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RESEARCH ARTICLE

Evaluating the impact of roads on the diversity pattern and density of trees to improve the conservation of species

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Abstract

Roadside trees alter biotic and abiotic factors of plants diversity in an ecosystem. Rows of plants grow along the roadside due to the interplay between the arrival of propagule and seedling establishment, which depends on the road's specifications, land pattern, and road administration and protection practices. A field study was conducted to measure the roadside tree diversity in the city of Karachi (Pakistan). A total of 180 plots, divided into three primary road groups, were surveyed. The highest quantity of tree biomass per unit area was found on wide roads, followed by medium roads. On narrow roads, the least biomass was detected. A single species or a limited number of species dominated the tree community. *Conocarpus erectus* was the most dominant non-native species on all types of sidewalks or roadsides, followed by *Guaiacum officinale*. A total of 76 species (32 non-natives and 44 natives) that were selectively spread along the roadsides of the city were studied. There was a significant difference in phylogenetic diversity (PD), phylogenetic mean pairwise distance (MPD), and phylogenetic mean nearest taxon distance (MNTD) among wide, medium, and narrow roads. Management practices have a significant positive correlation with diversity indices. Our study identified patterns of diversity in roadside trees in Karachi. It provides the basis for future planning for plant protection, such as the protection of plant species, the maintenance of plant habitats, and the coordination of plant management in Karachi.

Keywords Types of roads · Roadside trees · Tree diversity · Non-native trees

Introduction

Plant diversity is an important part of urban green space. It reflects the composition of a city's green space structure, urban diversity pattern, and management level and occupies an extremely important position in the entire ecosystem services (Enssle and Kabisch 2020). The number and configuration of plant species directly affect the ecology of greening function and landscape effect (Berthon et al. 2021). Moreover, roadside plants reflect the characteristics of the geographical environment to a certain extent and even become one of the characteristic signs of the city (Chen et al. 2021a, b).

The urban population is highly dense in metropolitan cities and the pace of urban life is accelerating, with traffic pressure is even greater (Lu et al. 2021). To solve the pressure of traffic and housing, urban roads have been widened, the road network is dense, and there are many tall buildings. This makes the urban hardened ground to increase, the temperature to rise, and the ventilation is not smooth, forming an urban heat island; the increase in vehicles and automobile exhaust emissions aggravate the urban air pollution; on the other hand, roads, buildings, and greening compete for land, which reduces urban green space (Badveeti et al. 2020). The urban environmental pollution problems brought by the process of urbanization are mainly manifested as noise pollution, light pollution, air pollution, and thermal pollution (Bhatti et al.

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2021). Urban plant communities are the basis for building a stable, multilevel, and sustainable green space system and a prerequisite for the urban green space system to exert its ecological functions and enhance the richness of the landscape. Therefore, research on the composition, structure, ecological benefits, ornamental characteristics, diversity, and related evaluation of urban plant communities has attracted more and more attention (Yingying et al. 2021). The study of plant species diversity patterns is the basis of other diversity (genetic diversity, ecosystem diversity, plant landscape diversity, etc.).

Roadside trees in urban systems play a vital role since roadside trees act as local biodiversity reservoirs and reduce atmospheric pollution by having a carbon stock (Xing and Brimblecombe 2020). The roadside ecosystem has significant importance because of its involvement in the diversity patterns of biological life. Various studies have concluded that the ecosystem along the roadside is novel and unique (Lindroos et al. 2021; Lázaro-Lobo and Ervin 2019). Over the last few years, the construction of roads has increased significantly because of the economic growth of countries and the increase in urbanization, which causes new surfaces in different landscapes. Therefore, the soil patterns along the roadside are gradually changing, resulting in a change in plants' diversity patterns (Krigas et al. 2021). Roads and highways are important infrastructures of the national economy, and the gradually increasing density of the highway network is the foundation for sustainable economic and social development. However, continuous construction and maintenance of roads cause the abiotic conditions of the system to change the physical and chemical environment of the surrounding area (Trombulak and Frissell 2000).

The original topography and the continuity of the original structure have been altered due to the huge volume of urbanization and excavation, resulting in a variety of environmental issues, such as soil degradation, environmental contamination, habitat loss, and changes in the original river system, causing air pollution and noise pollution. The environmental role of road greening is reflected in the mitigation of the environmental effect of road-building on the local area, such as dust collection and noise avoidance, air purification, water and soil protection, road temperature control, and biodiversity preservation along the road (Wu et al. 2019). The greening of urban roads is designed according to the form of the road, and therefore, it generally has linear characteristics. From this perspective, the greening of urban roads needs to be extended according to the actual needs of the road. Moreover, the planted varieties are diverse and have strong temporality. These varieties have different characteristics in different seasons. Therefore, the landscape of the entire city will also have seasonal changes, and the streetscape landscape effect is better (Zhao et al. 2020).

