北京城区树种多样性及其空间差异研究

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摘要：城市森林被认为是城市绿色基础设施中最重要的组成部分，树种多样性无论对城市森林美学等文化服务、稳定性和韧性等支撑服务，还是对公众身心健康、热岛效应缓解等调节服务功能均有重要影响。了解城市森林的物种组成和多样性是提高城市生物多样性的关键。论文以北京市城区为研究地区，比较了二环以内（R2）、二环到三环间（R3）、三环到四环间（R4）、四环到五环间（R5）以及以郊野公园为主的城郊森林（S-U）片林中树种多样性及其差异，旨在揭示城市化过程对城市树种多样性的 影响规律。

结果表明，北京环路沿线城市森林树种有 55 属 36 科 83 种，其中，乡土树种使用量占到 86.8%，归化种使用数量占 7.0%。北京城区片林绿化树种组成有较高的同质性， 毛白杨（Populus tomentoza）、国槐（Sophora japonica）、白蜡（Fraxinus spp.）、悬铃木（Platanus spp.）、白皮松（Pinus bungeana）、油松（Pinus tabuliformis）、圆柏（Juniperus chinensis）、刺槐（Robinia pseudoacacia）和栾树（Koelreuteria paniculata） 是重要值和使用频率较高的树种，重要值普遍大于 10，每个树种的使用率在 4.0%以上。在观赏功能多样性上，北京城区以观叶为主，观花树种仅占 44.6%，常绿树种只有 11 种。城市森林树种多样性在空间上有显著差异，综合 7 个生物多样性指数，R5 最高、R3 其次、S-U 最低；综合 2 个均匀度指数，R2 和 R5 较低，R3、R4 和 S-U 普遍较高， 这与 R3 的城市森林建设时间长、R5 的城市森林建设采用树种较丰富密切相关。

关键词：城市森林，树种组成，观赏性状，多样性，北京

Study on Tree Species Diversity and Its SpatialDifferences in Beijing City, China

Abstract: 【Objective】 Urban Forest is considered to be the most important part of urban green infrastructure. The diversity of tree species has an important impact on cultural services such as urban forest aesthetics, on supporting services such as stability and resilience of urban forest, as well as regulating services such as public physiological and mental health and mitigation of heat island. The aim of the study is to understand the species composition and diversity of urban forest in the capital city Beijing of China. 【Method】 Taking Beijing city as research area, species diversity of urban forests and its spatial variances were compared among within the 2nd ring (R2), from the 2nd ring to the 3rd ring (R3), from the 3rd ring to the 4th ring (R4), the 4th ring to the 5th rings (R5) and suburban forest (S-U) mainly country parks so that the effects of urbanization process on urban tree species diversity were to be revealed in the paper. 【Result】 The results show that there are 55 genera and 36 families and 83 species in the research area, of which 86.8% and 7.0% of utilized tree species are native and localized species. The high homogeneity in composition of greening tree species in woodlands in research area had been found. And the species of poplar (Populus tomentosa), locust (Sophora japonica), ash (Fraxinus spp.), sycamore (Platanus spp.), white bark pine (Pinus bungeana), Chinese pine (Pinus tabuliformis), Chinese juniper (Juniperus chinensis), black locust (Robinin pseudoacacia) and Koelreuteria paniculata have higher important values and higher frequency of utilization comparing with others, and significant values of these tree species are ranked as top 10, utilization rate per tree species was more than 4.0%. In terms of the diversity of ornamental function traits, tree species with leaf enjoyment are mainly dominated species while flowering tree species is only 44.6% and evergreen species is only 11. 【Conclusion】 Spatial difference of the tree species diversity in urban forest was found. The tree species diversity in R5 was the highest, followed by R3, and was the lowest in S-U by synthesizing the 5 biodiversity indices. The tree species evenness in R2 and R5 were lower than that in R3, R4 and S-U, which is closely related to urban forests established for long time in R3 and to urban forest established with richness tree species in R5.

Key words: urban forest; tree species composition; ornamental traits; diversity, Beijing

1. Introduction

Urban forestry is the care and management of single trees or tree populations in urban setting for the purpose of improving urban environment. Urban forestry is not a new concept, but it is one which appears to have growing potential. This is particularly true in developing countries, where urbanization is increasing at a rapid rate and a demographic switch from a predominantly rural to a predominantly urban society is taking place. UF is a merging of arboriculture, ornamental horticulture and forest management. It is closely related to landscape architecture and park management. In its broadest sense, UF embraces a multifaceted managerial system that includes municipal watersheds, wildlife habitats, outdoor recreation opportunities, landscape design, recycling of municipal wastes, tree care and the production of wood as a raw material. Although a true representation of what is UF is historically contextual and has been challenge to define, the first documented use of the term urban forestry appeared in 1894 (Konijendijk, et al., 2006). It is generally defined as "the art, science and technology of managing trees and forest resources in and around urban community ecosystems for the psychological, sociological, economical and aesthetic benefits trees provide society" (Kjell, 2005). The definition of UF given by Miller, 1988 is of, "an integrated, city-wide approach to the planting, care and management of trees in the city to secure multiple environmental and social benefits for urban dwellers."

Urbanization is an ongoing process throughout the world. The rapid urbanization without environmental planning creates serious environmental concerns that threaten the productivity of the urban economy and it brings with it a wide range of challenges. Especially in the developing world, where most mega-cities are located and urbanization is particularly rapid and not necessarily controlled, providing good living conditions to urban populations is one of the main challenges of our time (UN Habitat, 2004). This situation calls for active and innovative strategies for environmental measures to address such emerging issues. For this, UF has found broad following across the world, but its potential for cities and towns in developing countries is unrealized (Konijnendijk et al., 2004). Although FAO has been trying to promote UF in developing world since 1990, lack of information and strategic, coordinated action has hampered implementation of UF in the developing world (Rouchiche, 1999; FAO, 2002). Butwal sub metropolitan city is committed to address the mounting challenges of urbanization; its impact on the environment, society and economy. Rapid unplanned growth of the city without proper infrastructure and services has given rise to numerous environmental problems in the city affecting human health and welfare. Some of the major environmental problems are air pollution, noise pollution, sanitation and solid waste. The city has also witnessed an increase in industrialization and commercialization. Success of plantation cannot be guaranteed if it is not in keeping with the indigenous climatic and social conditions. Percentage of plant survival along the roads has been low owing to number of reasons, most important of them being vandalism. Number of incidents of vandalism can be curtailed if people are made to feel responsible for the care of plants. The best way to achieve this is their active involvement in plantation. An important factor that underscores the need for public participation in the plantation is lack of resources with administration. Community participation shapes individual and group perceptions of their environment and themselves (Burch and Grove, 1993). Olembo and Rham (1987) stated that in most development endeavors the active participation of the concerned was the key to success. Haque (1987) maintained that citizen groups could play a decisive role both in heightening public awareness of the value of trees in the urban environment and teaching people how to care for them. Keeping in this view, present study was intended to explore the current scenario, people's perception and challenges for the improvement of the urban forests in an acceptable and sustainable manner. The urban forest is an important location for city dwellers to connect with and comprehend nature, as well as a space for them to relax and exercise. It also serves as a habitat for a variety of creatures. More and more citizens want to visit the forest to experience nature's freshness and tranquility, as well as to appreciate natural scenery, green culture, outdoor activities, and leisure exercise. Forest recreation has become an essential component of modern tourism (Wei et al., 2006). As a result, constructing a well-structured urban forest community is critical to ensuring good living environment quality, biodiversity protection, and the efficient and effective use of resources. The Beijing Urban Master Plan (2004-2020) clearly states the need to improve the quality of the urban forest landscape. Simultaneously, the theory and practice of ecological garden development, as well as the necessity for inhabitants' leisure and recreation, highlight the significance of urban forest landscape. As a result, it is critical to expand the research of urban forest landscape construction theory based on landscape aesthetics. However, the general quality of the Beijing urban forest environment is now low, and the social service function is inadequate (Gan, 2007). A hot study topic is how to properly analyze and define the landscape aesthetic effect of the developed urban forest community while remaining rational and efficient in structure, in order to assure its optimal ecological and social service functions. The Beijing Urban Master Plan (2004-2020) clearly states the need to improve the quality of the urban forest landscape. Simultaneously, the theory and practice of ecological garden development, as well as the necessity for inhabitants' leisure and recreation, highlight the significance of urban forest landscape. However, the general quality of the Beijing urban forest environment is now low, and the social service function is inadequate (Gan, 2007). A hot study topic is how to properly analyze and define the effect of the developed urban forest community while remaining rational and efficient in structure, in order to assure its optimal ecological and social service functions. China's urbanization began late, but the pace of development has accelerated by leaps and bounds. China's urbanization rate is expected to reach 65 percent by 2020, when the urban population will account for 65 percent of the overall population. With the acceleration of urbanization, the intrinsic functions of cities are unable to meet the needs, urban ecological environment problems are becoming increasingly serious, and inhabitants' quality of life has been greatly impacted. As a result, preserving the virtuous cycle of the urban ecological environment and fostering sustainable growth of urban and natural coexistence has emerged as a key topic in modern urban building research. Building urban forests and increasing the quantity of green space in cities are critical steps toward improving the urban environment and achieving sustainable development. In this scenario, an urban forest is formed. As an urban "green lung," urban forest is a vital guarantee for promoting sustainable socioeconomic growth and improving people' quality of life.

This study selects typical urban forest plots in Beijing to analyze their basic structural characteristics, and provides a basic basis and recommendations for urban forest building in Beijing through basic analysis and research of urban forest type, plant composition, and structure. Generally the study objective is to access urban forestry in Beijing, China and identify tree species diversity to provide influence managers' decisions to plant those trees in urban areas that are more environmental tolerable and pollution resistant.

