Chapter

Using GIS and the Diversity Indices: A Combined Approach to Woody Plant Diversity in the Urban Landscape

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Abstract

Thanks to their recreational and psychological functions as well as plant diversity, open and green spaces in a city improve the life quality of the urban inhabitants. Woody plant diversity has significant value in urban green systems. The main purpose of this study was to determine the biodiversity values and the potential of the urban green infrastructure via floristic and spatial analyses of woody plant diversity. To this aim, field studies were carried out on the open and green infrastructure in selected areas of Duzce, having different spatial characteristics. The contribution of the identified species to urban biodiversity was examined as well as the spatial characteristics of the species in terms of landscape architecture. In this study, both statistical analyses (alpha and beta diversity of the species) and GIS analyses (species density and spatial distribution) were carried out. According to the results of the research, the most common of the 173 plant species detected were *Cupressocyparis leylandii* and *Tilia tomentosa*, found in the open green areas. As a result of the study, it was found that using the floristic diversity indices and GIS jointly enabled the UFD (Urban Floristic Diversity) of the city to be defined both statistically and positionally.

Keywords: Diversity index, floristic diversity, Geographic Information System (GIS), spatial density analysis, urban plant diversity

1. Introduction

In spatial diversity for many ecosystems, plant diversity is linked to the heterogeneity of resource availability [1]. However, the diversity of plants in cities can reflect social, economic, and cultural influences as well as the traditionally described ecological theorems [2]. Although urban areas have lost biodiversity in recent years, many plants, including endangered species, can grow and develop in cities [3]. For example, the diversity of woody species in Black Sea cities of Turkey and their environs is quite considerable, with tens of thousands of plant species representing a large source of biodiversity [4]. The temperate zone located around central Turkey is an attractive field in terms of plant diversity and features a great biogeography of genes that are different from those of many countries. However, no special interest has been shown in this wealth.

Turkey, because of its geological structure, soil composition, and different features due to varying climatic conditions, is one of the few countries worldwide that include the typical plants and characteristics of three distinct flora. Turkey with its extremely rich vegetation is a center and home to many plant species and genes present in the world [5, 6]. The advantage of this situation is that many studies have been conducted examining the plant diversity of landscape architecture in Turkey. The majority of these works were carried out in natural environments and are mostly based on flora detection [7–9]. However, in urban and designed areas, researchers have not only determined the plant material, but have also studied certain plant design elements and principles [10, 11], the importance of plant material [12], plant size and forms [13], seasonal changes of plants [14], plant compositions [15], problems in planting areas [16], the current status of plants [17], and the future status of plant issues. Nevertheless, the presence of plants important for cities also contributes significantly to urban biodiversity, although studies on the density, distribution, and diversity of these plants have not been compiled. The fact should not be ignored that examining the density of plants, especially in one area, can contribute as well to many different fields such as urban permeability, air purification, and wildlife development. The open green spaces in cities represent important parts of the ecological system by hosting many animal and plant species. However, the loss of green areas as a result of urbanization threatens urban biodiversity.

Düzce is located in zone A3 according to the grid system of [18] and has quite variable geomorphological landforms, climate types, and habitats [9]. The region is rich in herbaceous and woody species and hosts 700 different plant species, 10% of which are endemic [19]. A great deal of domestic and foreign research has been conducted on the plant material in the open and green areas of the city. In these earlier studies in the field of landscaping, the research area was visited and the use of the design was interpreted by advancing in line with the identification and counting of the plants [20–22], examination of plant patterns [23], and analysis of the context of composition [24]. However, individual plants were identified on the basis of species points and their general characteristics, but their mapping with the coordinate in which they actually were located and their contributions to the urban green infrastructure in terms of floristic diversity were not examined together.

The Geographic Information System (GIS) is a computer-based system for mapping and analyzing all kinds of data that are available on the earth [25]. It is a system of equipment and methods designed to solve complex planning and management problems, including the querying, processing, analysis, modeling, visualization, and management of data located in a space. It depends on spatial data, verbal and graphical information, etc., and has a structure that stores this data in an integrated way [26]. In landscape architecture, GIS studies refer to point and spatial analysis and evaluations, and to planning and decision-making stages on a much higher scale. Based on the assumption that plant density will be a very important underpinning for many phenomena in the city, and especially for urban green infrastructure, GIS was handled in a different dimension within the scope of our research, and the data were analyzed in a GIS environment with its spatial feature.

In this study, identification and determination studies were carried out for woody plant species in open and green areas in the city center of Duzce. The spatial and functional statuses of the species were evaluated. The aim of the study was to determine the types and numbers of plants used in different places in the city center such as the parks and playgrounds, shopping centers/squares, public and residential gardens, pedestrian and vehicle roads, the cemetery, and places of worship (mosques). According to the data obtained, the contributions of plant species to urban biodiversity were evaluated in terms of their spatial characteristics and esthetic and functional aspects. To this purpose, data were collected on six different space types in the city center and then evaluated according to alpha and beta diversity indices in order to reveal the woody plant diversity (WPD) status in the research area. Here, we used the data obtained from the sample-based field study to investigate the change in plant diversity in a large area in the city center by using statistical analysis of woody plants including trees, shrubs, and hedges. Plant diversity is important in predicting the biodiversity for the entire ecosystem [2]; therefore, in this study, we focused on the spatial variation in woody plant diversity.

The diversity of plant species should be considered due to its importance in helping determine the performance and future community composition of existing species [27, 28]. Studies have been conducted on the relationships between species diversity and habitat characteristics, and these have generally focused on the relationships between alpha diversity and habitat characteristics [29–31]. Within the scope of our research, the diversity status of the plant species detected in the open green areas of the Düzce city center was evaluated at alpha and beta levels.

The parameters of species diversity, urban green infrastructure relations, and positional characteristics of the plants were all considered together in this study, which included:

I. Determining the UFD (Urban Floristic Diversity), not only statistically, using floristic diversity indices, but also by using GIS as an important tool to positively establish the UFD,

II. Determining the presence of natural and exotic species at the levels of diversity and spatial characteristics that characterize the urban landscape in its environment,

III. Determining the contribution of green infrastructure potential to the city in terms of the spatial and characteristic relationships among the positional plant traits and discussing the floristic diversity results.

By exhibiting a dynamic structure and creating livable urban spaces, trees and shrubs contribute to urban esthetics and ecology and are the symbols of the modern city [31]. With this study, different plant species in various areas in the provincial city center of Düzce were examined, quantitatively studied, and their effects expressly seen. The study examined a total of 35 samplings of open and green areas, both public and private, located in the city. These included Monument Park, Avni Akyol Park, Celalaeddin Özdal Park, Düzce High School Park, İnönü Park, Urban Park, Konak Park, Küçüksu Park, the city cemetery, and areas around Özdilek Shopping Center, Krempark Shopping Center, Karaca Mosque, Cedidiye Mosque, Gürcü Osman Mosque, Hamidiye Mosque, Çağsu Hospital, Atatürk Hospital, Courthouse, Düzce Municipality, Düzce Cultural Center, Provincial Directorate of Youth Services and Sports, Provincial Public Library, Forestry Directorate, Meteorology Station, Düzce Governorship, Bus Terminal, Kuyumcuzade Boulevard, Düzce-Akçakoca Highway, D100 Highway and Kervan crossroads, İstanbul Street, Bolu Street, Haydar Gördebil Boulevard, Nezih Tütüncüoğlu Boulevard, Atatürk Boulevard, and Rasim Betir Boulevard. Species identified in these areas were esthetically and functionally evaluated via various analyses in order to determine their density and distribution.

