The Journal of Animal & Plant Sciences, 24(6): 2014, Page: 1636-1642
ISSN: 1018-7081

ANALYSIS OF URBAN FOREST STRUCTURE, DISTRIBUTION AND AMENITY VALUE: A CASE STUDY

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ABSTRACT

Trees are an important feature of urban ecosystems and provide different environmental and socio-economic benefits. Different habitats (roadsides, parks, streets, institutes, graveyards) in Sahiwal, a city in central Punjab, Pakistan were surveyed for the assessment of abundance, diversity and amenity value of urban trees. Forty five tree species belonging to 29 families were recorded. *Azadirachata indica, Morus alba, Eugenia jambolana and Dalbergia sissoo* are the most frequent species. Distribution of trees is highly uneven as only four species showed >50% frequency, seven species had >25% frequency and fourteen species exhibited 5% frequency. Roadside verges had the highest diversity of tree species followed by institutions and parks. Broadleaf deciduous species are abundant whereas conifers and palms are occasionally found in parks and institutions. From a functional point of view, most trees are ornamental type followed by shading trees. Exotic species are higher in number than native species but these are low frequency trees and were mainly found in parks and institutions. Despite higher number of exotic taxa, the number of individual trees belonging to native taxa (56%) was higher than to exotic groups (44%) in the area. Implications for long term tree management and development in Pakistani cities are discussed.

Key words: Urban trees, urban habitats, diversity of urban trees, amenity value.

INTRODUCTION

Urban trees provide multiple services and environmental benefits to urban environment. Their environmental benefits include improvement in air and water quality, building energy conservation, carbon sequestration, cooler air temperatures, reduction in ultraviolet radiation and noise reduction (Coder and Kim, 1996; Brack, 2002; Nowak *et al*., 2006). Their social benefits include decrease in psychological stresses **(**Ebenreck, 1989), quick recovery of patients (Miller, 1997) and a sense of well being. In economic terms, urban trees offer benefits in the areas of energy conservation, microclimate improvement and increase in property values (Akbari, 2002; Maco and McPherson, 2003).

The ecological services and environmental benefits offered by urban trees are greatly influenced by composition of species and number of trees. Urban forest structure is a measure of various attributes of urban tree vegetation including tree species composition, tree density and species diversity etc. High diversity of trees in urban areas is considered imperative for the maintenance and development of healthy urban tree vegetation (Bassuk *et al.*, 2009). It is expected to increase the chances of survival of urban vegetation under natural and anthropogenic disasters such as outbreak of diseases, increase in temperatures due to climate change, frequent dry summers and threat by invasive plants (Georgi and Zafiriadis, 2006; Raupp *et al*., 2006; IPCC, 2007, Negandra and Gopal, 2010).

Different habitats in a city vary in growth conditions for trees and accordingly exhibit varying levels of tree diversity. Pauleit *et al*., (2002) and Sabo *et al*., (2003) recorded higher diversity of tree species in parks and green spaces than in streets and paved areas in European cities. They attributed this difference in tree diversity due to higher levels of stressful conditions in later habitats such as elevated temperatures, low air humidity, increased pollution and limited soil volume.

The introduction of exotic trees in urban plantation is another important issue of urban vegetation planning and management. The introduced exotic plants in urban areas can spread to neighbouring rural areas as invasive plants and threaten the existence of native species (Hitchmough, 2011).

In Pakistan, the process of urbanization is quite fast but the importance of trees and green areas in urban management is not well recognized. Urban trees and green areas are shrinking due to rapid and unplanned urbanization, haphazard land-encroachment practices, environmental pollution and illegal cutting of trees. These trends have resulted in degradation of green areas and worsening urban landscapes. Information on the structure and functions of urban trees can be used to improve and augment support for urban green area management and to integrate urban vegetation management with urban development plans to improve the environmental sustainability of urban centers. An initial step to improve the management of urban trees is to evaluate its current

status, providing a baseline from which to set goals and to monitor any changes.

Keeping in view the above mentioned issues regarding management of urban treescape, the present research was carried out to survey and record information on the diversity and distribution of different urban trees in a rapidly growing city of Pakistan, Sahiwal. Other objectives of this study were the investigation of the impacts of different habitats on diversity of tree populations and analysis of the existence of native and non-native trees in urban vegetation in the study area.

