. We determined the extent to which communities are geographically distributed, and to what extent urbanization acts as a filter on species diversity. We discovered that different trees communities in general converge, but the response differed among trees communities showed the strongest convergence. In addition to sustainable development plus to conserve the available trees in the city to mitigate environmental problems associated with the vast developments. By preserving these valuable green assets, porbandar city would definitely score extra points for its effort in gaining the Heritage City status from the national heritage agencies such as the National Heritage Department and internationally such as the UNESCO and boost development of the tourism sector in saurashtra. This work will also be beneficial to natural science student, common people & researcher for plants identification. We then draw on the lessons from databases and, where appropriate and possible, make recommendations for issues that are likely to emerge.

REFRENCES

Anderson, M. J., Ellingsen, K. E. and McArdle, B. H. (2006). Multivariate dispersion as a measure of beta diversity Ecology Letters, 9: 683–693 doi: 10.1111/j.1461-0248.2006.00926.x

Andrieu, E., Thompson, J. D. and Debussche, M. (2007). The impact of forest spread on a marginal population of a protected peony (Paeonia officinalis L.): the importance of conserving the habitat mosaic. *Biodiversity and Conservation*, *16*(3), 643-658.

Anonymous (2007). United Nations Population Division, Urban Agglomerations www.un.org/esa/population/ publications pdf.

Burden, D. (2008). 22 Benefits of Urban Street Trees. www.michigan.gov/documents /dnr/22benefits2080847. pdf.

CBD (2005). Handbook on the convention of the biological diversity CBD Secetariate UNEP, Nairobi, Kenaya

Crane, P. and Kinzig, A. (2005). Nature in the metropolis. Science 308 (5726): 1225-1225.

Donovan, G. H., Butry, D. T., Michael, Y. L., Prestemon, J. P., Liebhold, A. M., Gatziolis, D. and Mao, M. Y. (2013). The relationship between trees and human health: evidence from the spread of the emerald ash borer. *American journal of preventive medicine*, *44*(2), 139-145.

Garcillán, P., Rebman, J. and Casillas, F. (2009). Analysis of the non-native flora of Ensenada, a fast growing city in north western Baja California. Urban Ecosyst 12:449–463

Hiremath, V. T. and Taranath, T. C. (2011). Phytotherapy associated with Jaundice in Chitradurga District, Karnataka. *International Journal of Medicinal and Aromatic Plants*, *1*(2), 162-165.

Jim, C.Y. and Chen, W.Y. (2009). Diversity and distribution of landscape trees in the compact Asian city of Taipei. Appl Geogr 29:577–587

Kendle, T. and Forbes, S. (1997). Urban Nature Conservation. London: Chapman and Hall.

Kühn, I., Brandl, R. and Klotz, S. (2004). The flora of German cities is naturally species rich. Evol. Ecol. Res. 6(5):749-764. Available from https://www.ufz.de/export/data/1/22488_kuehn.eer1629.pdf [accessed 8 March 2016].

Mack, R.N. and Lonsdale, W.M. (2001). Humans as global plant dispersers: Getting more than we bargained for. BioScience 51: 95–102.

Maco, S.E. and McPherson, E.G. (2003). A practical approach to assessing structure, function and value of street tree populations in small communities. Journal of Arboriculture29: 84–97.

McDonnel, M.J., Hans, A.K. and Breuste, J. H. (2009). Ecology of cities and towns. A comparative approach Cambridge university press

Magurran, A.E. & McGill, B.J. (2011). [Eds.]: Biological diversity: frontiers in measurement and assessment. XVII + 345 pp., Oxford University Press, Oxford.

McKinney, M.L. (2008). Effects of urbanization on species richness: a review of plants and animals. Urban Ecosyst 11:161–176

Miller, J. R. and R. J. Hobbs. (2002). Conservation where people live and work. Conservation Biology 16:330–337.

Miller, R.W. (1997). Urban Forestry: Planning and Managing Urban Green spaces, second ed. Prentice Hall, New Jersey

Nagendra, H. and Gopal, D. (2010). Street trees in Bangalore: density, diversity, composition and distribution. Urban For Urban Green. doi:10.1016/j.ufug.2009.1012.1005

Sala, O.E., Chapin, F.S. 3rd, Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., & Wall, D.H. (2000). Global biodiversity scenarios for the year 2100. Science 287:1770– 1774

Seth, M. K. (2004). Trees and their economic Importance Bot. Rev. 69 321-376

Stehlik, I., Friedman, J. and Barrett, S.C.H. (2008). Environmental influence on primary sex ratio in dioecious plant. Proc. Nat. Acad. Sci. USA 105: 10847-10852.

Stehlik, I., Kron, P., Barrett, S.C.H. and Husband, B.C. (2007). Sexing pollen reveals female bias in a dioecious plant. New Phytol. 175: 185-194.

Sukopp (2004). "Human-caused Impact on Preserved Vegetation." Landscape and Urban Planning 68: 347–355

TEEB (The Economics of Ecosystems and Biodiversity). (2011). The economics of ecosystems and biodiversity in national and international policy making. P. ten Brink, editor. Earth scan, London

UNEP-CBD, (1991). Convention on Biological Diversity (CBD), Secretariat on CBD, United Nations Environment Programme, Montreal,.

UNHABITAT (2010). Cities and climate change: global report on human settlements, 2011 / United Nations Human Settlements Programme.

United Nations Centre for Human Settlements (1996). An urbanizing world: global report on human settlements, 1996. Oxford University Press, Oxford

Vitousek, P.M., Mooney, H.A., Lubchenko, J. and Melillo, J.M. (1997). Human domination on Earth's ecosystems. Science 277:494–499

Wunderle, J. M. Jr. (1997). The role of animal seed dispersal in accelerating native forest regeneration on degraded tropical lands. For Ecol Manage; 99: 223-35.