2. Materials and methods

The main subject materials were the plants located in the open green areas in the Duzce central district. Plants were identified and plant compositions were evaluated. The plants in the sample areas were used to reveal the floristic diversity of the Duzce city center.

Within the scope of the research, the plants in the open green areas of Düzce were determined and analyzed. A total of 35 public spaces and residential areas (65 sample areas) were included in the study. Field studies lasted about 7 months and were carried out between March–September 2017. It was carried out on an area of approximately 40 km^2.

2.1 Research area

The research area encompassed the city of Düzce in the central district of Düzce Province, which is located between 40° 37′ and 41° 07′ north latitude and 30° 49′ to 31° 50′ east longitude [32] (**Figure 1**). In general, lime-free brown forest soils, yellow/red podsolics, and light podsol soils are widespread in the majority of the Düzce basin and the soil depth is medium to deep [9, 33].

Düzce Province is located in the Western Black Sea Region on the low wet and humid coast. Total rainfall ensures that the green cover remains constant except for the rocky areas [32]. The average temperature in Düzce is 13.41°C and the average annual rainfall is 840 mm [34]. The vegetation period begins in April and lasts until the end of October [9]. According to the land-use classification of the Düzce region, 24,369 ha are Class I land (9.36%), 8,148 ha Class II (14%), 6,546 ha Class III (2.52%), and 17,548 ha Class IV (77%) [35, 36]. Land classes I-IV in the region are generally agricultural land [37]. Düzce is rich in herbaceous and woody species and hosts 700 different plant species, 10% of which are endemic [19].

It has been repeatedly accepted that the number of plant species in the cities is higher than the number in the surrounding area [38–42]. Within the feature of the system known as the 'green infrastructure', which is expected to encircle the city like an ecological network, are different species with different characteristics in open green areas [43]. One of the most important factors contributing to the green

Figure 1.
Research area: (1) parks and recreation areas; (2) public open and green spaces; (3) shopping centers/squares; (4) cemetery and mosques; (5) residential sampling points.

infrastructure of a city is a high level of urban biodiversity and its density and distribution [44, 45].

This research was concerned with providing floristic information from various areas of Düzce in order to determine the important contributions to the urban landscape.

2.2 Determination of sample areas and floristic analysis

The research was carried out in public and private open and green spaces in Düzce city center. The boundary of the research area was determined by the east - west D100 highway. The border line in the north was the Özdilek Shopping Center and in the south, the Düzce Bus Terminal and the city cemetery were the last landmark points included in the research area. Our site selection was influenced by features such as intensive use areas and landscaping, or areas in the city partially demonstrating this potential. To this aim, defined spaces in the city were the subject of the research. The 35 sample areas and the identified residential areas represented the urban open green areas existing throughout the urban landscape (**Table 1**).

The research was conducted in two stages: field work (on-site observation) and office studies (analyses) (**Table 2**). Identification of species and number of woody plant species, usage areas, usage purposes, usage intensities, and seasonal change potentials of the species were determined in the research area.

Since science is a set of documents with generalizability, the extent to which the research is studied affects the reality of the research to the same extent [46]. In some cases it is possible to reach all the examples in the research area, but

Parks and Recreation Areas	Monument Park, Celalettin Özdal Park, Düzce High School Park, İnönü Park, Avni Akyol Park, Urban Park, Konak Park, Küçüksu Park
Shopping Centers/ Squares	Özdilek Shopping Center, Krempark Shopping Center
Public Open and Green spaces	Courthouse, Atatürk Hospital, Municipality of Düzce, Düzce Cultural Center, Duzce Youth Services and Sports Directorate, Çağsu Hospital, Provincial Public Library, Forest Management Directorate, Meteorology Station, Düzce Governorship, Bus Terminal
Cemetery and Mosques	Cedidiye Mosque, Gürcü Osman Mosque, Hamidiye Mosque, Karaca Mosque, The city cemetery
Roads	Kuyumcuzade Boulevard, Nezih Tütüncüoğlu Boulevard, Düzce – Akçakoca highway, Atatürk Boulevard, D100 highway and Kervan Crossroads, İstanbul Street, Bolu Street, Rasim Betir Boulevard, Haydar Gördebil Boulevard
Residential Areas	A total of 65 residential area samples

Table 1.
Sample areas subject to research.

Field observation	a. Determining woody plant diversity (WPD) b. Determining positional status of species c. Determining spatial characteristics of species d. Conducting density analysis of species
Office studies	a. Evaluation of spatial and functional characteristics of species b. Determination of spatial distribution of species c. Determination of species diversity d. Evaluation of results

Table 2.
Research plan.

sometimes this is impossible or too much time is required to examine all the values in the research universe. In fact, when a certain amount of information is sufficient, dealing with masses of information is meaningless [47]. In the research area, sampling was done in all open and green areas having different spatial characteristics, except for the residential areas, in which 7902 residences were subjected to stratified sampling. For example, in accordance with the 'random sampling' method, in the neighborhoods where the population and the number of dwellings were high, over-sampling was performed, and in the neighborhoods where they were lower, less sampling was performed [48].

By dividing the total number of dwellings of each neighborhood by the total number of dwellings in the research area, the weight of the dwellings of a neighborhood was obtained in relation to the total research area. After this process, by multiplying the resulting value by 77, the number of housing samples that should be taken from each neighborhood was calculated [49], with p = 1-α 77 as the sampling size and a confidence interval of 90–95%. As a result of the operations performed, a total of 65 residential sampling points were determined. These included those in the neighborhoods of Aziziye (13), Azmimilli (3), Burhaniye (3), Camikebir (2), Cedidiye (4), Cumhuriyet (2), Fevziçakmak (6), Hamidiye (2), Kültür (9), Kiremitocağı (4), Nusrettin (5), Uzunmustafa (6), Çay (2), and Şerefiye (4).

Within the scope of the study, species detection was carried out for plants belonging to each sample area in the research area. In the field studies, a field introduction table was prepared in which general evaluations of each area and each species were discussed. Features such as the height, phenological characterization, and seasonal status of each plant were recorded in the field introduction table. In order to perform the spatial analysis of the identified woody species in GIS, data regarding point and positional status were needed. For this purpose, a hand-held Global Positioning System (GPS) with high resolution (1–5 cm) sensitivity was used. The locations of trees and shrub groups, as the material of the study, were determined by the hand-held GPS device and marked on a previously printed satellite image of each area, along with their numbers.

2.3 Determination of woody plant diversity (WPD)

In order to determine the diversity status of the species, the data obtained from the field studies were converted into a Microsoft Excel file. After the detection and identification studies of the plant species, statistical data were digitized and used to characterize the structural characteristics of each plant [50]. The basis of this analysis was the existence of species and their numbers in the sample areas [51]. In other words, "Is that plant present in the sample area or not, and if so, how many?" Afterwards, classifications were made according to diversity indices in order to evaluate species diversity [52].