The rise of cities led to the decline of plants. In today's cities, the original vegetation has disappeared, and the existing green vegetation is man-made (Deacon and Samways 2021). Due to the decline of the urban natural environment, the number of urban plants has decreased, and the diversity of species is extremely less (Sol et al. 2020). Due to the intensification of urbanization, the spatial heterogeneity of the urban environment has decreased (Hu and Xu 2018), resulting in a decrease in the types of urban birds and a change in their composition, forming a relatively simple community of a few dominant species. These dominant species, such as house swallows, house martins, and sparrows, are the only birds that utilize artificially constructed nests. Another study reveals the important fact that the gradual decrease in urban biological species leads to a decline in biodiversity (Chen et al. 2021a, b).

Roadsides create new opportunities for the relationship between different species and, in some cases, help provide segmented ecosystems for different types of plants that have different growth patterns (Walsh et al. 2008). The age of the road provides significant information related to the plantation and habitat along the roadside. Only a few studies have focused on the temporal patterns of plant diversity along the roadside and the conditions of vegetation on these fragments. However, road age is not the only significant factor in the appearance of invasive species, as transportation is also a facilitator for the invasive species and causes them to spread out along the roadside (Hansen and Clevenger 2005). Many studies have concluded that the ecosystem damage and transfer of invasive species along the roadside are due to transportation (Crowl et al. 2008; Schwartz et al. 2006). Shams et al. (2020) conducted a study of flora diversity in the last 20 years in Karachi City and highlighted that the eucalyptus was extensively planted during the 1980s and 1990s along the streets, which was later removed due to their fast-growing roots and shoots that damaged many civic services.

A strategy for quantifying biodiversity is to assess phylogenetic diversity (PD), mean pairwise distance (MPD), and mean nearest taxon distance between organisms in a community, i.e., measuring the evolutionary history (or branch lengths) between taxa (Staab, 2021; Vellend, 2011). The original PD metric (PD) measures the total evolutionary distances among taxa in a community (Faith and Baker 2006). Since the introduction of the initial PD metrics over 20 years ago (e.g., Faith 1994; Purvis and Hector 2000; Foote 1997), multiple indices have been developed. Some metrics have been reviewed in attempts to distinguish them and their applications (Faith 2018; Tucker et al. 2018), but they have not all been applied in an empirical comparative study such that the differences between roadside trees can be detected.

With the continuous improvement of people's living standards, people have higher requirements for the environment. As an important part of urban infrastructure construction, the construction of urban roads has also received much attention.

Moreover, to improve the quality of urban road construction, it is necessary to consider road landscape design and optimize plant species. Only in this way we can effectively change the ecological environment of the city and create a wonderful visual experience for people's daily travel. Due to increasing importance and awareness, there is still less knowledge of species diversity analysis in metropolitan city Karachi. Due to continuous development and infrastructure planning, the diversity pattern is in continuous changes and even some roads contain no trees. Furthermore, road size and traffic also change with time, causing a different impact on the human health of different areas of Karachi. As mentioned previously, many studies have focused on the diversity of roadside plants and animals; however, few studies have focused on the analysis of the patterns of diversity along the roadside. The deficiency of knowledge and the importance concerning roadside trees in Karachi influenced us to study the roadside diversity pattern of trees. This study focuses on the analysis of the biodiversity patterns along the roadside and highlights the changes in the diversity patterns of plants by assessing the species richness, evenness, and biomass of trees. This study is focused on the diversity pattern, composition, tree density, and taxonomic diversity of the roadside tree community. Therefore, this article investigates the composition and configuration of plant species along the main streets of the metropolitan city Karachi in Pakistan, which will help in improving the quality of the diversity patterns and their ecological impact on the city.

Material and methods

Study area

We selected the metropolitan city Karachi, which is the most populous city in Pakistan and the sixth-largest city in the world (Govt. of Pakistan 2021). The reasons for selecting this city are the continuous development of roads and the implementation of new projects for underpasses under bridges. In 2009, the government began a monocultural mass planting of *Conocarpus erectus*, a coastal wetland tree native to the Americas (Shams 2016). There are three physiographic divisions of Karachi: (1) coastal area with mud or sand, (2) hilly area having a height of 580 feet, and (3) lower alluvial valleys of the Hub and the Malir River (Chaudhri 1961).