2. Material and Methods

2.1 Study Area

Beijing is China's capital and the hub of the country's political, economic, cultural, and international exchanges. It is located in the northern end of the North China Plain, at the southern foot of the Yanshan Mountains, is connected to Tianjin in the southeast, and is surrounded by Hebei Province in the north. Beijing is one of China's "four ancient capitals." It has a city construction history of about 3,000 years and a capital construction history of over 850 years. It contains various picturesque areas, historic landmarks, and cultural landscapes that date back to the Yuan, Ming, and Qing dynasties. 39°28′~41°05′ and 115°25'~117°30 ′ were the geographic coordinates. The city has a total area of 16,410.5 km2, which includes 1368.32 km2, an urban area of 1289.3 km2, a downtown centre within the fifth ring, an area of 652.2 km2, 7 districts. The fifth ring area includes Dongcheng District, Xicheng District, Chaoyang

District, Fengtai District, Haidian District, parts of Shijingshan District and Daxing District.

The urban elevation is 43.7 m, and it is located at the confluence of the plain and the mountains. It is part of the mild temperate semi-humid monsoon area, and the climate is a typical continental climate with four distinct seasons. The average temperature is 1012° C, the coldest average temperature is -7 -4° C, the hottest average temperature is 2536° C, the extreme lowest temperature is 27.4° C, and the extreme maximum temperature is 42° C. Frost-free period of 180-200 days, average annual rainfall of 600 mm, rain and heat in the same season. Beijing is located at the crossroads of the Inner Mongolia Plateau and the North China Plain. The Beijing area is often split into two geomorphic units: mountain and plain, based on differences in geological structure, bedrock, climate, hydrology, and anthropogenic influence. Mountain is primarily dispersed in the northwest, is the new tectonic movement rising area, and is cut by external pressures through long-term erosion. The mountain landform structure contains apparent layers, which creates horizontal and vertical variances in water, heat, light, and other resources. Beijing's soil zone is brownies in the semi-humid warm-temperate zone. The city's soil was categorized into 9 soil categories, 20 subcategories, and 64 genera based on the classification principle of unity of occurrence, natural soil, and agricultural soil. Vertical distribution rules are clearly visible (Hoyazhen, 1989). Beijing is part of the Haihe River basin, which includes five water systems: the Daqing and Yongding rivers in the west, the Chaobai and Ji Rivers in the east, and the North Canal in the middle. It is made up of over 200 rivers of various sizes, the majority of which flow from northwest to southeast. Prior to independence, the rate of forest reclamation in the entire Beijing area was very low, with only a limited quantity of natural secondary forest in isolated mountainous areas, and urban vegetation was inadequate. This study focuses urban forests of second, third, fourth, fifth ring roads along with the sub- urban area out of the fifth ring.

2.2 Field investigation

To compare tree species composition and tree diversity in different areas, we divided all of investigation area into 5 parts: (1) within 2nd ring road area, marked by R2, (2) the area from 2nd ring road to 3rd ring road, marked by R3, (3) the area from 3rd ring road to 4th ring road, marked by R4, (4) the area from 4th ring road to 5th ring road, marked by R5, (5) area in outside of 5th ring road representing suburban area, marked by S-U.

2.2.1 Plot setting

Compare the Beijing traffic tourism map, radiate from Beijing Tian'anmen Square as the central point, and set samples for different urban forest green space types in the Beijing built- up area using mechanical distribution points combined with stratified sampling and typical sampling. Representative sample surveys can provide a more comprehensive view of the state of mechanical plant communities and are therefore better suited to examining mechanical plant communities (Shen and Shi, 2009). Public green space, production green space, green protection green space, scenic spot green space, special green space, and street green space are all more abundant than public green space, production green space, green protection green space, scenic spot green space, special green space, and street green space. The Ministry of Construction created the Urban Green Space Classification Standard (CJJ/T85-2002) on September 1, 2002, which divided urban green space into five categories: 13 central, park, production, protective, associated, and other green Spaces. Given the characteristics of urban forest green space and the large area of various parks, campuses, and road green space, four types of urban forest green areas were selected to investigate the vegetation structure attributes on every functional type: urban park, country park, near-natural, and affiliated green (primarily road and campus) space (Xu er al., 2010). (Table 4-1, Figure 4-1). In order to define the term of urban forest plant community, it can be defined as: an urban or regional scope of diverse green space, with distinctive community ecological significance that meets the requirements of ecosystems of diverse plant individual assemblages (Yang and Tang, 2011). Because the urban forest in Beijing is artificially built-in urban areas and suffers from strong artificial interference, fragmentation, or even highly fragmented, determining the type, appearance, boundary, and other characteristics of objects is difficult, so patches with clear boundaries are generally taken as the object. (Yang et al., 2000).

2.2.2 Secondary data collection

Secondary data was collected in the form of reports, published and unpublished articles from different government office and related website from the internet and thesis of various individual. In table 3.1 depicts the characteristics and distribution of urban forests based on the methodologies and types listed below. Different urban forest green Spaces were selected within the adult area, 20 m 20 m standard samples were set up for community survey, trees with chest diameter greater than 4 cm per wood meter, based on the characteristics of urban forest in Beijing's built-up area, on the basis of comprehensive inspection, from 2020-2021.

表*2. 1* 野外调查点的分布

Table 2.1. Distribution of field plots in the study

Types of urban forest green space	Range	main feature
City park green space	Green areas such as comprehensive parks, community parks, and specialized parks, all of which are located within and around the fourth ring road, are referred to as specialized parks.	Its primary role is recreation, but it also serves ecological, aesthetic, and disaster-prevention purposes, and the overall building time is more than five years.
Country Park Green Space	Generally refers to country parks and other green spaces built in the last two to three years outside of Beijing's Fourth Ring Road and extending to the green isolation area outside the Fifth Ring Road.	The rural park, which has been planned and built since 2007 to give inhabitants with observation and recreation opportunities, is a perfect area for citizens to "come near to and love nature." In general, it is developed following vegetation modification and infrastructure development on the initial artificial shelterbelt, garden nursery, flaky shelterbelt, and so on.
Close to nature park green space	Refer to Parks, forest parks, green spaces, and scenic recreational forests around and beyond the Fifth Ring Road.	The vegetation covering rate is normally high, the construction period is lengthy, or, even if the construction period is short, the land has always had good vegetation before, and the area is generally large. On weekends, it is a popular destination for citizens to engage in recreational activities.
Attached green space	Specifically refers to the urban campus green space as well as the road green space alongside the main road.	Exist on college campuses and main roads. Colleges and universities are mainly concentrated in Haidian District and Chaoyang District. The roads mainly include Jianguomenwai Street, Fuxing Road, Jianguo Road, Shijingshan, Fuxingmenwai Street, Road, Airport Expressway, East (South and Northwest) Third Ring Middle Road, East (South Northwest) Fourth Ring Middle Road, East (South Northwest) Fifth Ring Middle Road, etc.

In the field recorded the name, height, and chest diameter of the tree (shrub geodesic diameter). The species name, height, crown size, and growth status of each plant were recorded in the shrub layer; the herbaceous layer was investigated according to different community characteristics, but the main focus of our study investigated the woody flora. The level of human interference (mowing, trampling, etc.) is higher. A typical sampling method was used to estimate the capping of herbaceous layers; typically, 1 1-meter square samples were set up at the four corners. Sample plots measuring 20 m × 20 m were placed out throughout the highways, streets, and corridors of the study area to collect data on tree species, DBH and height measurements, morphological characteristics, health, and other management features. Leaf samples were collected and taken away in order to identify an unknown species. The survey focused on roadside plantations, urban parks, and institutional plantations. A transect survey was carried out along the road. Concerned government entities, municipal offices, and private nurseries were visited in order to gather information about urban forestry planning, ongoing activities, existing challenges, and the support required to promote urban forestry in urban areas. Different city parks were visited, and conversations with park users and authorities were held about tree management and difficulties, the availability of planting material, species selection, plantation, survival rate, silviculture, and spacing. The roadside study recorded the number of species and their conditions (sapling or tree), pruned species, hazardous species, and their frequency.

2.3 Statistical methods for biodiversity assessment

To compare species diversity among five urban forest types and distinct urbanization gradients, species diversity indices were constructed for each type of urban forest and each gradient of urbanization. These indexes are the Berger-Parker species richness index (BPI), the Shannon-Wiener species diversity index (H′), the evenness index (J), and the species Importance Value (IV). Berger-Parker index (Berger-Parker index):

Alpha diversity index is used to measure the diversity within a particular area or the ecosystem and it usually express the number of species in the particular ecosystem i-e species richness.

Density

It is measurement of numerical strength of species where the total number of individuals of each species was divided by the number of quadrats. It was calculated by the method of Ahmed and Shauket, (2012) which is given as "the number of individuals per unit area sampled". $Density = \textbf{No of individuals of single species/total no of quadrats}$

Frequency

It is defined as total no. of time in which a species occurred divided by total no of quadrats and multiplied by hundred. It was calculated after Cox (1976).

$$Frequency = \textbf{No of quadrat in which species occur/total no of quadrat} \times \textbf{100}$$

Canopy Cover

It is defined as, "the proportion of the ground occupied by perpendicular projection of the areal parts of the individuals of the species under consideration" (Greig and Smith, 1957). It is in fact the estimation of the area covered by a given species.

For trees diameter at breast height was taken. The trees having circumference less than 5cm were considered as shrubs. For trees DBH was recorded according to the formula: Circumference where D= C/π

Area= $\pi d/4$ => A= ORA =C/2.56

$Canopy\ cover$ = total canopy cover of a species/no of quadrates × size of quadrates

Relative Density

It is determined by expressing the density of species as a % age of the proportion of total density of all the species present. Relative density (Dr) is: $Dr =$ density of a species/total density of all the species × 100

Relative Frequency

It is defined as "the percentage proportion of the frequency of a given species to the total frequency of all the species. Relative Frequency (Fr) is: $Fr =$ frequency value of a species /total frequency of all the species × 100

Importance Value

It is the sum of all relative values of frequency, density and cover of all the species present in each quadrat.

$$IV = (D_r + P_r + F_r)/3$$

Importance value: Ⅵ $= (Dr + Pr + Fr)/3$ (Ellenberg and Mueller-Dombois 1974)

Equitability is obtained by dividing the Shannon diversity with logarithm of number of taxa where it measures the evenness with which the individuals are divided among all the taxa present in study area.