According to [50], the Shannon, Margalef, and Berger-Parker indices are generally used for the evaluation of species diversity. In order to determine the distribution of species in the area, analyses were made using numerical classifications. Community Analysis Package (CAP) 1.4.1 software was used to investigate the relationships among species [50, 51]. Whittaker [53], explained that species diversity can be evaluated from three perspectives as alpha (α), beta (β) and gamma (γ) diversity. Alpha and gamma diversity are defined as inventory diversity and share the same characteristics. The only difference between them is that of the scale; alpha represents a sample area or habitat, while gamma diversity represents the ecosystem. Beta diversity is directly linked to alpha and gamma diversity. Beta diversity indices are used to compare the variation between two different areas (sample area, plant association, ecosystem, etc.) [53]. In this study, alpha (α) and beta (β) diversity indices were used. There are many indices used to determine alpha species diversity. Although the direct determination of the number of species may be an index value, the Shannon Wiener, Simpson's D, Margelef D, Berger-Parker Dominance, McIntosh D, Brilouin D, Fisher's Alpha, and Q Statistics are different indices commonly used in determining alpha diversity [22, 52, 54–56]. As suggested in many studies, in this study, the Shannon-Wiener, Simpson's D, Margelef D, and Berger-Parker Dominance indices were used, respectively.

2.3.1 Shannon-wiener function (H)

The Shannon-Wiener Function (H) was obtained using Eq. (1).

$$H = -\sum\{p_i \ \log \ (p_i)\} \tag{1}$$

According to the formula, the proportional value of the species is expressed by p. The natural logarithm (ln) of the proportion of species is taken and this value is multiplied by the number of species. The Shannon-Wienner (H) gives the negative multiplication value of the sum of the products and the number of "ln" values of all species [57].

2.3.2 Simpson's index (D)

This diversity index was proposed by Simpson (1949) [58] and is used to determine the likelihood of a second sample from a population being the same as the original [52]. The index is expressed by the formula D = 1/C. In Eq. (2) the greater the value obtained, the greater the proportionality.

$$C = \sum_i^s p_i^{\,2}, \mathrm{p_i}^2 = \frac{Ni\ (Ni-1)}{Nt\ (Nt-1)} \tag{2}$$

Ni is the number of species corresponding to the number i and Nt is the total number of individuals in the sample.

2.3.3 Margalef D

The Margalef D Index is calculated with the formula in Eq. (3).

$$D = (S-1)/(\mathrm{In}\ N). \tag{3}$$

Here, S is the number of species and N is the total number of individuals in the sample [52].

2.3.4 Evenness (Berger-Parker dominance) index

The Evenness/Berger-Parker Dominance Index is calculated with Eq. (4).

$$d = \frac{Nmax}{Nt}. \tag{4}$$

Here, Nt represents the total species ratio and Nmax is the most dominant species in this ratio. The evenness index, like the others, is used to calculate diversity results [54–57].

In the calculations based on alpha diversity indices, open green areas with the same spatial characteristics were considered as a single group and the arithmetic means of the index values were taken and a general evaluation made about the species diversity of the places such as parks, public gardens and roadsides. At this stage, the 'arithmetic mean' which is a statistical evaluation method, was used.

2.4 Density and spatial distribution analysis of plant species

Woody plant data for points obtained from all sample areas were used to evaluate the spatial relationships via GIS. The study carried out for this purpose consisted of the following steps:

A database was created in ArcGIS 10.4 to evaluate the information obtained from the sample areas via GIS. First, point data (coordinates) of the plants obtained from the field studies and recorded in the field introduction table were then transferred to the ArcGIS environment. Subsequently, entries in each field and the positional data of each plant species were realized in the database. The headings of the plant data in the database were as follows:

Species name: The plant name analysis, the number of plants, and the area covered were determined and the density map was prepared, taking into consideration the community.

Plant family: Plants were analyzed by considering density according to families.

Phenological properties: Visualization and analysis of the plants were conducted in ArcGIS and they were classified according to their phenological status using the table. We coded each of the identified phenological features as: Species in the foreground with leaf beauty = 1, Species in the foreground with beauty of flowers = 2, leaves and flowers = 3, leaves and fruits = 4, leaves and stems = 5, flowers and stems = 6, leaves, flowers and fruits = 7.

Seasonal situation: According to the seasonal status of the plants, the GIS database was coded as evergreen (1) or deciduous (2) and displayed on ArcGIS.

2.5 Spatial density analysis

Density analysis was performed on the database. After entering the required information in point layers, point density was selected under Arctoolbox 'Spatial Analyst Tools-Density'. In the screen that opens, the point layer we wanted to analyze in the input features section was selected and the field in the population field section was selected. In the output raster section, the result of the density and distribution analysis was completed by selecting the map name and the desired location to be recorded. As a result of these processes, density maps were created for each sample area.

2.6 Spatial interpolation method

In order to see the distribution of the species identified in the sample areas, we conducted spatial distribution analyses in the GIS environment. The 'Analysis Tools - Proximity - Create Thiessen Polygons' command located under the Toolbox was applied to the database. The spatial interpolation method was used to determine the spatial distribution maps of the individual research areas according to the species, family, seasonal conditions and phenological properties of the plants and then the results were evaluated.

3. Results

In evaluating the floral design of the research area, the sample areas identified in the city center were examined separately and as a whole for the entire research area and then were analyzed and the results of the analysis interpreted. In the research area, 173 plant species were found (**Table 3**) from the different sample areas (**Figure 2**). Although most of the identified species were tall trees, 38 shrub species

Species	Botanical family	Number of species
Abelia grandiflora	Caprifoliaceae	22
Abies nordmanniana subsp. nordmanniana	Pinaceae	45
Abies nordmanniana subsp. bornmuelleriana	Pinaceae	3
Acer campestre	Aceraceae	2
Acer negundo	Aceraceae	361
Acer negundo 'Flamingo'	Aceraceae	8
Acer palmatum 'Atropurpurea'	Aceraceae	7
Acer platanoides	Aceraceae	1
Acer platanoides 'Crimson King'	Aceraceae	122
Acer pseudoplatanus	Aceraceae	27
Aesculus hippocastanum	Hippocastanaceae	32
Ailanthus altissima	Simoribaceae	33
Albizia julibrissin	Leguminosae	2
Berberis thunbergii 'Atropurpurea'	Berberidaceae	71
Berberis thunbergii 'Atropurpurea Nana'	Berberidaceae	200
Betula pendula	Betulaceae	11
Buddleia davidii	Buddlejaceae	3
Buxus sempervirens	Buxaceae	173
Buxus sempervirens 'Nana'	Buxaceae	68
Calocedrus decurrens	Cupressaceae	9
Calocedrus decurrens 'Aurea'	Cupressaceae	14
Callistemon citrinus	Myrtaceae	2
Carpinus betulus	Betulaceae	10
Catalpa bignonioides	Bignonaceae	29
Cedrus atlantica	Pinaceae	59
Cedrus atlantica 'Glauca'	Pinaceae	41
Cedrus atlantica 'Glauca Pendula'	Pinaceae	2
Cedrus atlantica 'Glauca Pyramidalis'	Pinaceae	65
Cedrus deodora	Pinaceae	21
Cedrus deodora 'Aurea'	Pinaceae	11
Cedrus deodora 'Pendula'	Pinaceae	2
Cedrus libani	Pinaceae	45
Cercis siliquastrum	Leguminosae	143
Chaenomeles japonica	Rosaceae	7