This study highlights the significance of diversity patterns for the government for planning the roadside tree species. Karachi is located at 24° 45′ N to 25° 37′ N and 66° 42′ E to 67° 34′ E along the coast of the Arabian Sea (Fig. 1a shows geospatial locations of studied sampling points), and it is 8 m above sea level (KMC 2021). The weather of Karachi is warm in the summer and moderate in the winter. In the summer, the temperature is between 25 and 35°C, and there is an average rainfall of 174.6 mm yearly. The winter is from the end of November to the beginning of February, and the daily average temperature is between 16 and 21°C. The winter is mostly dry, while the summer is mostly wet with high humidity. According to the 2020 World Population Survey, around 16 million people were living in the city, which covers an area of 3580 km^2 (Karachi Metropolitan Corporation, 2020). This study examines the diversity pattern, composition, tree density, and taxonomic diversity of the roadside tree community. Some of the famous and long-distance roads are I. I. Chundrigar Road (2.2 km), M. A. Jinnah Road (6.1 km), Napier Road (1.6 km), Zaibunnisa Street (1.1 km), Shahrah-e-Faisal (18.0 km), Rashid Minhas Road (3.0 km), New Muhammad Ali Jinnah Road (6.1 km), and Nishtar Road (5.6 km). The study area of Karachi is shown in Fig. 1a, b.

Data collection

To examine the diversity pattern along the roads, categories of roads are divided into wide (24 m or wider), medium (12 to 24 m wide), and narrow (less than 12 m wide) roads (Nagendra and Gopal 2010). Roads of Karachi which are in the wide category are known as the main roads and are more in length than other road types. The linking roads between these wider roads are medium. Usually, narrow roads are narrower than these two types. The local government department manages roads, while the Directorate of Parks and Horticulture of Karachi Metropolitan Corporation manages and cares for trees. We used R software packages "ape" and "picante" to estimate MNTD and PD.

The sampling plots were chosen with the aid of Google Earth (https://www.google.com/earth/) and by using a GPS device to record the location of plots on each road. On each road, the 3 locations were randomly selected with a distance of more than 1 km at least, and further detail of roads and survey period is shown in Table 1(GPS locations shown in Fig. 1b). All selected roads have characteristics of road width as wide, medium, and narrow. The attribute lines are the width of each lane on each side of the road. On all types of roads, a total of 180 plots have been measured; each type of road has equivalent parcels. The key details calculated at the point of sampling are the name of the tree species, the number of branches, the diameter (cm), the height (cm), and the width of the crown of each roadside tree. The strength of the management of each type of road was ascertained in interviews with maintenance staff and local people.

Data analysis

Species diversity data

To identify the species diversity in the plant community, the plant species diversity index was used as the most simple and