MATERIALS AND METHODS

Study Area: Sahiwal city (30º31´ 02″ N; 72º 25´ 74´07″ E) lies in the central Punjab of Pakistan with a population of 0.35million. It was built by the British in 1860 and now it is divisional head quarter and is situated on Lahore-Karachi highway (N-5) at a distance of 180km from Lahore and at a distance of 190km from Multan. The river Ravi flows at a distance of 20km from the north of the city and the Sutlej at a distance of 50km from its south. The soils are mainly alluvial and the area has a large network of canals for irrigation. The climate is dry and hot and the area has agrarian character with wheat, potato, maize, cotton and vegetables as the main crops. Sahiwal is famous for its dairy production and its breeds of cow (Sahiwal) and buffalo (Nili Ravi) are famous throughout the world. Harappa, a globally famous archaeological site (2600 BC) lies about 25 km from Sahiwal city.

Field work: Initially, a reconnaissance survey of the City was made. During this survey, a list of all tree species in the city was prepared and five habitat types (parks, institutions, roadside verges, streets and grave yards) were selected for further data collection. In these habitat types, in total, fifty five sites were marked for data collection. At each site, a 30x3 meter quadrat was marked. All trees in the quadrat were recorded and the number of each tree species was noted. Each sampled tree was evaluated in terms of species, growth form (evergreen broadleaf, deciduous broadleaf, palm, conifer) and its amenity use (shade, fruit, ornamental, flower/fruit) based on both field observation and published literature. The nomenclature of trees follows Baquar (1995).

Descriptive statistics was used to analyze the data. The percentage frequency and density of each species in each habitat and in the city was calculated by the following formulae (Kent and Coker, 1995).

Frequency % = (No. of quadrats including a species / Total No. of quadrats) X 100

Density = (Total no of individual of a species in the quadrats / Total number of quadrats**)**

RESULTS

General urban forest structure: The urban tree vegetation in Sahiwal is typically subtropical type, mainly dominated by broadleaf deciduous trees. It includes 45 species belonging to 29 families.

Azadirachta indica, Morus alba, Eugenia jambolana and *Dalbergia sissoo* are the most frequent trees with 65%, 63%, 60% and 60% frequency respectively (Table. 1). These are followed by *Eucalyptus camadulensis, Pongamia pinnata, Acacia nilotica and Mangifera indica.*

Analysis of number of species of the genera observed exhibited *Acacia* and *Ficus* as common genera with three species of each genus. In terms of genus distribution of the individual habitats, *Dalbergia* was the dominant genus in roadsides and institutes while *Azadirachta* and *Acacia* were dominant genera in graveyards. In parks and residential areas, *Eugenia* and *Morus* are the dominant genera respectively.

The distribution patterns of individual species are highly uneven (Table. 1). Only four species showed >50% frequency whereas seven species had >25% frequency and fourteen species exhibited 5% frequency. The remaining 20 recorded species had <5% frequency. Out of these, six species had solitary occurrence and another four with 2-3 individuals each. These atypical entities contributed significantly to overall species diversity.

Tree species composition in different habitats: Among the various habitats and land uses, roadside verges had the highest number of tree species (22) followed by parks (21) and educational institutions (20). Residential streets (14) and grave yards (12) had relatively lower number of tree species.

Roadside verges: With the largest area and population of trees, roadside verges had the highest diversity of species. The roadside forest embodied 22 species belonging to 10 families. Prominent among them are *Dalbergia sissoo, Eucalyptus camadulensis, Azadirachta indica, Acacia nilotica and Bombax malabarica.* Roadside have a relatively large set of dominant trees as ten species had frequencies higher than 50% far greater than streets and graveyards. The roadside verges are overwhelmingly dominated by native broadleaved trees occupying 70% of its species (Table. 2). Deciduous members outnumber the evergreen by a wide margin.

From a functional point of view, roadside trees are biased towards shading and ecosystem services such as pollution removal, temperature mitigation and noise reduction. Most of the species in this group are large size, a dense and spreading crown, adequately adapted to inhospitable and polluted roadside environment. The *Dalbergia, Ficus* and *Acacia* species have for centuries been extensively grown as best shade trees in the Punjab.

Their large biomass, perseverance and longevity have helped these species in having a dominant position in local urban landscapes.

Public Parks: The parks in Sahiwal varied significantly in the terms of area, age, species-count and management pattern. The smallest park has an area of 0.5 ha with 7 species and the largest covers 15 ha with 18 species. All parks are managed by municipal authorities. These parks were established at different times exhibiting various designs, styles and ecological conditions. These parks include many exotic and introduced trees which are confined to these parks only.