Species	Botanical family	Number of species
Chamaecyparis lawsoniana	Cupressaceae	130
Chamaecyparis lawsoniana 'Columnaris Glauca'	Cupressaceae	1
Chamaecyparis lawsoniana 'Ellwoodii'	Cupressaceae	25
Chamaecyparis lawsoniana 'Fleckellwood'	Cupressaceae	5
Chamaecyparis nootkatensis 'Pendula'	Cupressaceae	5
Chamaecyparis pisifera 'Boulevard'	Cupressaceae	1
Cornus alba	Cornaceae	24
Corylus avellana	Betulaceae	1
Cotinus coggygria	Anacardiaceae	2
Cotinus coggygria 'Royal Purple'	Anacardiaceae	21
Cotoneaster dammeri	Rosaceae	17
Cotoneaster franchetti	Rosaceae	46
Cotoneaster lacteus	Rosaceae	3
Cotoneaster microphylla	Rosaceae	8
Crataegus oxyacantha	Rosaceae	2
Cryptomeria japonica 'Elegans'	Taxodiaceae	2
Cupressocyparis leylandii	Cupressaceae	2066
Cupressocyparis leylandii 'Aurea'	Cupressaceae	15
Cupressocyparis leylandii 'Fastigiata'	Cupressaceae	37
Cupressocyparis leylandii 'Pyramidalis'	Cupressaceae	10
Cupressus arizonica	Cupressaceae	136
Cupressus arizonica 'Glauca'	Cupressaceae	44
Cupressus macrocarpa 'Gold Crest'	Cupressaceae	87
Cupressus sempervirens	Cupressaceae	55
Cupressus sempervirens 'Pyramidalis'	Cupressaceae	1
Cycas revoluta	Cycadaceae	5
Cydonia oblonga	Rosaceae	1
Diospyros kaki	Ebenaceae	2
Elaeagnus angustifolia	Elaeagnaceae	17
Eriobotrya japonica	Rosaceae	3
Euonymus japonica	Celastraceae	62
Euonymus japonica 'Aurea'	Celastraceae	164
Euonymus japonica 'Aurea Nana'	Celastraceae	27
Ficus carica	Moraceae	18
Forsythia × *intermedia*	Oleaceae	31
Fraxinus angustifolia	Oleaceae	73
Fraxinus excelsior	Oleaceae	32
Ginkgo biloba	Ginkgoaceae	4
Hedera helix	Araliaceae	31
Hedera helix 'Aurea'	Araliaceae	1

Species	Botanical family	Number of species
Hibiscus syriacus	Malvaceae	148
Hydrangea macrophylla	Saxifragaceae	64
Ilex aquifolium 'Golden Queen'	Aquifoliaceae	1
Juglans regia	Juglandaceae	17
Juniperus chinensis 'Pfitzeriana Glauca'	Cupressaceae	1
Juniperus chinensis 'Stricta'	Cupressaceae	2
Juniperus communis 'Compressa'	Cupressaceae	1
Juniperus horizontalis	Cupressaceae	329
Kerria japonica	Rosaceae	1
Koelreuteria paniculata	Sapindaceae	1
Lagerstroemia indica	Lythraceae	72
Laurocerasus officinalis	Rosaceae	79
Laurus nobilis	Lauraceae	15
Ligustrum japonicum	Oleaceae	45
Ligustrum vulgare	Oleaceae	423
Ligustrum vulgare 'Aurea'	Oleaceae	1
Liquidambar styraciflua	Altingiaceae	6
Lonicera caprifolium	Caprifoliaceae	7
Lonicera japonica	Caprifoliaceae	2
Lonicera japonica 'Chinensis'	Caprifoliaceae	6
Magnolia grandiflora	Magnoliaceae	24
Mahonia aquifolium	Berberidaceae	4
Malus domestica	Rosaceae	2
Morus alba	Moraceae	29
Morus nigra 'Pendula'	Moraceae	13
Musa × paradisiaca	Musaceae	7
Nerium oleander	Apocynaceae	11
Olea europaea	Oleaceae	16
Philadelphus coronarius	Hydrangeaceae	1
Phoenix canariensis	Arecaceae	1
Photinia x fraseri 'Red Robin'	Rosaceae	200
Picea abies	Pinaceae	8
Picea glauca	Pinaceae	3
Picea glauca 'Conica'	Pinaceae	23
Picea orientalis	Pinaceae	147
Picea pungens	Pinaceae	13
Picea pungens 'Glauca'	Pinaceae	5
Picea pungens 'Globosa Nana'	Pinaceae	9
Picea pungens 'Hoopsii'	Pinaceae	11
Pinus brutia	Pinaceae	8

Species	Botanical family	Number of species
Pinus griffithii	Pinaceae	2
Pinus nigra	Pinaceae	69
Pinus pinea	Pinaceae	37
Pinus sylvestris	Pinaceae	140
Pittosporum tobira	Pittosporaceae	3
Pittosporum tobira 'Nana'	Pittosporaceae	11
Platanus occidentalis	Platanaceae	1
Platanus orientalis	Platanaceae	174
Populus alba	Salicaceae	1
Populus nigra	Salicaceae	1
Prunus avium	Rosaceae	1
Prunus cerasifera	Rosaceae	2
Prunus cerasifera 'Pissardii Nigra'	Rosaceae	195
Prunus cerasus	Rosaceae	18
Prunus domestica	Rosaceae	1
Prunus laurocerasus 'Otto Luyken'	Rosaceae	15
Prunus persica	Rosaceae	8
Prunus serrulata 'Kanzan'	Rosaceae	3
Pseudotsuga menziesii var. glauca	Pinaceae	1
Pseudotsuga menziesii var. viridis	Pinaceae	2
Pyracantha coccinea	Rosaceae	14
Pyracantha coccinea 'Nana'	Rosaceae	42
Pyrus communis	Rosaceae	5
Quercus ilex	Fagaceae	5
Quercus robur	Fagaceae	4
Robinia pseudoacacia	Leguminosae	115
Robinia pseudoacacia 'Umbraculifera'	Leguminosae	274
Rosa sp.	Rosaceae	418
Rosmarinus officinalis	Lamiaceae	30
Salix babylonica	Salicaceae	4
Salix caprea 'Pendula'	Salicaceae	1
Sequoia sempervirens	Taxodiaceae	6
Sophora japonica	Leguminosae	3
Syringa vulgaris	Oleaceae	8
Taxus baccata	Taxaceae	41
Taxus baccata 'Fastigiata'	Taxaceae	2
Taxus baccata 'Pyramidalis'	Taxaceae	1
Thuja occidentalis	Cupressaceae	1
Thuja occidetalis 'Aurea'	Cupressaceae	1
Thuja occidentalis 'Fastigiata'	Cupressaceae	2

Species	Botanical family	Number of species
Thuja occidentalis 'Globosa Nana'	Cupressaceae	14
Thuja occidentalis 'Golden Globe'	Cupressaceae	73
Thuja occidentalis 'Pyramidalis'	Cupressaceae	2
Thuja occidentalis 'Sunkist'	Cupressaceae	5
Thuja orientalis	Cupressaceae	132
Thuja orientalis 'Aurea'	Cupressaceae	21
Thuja orientalis 'Nana'	Cupressaceae	61
Thuja orientalis 'Compacta Aurea Nana'	Cupressaceae	36
Thuja orientalis 'Compacta Nana'	Cupressaceae	1
Thuja orientalis 'Pyramidalis'	Cupressaceae	53
Thuja orientalis 'Pyramidalis Aurea'	Cupressaceae	190
Thuja plicata	Cupressaceae	25
Tilia cordata	Tiliaceae	1
Tilia platyphyllos	Tiliaceae	3
Tilia tomentosa	Tiliaceae	324
Viburnum opulus	Caprifoliaceae	6
Viburnum tinus	Caprifoliaceae	10
Wisteria sinensis	Fabaceae	1
Yucca flamentosa	Agavaceae	26

Table 3.
Abundance values of the species recorded in sample areas for Duzce city.

were also determined. *Cupressocyparis leylandii* M.L., *Tilia tomentosa*, *Acer negundo* L., Rosa sp., and *Juniperus horizontalis* were the most common species in the research area.