The formula for Fisher's alpha is S=a*ln(1+n/a) where S is number of taxa, n is number of individuals and a is the Fisher's alpha.

Chao 1 is diversity index method that is actually a nonparametric method for estimating the number of species in a community that mostly refer data about the number of missing species in the community.

The Principal Component Analysis (PCA) method was used to evaluate the impact of urban forest type and urbanization on species composition (Austin 2013; McCune et al. 2002). The species abundance was log-transformed before to PCA analysis. The final optimal solution, as indicated by 2-D, accounted for the greatest percentage of variance in species data. PAST software was used for PCA ordination.

3. Results

3.1 Taxonomic composition in different areas

3.1.1 The general statistics

There are 83 species of plants, 55 genera belonging to 34 families in urban and sub- urban parks including 47 wild trees 14 arbor trees and 22 shrubs respectively (Figure 3.1). The species were grouped in three categories Arbor trees and shrubs. All the three categories of plant species were classified according to the presence within urban forests of 5 ring roads or in the sub-urban parks outside of the ring road.

Further statistical analysis of the investigated plant species by family and genus, 1 family contained more than 11 kinds of plant species,1 family contain 8 kind of plant species, 2 families containing 6-7 plant species, 3 families containing 4-5 plant species, 9 families containing 2-3 plant species, and 18 families containing single plant species. Rosaceae (Rosaceae) was found with the largest number of plant species. Among woody plants Rosaceae, Sapindaceae, Pinaceae, Oleaceae and Saliaceae contain the most plants, forming the dominant species of urban forest plant community within the five-ring roads of urban and out of ring road in suburban parks of Beijing. In addition, the proportion of fewer and individual families is also high like Fabaceae. This shows that Beijing urban forest plant characteristics are affected by the zone nature and show some variability under the artificial disturbance of urbanization construction. For genera, 3 genera contain 6 and 4 plant species respectively, 4 genera contain 3 plant species, 9 genera contain 2 species and 39 genera are single-genus species. The Prunus genera, Pine genera, Acer genera, Populus and Salix genera contain the top five arrangements of plant species

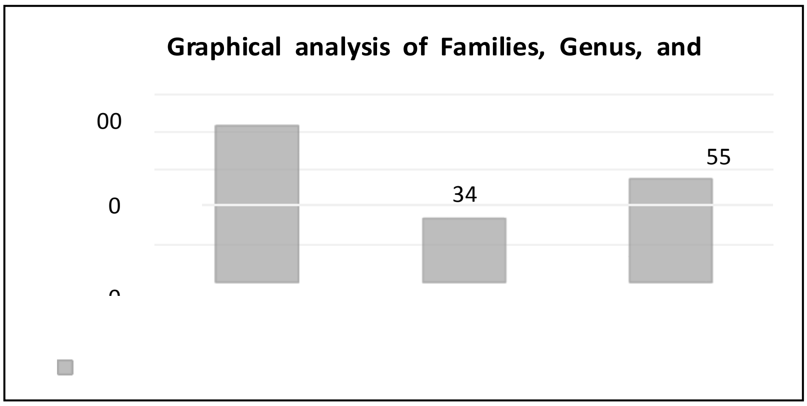
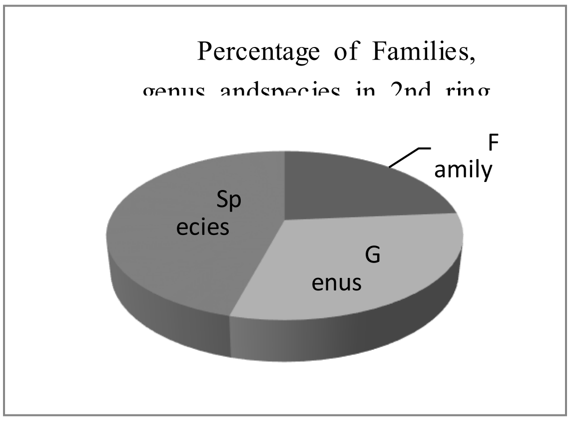


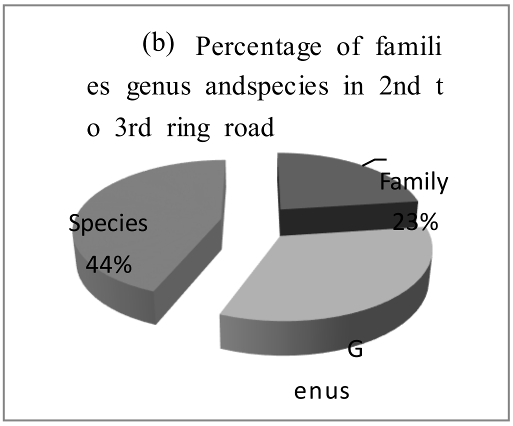
图 3.1 北京市五环内及城郊树木分类学组成

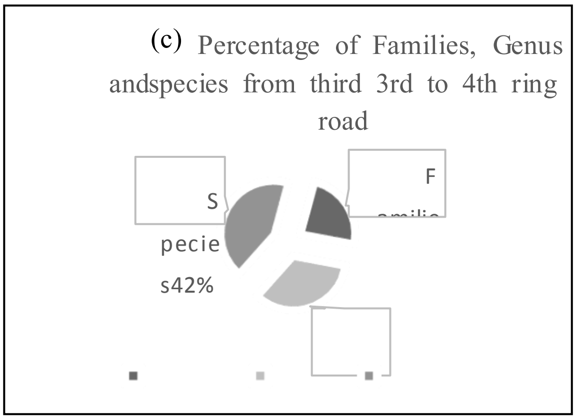
Figure 3.1. Graphical analysis of Families, Genus, and Composition

Our studies are just limited to the urban parks with the limited number of study areas. The number of plants, genera and species within the in parks of 5 ring roads of Beijing accounts for 20%, 32% and 48% (shown in figure3.1) of the total plant families, genera and plant species in Beijing, respectively, which is generally low due to the limited time and limited study areas.

In the following figure 3.2 (a, b, c, d, e) representing the distribution of families, genus and species of trees, arbor trees and shrubs in all the urban forests of ring roads and sub-urban forests. According to our studies Urban forests in 2nd ring consist of 17 families 22 genus and 23 species representing the percentage of 24% families, 30% genus and 46 % species. Urban forests from 2nd to 3rd ring road consist of 25 families, 36 genus and 48 species representing the percentage of 23% families, 33% genus and 44 % species that has less resemblance with the distribution of number of families, genus and species in 2nd ring road. In the urban forests from 3rd to 4th ring road number of families, genus and species were 24, 34 and 43 respectively representing the percentage of 24% families, 34% genus and 42 % species which means the more presence of single type of family genus and species within 3rd to 4th ring road. In the green spaces from 4th to 5th ring road number of families, genus and species were found 31, 44 and 58 respectively with the 23%, 33% and 44 % distribution in this area that shows the highest number of species among all the roads. The percentage distribution of ring road 2nd to 3rd and 4th to fifth has more resemblance while the percentage distribution of families, genus and species within 2nd and 3rd to 4th ring roads resemble with one another. In the urban forests of sub-urban area has recorded the 14, 23 and 29 families, genus and species respectively showing 21%, 35% and 44% families, genus and species recorded in this area. the percentage distribution of number of genera in the sub-urban forests are higher than others among ring roads.







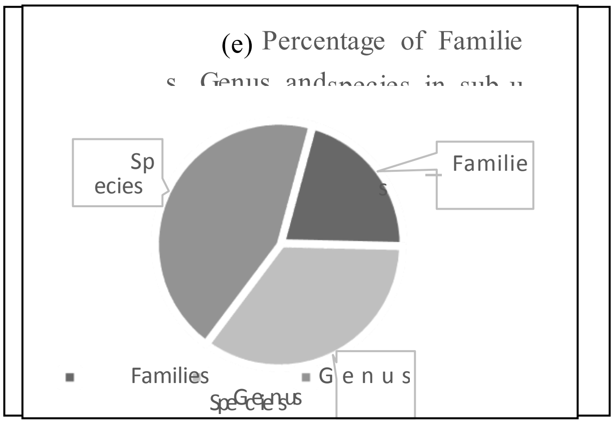


Figure 3.2 Number of distributions of family, genus and species among all ring roads (a) within 2nd ring road (b) from 2nd to 3rd ring road (c) from 3rd to 4th ring road (d) from 4th to5th ring road (e) within sub-urban forests.

3.1.2 Changes of taxonomic composition among different areas

- **Taxonomic composition of Urban forests within the 2nd Ring Road**

The study reveals 33 type of plant species belonging to 17 families belonging to 22 were recorded in the 2nd ring road of study area (Table 3.1). Plant species recorded in 2nd ring roads were *Sophora japonica, Populus tomentosa, Ginkgo biloba , Pinus tabuliformis , Juniperus chinensis , Salix babylonica , Sorbaria kirilowii , Platanus spp., Ailanthus altissima, Euonymus japonicus, Koelreuteria paniculata, Fraxinus spp., Robinia pseudoacacia, Malus × micromalus, Hibiscus syriacus, Lagerstroemia indica, Populus × Canadensis, Pinus bungeana, Picea wilsonii, Platycladus orientalis, Euonymus maackii, Vitex negundo* var. *heterophylla, Acer mono, Diospyros kaki, Picea asperata, Pinus parviflora, Juniperus ridgia, Forsythia suspense, Prunus serrulata, Pyrus betulifolia, Cercis chinensis, Lonicera maackii, Prunus ceraifera* cv. *Pissardi*i. Total number of plant species recorded in the 7 sub-plots of urban forests in second ring road were 279 individuals.