The park-tree vegetation encompasses 20 species. By comparing with roadside verges, the park trees showed higher diversity and lower abundance of common trees. By considering the growth form, broadleaf species dominated the park trees with 12 species and 74.0% of its trees. Another notable component of parks is conifers and palms. The ratio of large trees was low in parks and most of the park trees were of medium to small sizes exhibiting a more equitable habitat.

The most frequent trees in parks are *Eugenia jambolana, Pongomia pinnata, Eucalyptus camadulensis, Dalbergia sissoo, Bombax malabrica, Hetrophragma adonsonii, Acacia nilotica, Phoenix dactylifera and Mangifera indica.* Most of park trees are of fruit and flower bearing ornamental type (Table.3). On the outer margins of old parks however, large size shade providing trees were common.

Institutions: The institutions contributed significantly to urban forest diversity in Sahiwal. The institutions vary in age from 20 to 120 years and their trees demonstrated significant variations. There were wide variations in the areas of institutional forests from the smallest of 2.0 ha with 11 species and 80 trees to the largest 30 ha with 20 species and 1920 trees. In all 20 species were recorded with an average of 32 trees/species. The exotic species had higher percentage (55%) whereas local species constituted 45% of these areas. Most trees are ornamental in function, followed by fruit and flower characteristics. In institutions, broadleaf trees are dominant but the share of palms significantly exceeds than other habitats. From size perspective, institutions contain the largest share of the small sized trees.

Some rare, exotic and few trees of conifers and palm groups were recorded in institutions such as *Cycus revoluta*, *Cycas ciricinlis*, fish tail palm (*Careota urans*) and bottle palm (*Oreodoxa regia*). Although the dominant trees are mostly similar to parks, their rankings are different. *Dalbergia sissoo. Eucalyptus camadulensis, Azadirachta indica, Pongamia pinnata, Cassia fistula, Morus alba, Mangifera indica, Acacia nilotica, Bombax malabrica* and *Eugenia jambolana* are the frequent tree species.

Residential streets: Street trees are important part of urban greenery due to their visibility to motorists and pedestrians (Cummings *et al*; 2003). The streets had twelve species belonging to five families representing a low diversity. The most common genus of the street trees was *Morus*. The next common genera were *Eugenia* and *Punica* and they comprised 35% and 25% of the street trees. The common trees in streets are *Morus alba, Eugenia jambolana, Punica granatum, Oreodoxa regia, Psidium guyava, Azadirachta indica* and *Mangifera indica.* Most of these trees are small to medium size, with flower/fruit as main amenity function (Table 3).

Graveyards: Graveyards are relatively protected habitats and these offer an opportunity to study old and undisturbed vegetation in urban areas. Twelve species were recorded with *Azadirachta indica* and *Acacia modesta* as the dominant trees. The second level dominants were *Ficus bengalensis*, *Acacia nilotica* and *Dalbergia sissoo*. The stratification of plants was higher in graveyards than other habitats and some indigenous trees were exclusively found there. These include *Prosopis juliflora, Salvodora oleoides* and *Casuarina equistifolia.* From functional perspective, graveyards mainly include shade trees but some flowering and fruit trees were also common.

Origin of Urban trees: By considering the number of exotic versus native tree species, exotic species outnumbered (62%) native species (38%) (Table.2). The exotic trees are however, usually low frequency trees and are common in residential areas, parks and institutes introduced by different sources.

Roadside verges had thirteen exotic and nine native species whereas parks were also dominated by higher number of exotic species (13) than native species (8) (Table.2). In institutes, the difference between number of exotic and native species was maximum, 14 exotic and 6 native. The streets had significantly higher number of exotic trees (10) than native species (4) due to diverse collection of trees. As expected, graveyards had higher ratio of native to exotic trees with seven native and five exotic species.

Despite higher number of exotic taxa, the number of individual trees belonging to native taxa (56%) was higher than to exotic groups (44%) in the area (Table.2). In Sahiwal, the most frequent trees are native broadleaved with distinctive amenity roles. *Dalbergia*, *Azadirachta*, *Morus* and *Eugenia* have a long history of domestication and naturalization as common trees of human settlements in the area. These trees have many beneficial functions such as fruit, shade, fuel wood, timber and raw material for cottage industry etc and have been actively grown on roadsides, canal banks, streets and farm boundaries.