The results of the research are presented in two parts, as a statistical analysis and as a spatial analysis performed in GIS.

3.1 Diversity and distribution of species (diversity analysis)

In order to determine the WPD in the open and green areas of Düzce city center, the distribution and diversity statuses of the species in the research area were obtained as a result of the statistical evaluations for alpha diversity (**Table 4**). **Table 4** shows that:

- According to the Shannon Index, species diversity was observed the most in the area of the Governorship and in residential gardens, and the least along the Düzce - Akçakoca highway.

- According to Simpson's Index, species diversity was observed the most in residential gardens, around the Governorship and in Monument Park, and the least along the Düzce - Akçakoca highway.

- According to the Margalef Index, species diversity was observed the most in residential gardens and around the Governorship, and least along the Düzce - Akçakoca highway.

Figure 2.
(A) Avni Akyol Park; (B) Düzce municipality; (C) D100 highway and Kervan crossroads; (D) İnönü park; (E) İstanbul street; (F) Düzce - Akçakoca inter-city highway.

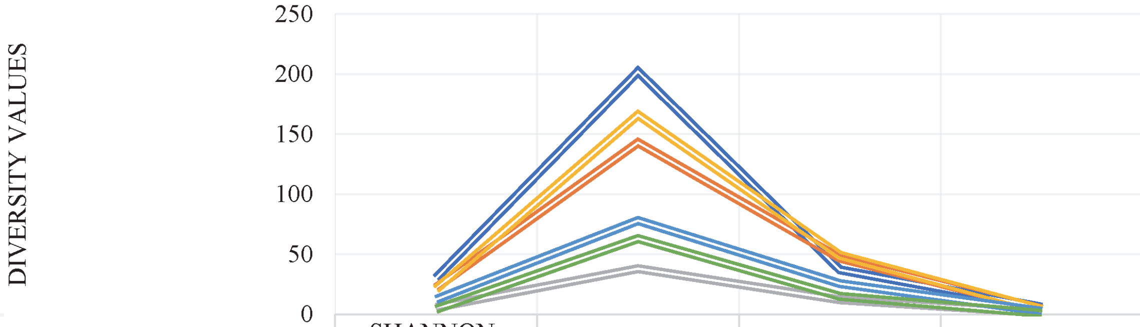
- According to the Evenness index, species diversity was observed the most in residential gardens, Monument Park, and İnönü Park, and the least along the Düzce - Akçakoca highway.

The arithmetic means of the alpha diversity index values were taken by considering the same spatial open green areas as a single group. A general evaluation was made about species diversity in the context of space (**Figure 3**). According to the Shannon Index, the highest species diversity was observed in public areas and the least in residential areas. According to Simpson's Index, the most species diversity was again seen in public areas and the least in shopping centers. According to the Margalef Index, the most species diversity was observed in parks and the least species diversity in shopping centers. According to the Evenness Index, the diversity of species was highest in public areas and lowest in residential gardens.

Samples	Sample Areas	Shannon-Wiener	Simpson's	Margalef D	Evenness
1	1.1.	2.99	20	6.34	0.58
	1.2.	2.56	13	4.68	0.50
	1.3.	2.48	12	4.43	0.48
	1.4.	2.89	18	5.88	0.56
	1.5.	4.03	56	13.66	0.78
	1.6.	1.79	6	2.79	0.35
	1.7.	2.89	18	5.88	0.56
	1.8.	2.94	19	6.11	0.57
	1.9.	2.94	19	6.11	0.57
	1.10.	2.30	10	3.91	0.45
	1.11.	2.40	11	4.17	0.47
2	2.1.	2.83	17	5.65	0.55
	2.2.	3.85	47	11.95	0.75
	2.3.	3.66	39	10.37	0.71
	2.4.	1.79	6	2.79	0.35
	2.5.	2.77	16	5.41	0.54
	2.6.	2.94	19	6.11	0.57
	2.7.	3.09	22	6.79	0.60
3	3.1.	2.48	12	4.43	0.48
	3.2.	3.26	26	7.67	0.63
4	4.1.	2.83	17	5.65	0.55
	4.2.	2.56	13	4.68	0.50
	4.3.	1.79	6	2.79	0.35
	4.4.	1.79	6	2.79	0.35
	4.5.	3.50	33	9.15	0.68
	4.6.	0.69	2	1.44	0.13
	4.7.	2.48	12	4.43	0.48
5	5.1.	3.74	42	10.97	0.73
	5.2.	2.20	9	3.64	0.43
	5.3.	2.56	13	4.68	0.50
	5.4.	2.08	8	3.37	0.40
	5.5.	1.79	6	2.79	0.35
6		4.14	63	14.97	0.80

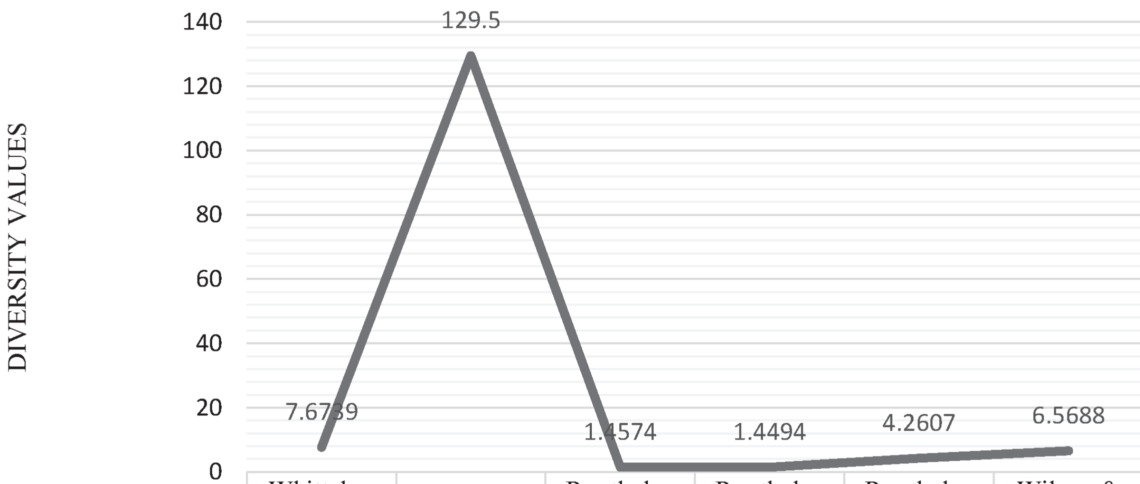
Table 4.
Diversity of plant species: 1: Public open and green spaces (11 sample areas); 2: Roads (7 sample areas); 3: Squares (2 sample areas); 4: Parks (7 sample areas); 5: Cemetery and mosques (5 sample areas), 6: Residential area gardens.