- **Taxonomic composition of Urban forests from the 2nd to 3rd Ring Road**

The study reveals 48 type of plant species belonging to 25 families belonging to 36 Genus were recorded in the 3rd ring road of study area (Table 3.1). *Sophora japonica, Eucommia ulmoides, Populus tomentosa, Ginkgo biloba, Pinus tabuliformis, Juniperus chinensis, Salix babylonica, Sorbaria kirilowii, Platanus spp., Ailanthus altissima, Euonymus japonicus, Koelreuteria paniculata, Fraxinus spp., Amorpha fruticosa, Buxus megistophylla, Acer truncatum, Robinia pseudoacacia, Platycladus orientalis, Acer mono, Pinus parviflora, Juniperus ridgia, Forsythia suspense, Prunus serrulata, Viburnum opulus subsp. calvescens, Ligustrum vulgare, Catalpa bungei, Lonicera maackii, Prunus ceraifera cv.Pissardii, Ligustrum quihoui, Malus × micromalus, Hibiscus syriacus, Salix matsudana, Lagerstroemia indica, Pinus bungeana, Diospyros virginiana, Buxus microphylla, Picea wilsonii, Cotinus coggygria, Prunus armeniaca, Prunus domestica, Yulania liliiflora, Cedrus deodara, Ligustrum vulgare, Juniperus sabina, Ziziphus jujuba var. spinosa, Cercis chinensis, Syringa oblata, Chimonanthus praecox, Prunus persica, ligustrum ×vicaryi, Berberis thunbergii 'Atropurpurea', Picea asperata*. Total number of plant species recorded in the 16 sub-plots of urban forests in third ring road were 668 individuals.

- **Taxonomic composition of Urban forests from the 3rd to 4th Ring Road**

The study reveals 42 type of plant species belonging to 23 families were recorded in the 4th ring road of study area (Table 3.1). Plant species recorded in 4th ring roads were *Sophora japonica, Populus tomentosa, Ginkgo biloba , Pinus tabuliformis, Juniperus chinensis, Sorbaria kirilowii, Platanus spp., Ailanthus altissima, Euonymus japonicus,* *Koelreuteria paniculata, Fraxinus spp., Populus × Canadensis, Acer truncatum, Robinia pseudoacacia, Pinus bungeana, Platycladus orientalis, Acer mono, Prunus serrulata, Viburnum opulus subsp. calvescens, Lonicera maackii, Prunus ceraifera cv. pissardii, Ligustrum quihoui, Malus × micromalus, Hibiscus syriacus, Salix matsudana, Lagerstroemia indica, Hydrangea macrophylla, Broussonetia papyrifera, Juglans regia, Syringa vulgaris, Prunus domestica, Rhus typhina, Diospyros kaki, Populus nigra, Syringa oblata, Pinus armandii, Ulmus pumila, Yulania denudate, Picea wilsonii, Berberis thunbergii 'Atropurpurea', Punica granatum, Weigela florida, Aesculus chinensis, Cercis chinensis.* Total number of plant species recorded in the 13 sub-plots of urban forests in fourth ring road were 461 individuals.

- **Taxonomic composition of Urban forests from the 4th to 5th Ring Road**

The study reveals 64 type of plant species belonging to 22 families were recorded in the 5th ring road of study area (Table 3.1). Plant species recorded in 5th ring roads were *Sophora japonica, Eucommia ulmoides, Populus tomentosa, Ginkgo biloba, Pinus tabuliformis, Juniperus chinensis, Salix babylonica, Sorbaria kirilowii, Platanus spp., Ailanthus altissima, Euonymus japonicus, Koelreuteria paniculata, Fraxinus spp., Amorpha fruticosa, Acer truncatum, Robinia pseudoacacia, Platycladus orientalis, Acer mono, Pinus parviflora, Juniperus rigida, Forsythia suspense, Prunus serrulata, Salix alba, Rhus typhina, Albizia julibrissin, Viburnum opulus subsp. calvescens, Ligustrum vulgare, Catalpa bungei, Lonicera maackii, Prunus ceraifera* cv. *pissardii, Ligustrum quihoui, Malus × micromalus, Hibiscus syriacus, Salix matsudana, Lagerstroemia indica, Hydrangea macrophylla, Broussonetia papyrifera, Diospyros lotus, Juglans regia, Morus alba, Vitex negundo var. heterophylla, Diospyros virginiana, Buxus microphylla, Cotinus coggygria, Prunus armeniaca, Cercis chinensis, Syringa vulgaris, Padus avium, Prunus davidiana, Metasequoia glyptostroboides, Cedrus deodara, Salix alba, Rhus typhina, Albizia julibrissin, Picea asperata, Viburnum opulus subsp. calvescens, Ligustrum vulgare, Celtis bungeana, Juniperus sabina, Acer palmatum, Ziziphus jujuba var. spinosa, Cercis chinensis, Syringa oblata, Populus alba, Pinus armandii, Ulmus pumila, Yulania denudate, Euonymus maackii and Morus mongolica*. Total number of plant species recorded in the 15 sub-plots of urban forests in fifth ring road were 1080 individuals, which shows the dominancy of urban vegetation in the fifth ring of Beijing.

- **Taxonomic composition of Urban forests in sub-urban forests**

The study reveals 29 type of plant species belonging to 14 families and 23 Genus were recorded in the sub-urban forests in outside of ring road in Beijing (Table 3.1). Plant species recorded in the sub-urban forests outside of 5th ring roads were *Sophora japonica, Populus tomentosa, Pinus tabuliformis, Juniperus chinensis, Salix babylonica, Sorbaria kirilowii, Platanus spp., Koelreuteria paniculata, Fraxinus* spp., *Acer truncatum, Robinia pseudoacacia, Populus × Canadensis, Pinus bungeana, Platycladus orientalis, Acer mono, Rosa xanthine, , Salix alba, Rhus typhina, Albizia julibrissin, Pinus parviflora, Viburnum opulus* subsp. *calvescens, Ligustrum vulgare, Prunus persica, Catalpa bungei, Cercis chinensis, Lonicera maackii, Amygdalus davidiana, Prunus ceraifera* cv. *pissardii, Ligustrum quihoui*. Total number of plant species recorded in the 6 sub-urban forests were 281 individuals, showing the least documented plant species in urban forest area among all the plots.

Further statistical analysis of the investigated plant species by family and genus, and species among all the areas recorded the 10-common species in all the urban forests of ring roads and sub-urban forests. The common species among all the areas were *Acer mono, Ailanthus altissima, Fraxinus spp., Juniperus chinensis, Koelreuteria paniculata, Lonicera maackii, Pinus tabuliformis, Platanus spp., Pinus bungeana, Populus tomentosa, Prunus ceraifera, Robinia pseudoacacia, Salix matsudana, Sorbaria kirilowii, Syringa oblate, Salix babylonica and Sophora japonica*. The main specie within the 2nd ring road were *Pinus bungeana, Fraxinus* spp., *Juniperus chinensis* and *Pinus tabuliformis* as these tree species were with dominant numbers. The main dominant species in the middle of 2nd to 3rd were recorded *Syringa oblata, Fraxinus* spp., *Juniperus chinensis, Platycladus orientalis,* *Sophora japonica* and *Pinus tabuliformis*, 3rd to 4th ring road the main dominant species Fraxinus spp., Populus × Canadensis and Sophora japonica were recorded. *Sophora japonica, Eucommia ulmoides, Populus tomentosa, Fraxinus* spp., *Juniperus chinensis, Salix babylonica, Gingko biloba, Salix matsudana, Robinia pseudoacacia, Koelreuteria paniculata, Pinus orientalus, prunus davidiana* were recorded within the urban forests of 4th and 5th ring road. In the green spaces of sub-urban area of Beijing the main species *Sophora japonica* and *Rhus typhina* were recorded. The main difference among the species in urban forests among different ring roads is the taxonomic composition of the species. The number of the wild trees were recorded as 44 along with 22 shrubs and 14 arbor trees in the study area. In the recent study it has been noted that the number of the arbor trees are very less in count in the term of family, genus and species in all the green spaces of the Beijing ring roads and sub-urban region. The main reason is the construction of the buildings and the industries for economic purpose that can lead to harm the society in the term of losing biodiversity, decline of local fauna, health and destruction of scenic areas along with other problems for the society. The number of arbor trees must be more focus as they must be of more interest in urban green areas, therefore the arbor trees must be more focused along with other plant species in the urban forests of Beijing.

3.2 Change in frequency of top 10 tree species among different areas

Among different areas there is considerable changes can be seen in frequencies in the top 10 species among different area. The highest percentage of frequency was recorded for *Populus tomentosa* in the green spaces of sub-urban areas with 14% following with the 12% and 10 % in 4th to 5th ring road and 2nd, 3rd ring road respectively. The second highest percentage of the species recorded were *Juniperus chinensis* and *Platanus* spp. with the frequency of 10% within the 2nd ring road and 6% among 3rd and 4th ring road respectively. *Fraxinus* spp., *Juniperus chinensis, Koelreuteria paniculata, Pinus bungeana, Sorbaria kirilowii* were recorded with the frequency percentage of 8%, 6% and 4% among different green areas. In the table (3.2) shows the values of frequency of top 10 species present among different areas and in figure (3.3) shows the graphical representation of the top 10 species among different areas.