The species diversity index differed among habitats from 2.4 in roadsides to 6.4 in streets. The largest

species diversity index among the habitats was found in institutes and streets with 6.4 and 5.9 respectively (Table 2).

Table.1. Frequency (F) and density (D) of dominant Trees (Frequency>25%) amongst different habitats in Sahiwal City *Frequency (%), Density (tree number/quadrat)*

No	Species	Total		Roadside		Grave yards		Streets		Parks		Institutions	
		45		22		12		14		20		21	
		F	D	F	D	F	D	F	D	F	D	F	D
1	*Azadirachta indica*	65	2.3	81	3.4	10	2.1	50	1.0	33	1.3	70	2.3
2	*Morus alba*	63	2.0	69	4.2	25	1.2	75	0.7	33	1.3	60	3.4
3	*Eugenia jambolana*	60	0.1	50	1.5	0	0	70	0.7	100	2.3	50	2.4
4	*Dalbergia sissoo*	60	4.7	94	10	50	6.5	25	0.2	66	8.3	90	8.7
5	*Eucalyptus camadulensis*	42	5.2	81	1.3	0	0	8	0.1	66	1.8	70	4.4
6	*Pongamia pinnata*	35	3.8	62	6.2	25	3.2	0	0	65	3.2	70	4.5
7	*Acacia nilotica*	35	2.3	69	7.0	50	1.5	0	0	67	4.3	50	3.1
8	*Mangifera indica*	33	0.7	0	0	0	0	46	0.4	66	2.0	60	2.9
9	*Bombax malabarica*	32	1.5	69	3.4	0	0	0	0	6	6.3	50	2.7
10	*Oreodoxa regia*	26	0.1	0	0	0	0	50	0.5	0	0	40	1.2
11	*Punica granatum*	26	0.2	0	0	0	0	58	0.5	0	0	0	0

Table: 2. Species Diversity and geographical origin of trees in different urban habitats in Sahiwal

Diversity Parameter	Roadsides	Parks	Institutes	Streets	Graveyards	Total
Species Number	22	21	20	14	12	45
Species diversity Index[a]	2.4	4.4	6.4	5.9	4.3	4.5
Simpson diversity; D^d	0.87	0.91	0.98	0.96	0.82	0.94
Native Species (%)	40	35	30	30	56	38
Exotic Species (%)	60	65	70	70	44	62
Exotic/Native species ratio	1.2	2.5	1.7	2.2	0.78	1.6
Native Trees (%)	63	48	45	53	58	56
Exotic Trees (%)	37	52	55	47	42	44
Exotic/Native Tree Ratio	0.6	1.1	1.2	0.9	0.7	0.9

[a] Species diversity index = [Species count/tree count]X1000

[b] Simpson diversity, D = $\sum p^2_i$ (Simpson, 1949)

Table .3. Amenity functions of trees in different habitats

Functions	City	Roadside	Parks	Edu. institute	Res. areas	Graveyards
Shade (%)	28	44	28	19	20	65
Ornamental/Aesthetic (%)	48	29	46	50	33	22
Fruit/food/fodder (%)	18	13	14	15	47	11
Environmental (%)	6	14	12	16	0	2

Table.4. Leaf Growth form of trees.

Leaf Phenology of trees	City	Roadside	Parks	Edu. institute	Res. areas	Graveyards
Evergreen (%)	32	42	32	37	53	58
Deciduous (%)	51	54	42	33	26	42
Coniferous evergreen (%)	6	0	14	16	5	0
Palm evergreen (%)	9	4	12	14	6	0

DISCUSSION

In Pakistan, despite its acclaimed importance, urban forestry remains a neglected area of research and development. Urban forests are strongly influenced by human activities and inputs. Their survival and development depends upon the public awareness and acceptance of their benefits, the scientific and technical expertise of the management agencies and the local ecological conditions. In Pakistan, unregulated urban development and large scale commercialization of urban areas have seriously damaged urban tree-scape of cities causing serious environmental issues.

To save existing urban trees and their dependent wildlife, it is imperative to carry out studies to document information about diversity and distribution of trees in different cities. This study provided valuable information about the diversity of tree species, its variation in different urban habitats and relative abundance of native and exotic trees in a rapidly growing city and its findings may help in management of urban trees in other Pakistani cities.This information will also be useful for designing programs for protecting urban trees from pest attacks and impacts of climate change.