The distribution and diversity status of the species in the research area according to the results of the statistical evaluations made for the beta diversity are expressed graphically in **Figure 4**. According to this graph, the greatest changes in the field were Cody's βc values.



	SHANNON-WİENER	SİMPSON	MARGALEF D	EVENNESS
Public Areas	30.2328	202	36.9698	5.87329
Roads	22.178	143	46.628	4.308
Squares	5.743	38	12.099	1.115
Parks	20.946	166	49.075	4.069
Cemetery and Mosques	12.371	78	25.445	2.403
Residential Gardens	4.1431	63	14.965	0.80488

Figure 3.
Diversity values of species according to space types (the arithmetic means of the alpha diversity index values were taken by considering the same spatial open green areas as a single group).



	Whittaker Bw	Cody Bc	Routledge Br	Routledge Bi	Routledge Be	Wilson & Shmida Bt
Beta Diversity	7.6739	129.5	1.4574	1.4494	4.2607	6.5688

Figure 4.
Beta index and diversity distribution graph.

3.2 Results of data evaluation on GIS environment

According to the results of the analysis, the density of the point data obtained from the sample areas was determined according to the species, families, seasonal conditions and phenological properties of the species;

The most common species in the sample areas was *Cupressocyparis leylandii* (Hybrid Cypress), followed by *Rosa* sp. and *Tilia tomentosa* (Silver Linden) (**Figure 5A**). Species represented by a single individual included *Acer platanoides* L., *Chamaecyparis lawsoniana* 'Columnaris Glauca', *Chamaecyparis pisifera* 'Boulevard', *Corylus avellana, Cupressus sempervirens* 'Pyramidalis', *Cydonia oblonga, Ilex aquifolium* 'Golden Queen', *Juniperus chinensis* 'Pfitzeriana Glauca', *Juniperus communis* 'Compressa', *Kerria japonica, Koelreuteria paniculata, Ligustrum vulgare* 'Aurea', *Philadelphus coronarius, Phoenix canariensis, Platanus occidentalis, Populus alba, Populus nigra, Prunus avium, Prunus domestica, Pseudotsuga menziesii* var.

Glauca, *Salix caprea* 'Pendula', *Taxus baccata* 'Pyramidalis', *Thuja occidentalis, Thuja occidetalis 'Aurea', Thuja orientalis 'Compacta Nana', Tilia cordata, Wisteria sinensis.*

In Avni Akyol Park and İnönü Park and around the D100 highway-Kervan crossroads species density was high. On the other hand, in the residential areas and along the Düzce - Akçakoca highway and Bolu Street, the density of species was low.

When the distribution of the identified species was considered according to families, Cupressaceae was the most common. İnönü Park and the D100 highway-Kervan crossroads were observed as the areas with the highest family density depending on the species density (**Figure 5B**). When the phenological properties of the species were considered, the plants with highest density in the area were those having 'beauty of leaves' (**Figure 5C**). When the seasonal status of the species was taken into consideration, it was seen that the density of evergreen species was higher than that of deciduous species (**Figure 5D**).

The spatial distribution of the species was similar to the results of the density analysis. The results of the spatial distribution of plants on a species basis were significant. In the research area, *Cupressocyparis leylandii* was the most widespread species, spreading over 2.8 km^2, followed by *Photinia x fraserii* 'Red Robin', and *Tilia tomentosa*, *Acer platanoides* L., *Cotinus coggygria.*, *Cupressus sempervirens* L. 'Pyramidalis', *Ilex aquifolium* L. 'Golden Queen', *Taxus baccata* 'Pyramidalis', and *Thuja occidentalis* 'Aurea' were the least distributed species in the area.

When the spatial distribution analysis results of floristic diversity according to families were evaluated, the Rosaceae family, dominant over an area of approximately 5.9 km^2 and represented by 24 species in the sample areas, was the most highly distributed family, followed by the Cupressaceae family, with 16 species represented. The Aquifoliaceae, Arecaceae, and Sapindaceae families were the least encountered families (**Figure 6**).

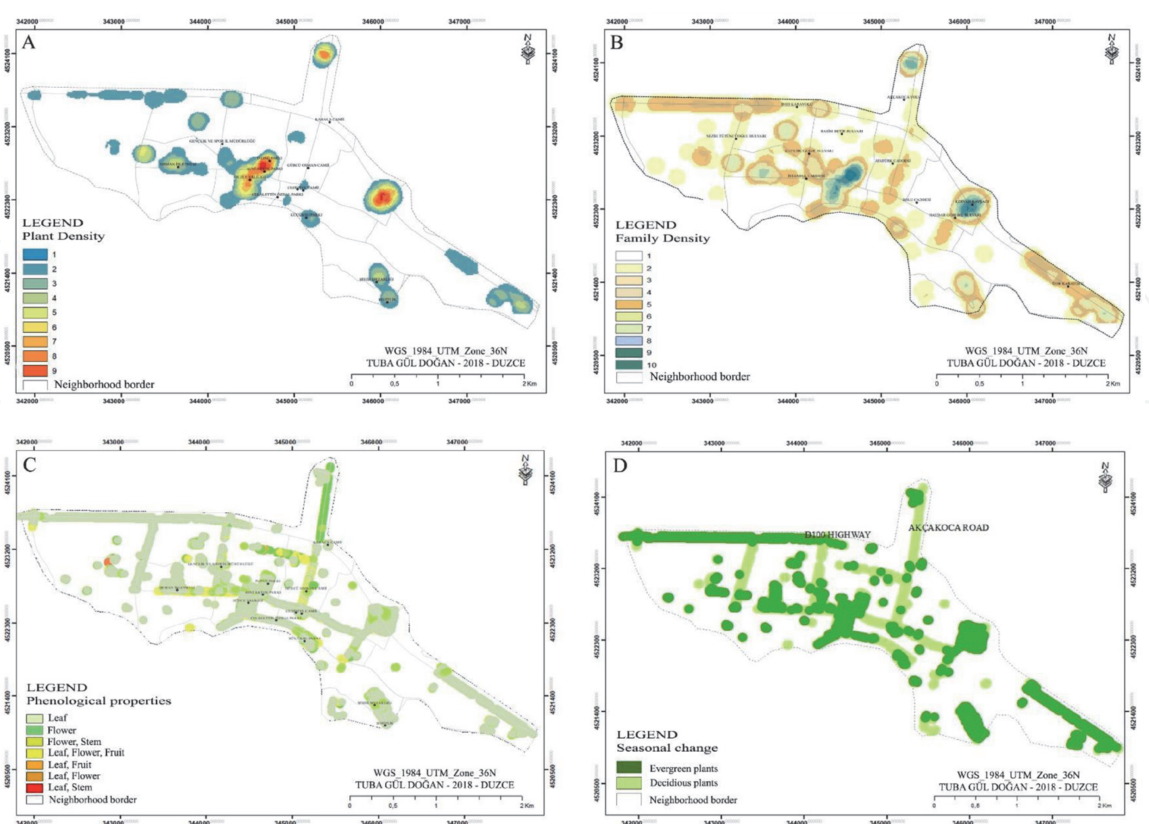


Figure 5.
Density analysis of floristic diversity: (A) according to species; (B) according to families; (C) according to phenological status; (D) according to seasonal conditions.

