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Dear readers,

Urban forests provide many environmental, social and economic benefits and contribute to quality of life of people in urban areas. Taking into consideration constantly growing population in urban areas all around the world, and all what comes with it, we cannot but to agree that urban forests are our urban future. Therefore the way how we treat them and how we make decisions about them becomes very important.

With the aim to highlight the importance of the urban forests and to present it to the wider scientific and professional audience, Croatian Forest Research Institute together with IUFRO (Division 6 – Social Aspects of Forests and Forestry; unit 6.07.00 - Urban Forestry) and FOPER project of the European Forest Institute organised conference "***Forests for cities, forests for people: perspectives on urban forest governance***". The idea for the Conference came from the ongoing South East European regional project FORCITY ("*Citizens and urban forest governance in SEE: case studies in selected cities*") that addresses urban forest governance and satisfaction of citizens with their urban forests.

The Conference was held on 27th and 28th of October 2012 in Zagreb and has attracted many scientists and experts that deal with urban forestry. On the behalf of the organizers the Conference was opened by the welcoming words of the Director of Croatian Forest Research Institute, Dr. Dijana Vuletić, and then followed by keynotes of Prof. Dr. Margaret A. Shannon, Prof. Dr. Maureen McDonough and Prof. Dr. Cecil C. Konijnendijk. During two days, 20 oral and 14 poster presentations were presented. In total, the Conference was attended by 80 participants from 20 countries, 15 European and 5 non-Europe (USA, Turkey, India, Iran, Colombia). After the official part of the Conference, attendees had opportunity to visit The Green Horseshoe of Zagreb, a series of parks and tree-lined squares that run from Zagreb's main station, up to the city's main square and loop around in the shape of horseshoe. Once again, on behalf of organizers we use the opportunity to thank all those who contributed in any way to the successful organization of the Conference.

Since many interesting and meaningful research on urban forests were presented at the Conference, we decided to publish this thematic issue of SEEFOR Journal. All presenters have been invited to prepare their paper for publishing in SEEFOR Journal. After standard procedure of peer-reviewing, we brought you seven accepted papers and truly hope that they will occupy your interest.

Dijana Vuletić
Editor-in-chief

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Original scientific paper

Status, Use and Management of Urban Forests in Turkey

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Abstract

Background and purpose: From the 1950s onwards the urban population in Turkey has been increasing. Today, 77% of the population is living in cities and urban conglomerates. Public expectations from forest resources have changed, together with the migration of people from rural to urban centers. Due to rapid urbanization, the expectations from green areas and forests in and near cities have increased and changed for people living in the vicinity of cities. Following the world-wide trend in providing special attention to urban forests and to meet the demand and expectations from urban forests, the General Directorate of Forestry (OGM) has begun to deal with urban forestry from 2003 onwards. There are 112 urban forests in Turkey as of 2012. Out of these 72 are in provinces and the other 40 are in counties. The aim of the study is to determine general characteristics of urban forests in Turkey, to identify similarities and differences among the urban forests and to evaluate their appropriateness for the discipline of urban forestry.

Materials and methods: Studies were conducted from the beginning of May until the end of October 2010. This study was able to collect a sufficient amount of information for only 52 of the active urban forests. In total, 35 variables were derived by a literature study and interviews. Data was assembled from the Forest Regional Directorates through OGM. Frequency, minimum, maximum and mean values of the collected variables were calculated.

Results and conclusions: In conclusion, the analyses have focused on the general characteristics and accessibility of urban forests, urban forest infrastructure, urban forest management and urban forest services. Consequently, it was found that a standard was not reached for establishing urban forests in Turkey. Urban forests showed significant differences from each other in terms of various characteristics such as distance, accessibility, plant and animal diversity, water surfaces, facilities and infrastructure circumstances. Population and urbanization ratio were not considered in establishing and planning the related urban forests. Urban forests were mostly used for picnic and entertainment. Urban forests were not managed based on scientific and technical principles. Finally, some recommendations were presented to create a management infrastructure for urban forests in Turkey.

Keywords: administration, planning, recreation, urban forest, urban forestry, urbanization

INTRODUCTION

In developing countries urbanization has caused dramatic impacts by creating environments that lack amenities [1]. In this sense, since the 1950s onwards, the urban population in Turkey has begun to increase. Today, 77% of the population is living in cities and urban conglomerates. Public expectations from forest resources have changed together with the migration of people from rural to urban centers [2, 3]. Due to rapid urbanization, people's expectations from green areas and forests in and near cities have increased and changed.

Following the world-wide trend in providing special attention to urban forests and to meet the demand and expectations from urban forests, the General Directorate of Forestry (OGM) has started to show interest in urban forestry from 2003 onwards. There are 112 urban forests in Turkey as of 2012. 72 out of them are in provinces and the other 40 are in counties. The total area of urban forests is 11 230 ha [4]. Urban forests cover 0.01% of surface area and 0.05% of forest area in Turkey.