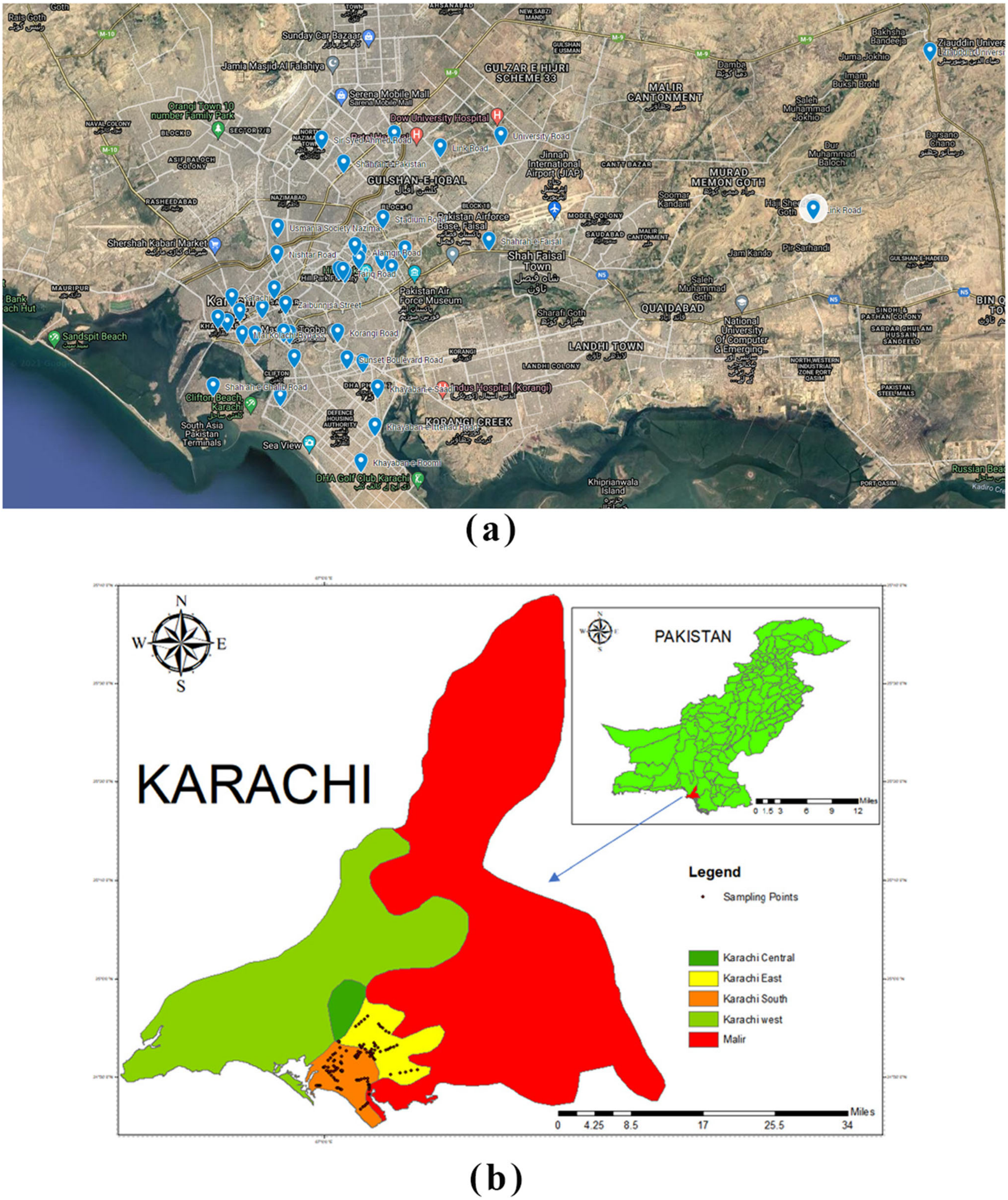

Fig. 1 a Geo-coordinates of sampling points in Google map. b Study area with sampling points

succinct attribute, and the Simpson diversity index was used to assess ecosystem stability (Rad et al. 2009). Biodiversity can be quantified in many ways, and there are two major factors: richness and uniformity (evenness). Species richness does not consider conceptually how many individuals (in the sample) each species has. It gives the same weight to a species with a small number of individuals as a species with many individuals. Uniformity refers to the relative abundance of

Table 1 Number of different sampling points and date of the survey carried out

Row labels	Number of sampling point	Category	Survey period
5000 Link Road	2	Narrow	20 July 2020 to 25 July 2020
5001 Link Road	2	Narrow	20 July 2020 to 25 July 2020
5002 Link Road	2	Narrow	20 July 2020 to 25 July 2020
5003 Link Road	2	Narrow	20 July 2020 to 25 July 2020
5004 Link Road	2	Narrow	20 July 2020 to 25 July 2020
Alamgir Road	4	Narrow	20 July 2020 to 25 July 2020
Allama Iqbal Road	4	Narrow	20 July 2020 to 25 July 2020
Amir Khusro Road	4	Narrow	20 July 2020 to 25 July 2020
Beach Avenue Road	4	Narrow	20 July 2020 to 25 July 2020
Burns Road	4	Narrow	20 July 2020 to 25 July 2020
Clifton Road	4	Narrow	25 May to 2 August 2020
Dr. Ziauddin Ahmed Road	4	Narrow	25 May to 2 August 2020
G. Alana Road	4	Narrow	25 May to 2 August 2020
Habib Ibrahim Rahmatullah Road (Karsaz Road)	4	Medium	25 May to 2 August 2020
Hoshang Road	4	Medium	25 May to 2 August 2020
I. I. Chundrigar Road	4	Medium	25 May to 2 August 2020
Jamalludin Afghani Road	4	Medium	25 May to 2 August 2020
Khalid bin Waleed Road	4	Medium	25 May to 2 August 2020
Khayaban-e-Iqbal	4	Medium	25 May to 2 August 2020
Khayaban-e-Ittehad	4	Medium	25 May to 2 August 2020
Khayaban-e-Jami	4	Medium	4 June 2020 to 2 July 2020
Khayaban-e-Roomi	4	Medium	4 June 2020 to 2 July 2020
Khayaban-e-Saadi	4	Medium	4 June 2020 to 2 July 2020
Korangi Road	4	Medium	4 June 2020 to 2 July 2020
M. A. Jinnah Road	4	Medium	4 June 2020 to 2 July 2020
Mai Kolachi Bypass	5	Medium	4 June 2020 to 2 July 2020
Moulvi Tamiz-Uddin Khan Road	5	Medium	4 June 2020 to 2 July 2020
Napier Road	5	Medium	4 June 2020 to 2 July 2020
Nazimabad A Road	5	Wide	4 June 2020 to 2 July 2020
Nishtar Road	5	Wide	4 June 2020 to 2 July 2020
Rashid Minhas Road	5	Wide	4 June 2020 to 2 July 2020
Shaheed-e-Millat Road	5	Wide	8 October to 20 October 2019
Shahrah-e-Firdousi	5	Wide	8 October to 20 October 2019
Shahrah-e-Ghalib	5	Wide	8 October to 20 October 2019
Shahrah-e-Pakistan	5	Wide	8 October to 20 October 2019
Shara-e-Faisal	5	Wide	8 October to 20 October 2019
Sir Syed Ahmed Road	5	Wide	8 October to 20 October 2019
Stadium Road	5	Wide	8 October to 20 October 2019
Sunset Boulevard	5	Wide	8 October to 20 October 2019
Tariq Road	5	Wide	8 October to 20 October 2019
Tipu Sultan Road	5	Wide	8 October to 20 October 2019
University Road	5	Wide	8 October to 20 October 2019
Zaibunnisa Street	5	Wide	8 October to 20 October 2019
Total samples	180		