Diversity of tree species in a city is considered as an important factor determining the survival value of its trees in case of different threats such as pest attack, changes in temperature and anthropogenic pressures etc. A general rule about diversity observed in USA and other countries with well-organized urban forestry programs, is that no species in a city should exceedmore than 10% of the total tree population (Grey and Deneke, 1986; Smiley *et al*., 1986; Santamour, 1990; Miller and Miller, 1991). In Sahiwal, *Azadirachta, Morus, Eugenia and Dalbergia* are the most common trees, representing 45% of the total tree population indicating high susceptibility to threats of pests and diseases.

There were differences in diversity of trees in different habitats as roadside and graveyards niches having the highest and lowest number of dominant species among respectively (Table 2). In old city with narrow roads, most trees were planted before 1940 when focus was on native trees with large biomass (*Dalbergia, Ficus, Eugenia*) to achieve green roads in a cheaper way. These roads have only two rows of trees because of their smaller width. The main roads and roads in new settlements are wider and provide habitats to greater diversity of tree species. This could be attributed to adverse growing conditions in residential areas such as higher level of pavement and pollution. This has been reported by other authors in earlier studies (Paulet, 2003; Sabo *et al*., 2003). There is a need to select and evaluate non-traditional species that can withstand the relatively adverse conditions in streets.

The parks and educational institutions need to be developed and managed as centers for conservation of local trees and associated herbaceous flora. These can act as local knowledge base providing scientific and technical data and guidance regarding ecology of urban trees and reforestation of other urban habitats. In general, there is a trend to grow exotic trees in these parks but these should emphasize on popularizing native trees which are better adapted to local conditions and can resist pest attacks and other threats. These habitats may also serve as testing centers for newly introduced trees before their large scale adaptation for urban reforestation program. Age and diameter at breast height are the important characteristics of trees in determining their long-term tolerance in local urban environments (Dorney *et al*., 1984).

Another factor determining survival of urban tree population is the pattern of its distribution. For example, in Sahiwal, the most of the tree diversity of parks and educational institutions was limited to one park and one institution providing a distorted picture. In order to develop a healthy and sustainable urban tree population, a diversity of species must be evenly distributed throughout the city parks and institutions.

Concerning species origin, non native species outnumbered native species especially in residential areas and parks. However, although exotic species were in high proportion, the native trees populations were larger in number. There are conflicting views on the use of non-native tree species in urban greening plans. The exotic trees may spread into neighboring areas and affect negatively the ecosystems and compete with native species (Hitchmough, 2011). Some exotic species may become invasive species and create serious ecological problems for the local flora (Pysek *et al*., 2009). In Sahiwal, the populations of native trees dominate the urban tree stock and at present, the exotic trees do not pose a threat to the local flora. In future, however pests, diseases or anthropogenic pressures may reduce populations of native trees and exotic trees may increase in number and escape into neighboring areas. This topic needs extensive research to provide information on the possible interactions of exotic species with native ones to identify at earlier stages, potentially invasive species. The extreme urban ecological conditions of high temperature, drought and paved surfaces sometimes favour the exotic species which have higher tolerance levels to these stresses than the native trees. The trees from other regions with similar conditions may adapt better to new urban habitats and spread into these cities (Takhtajan, 1986). In future, with possibilities of increased average temperatures, frequent heat waves and drought due to climate change, these factors may prove more important in determining the composition of urban forests.

Urban trees are strongly affected by human activities. Their survival and future growth mainly depends upon the urban development policies, awareness and commitment of urban residents towards urban

forestry. Pakistan has not made any serious efforts to popularize urban forestry and this sector lacks coordinated and adequate inputs both from the public and private sides. In some cities, isolated efforts were made to plant exotic trees in cities but these efforts are far from success in delivering intended benefits to urban populations. Many trees have been planted, but with far from-successful impacts on the distribution of goods and services to intended populations. Of equal or more importance has been the inability of most of the programs to stem resource degradation. Future success of all programs involving trees outside forests will depend on the application of principles that have been learned with great difficulties. First and foremost of these principles is the involvement of local communities in the planning, implementation, and reaping of benefits. This local involvement is crucial for social forestry and agro-forestry programs in poor rural areas, as well as for urban forests in large cities (Schoeneman and Ries, 1994). Planning and implementation include the selection of what will be planted or managed, sharing of responsibilities, and often some form of trade-off with other activities and needs. Carrying out these steps will require new organizational arrangements that are effective in enabling local management to function without interference from higher levels (Gregersen *et al*., 1993).

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