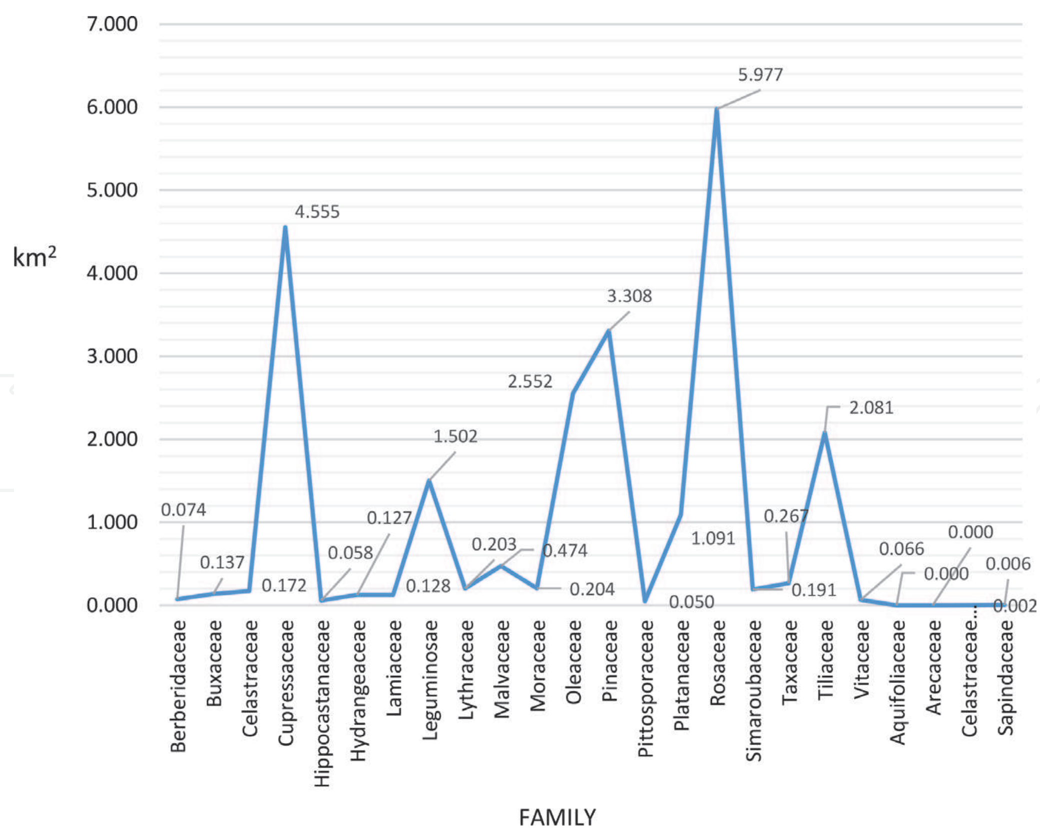


Figure 6.
Spatial distribution of woody plant diversity (WPD) according to families.

In the spatial distribution analysis of WPD, the plants with the most important leaf beauty had the widest distribution, with around 75% of the species consisting of *Euonymus japonica* 'Aurea', *Photinia x fraseri* 'Red Robin', and *Prunus laurocerasus* 'Otto Luyken'. Species having leaf and stem beauty (*Lagerstroemia indica* L., *Olea europaea* L.) were represented by 0.2% and had the least distribution (**Figure 7**).

Just as in the results of the density analysis, in the spatial distribution analysis of the plants according to phenological properties, those with leaf beauty were in the foreground and had the widest distribution. Evergreen species exhibited wide distribution compared to deciduous species (**Figure 8**). It is thought that the use of

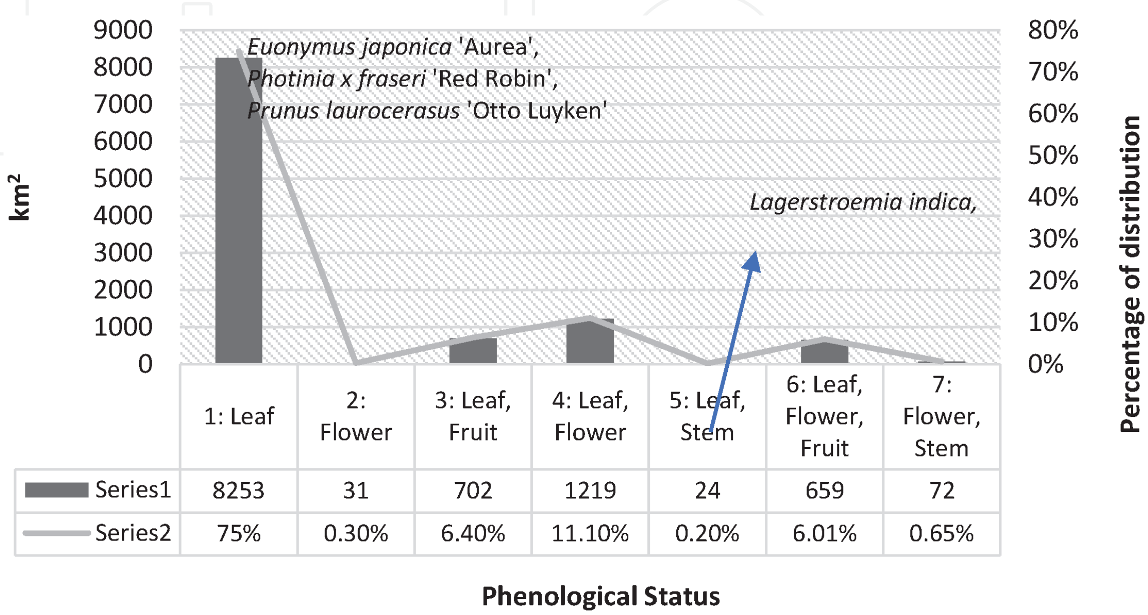


Figure 7.
Distribution of floristic diversity according to phenological status.

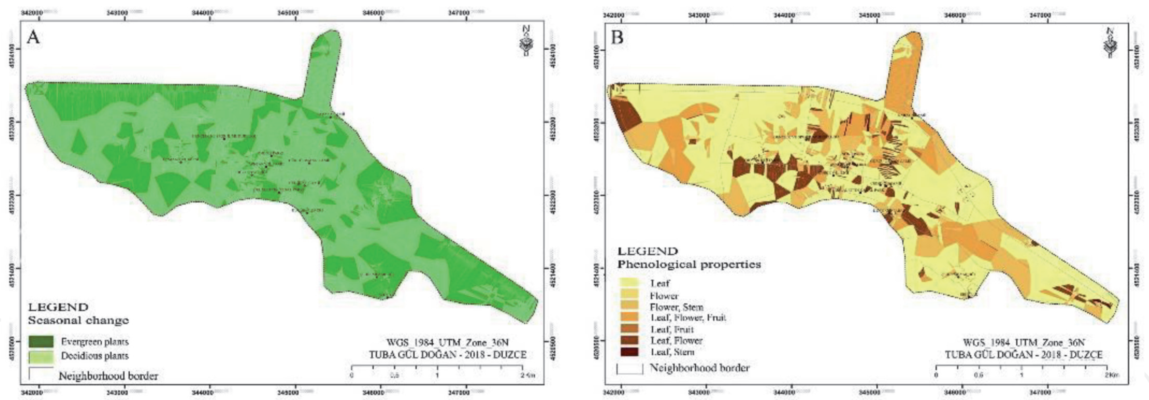


Figure 8.
Spatial distribution analysis of WPD: (A) according to seasonal conditions; (B) according to phenological status.