different species (abundance), which complements each other and makes up. Diversity increases with the increase in species richness and uniformity (Hurlbert 1971). The Simpson diversity index considers both richness and uniformity (Simpson 1949). We used indices of species diversity from Simpson (1949) and Pielou (1966). The computational formulas are clarified as follows:

1. Species richness (S) refers to the number of species of trees in each systemic urban unit.
2. The Simpson diversity index (D) corresponds to the possibility that two consecutive samples of a population that belong to the same species derive the corresponding number of individuals:

$$D = 1 - \sum_{i=1}^{n} Pi^2 P_i^2 = \frac{n_i(n_i - 1)}{N(N-1)} \tag{1}$$

This reflects the probability that two individuals are randomly selected from the same sample, and the two individuals are from the same class. The value of N is between 0 and 1, where 0 means unlimited diversity and 1 means no diversity, that is, the larger the D value, the lower the diversity.

The Pielou evenness index (J) applies to the distribution in a group or society of the number of individuals:

$$J'_e = \frac{H'_e}{H'_{emax}} \tag{2}$$

The value of Pielou's evenness lies between 0 (no evenness) and 1 (complete evenness).

Calculation of aboveground tree biomass

Xue (2016) summarized a vast volume of data and used the model-fitting approach for Haikou's tree biomass to estimate and synthesize the following formula. We used it to quantify the biomass of the urban functional units of the aboveground trees:

- AGB: aboveground biomass of trees (g)
- DBH: diameter at breast height (cm)
- Height: tree height (cm)
- Wood density: wood density (g/cm^3)

The wood density of every species was derived from the TRY trait database (https://www.try-db.org/TryWeb/Home.php).

Taxonomic and phylogenetic diversity

For each map, we also estimated the number of species, mean phylogenetic distance (MPD), mean nearest taxon distance (MNTD), and phylogenetic diversity (PD). Over millions of years, PD is the sum of evolutionary history (Cadotte et al. 2010). The average distance between an individual and the most closely connected (non-conspecific) individual is the MNTD. The MNTD in terminal branches is influenced by phylogenetic distance (Mazel et al. 2016).

Results

Overall, lower indices of species richness and diversity were observed. The range of species richness was 4.27–2.44, the range of the Simpson diversity index was 0.62–0.32, and the range of Pielou's evenness index was 0.31–0.26. Maximum richness and diversity were observed along wide roads, followed by medium roads and then narrow roads (Fig. 2).

Conocarpus erectus had the largest number of trees and was followed by *Guaiacum officinale*. The native species *Azadirachta indica* had the largest number of trees, followed by *Ficus virens*. Overall, 32 non-native and 44 native specimens were found. On all path types, non-native species accounted for 79.16%, and native species accounted for 20.84% of the tree population. The flowers of common species of non-native trees observed in the region are shown in Fig. S1. The non-native *Conocarpus erectus* constituted 61.87% of the total tree population, and it was followed by *Guaiacum officinale* with 9.02%. The native *Azadirachta*