表3.2 不同区域使用频率最高的 10 个树种变化

Table 3.2. Statistics of top 10 species ranked by using frequency among different areas

	Species name	**Frequency /%**				
		R2	R3	R4	R5	S-U
1	*Juniperus chinensis*	10.0%	5.6%	3.4%	3.8%	4.2%
2	*Fraxinus* spp.	5.00%	5.61%	6.14%	3.89%	5.26%
3	*Pinus bungeana*	5.00%	2.99%	1.53%	0%	4.21%
4	*Sophora japonica*	6.66%	1.49%	4.09%	3.89%	5.26%
5	*Pinus tabuliformis*	3.33%	5.61%	3.07%	3.89%	3.15%
6	*Robinia pseudoacacia*	5.00%	4.48%	6.14%	3.89%	2.10%
7	*Populus tomentosa*	10.07%	9.96%	6.55%	11.44%	14.67%
8	*Sorbaria kirilowii*	3.33%	2.99%	0.51%	2.39%	1.05%
9	*Platanus* spp.	10.52%	5.53%	5.40%	2.86%	4.51%
10	*Koelreuteria paniculata*	3.33%	2.99%	6.14%	3.89%	4.21%

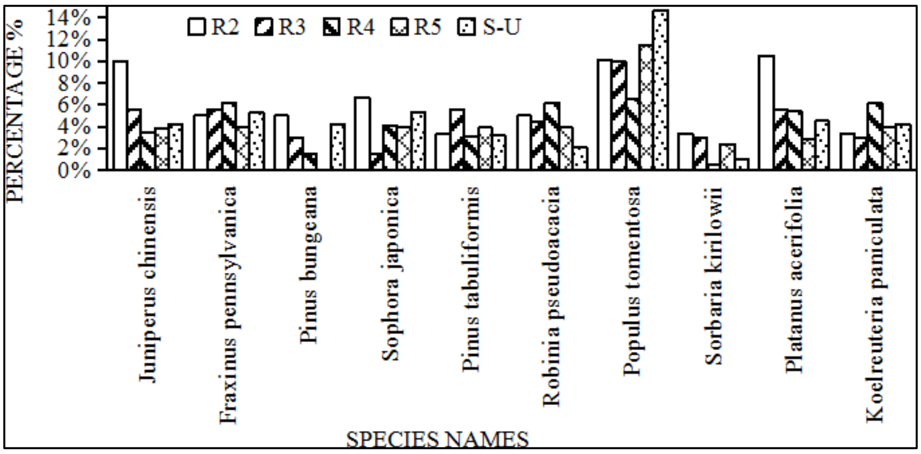


图3.3 使用频率前 10 位树种在各环路中的变化

Figure 3.3. Change in frequency of top 10 tree species among different areas.

3.3 Functional diversity of plant species

3.3.1 Life form composition

As we mentioned above there are 83 species of plants, 55 genera's belonging to 34 families in urban and sub-urban parks including 43 tall arbor trees, 10 dwarf arbor trees and 29 shrubs respectively (Figure 3.1).The tall arbor trees counted in the study area were *Acer mono, Acer palmatum, Acer truncatum, Aesculus chinensis, Ailanthus altissima, Albizia julibrissin, Broussonetia papyrifera, Cedrus deodara, Diospyros lotus, Diospyros virginiana, Eucommia ulmoides, Fraxinus spp. , Fraxinus velutina, Ginkgo biloba, Juglans regia, Juniperus rigida, Juniperus chinensis, Koelreuteria paniculata, Yulania denudate, Metasequoia glyptostroboides, Padus avium, Paulownia tomentosa, Picea koraiensis, Picea wilsonii , Pinus armandii , Pinus bungeana , Pinus parviflora, Pinus tabuliformis, Platanus spp., Platycladus orientalis, Populus × Canadensis, Populus alba, Populus nigra, Populus tomentosa, Prunus armeniaca, Pyrus betulifolia, Robinia pseudoacacia, Salix alba, Salix babylonica, Salix matsudana, Sophora japonica, Ulmus pumila and the shrubs recorded from the green spaces of the Beijing ring road and sub-urban areas were Amorpha fruticosa, Berberis thunbergii 'Atropurpurea', Buxus megistophylla , Buxus microphylla, Cercis chinensis, Chimonanthus praecox, Cotinus coggygria, Euonymus japonicas, Euphorbia milii, Forsythia suspense, Hibiscus syriacus, Hydrangea macrophylla , Juniperus Sabina, Lagerstroemia indica , Ligustrum × vicaryi, Ligustrum quihoui, Lonicera maackii , Yulania liliiflora, Paeonia suffruticosa, Punica granatum , Rhus typhina, Rosa xanthine, Sorbaria kirilowii, Syringa oblate, Syringa vulgaris, Viburnum opulus subsp. Calvescens, Vitex negundo var. heterophylla , Weigela florida, Ziziphus jujuba var. spinosa. Dwarf arbor trees were recorded as Chimonanthus praecox, Catalpa bungei, Diospyros kaki, Euonymus maackii, Malus × micromalus, Morus alba, Morus mongolica, Prunus ceraifera cv. Pissardii, Prunus davidiana, Prunus domestica, Prunus persica, Prunus serrulata var. lannesiana, Syringa reticulata subsp. Amurensis, Celtis bungeana*

According to the functional diversity of plant species recorded from the study areas shows life form composition of the plant species recorded in the study area that represent the percentage of life form composition of species with 53% tall arbor, 35% shrubs and 12% dwarf arbor tree species respectively. In the figure no. 3.4 mentioned below shows the number and percentage of arbor tree species, (tall, dwarf) and shrubs. Figure 3.4 shows that the number of tall tree species are greater than shrubs and dwarf arbor trees. This is obvious urban forest usually represent a greater number of species but sometimes the height of trees used along the road sides failed to fulfil the requirement of being trees so we called them trees same in our studies many tree species due to the limited height fall in the category of shrubs. In the recent studies more, attention been paid towards the arbor trees and shrubs.

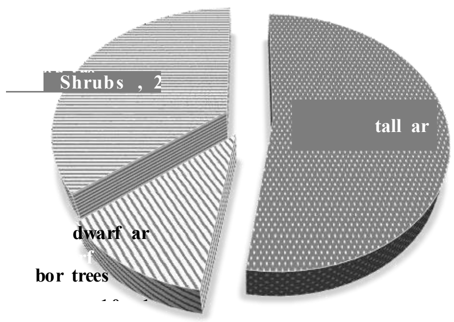


图3.4. 不同生活型树种构成

Figure 3.4. Graphical representation of trees, shrubs, and herbs.

The tall arbor species were obviously increase from R2 to R5 beside S-U, and it was the lowest one in S-U (Figure 3.5). The further analysis for the life form difference among different areas showed the regular trend among wild trees with the number of wild trees 23, 29, 27, 37 and 19 in R1, R2, R3, R4, R5 and sub-urban green areas. Figure 3.5 shows the highest number of trees recorded in R5, the area between the ring road 4th and 5th. The low number of trees were recorded in sub-urban areas with the number of 19 trees and the tall arbor trees were found equal number in area between 2nd and 3rd ring road and 4th and 5th ring road respectively. There were only one tall arbor trees was found in sub-urban area that showed the negligence of sub-urban areas toward the greenery and sub-urban parks, likewise there were zero dwarf arbor trees recorded in sub-urban green area with only one tree species in 2nd, and 4th ring road respectively. In case of urban shrubs and shrubby structure trees the number was high within the ring road 4th and 5th with 16 types of shrubs while only 5 kinds of shrubs were recorded in sub-urban areas. In relation to 4th and 5th ring road the green area between 2nd to 3rd and 3rd to 4th also have adequate number of shrubs with 13 and 15 respectively.

Figure 3.5. Changes in life form of tree species among different areas.

3.3.2 Provenance of plant species

In figure no. 3.4 and table (3.3) shows the provenance of plant species recorded in the urban forests of 5 rings of Beijing and the sub-urban parks in terms of percentage and graphically. It reveals that the native species are higher in number with the percentage of 86.80% while the exotic and naturalized species that has been planted with in these urban and sub-urban parks recorded the percentage of 6.06% respectively. Only 1.01% invasive species has been recorded in the recent investigation

表 3.4. 北京市五环内及城郊城市森林树种来源

Table 3.4. Percentage representation of the provenance of flora.

serial no.	Provenance type	Percentage %
1.	Native species	86%
2.	Exotic species	6%
3.	Naturalized species	7%
4.	Invasive species	1%

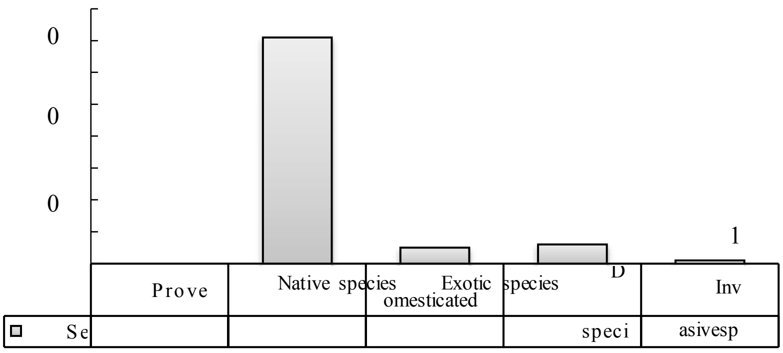


图 3.6 北京市城市森林树种来源

Figure 3.6. Provenance of plant species in urban forest in Beijing

3.4 Species diversity in different areas

Species diversity is a process which provides data on species richness and evenness. The diversity is typically carried out in order to investigate its relationship to other community qualities such as productivity and stability, as well as the current environmental conditions. Species diversity, also known as species heterogeneity, is a manifestation of community organization. It is also one of the fundamental notions of ecology that has been used to characterize communities and ecosystems, and it is evaluated by species richness (the number of species present in a given community) and species evenness (the relative abundance of the different species). The biodiversity did not differ significantly from plot to plot across the whole research area (Table 3.3). Shannon-wiener, Simpson, and Berger Parker indexes all produced similar results, revealing that the diversity of ring 3 and ring 5 (R3, R5) urban forests is greater than that of R2, R4, and sub-urban forests.

表*3.5* 城区不同区域树木多样性统计

Table 3.5. Diversity indices of all the plant species recorded in study area.