Urban forestry has been coined as the new face of forestry [5], as urbanization and increased availability of leisure time is increasing the importance of urban forests [6]. Its purpose is the cultivation and management of trees for their present and potential contribution to the physiological, sociological and economic well-being of the urban society [7, 8]. Therefore, urban forests are integral components of the urban ecosystems [9]. Compared with other forests and nature areas, urban forests are thus real 'social forests', used by many local residents [10]. Most of the values attached to urban forests are non-priced environmental benefits. These values include those derived from pleasant landscapes, energy saving, clean air, peace and quietness, as well as potential recreational activities in wooded green spaces. Other benefits include a reduced wind velocity, noise prevention, balanced microclimate, shading, and erosion control [2, 11, 12].

Urban forestry in Turkey lacks a legal and administrative basis, due to the spontaneous and unplanned start of the OGM to work on urban forestry. In addition, central directives were launched all of a sudden to establish urban forests in all provinces. The problems that arose from poor planning, the random selection of urban forest locations and insufficient funding for attracting the right personnel have been observed by various authors. According to Coşkun and Velioğlu [13], urban forests remain mainly a concept and it is not part of the planning process and related legal regulations. The criteria for establishing urban forests are insufficient [14]. The basic needs and demands of those living in the city are not considered [15, 16]. Moreover, uncertainties among authorities are in the way to resolve the debate among relevant institutions [17].

OGM recorded a number of existing plants and equipments in urban forests to amend their management. Moreover, open fire during picnics was banned in the "Picnic Spots Regulation" published in the Official Gazette dated 30 September 2006. But this has been far from enough to form the legal and administrative infrastructure for urban forests. In this Regulation, urban forest is defined as; "areas that are arranged in adjacent to or around settlements such as metropolis, provinces and big counties to present health, sport, aesthetic, cultural etc. social functions of forests to the public, but also to introduce technical forestry activities and flora and fauna in the district without traditional picnic understanding" [18].

The aim of this study is to determine the general characteristics of urban forests in Turkey, to identify similarities and differences among urban forests and to evaluate their appropriateness for the discipline of urban forestry. For this purpose, various variables were obtained and statistically analyzed. The analyses focused on the general characteristics and accessibility of urban forests, urban forest infrastructure, urban forest management and urban forest services.

MATERIALS AND METHODS

Studies were conducted from the beginning of May until the end of October 2010. Taking into account that some urban forests are inactive, whereas other urban forests have insufficient information, this study has been able to collect a sufficient amount of information for only 52 of the active urban forests.

A detailed literature study relating to urban forests was initially undertaken both at the national and the international level. Furthermore, to obtain quantitative information on urban forests in Turkey, we interviewed people from the forestry organization and representatives at the central and provincial level and examined related documents in the OGM archive in detail. A part of the data has been obtained in this way. Another part of the data was assembled from the Forest Regional Directorates through OGM. For this purpose, OGM sent a data collection form created by us to each of the 27 Forest Regional Directorates. The filled forms were returned to us afterwards.

As a result, in total 35 variables were derived from the literature study and interviews. The names and definitions of these variables are given in Table 1. Frequency, minimum, maximum and mean values of the derived

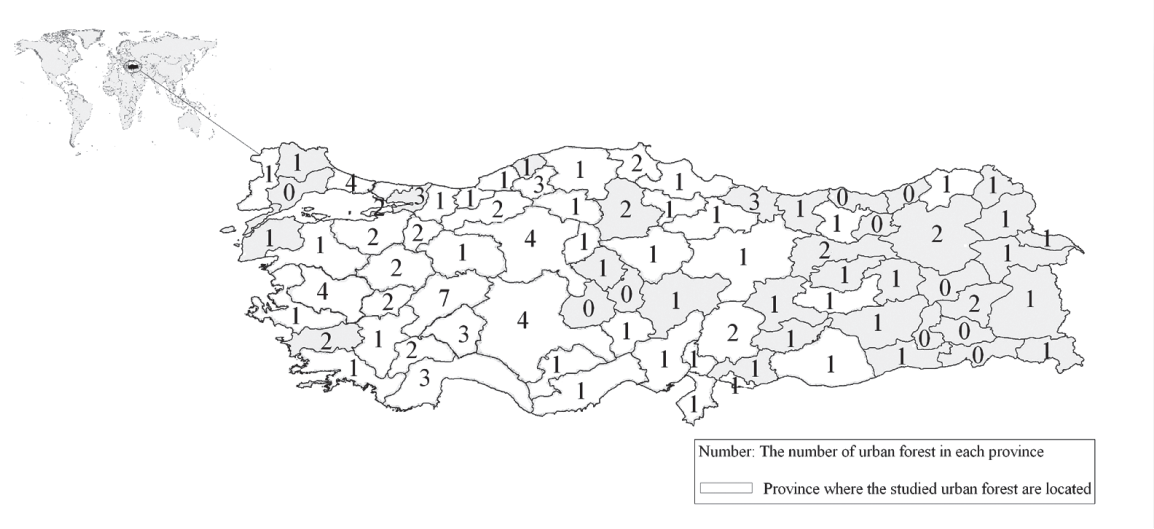

FIGURE 1
Distribution of urban forests in Turkey

variables were calculated by using SPSS 16 (Statistical Package for the Social Sciences). The calculation results were evaluated under the following headings: general characteristics and accessibility of urban forests, urban forest infrastructure, urban forest management and urban forest services. These have been discussed based on the literature. In addition, the distribution of urban forests studied is presented in Figure 1.