Cupressocyparis leylandii along the road in the sample area of the D100 highway resulted in the evergreen species being in the foreground of the density analysis. However, when the same results were obtained in the spatial distribution analysis, it is possible to conclude that evergreen species were scattered throughout the research area.

As a result of the analyses carried out in order to reveal density variation of the species identified in the sample areas according to the seasonal conditions, it was found that deciduous species were used extensively in Monument Park and İnönü Park, and along İstanbul Street and the Düzce – Akçakoca highway, while the evergreen species were concentrated around the D100 highway-Kervan crossroads and in the city cemetery. The Kervan crossroads, the Governorship and the Provincial Directorate of Forestry were seen as areas where evergreen and deciduous species were combined and dense.

In the park and recreation areas, the density of species was mostly observed in İnönü Park, while the least density was observed in Celaleddin Özdal Park, where six different species were identified. According to the density analysis of WPD in public spaces, it was found that the density was highest in the vicinity of the Governorship. As a result of the analysis applied to determine the density of floristic diversity along the roads, the Kervan crosssroads on the D100 highway was seen as the area where the density increased the most. As a result of the density analysis, which was in parallel with the diversity analysis, the Düzce - Akçakoca highway was determined as the road with the least density. In the category of cemetery and worship areas, the density of the city cemetery was seen to be increasing.

4. Conclusions

The green texture created by the rich plant diversity in cities also provides a living space for different species [59]. According to Nero, urban biodiversity is crucial to building resistant and sustainable cities [60]. In recent years, biodiversity has gained importance in cities. Consequently, our study focusing on WPD was carried out in the central district city of Düzce in areas with different spatial usage potential. The results on existing flora were revealed to be parallel with previous studies on this urban landscape [7, 14]. The number of plant species in the selected sampling spaces in the research area was quite high in terms of species richness. The wealth of species can be mentioned especially in the open green areas of the Düzce city center.

Open green areas in a city representing the diversity of species include parks, public gardens, urban forests, and cemeteries [61]. In addition, highway plantings, which are defined as artificial corridors [62], are the passageways connecting green areas in cities [63], and species diversity is high in these areas. This was not the case in our research area. A single species (*Cupressocyparis leylandii*) was encountered along the D100 highway, one of the main urban corridors in Düzce. Moreover, the D100 highway was included in the list of exemplary areas, verified by diversity analyses, where there was little diversity.

Species studies were also carried out on the plants located on the banks of Asar Creek within the boundaries of the research area. The diversity of vegetation along a watercourse normally reflects the diversity in the physical environmental conditions [64, 65]. However, the diversity of vegetation located on the banks of the Asar Creek was different from that of the overall research area. The main reason for this is because the destruction of natural habitats is low and the creek exhibits a relationship with the immediate environment, although excessive degradation has occurred in the areas landscaped with unnatural species. Urban areas are places where structural and physical changes are intense.

According to Eroğlu et al., at Düzce intersections in general, the species were randomly positioned in the space and although they were correct in some points in terms of species selection, they were positioned in a scattered way and too many color types were used, contrary to the regulation principles [7]. The findings of this study conducted in 2005 are similar to the results of our research. At the Düzce intersections discussed within the scope of the study, attention was drawn to wrong type selection and designs that were not suitable for the space. According to Acar et al., the diversity of plants in urban landscape areas plays an important role in the protection of urban nature and in the determination of planning and policies [50]. Accordingly, their study in Trabzon shows parallels with our research. The results of the diversity analysis obtained from the research area of Düzce show that diversity was high on the Shannon-Wiener, Evenness, and Margalef indices, but not on Simpson's Index. In the scope of our research, vegetative arrangements were found on private properties, but the diversity in public housing was higher. In other housing types, natural landscape effects were observed.

In order to determine the WPD in open and green spaces in the city center, sample areas were examined and the results were evaluated. According to this, *Tilia tomentosa* was the most frequently used tree in Düzce parks, and thus determined the general characteristics of these parks. Species diversity was quite high in the parks, which were mostly composed of tall trees; however, planting criteria were generally not followed and the plants did not display their natural forms. The situation was no different with road, median and junction arrangements. The planting at central intersections was considered a negative factor due to the random planting of species below eye level. At the Kervan crossroads, there was a dense variety of species which were generally positioned according to the correct design criteria. This could be considered as a very accurate design if it were to be used as a recreation area. However, because of the characteristics of the space, the design was found to be unsuitable for the intersection landscape. Since the *Cercis siliquastrum* L. planted along the Düzce - Akçakoca highway is not suitable for roadside use, it was evaluated as the wrong species selection for this area. There are many plant types in public spaces, ranging from tall trees to shrubs, but poor and inadequate designs were often encountered in the garden outside the Governorship. The dense, hard ground and random location of species around the Municipality Building were considered as negative features. These factors add a negative esthetic value to the image of the city and the municipality.

Hybrid Cypress (*Cupressocyparis leylandii*) was the most common species in the research area, while Silver Linden (*Tilia tomentosa*) determined the general characteristic of Düzce urban parks. *Cupressocyparis leylandii* was identified as the dominant species in the research area and showed the highest distribution. Within the boundary of the research area there is a high use of *Cupressocyparis leylandii* for 8 km between the Ankara and the Istanbul sections of the D100 highway.

It is possible to discuss the diversity in the open and green areas of central Düzce in terms of the spatial distribution and diversity of species. The Governorship and residential areas were the richest in terms of species diversity and the Düzce - Akçakoca highway was observed as the area with the least diversity. When the sample areas of similar characteristics were evaluated as a group, public areas and parks were rich in species diversity, whereas residential gardens and shopping centers/squares were the areas where diversity was low, according to different diversity indices. İnönü Park, which is one of the most important and intensely used recreational areas of the city, was observed as having a rich variety of species.

As a result of the study, it was found that using the floristic diversity indices and GIS jointly enabled the UFD of the city to be defined both statistically and positionally.

It is possible to make current and past evaluations of a place using a database known as the Urban Information System (UIS), as an important new concept that can contribute to the creation of more livable and accessible cities. Once the infrastructure is prepared, plant species analysis, space analysis, layer analysis, and spatial distribution analysis can be carried out in an area to determine which layers (trees, shrubs, ground cover, etc.) are dominant. In addition, with the use of the ArcGIS program, the location of plants can be determined and current photographs of the plants uploaded to that point along with information about their appearance, all of which are easily accessible. In addition, the newly proposed UIS can contribute to the evaluation and interpretation of the concept of 'Green Infrastructure', which has played such an important role in the urban model in recent years. It will also be able to propose methods and locations for implementation of applications having the potential to respond to the green infrastructure of a city. It is seen as playing an important role in shaping the infrastructure of a system that, working from this standpoint, could be established for stakeholder institutions, organizations, and municipalities that will need such information within the UIS.

Acknowledgements

The author would like to thank Prof. Dr. Cengiz Acar for analyzed the data on diversity and Dr. Ahmet Salih Değermenci for all his support for this study. This research was self-funded.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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