Alpha diversity indices	R2	R3	R4	R5	S.U

Taxa_S	34	53	43	67	28
Individual	279	668	461	1180	291
Dominance_D	0.093	0.045	0.068	0.043	0.084
Simpson 1_D	0.907	0.955	0.932	0.957	0.916
Shannon _H	2.734	3.395	3.159	3.454	2.798
Evenness_e^H/S	0.453	0.563	0.548	0.472	0.586
Equitability_J	0.775	0.855	0.840	0.870	0.840
Fisher_alpha	10.15	13.52	11.6	13.52	7.637
Berger_Parker	0.151	0.089	0.193	0.112	0.172
Chao_1	43.43	58.14	52.00	71.20	35.50

Table 3.4 shows the values of (a) Shannon index H (b) Alpha diversity index (c) Fisher alpha diversity (d)simpson diversity Ds (e) Berger Parker indexes

3.4.1 Other Biodiversity Indexes

Other analyses of the biodiversity made by applying the other indices such as the index of Fisher_alpha revealed interesting information. Whereas with the Shannon diversity index, it is in plot 11 that we noted the weakest biodiversity, the application of the index Fisher (Table 3.4) showed that the low value of the biodiversity was obtained in plot ring road second and suburban forests R2 and S-U with value of 10.15 and the 7.63 respectively whereas the strongest value of fisher-alpha is observed in with values of 13.52 and 15.39 in plot ring third and fifth (R3 and R5) respectively, which is a mosaic of all the recorded species. The species richness of 58 and 72 species was observed in ring road 3 and ring road 5 of the Urban forests of Beijing, China. Sophora japonica and Robinia pseudoacacia were the most dominant in R5 with 88 and 85 trees while Fraxinus spp. was dominant with 89 trees in R4 and Pinus tabuliformis was dominant in R3 with 60 trees.

- **Q Diversity**

β Diversity quantifies the increase in species diversity along transects, as well as diversity among ecosystems, and is particularly useful in the study of environmental gradients. It counts the number of various habitats within a region as well as the replacement of one species by another between discontinuous parts of the same habitat. In the recent studies Whittaker index for beta-diversity shows the pair wise comparison of all the five areas in the table 3.6.

表*3.6* 所有样地成对比较

Table 3.6. Beta diversity analysis (pair wise comparison) of all plots.

	R2	**R3**	**R4**	**R5**
R3	0.402			
R4	0.377	0.417		
R5	0.465	0.35	0.382	
S-U	0.419	0.531	0.408	0.516

All the Plots of rings and sub-urban forests showed the similarity while comparing with one another. While comparison there is low level of similarity in all plots having high beta diversity. In other words, a high beta diversity index implies a low amount of resemblance, whereas a low beta diversity index indicates a high level of similarity. The highest comparison value of R3 and sub-urban plots is 0.531, indicating that there is less similarity between these two ecosystems or communities.

3.5 Tree species diversity in different types of green spaces

The Shannon index has given the information statistics of all the species present among different areas while the Simpson index provided the dominant species present among different areas. Major portion of our study constitute of comprehensive park (or called it integrated park), community forest (campus, government department etc), road side green space, country park and close-to-natural park. In the 2nd ring road 7 plots were recorded that were consisted of 34 taxa 279 species. Most of them were comprehensive parks named as Houhai Park, Taoranting Park, Yuantucheng Ruins Park, Ditan Park, Huichengmen Park, Songlin Park and Jingshan Park. The green spaces of second ring road showes the Shannon and Simpson index shows the value of 2.734 and 0.907 respectively.

16 plots were recorded that were consisted of 58 taxa 668 species in R3. Most of them were comprehensive parks along with the green named as Baiwang Park, Changpu River Park, Lotus Pond Park, Shuangyushu Park, Tuanjiehu Park, Madian Park, Yuan Dynasty City Wall Ruins Park, and Youth Lake Park, Yuquan Huigu (Tsinghua Science and Technology Park, Yuquan Huigu Entrance East Greenbelt, Flower Grand View Garden, Lianhuachi Park, Zhongshan Park, Shuangxiu Park, Linglong Park and Yuyuantan Park. The green spaces of second ring road illustrate the Shannon and Simpson index shows the value of 3.395 and 0.045 respectively. 13 plots were recorded that were consisted of 43 taxa 461 species in R4. Most of them were parks and green road belts of universities roads named as Red Scarf Park, Chaoyang Park, Xinghai Park, Hot spring park, Beijing Language and Culture University, Beihai Park, China Mining University, Greenbelt of Tsinghua East Road, Honglingjin Park, Yaowa Lake, Side Park and Huaixin Park. The green spaces of second ring road illustrate the Shannon and Simpson index shows the value of 3.3159 and 0.932 respectively. 15 plots were documented that were consisted of 67 taxa 1180 species in R5. Most of them were parks and green belts of universities roads and named as Shucun Country Park, old summer palace, Baiwangshan Forest Park, Greenbelt in the north of Dongwangzhuang, Chaolai Forest Park, Olympic Forest Park, Bajia Country Park, Haidian Park, Changying Park, Anti-Japanese War Sculpture Garden, Duzhong Park, Laoshan Park, yuanmingyuan Park, Greenbelt in the north of Dongwangzhuang, Huangcaowan Country Park. The green spaces of second ring road illustrate the Shannon and Simpson index shows the value of 3.454 and 0.957 respectively. In sub-urban area 6 plots were recorded that were consisted of 28 taxa 291 species. The parks were consisted of country parks, forests parks and comprehensive parks named as Park, Eight Country Parks, Beiwu Village Road Street Green, Yukang Park, Bishui Fenghe Park, Dongxiaokou Forest Park, Gucheng Park. The green spaces of second ring road illustrate the Shannon and Simpson index shows the value of 2.798 and 0.916 respectively. Dominance D value in table 3.4 shows the least dominance value in R5 and highest dominance was recorded within 2nd ring road and sub-urban with value of 0.093 and 0.084 respectively. It means the diversity of these regions is lower than other ring roads but the dominance is greater in these regions. The greater dominance the lower diverse region. The 4th to 5th ring road were recorded more diverse but less dominant and 2nd ring road and sub-urban regions found to be less diverse but more dominant. The dominance index negatively correlated with th alpha diversity indices.

Bar chart in the figure (3.8) showing plot ring 5 (R5) with the highest peak in bar chart as well as highest peak lies in the figure (3.9) Jitter plot due to the maximum number of tree species in the ring 5 (R5) i-e more than 80 plant species including trees and shrubs. Ring 3 (R3) showing the second highest peak for the standard error as well as the second top peak on Jitter plots reveals the maximum number of plant diversity in the ring 3 after ring 5. The black dots of Jitter plots show the number of trees and shrubs present among different areas and the Normal probability plot in figure (3.10) shows the distribution of all the samples in the plots how evenly they are distributed. Different colors showing different plots black shows R2, red R3, blue R4, green R5 and light-blue shows the sub-urban plots. The probability curve shows that the highest peak representing with green color formed in the ring 5 where the highest variability of the plant species separated that plot from other plots with the mean value of 2.29. The second top most peak is for the R3 with red color shows the values of normality curve lies in mean value of 2.28. Ring 2 shows the mean value of approximately 0.75 for the normal order curve that means the low plant species distribution in that plot.

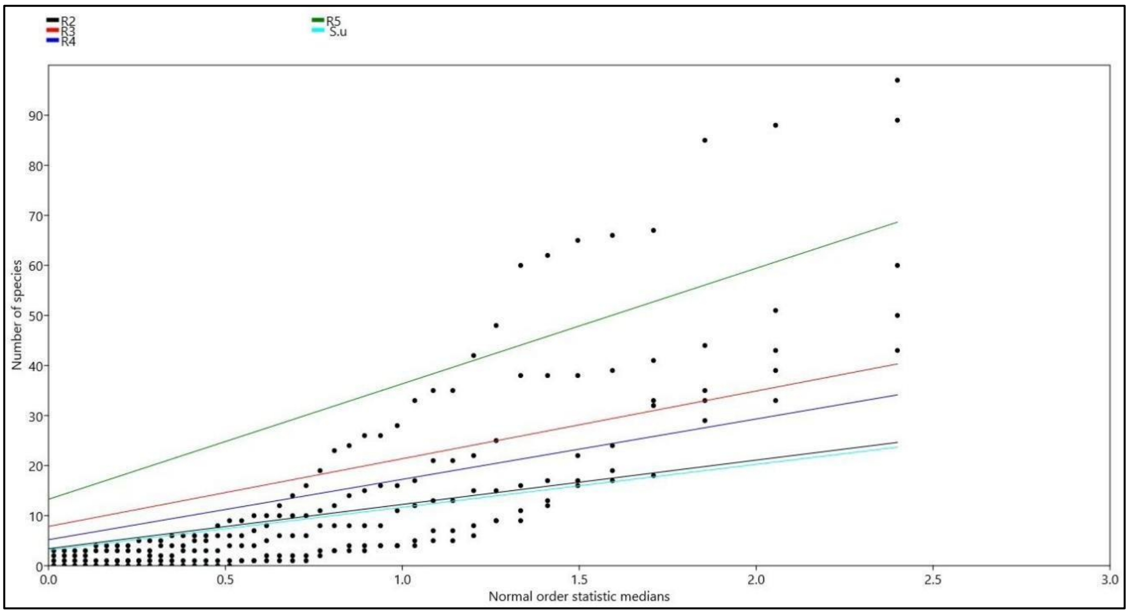


Figure 3.10. Normal probability plot.

In the figure 3.11, the stem style graph on log Y shows the number of species along with log X clearly shows the distribution of all the species in all plots that proves our results that the highest diversity of plants recorded in the ring 5 representing with the green color stems showing the highest number of plants along with the presence of all the similar plants in other plots showing in the form of stem.