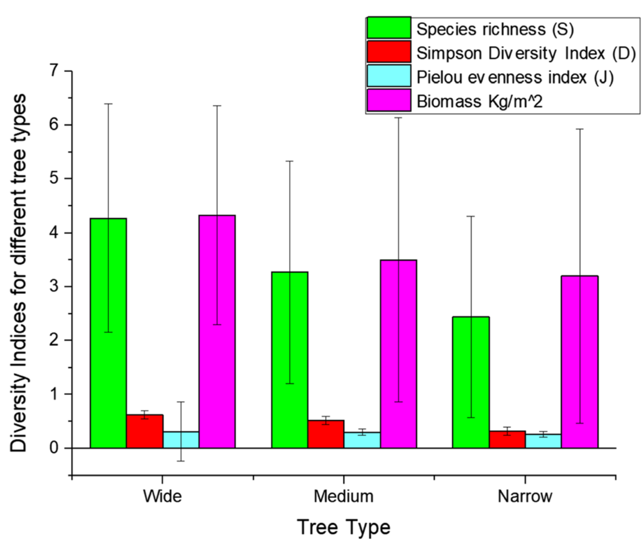

Fig. 2 Diversity indices for different tree types

indica accounted for 8.51% of the entire tree population, and it was followed by *Ficus virens* with 2.47%. The relative distribution of the non-native species was greater than that of the native species in the field under study. Optimum maintenance activities perform in a manner that maximizes benefit avoid abnormal growth with affect traffic. Wide roads and medium roads have optimum maintenance activities (Table 2 and Fig. 3). Furthermore, 14 indigenous tree species are at high risk (Table S1 and Table S2). High risk means a high level of danger and if they were not conserved properly will disappear soon from the area.

The study found that the PD, MPD, and MNTD of non-native tree species were higher than those of native tree species. The PD, MPD, and MNTD of wide roads were higher than those of medium and narrow roads for non-native and native tree species (Table 3). Analysis of variance results reveals that a statistically significant difference was observed among three road types for all diversity indexes and management practices (Table 4).

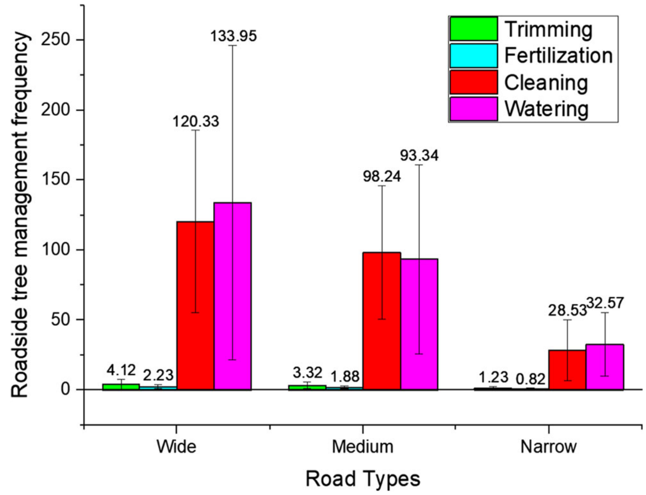

Fig. 3 Roadside tree management activity

Discussion

Importance of roadside tree communities

In the last few years, numerous studies demonstrated the effects of roads and their sidewalk characteristics on the distribution and dispersal of plant species (Shams 2016). However, this study focuses on the roadside tree diversity in a metropolitan city, which attracts attention to diversity patterns in an urban ecosystem. Results showed the strong superiority of *Conocarpus erectus* along the roadsides of Karachi, followed by *Guaiacum officinale* (Tables 4, S1 and S2). Analysis of variance reveals a significant difference among the three road types for all diversity indices and management practices (Table 4). The non-native species accounted for 79.16%, and the native species accounted for 20.84% of the tree communities along with all road types, the same as the results reported by Shams et al. (2020). The diversity pattern of the roadside species in Karachi is similar to the tree community structure of five American municipalities at the end of the 1980s (McPherson and Rowntree 1989). Conversely, the prevalence of *Conocarpus erectus* is more important along with all road types since the plant has been grown extensively in the past decade. The typical DBH of the *Conocarpus erectus* is smaller than that of the tree community's native species. Upright trees with a large diameter were not commonly found along urban roads in the research. Trees on a wide scale with a high DBH are the major tree species on American urban paths. In comparison, they are much older than those in Karachi (McPherson and Rowntree 1989).

Roadside trees provide habitat and serve as dispersal routes for different types of plants, including threatened, expansive, weed, and exotic species, which can disperse to the adjacent landscape and exert a negative impact on the environment (Lázaro-Lobo and Ervin 2019). Non-native species have been introduced in different projects for the development of the green environment by the government (Shams et al. 2020). Usually, civilian agencies grow and care for road trees. Residents typically plant trees along the roads near their homes. This boosts the food access of other animals and decreases monoculture. Residents generally grow *Azadirachta indica* due to the preference for native species. Multiple species are more immune to viruses, predators, and infections than a single species (Shams et al. 2020).