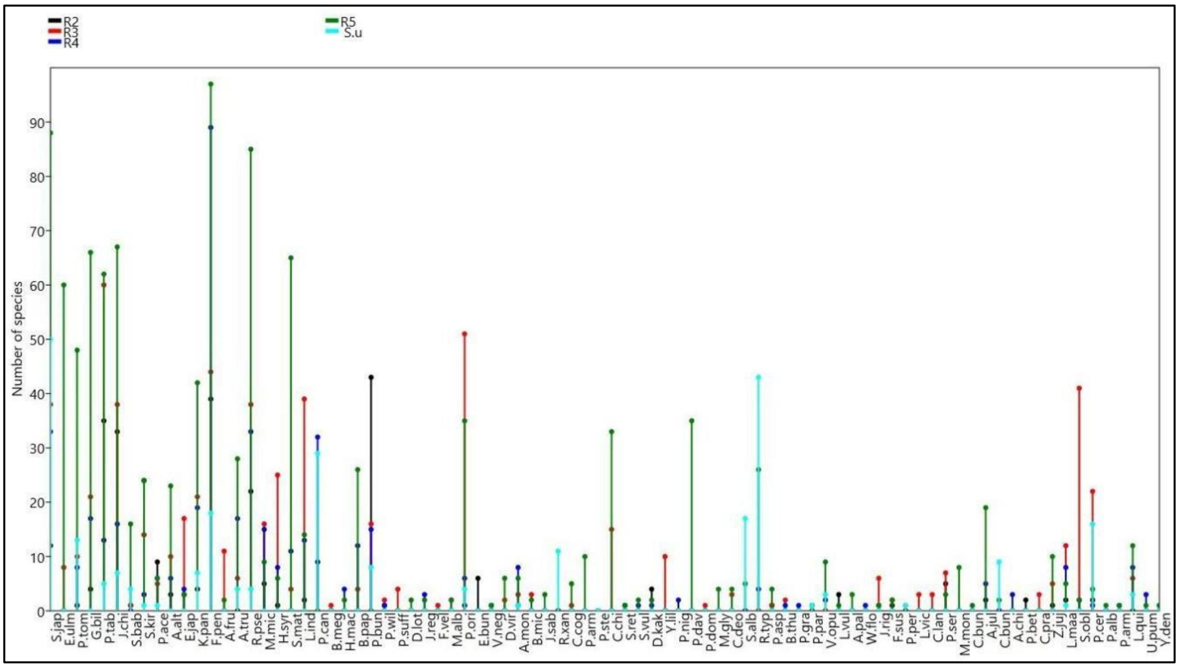


Figure 3.11. Stem style graph with log Y.

3.6 Principal component analysis

Figure 3.12 and figure 3.13 shows the principal component analysis on the basis of DBH and number of plants among different of the data set. Results reveals that the high variation is at the site ring fifth (R5) that shows the positive relation between the PC1. The distance between the ring third (R3) and ring fifth (R5) is approximately same but the angle fluctuates, which shows that density of the tree species in both of these sites are same but the variation of angle reveals the difference in the number of tree species that is the frequency. The ring fifth (R5) in relation with the sub-urban site shows the positive relation with each other but the difference lies between the distances, that reveals that the variation in the number of tree species but the positive relation shows the density of some trees in both of the plots are same.

The variation in the ring second (R2) and fourth (R4) shows the difference in the both density and the frequency of the tree species.

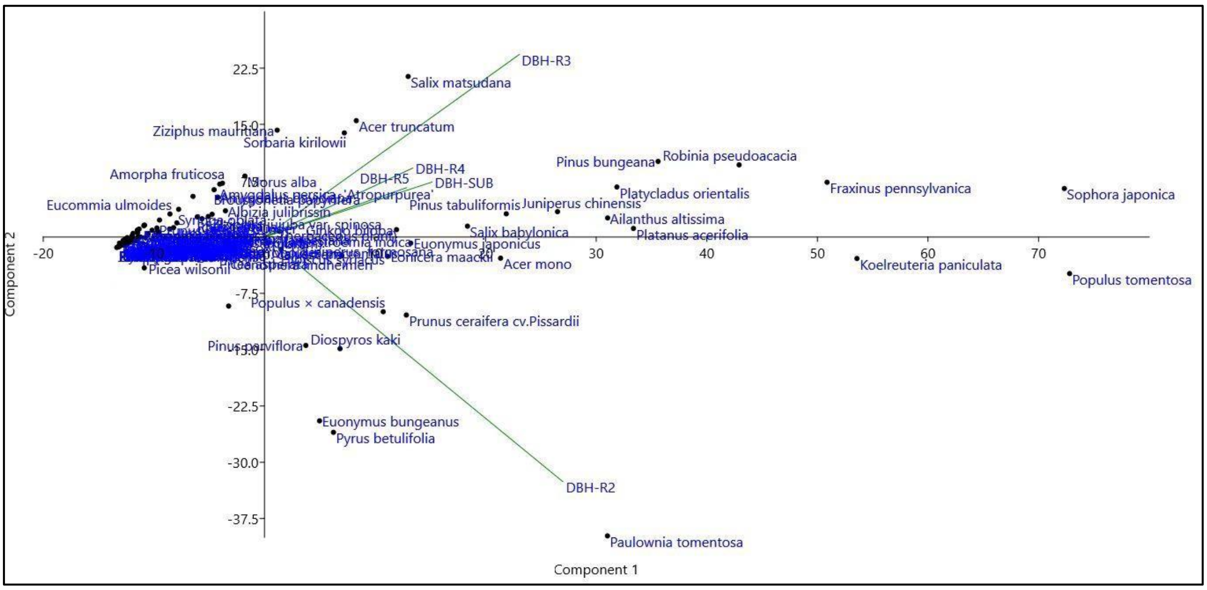


图 3.12 城区不同区域间树木多样性主成分分析

Figure 3.12. Principal component analysis on the basis of species DBH.

PC1 reveals the highest variation of 74.53% among all the studied sites (R2, R3, R4, sub- urban area). Similarly, the PC2 showed less variation (9.79%), followed by PC3 (7.79%), PC4 (4.90) and PC5 (2.97%) (Table 3.8). The greater angle between the biplots of the ring roads showed the high variability while fewer angles between them showed less variability among the studied ring roads.

Figure 3.13 reveals the clear image of the species present on both components of PC, it shows the dense cluster at PC2 that represents the species merge in one another which means the presence of same kind of species in all the plots of study area. PC2 shows the negative relation with all the plots relative to PC1. The highest occurring species both in term of density and frequency mentioned above.

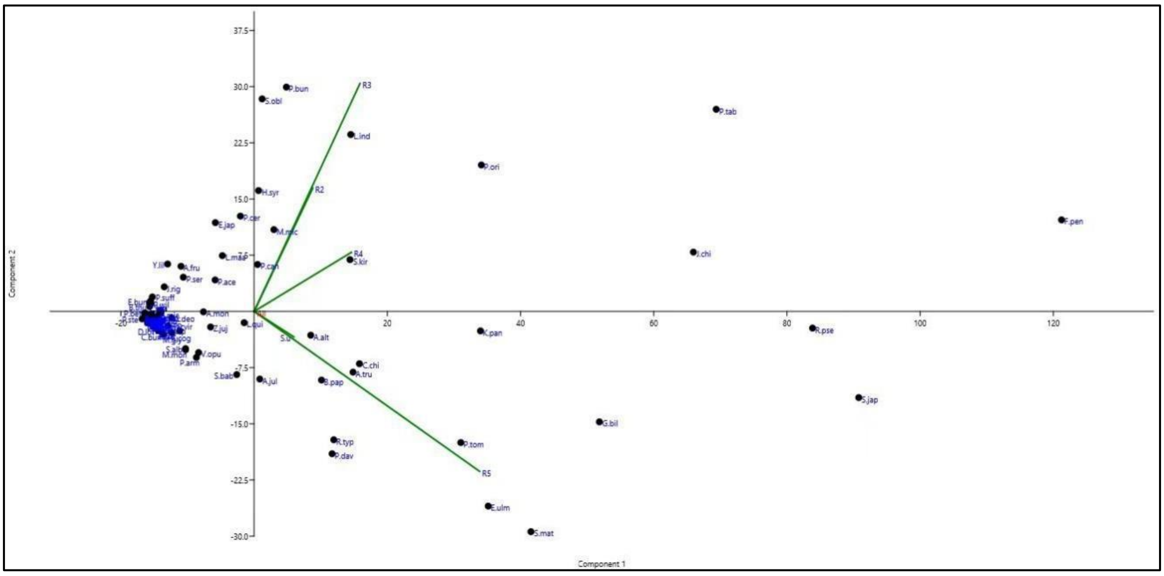


图*3.13* 城区不同区域树种间关系

Figure 3.13. Principal component analysis based on number of species in all the ring roads.

4. Discussion

For each ring-road, Beijing urban forest can be split into five community type based on community appearance. Beijing's urban forest families, genera, and species account for 36, 64, and 99 percent of the city's total plant families, genera, and species, respectively. The overall number of total plants in the fifth ring was greater with 1180 plants, compared to 668 plants in Beijing's third ring, and the overall number is low in the second ring and the sub- urban area, with 279 and 291 plants, respectively. Rosaceae, Sapindaceae, Pinaceae, Oleaceae, and Saliaceae are the most common woody plants in Beijing's urban forest plant group. It also shows some diversity under the artificial interference of urbanization construction due to the influence of strip nature. Local species account for just 86.8% of native species in Beijing, which is a small proportion, whereas introduced species and naturalized species account for 6.00% and 6.00% of the introduced plants in Beijing, respectively. The proportion of foreign introduced species is relatively low, accounting for only 1%, and recent studies show that the trend has shifted from the past, when exotic or foreign species accounted for more than the native one, indicating that managers replaced the exotic woody flora with the native flora of China. There are 86 native species of woody plants, 6 of which are planted at home, 6 of which are foreign species, and 1 invasive species, all of which are less common than native species. Native trees, shrubs, and herbaceous species make up 58.5 percent, 38.3 percent, and 3.3 percent of the wild trees, shrubs, and herbs in Beijing's five rings, respectively. In Beijing's urbanization process, the proportion of native woody plant flora in urban forests is high, and the utilization of native shrubs and herbs flora is insufficient. Shrubs and herbaceous native species, in particular, have a lot of potential for use. Because of the high level of human disturbance, the diversity index varies at different levels in different urban forests, with the arbor tree layer having the highest diversity index and the herbs having the lowest. The slightly higher application frequency of plant species is concentrated in a few species, the majority of which have a very low application frequency, resulting in a single vegetation scene in nearly all of the five ring roads.

During field visits, it was discovered that human interference has a significant impact on the construction of urban forests. We sought to focus our attention in this study not only on the biodiversity indices to measure the amount of biodiversity across the study region, but also on the micro-variations that would exist between the plots of the study area. Furthermore, in the scope of this study, we evaluated the role that vegetation indexes might have in evaluating urban forest degradation or decline in distinct ring-roads. Regarding the Shannon diversity index, our research found that ring-road 2 and the sub-urban plot have lower Shannon indexes of 2.7 and 2.7, respectively, whereas ring-road 3 and 5 have Shannon indexes of 3.7 and 3.7, respectively. Shannon index 3.1 is also seen in the rest of the plot ring-road 4. Many woods are distinguished by a high species richness. In terms of the plantation, our study found less biodiversity heterogeneity in the studied region.