Moreover, planting a single species requires lower maintenance costs. However, huge costs for its elimination and reconstruction can be sustained within a few years due to disease infection or aging of the dominant species (Dobrzański et al. 2020). Planting road trees alone has caused significant damage in various metropolitan regions of the world. For example, millions of American elm trees (*Ulmus americana*) extensively planted along

Table 2 Frequency of roadside tree management variables per year

Road types	Trimming	Fertilization	Cleaning	Watering
Wide	4.12 ± 3.42	2.23 ± 1.45	120.33 ± 65.12	133.95 ± 112.32
Medium	3.32 ± 2.21	1.88 ± 1.10	98.24 ± 47.48	93.34 ± 67.54
Narrow	1.23 ± 1.01	0.82 ± 0.41	28.53 ± 21.67	32.57 ± 22.65

Table 3 Mean value of PD, MPD, and MNTD of three road types in Karachi

Road types	Non-native PD	Native PD	Non-native MPD	Native MPD	Non-native MNTD	Native MNTD
Wide	1366.51 ± 345.88	549.75 ± 146.86	297.41 ± 34.50	151.77 ± 35.97	145.16 ± 35.68	125.81 ± 44.12
Medium	1086.57 ± 265.88	463.59 ± 122.36	195.57 ± 29.29	134.08 ± 35.59	127.01 ± 28.77	120.40 ± 34.63
Narrow	836.53 ± 165.88	320.87 ± 104.36	184.23 ± 31.99	126.68 ± 32.76	110.45 ± 33.88	109.82 ± 24.69

Note: *PD*, Faith's phylogenetic diversity; *MPD*, phylogenetic mean pairwise distance; *MNTD*, phylogenetic mean nearest taxon distance

North American roads have been destroyed due to Dutch elm disease (*Ophiostoma ulmi*). The risk of damage caused by rodents, viruses, insects, and environmental changes is reduced by increased taxonomic diversity in roadside tree communities (Schaafsma and Bartkowski 2021).

The extensive cultivation of exotic species in Karachi is another area of concern. Alien species are less suitable for agriculture in urban areas than native species. Furthermore, native roadside trees have more range and density than tropical trees (Singh et al. 2020). Conversely, the occurrence of mistletoe in foreign species is even greater relative to native species (Cocoletzi et al. 2020). However, with the stability of the urban ecosystem, foreign and indigenous animals have the same ecological resources (Zhang et al. 2017). In under development urban areas, many non-native species have better ecological services than native species. Civilian organizations prefer to utilize alien species mainly because of their accelerated expansion; this is primarily due to the presence of government departments, thereby growing the proportion of coastal cities. It is worth recalling that this study found that species diversity was smaller along Karachi's roads than in 22 cities in the United States (McPherson and Rowntree 1989). and South Africa's Eastern Cape Province (Gwedla and Shackleton 2017).

Variation of aboveground tree biomass in urban functional units

Our analysis revealed that on large paths, the aboveground tree biomass per unit area significantly exceeded that of other urban functional units. This suggests that the density of species is high and/or the number of trees on wide roads per unit area is significant. The greening rate of this region is one explanation for the fluctuations in tree biomass along large roads. Via land-use adjustments, the trees used for natural resources will be preserved, and this positive pattern has been seen in many places (Wang et al. 2018). Increasing global changes and accelerating urbanization and quantifying the function of urban forests play an important role. Jaman et al. (2020) did the investigation of land cover change and woody plant diversity in Dhaka city; the relationship between land cover change and coastal vegetation distribution and biodiversity is analyzed, and based on the improved volume source biomass method, the calculation of the impact of coastal landscape fragmentation on the carbon storage of forest ecosystems is aimed at providing a scientific basis for the allocation of urban greening species under the background of building a low-carbon city in Dhaka. Pike et al. (2021) found that trees used for natural goods have been maintained for financial and decorative reasons on private property. The practical uses of

Table 4 Analysis of variance of diversity indexes and management practices among three road types

	Degree of freedom	Sum of squares	Mean squares	*F*	*P*
Species diversity (S)	2	93.62	46.81	12.1	0.0000
Simpson diversity index (D)	2	2.82	1.41	241	0.0000
Pielou evenness index (J)	2	0.074	0.037	11.7	0.0000
Native.PD	2	1,544,255	772,127	15,218	0.0000
Nonnative.PD	2	7,907,736	3,953,868	12,906	0.0000
Native.MPD	2	21,438.9	10,719.4	317	0.0000
Nonnative.MPD	2	476,704	238,352	3507	0.0000
Native.MNTD	2	6707.7	3353.85	124	0.0000
Nonnative.MNTD	2	37,079.9	18,539.9	429	0.0000
Cleaning	2	262,466	131,233	4793	0.0000
Fertilization	2	51.86	25.93	56.9	0.0000
Trimming	2	112.421	56.2105	88.3	0.0000
Watering	2	301,715	150,857	7958	0.0000

urban greenspace for individuals are illustrated by urban inhabitants (Song et al. 2020). The superiority of species with desirable and emblematic characteristics was further illustrated by studies of trees in Hong Kong (Stange et al. 2020).