4.1 Urbanization effects on species composition and diversity

A positive relationship was observed between species richness and regional-level urbanization (Ricketts and Imhoff 2003). According to some investigators, urban environments have unusually high spatial habitat variability (Thompson et al. 2003). Such kind of spatial habitat variability can result in very high beta diversity (Niemela 1999) and greater species richness than neighboring rural areas (Wania et al. 2006). According to several studies, plant species richness is higher in suburban areas than in urban and rural areas (Zerbe et al. 2003). Suburban areas were particularly diversified due to the intermixing of urban and rural landscape components (Schmidt et al. 2014). The results of our study showed that species richness and diversity were higher in the urban region (third and fifth rings) than in the second, fourth, and sub-urban, which was consistent with the previous researchers' findings (Wania et al. 2006). In the urban core, species richness and diversity were the lowest (the second ring and sub-urban forests). This anomaly was most likely caused by low urban forest cover (Fig. 5) and high commercial district density, which also contributed to higher species dissimilarity with the remaining gradients.

The principal contributors to all of the ring-roads were two signature species, Sophora japonica and Fraxinus spp., and six dominating species, *Juniperus chinensis, Koelreuteria paniculata, Robinia pseudoacacia, Populus tomentosa, Salix babylonica, Sorbaria kirilowii*, and Platanus spp.. The greater diversity in the third and fifth ring-roads showed that diversity at the species level should be raised in the second and fourth rings, and species diversity should be expanded at the family level in all ring-roads, included suburban green areas. The major forms of urban forests in the third ring were *Fraxinus* spp. *and Platycladus orientalis*, which contributed to the maximum species richness and diversity in different rings. The diversity of species was smaller in the second and fourth rings than in the third and fifth rings. This was mostly due to the fact that parts of these regions were still in the midst of development and building, and the green infrastructure was still in its infancy. As a result, there will be a significant opportunity to increase species diversity in these areas. Understanding species diversity and the key factors to differentiation along urbanization gradients is useful for increasing variety and maintaining urban ecosystem stability by selecting appropriate species.

4.2 Evaluation of urban forest tree species in Beijing

The establishment of an urban forest ecosystem should be based on a careful selection and matching of plants, which should be based on a thorough research of the ecological properties of urban green plants. And woody plants are the skeleton of urban forest formation, is an important component of the landscape, its selection to meet the versatility of greening, and suitable tree, make different tree species can give better play to their advantages, save and protect resources, but also on the landscape effect. Tree trunk, dignified crown, majestic landscape, have become the backbone tree species, dominating a large proportion and becoming the main theme of urban greening level and urban aesthetic and culture, can reflect unique traits and style shrub landscape, various shades, play an important role in determining the efficiency quality of urban forest, there are many different types of garden landscape trees, each with its own unique form, color, charm, aroma, and other attractive qualities. It is critical to investigate the surroundings.

The structural variance ratio of the woody Simpson indexes is the largest, whereas the structural variance ratio of the wood plant Simpson index is insufficient in all directions. The Simpson values for ring-road 2 and sub-urban region are generally low (0.90 and 0.91, respectively), whereas ring-road 5 has the highest Simpson value of 0.957. The utilization of woody plants in the fifth ring road differs from that of the second ring and sub-urban flora. The highest level of the fifth ring. The rest of the ring, from the outskirts to the city center, is developed. Explain how, as cities become more densely inhabited, exotic tree species find less applications. During urbanization, natural ecosystems are replaced by man-made structures, and natural soil is substituted by green spaces characterized by ornamental plants, which has a substantial impact on biodiversity. Many domestic experts believe that species diversity in downtown-suburban-exurbs displays gradient changes with environmental gradient variations and man-made disruption (Zhang and Pickett,1999; MakMing and Fu, 2001). Urbanization is to account for the homogeneity of urban species (Byers,2002; McKinney,2008). Walker discovered in 2009 that as urbanization increases, species richness decreases. A recent study discovered that native species outnumbered invasive species, particularly in the fifth ring of urban forests. As a result of the various methods, locations, and sampling, the results show two trends: the first is that the richness of plant species increases along the urban-urban junction-suburban space with the intensity of urban interference; the second is that the richness of plant species decreases along the urban-urban junction-suburban space with the intensity of urban interference (Moffatt et al., 2004), Another study found that plant diversity within a region tends to increase with the urban development gradient (Honnay et al., 2003), owing to the greater use of exotic plants in urban areas than in surrounding suburbs. McKinney (2006) discovered that urban vegetation cover is quite often greater than that of rural areas especially due to urban components and food intake. Several species' richness has increased over urban and suburban areas at substantially damaged urban and suburban crossings (McKinney, 2008). Our technique of investigation asserted a higher native plant richness in urban –suburban junctions such as urban woods of the fifth ring road, owing to less building and human disturbance in this zone. At the moment, few studies on the effects of artificial disturbance in metropolitan areas exist, and most of them remain at the level of qualitative and semi-quantitative description of events, and few studies can clearly reveal inherent mechanisms of action. The diversity of urban road forests should be increased by a proper and diverse combination of large and small tree species (Nagendra and Gopal 2010). It's worth noting that, as urbanization has progressed, several places have lost their tree cover to make room for building construction and widening activities for the new metro and flyover project (Jim and Liu 2001).

In the future, the influence and mechanisms of plant diversity in urban settings should be recognized as significant study objects, which can be carried out from the following perspectives: First, establish positioning research stations in cities, suburbs, and distant suburbs. Conducting long-term positioning monitoring, Second, carry out research at the molecular level to reveal the physiological and biochemical mechanisms of human interference in urban areas, as well as the genetic basis leading to extermination, in order to uncover the nature of physiochemical victimization at the molecular scale; third, actively carry out international exchanges and cooperation research, to raise the relevant research to a new level, to obtain valuable research results, and To provide a scientific basis for the protection of plant diversity in urban areas, To further improve and protect the ecological environment of the city.

5. Conclusion and Recommendations

The diversity of urban forest species is critical to the stability and operation of the urban ecosystem. Increasing street tree diversity is not a solution for conserving municipal street tree populations at their current levels and, as a result, the ecosystem services and community benefits they offer. Many other factors, such as urban development, state and local budgets, and climate change, have influenced or will influence street tree populations. Even yet, improving street tree diversity by making the most frequent species less common is a significant step toward sustainable street tree management.

This study looked at the species composition of the urban forest in Beijing, China, as well as the effects of forest type and urbanization on the species composition and differentiation of the urban forest. The findings of our study show that there are 55 genera and 36 families and 83 species in the research area, of which 86.8% and 7.0% of utilized tree species are native and localized species. The high homogeneity in composition of greening tree species in woodlands in research area had been found. And the species of poplar (*Populus tomentosa*), locust (*Sophora japonica*), ash (*Fraxinus* spp.), sycamore (*Platanus* spp.), white bark pine (*Pinus bungeana*), Chinese pine (*Pinus tabuliformis*), Chinese juniper (*Juniperus chinensis*), black locust (*Robinia pseudoacacia*) and *Koelreuteria paniculata* have higher important values and higher frequency of utilization comparing with others, and significant values of these tree species are ranked as top 10, utilization rate per tree species was more than 4.0%. In terms of the diversity of ornamental function traits, tree species with leaf enjoyment are mainly dominated species while flowering tree species is only 44.6% and evergreen species is only 11. Spatial difference of the tree species diversity in urban forest was found. The tree species diversity in R5 was the highest, followed by R3, and was the lowest in S-U by synthesizing the 5 biodiversity indices. The tree species evenness in R2 and R5 were lower than that in R3, R4 and S-U, which is closely related to urban forests established for long time in R3 and to urban forest established with richness tree species in R5.

The findings and implications were as follows: (1) The species richness of urban forest in ring road 3 (R3) and ring road 5 (R5) in Beijing China's urban and sub-urban forests is more than in the other ring roads (R2, R4), contributing mostly to the construction of buildings and industries. Native plants were given a high priority in Beijing's urban forest. (2) There was significant species differentiation among different types of urban forests. The species composition and diversity of species were heavily altered by anthropogenic attitudes and management techniques. Replanting and replacing unhealthy trees on Beijing's ring roads 2 and 4 (R2, R4), as well as sub-urban forests, are effective ways to increase the species diversity of the city's urban forests. For urban forest plantations, increasing genus and family variety is essential. The diversity of urban road forests should be increased by a suitable and diverse mix of large and small tree species. To improve ecological stability and anti- interference ability, diversity must be increased at the species, genus, and family levels in rings 2 and 4 (R2 and R4). (3) As urbanization expanded, the species composition exhibited some diversity. The dissimilarity of species composition amid different urbanization gradients is mostly due to the distribution of different types of urban forests. It's worth mentioning that, as urbanization has accelerated, certain areas have been stripped of their tree cover to make way for building construction and widening activities for the new metro and flyover project. As a result, extra care should be given to such trees right away. Furthermore, creating massive areas of landscape forest and boosting native plants around all rings are efficient approaches to improve urban biodiversity. To summarize, understanding species differentiation among different types of urban forests and distinct urbanization gradients is critical for species selection and optimization of urban forests. Furthermore, it will aid in increasing urban biodiversity and improving the stability and resistance to disturbance of urban ecosystems. The findings of a recent study improve our understanding of tree biodiversity and its link with the environment, as well as the appropriate documentation of plantations in Beijing's urban and sub-urban areas. Furthermore, the results will be useful in the formulation and prediction of most appropriate tree species for planting in urban sites that can withstand increased environmental stress and human disturbance. If an inventory is produced, stakeholders, decision-makers, and managers will be able to plant more appropriate trees and conserve other urban biodiversity. The study will also quantify in order to make a more informed decision on how to govern and maintain this urban forest.

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