Taxonomic diversity and PD

The PD, MPD, and MNTD values of the trees were significantly different between wide, medium, and narrow roads. The composition of the plants in Karachi has been influenced by changes in management frequency and type of road (Nizamani et al. 2021). Human management and environmental factors have been closely linked to plant diversity (Chen et al. 2018). Various applications of fertilizers, pests, and pathogen attacks that caused varying habitat conditions among the vegetation formations have led to different plant diversity patterns. Karachi has many important tourist attractions that have also impacted the diversity of the plants. Mangubhai et al. (2020) found that, particularly in the coastal regions, tourism-related practices contribute to biodiversity loss. The number of ornamental plants on the study site is high because of tourism. For beauty and leisure, native and invasive plants were introduced at the same time. On the large paths, PD, MPD, and MNTD values were the highest. This showed that plant diversity was high; the phylogenetic structure was over-dispersed due to the enormous phylogenetic gap between plants. Fewer management practices were implemented along the narrow roads. Roadside trees here were planted decades ago and added to the plant diversity. On the narrow roads, PD, MPD, and MNTD values were the lowest, indicating that the phylogenetic structure of the species is clustered, and the diversity of the plants is significantly lower. These results may have been because narrow roads have a more stressful environment for plants due to human activities. Since species sharing traits along near-phylogenetic lines may have similar environmental reactions, extreme environmental conditions are likely to be associated with species, leading to low species resources and low PD. PD may be related to the species richness distribution pattern along narrow roads. In a population, lower species diversity contributes to reduced PD (LaManna et al. 2017).

The damage to the radiation and surface soil along the line is one of the most significant and intuitive effects (Wemple et al. 2018). The initial stage of roadside construction will completely clear the resettlement and topsoil within the land occupation boundary. This is the most important stage of resettlement and topsoil destruction, which will cause a large amount of biomass loss and soil erosion along the line. The large area of exposed ground formed by the excavation of highway construction is not a difficulty in the reconstruction and restoration of roadside construction and will adversely affect the stability of the local ecosystem in the future (Jiayin et al. 2020). The local plants with parasites distributed along the highway are characterized by good landscape integration, which is of great significance for maintaining the stability of the local ecosystem. Quantifying plant biodiversity in tropical forests is a major challenge. Increasingly, large-scale synthetic studies are attempting to meet this challenge but are limited by insufficient species occurrence data that is exacerbated by taxonomic uncertainties.

To quantify tropical forest biodiversity fully depends upon accurate species identifications, and Draper et al. (2020) elaborated that these can be achieved by using an integrated synthesis of technological approaches including spectroscopy, DNA sequencing, and image recognition, alongside traditional morphological approaches to species delimitation and identification. The topsoil along the road is also a type of scarce, non-renewable, and important ecological soil surface in nature. The basic resources of value, including the cultivated layer of cultivated land; the surface and humus layers of the garden, woodland, and grassland; and the content of organic matter, microorganisms, and local seeds, are most beneficial to the rapid restoration of soil fertility and plant growth. Radiation and topsoil along the highway are an important part of the local ecosystem. Therefore, studying the characteristics of plant species diversity patterns and soil environmental quality along the highway is of great significance for roadside environmental protection and green highway construction. In the future, this work can be extended with aboveground biomass and belowground biomass with different metropolitan cities.

Conclusion

To assess the taxonomic and phylogenetic richness of roadside trees in Karachi, the financial hub of the country, we utilized a variety of approaches. In our study site, the richness and composition of plants were significantly affected by road types. Our study revealed the link between diversity and the structure of the community. Although few species are dominant, it is vital to plant other species that are more eco-friendly and helps in improving the ecological system. Effective roadside management is highly important to reduce the viability of exotic/weed populations while facilitating the presence of desirable species. To create productive and balanced urban forests, trees with a high degree of taxonomic diversity must be spread equally along the roads. The tree community must not be governed by one or two species. In urban tree ecosystems, the proportion of any single species does not exceed 5%. In Karachi, more than 50% is constituted by one single species. This study recommends planting more trees along the roadside because they increase urban greening, make the environment more sustainable, and help maintain plant diversity. Our research offers information that helps to control habitat protection and resources for the environment. In the future, this research will be expanded towards urban parks and highway roads to study the further impact of plant diversity in urban areas.

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Data availability statement All data is available in a tabular format inside the paper.

Author contribution Uzair Aslam Bhatti and Zhaoyuan Yu were responsible for data collection; Ahmad Hasnain, Saqib Ali Nawaz, Linwang Yuan, Luo Wen, and Mughair Aslam Bhatti did data analysis; Uzair Aslam Bhatti, Zhaoyuan Yu, Ahmad Hasnain, Saqib Ali Nawaz, Linwang Yuan, Luo Wen, and Mughair Aslam Bhatti wrote the manuscript and were involved in text corrections. All the authors read and approved the final manuscript.

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Declarations

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