TABLE 1
Names and definitions of variables

No	Names of Variables	Definitions of Variables
1	Activity period	Activity duration of urban forest
2	Population of province-county	Urban population in province or county
3	Distance	Distance between city center and urban forest
4	The ratio of forest area	The ratio of forest area in province or county
5	Urban forest area	Urban forest area
6	Forest area per capita	Forest area per capita in province or county
7	The number of picnic area	The number of picnic area in province or county
8	Persons per picnic area	The Number of persons per picnic area in province or county
9	Urbanization ratio	The Ratio of Urban population in province or county population
10	The annual urban forest visitors	Visitor number of urban forest in a year
11	Usage level	The ratio of annual visitor number of urban forest in province or county population
12	The number of tree species	The number of tree species in an urban forest
13	The number of coniferous tree sp	The number of coniferous tree species in an urban forest
14	The number of broad-leaved tree sp	The number of broad-leaved tree species in an urban forest
15	The number of animal species	The number of animal species in an urban forest
16	Urban forest area per capita	Urban forest area per person in province or county
17	Sedile	The existence of sedile in an urban forest
18	Viewpoint	The existence of viewpoint in an urban forest
19	Fountain	The existence of fountain in an urban forest
20	Sport Area	The existence of sport area in an urban forest
21	Walking	The existence of walking path in an urban forest
22	Playground	The existence of playground in an urban forest
23	Toilet	The existence of toilet in an urban forest
24	Parking area	The existence of parking area in an urban forest
25	Bicycle road	The existence of bicycle road in an urban forest
26	Information	The existence of information center in urban forest
27	Province-county	The settlement where an urban forest is located
28	Transportation possibilities	Transportation possibilities between city center and urban forest
29	Water resources	The existence of water resources or surface in an urban forest
30	Origin of urban forests	The situation of urban forest before its establishment
31	Management plan	The existence of management plan for urban forest
32	Urban forest management	Enterprise type of urban forest
33	The number of personnel	The number of personnel in an urban forest
34	The number of technical person	The number of technical personnel in an urban forest
35	Functions of urban forest	The functions of urban forest (recreation, sport activities, health facilities, flora-fauna wealth etc)

RESULTS AND DISCUSSIONS

General Characteristics and Accessibility of Urban Forests

Eight of the studied urban forests are located in counties, whereas the other 44 are located in provinces. The population of the smallest and largest settlements (Isparta-Sütçüler and Istanbul) where urban forests were established are 12 459 and 13 million, respectively (Table 2). In this context, Zhu and Zhang [19] claim that the urban forest area tends to increase with the number of urban population. As considered in this paper, the size of the settlements is very variable, but this variability has not been taken into consideration in planning urban forests. The size of settlements may essentially comprise different demands.

The minimum and maximum ratios of forest area in the studied provinces vary from 0.5% to 68%, whereas the average ratio of forest area for 52 settlements is 38% (Table 2). This also indicates that urban forests are established in both poor and rich cities as far as forest area are concerned.

The minimum and maximum forest area per capita varies from 0.01 m^2 (Şanlıurfa Urban Forest) to 36 m^2 (Kütahya- Domaniç Urban Forest), while the average forest area per capita is 4 m^2 (Table 2). This is about half of the minimum green area per capita (9 m^2) reported by World Health Organization [20, 21].

Urban forests in Turkey have met the needs of visitors for picnic areas. The minimum and maximum numbers of picnic area in settlements are 1 and 165, whereas the average is 21 (Table 2). Istanbul has 165 picnic areas, and this increases the mean value.

The minimum and maximum numbers of persons per picnic area are 655 and 698 887 (Table 2), whereas its mean value is 45 616. Inclusion of the Istanbul province (or metropolitan) with a population of 13 million, with 78 274 persons per picnic area has increased the mean value considerably.

In this study, the urbanization ratio (urban population/general population) is also calculated for settlements. The minimum and maximum urbanization ratio varies from 43% to 99% and its mean value is 68% (Table 2). It is well-known that people who are living in highly urbanized provinces/counties demand more recreational activities [22].

Out of 52 urban forests, the two newest ones are three years old, whereas the twelve oldest ones are eight years old. Besides, four urban forests are 5 years old, five of them are 6 years old and 29 of them are 7 years old. On average urban forests are 6.8 years old (Table 3).

The minimum and maximum distance within a province/county to urban forests varies between 1 to 40 km, whereas the average distance is 7.9 km. Distance is of great importance for visitors. Likewise, Hörnsten and Fredman [23] stated that over 40% of the population in Sweden would prefer urban forests which are within a distance of less than 1 km to settlements for recreational activities. The literature also shows that there is a negative relation between visitor frequency and distance [24, 25]. According to studies done in 16 European countries, Konijnendijk [26] reported that urban forests were at a maximum distance of 50 km to city centers. On the other hand, Coles and Bussey [27] indicated that urban forests should ideally be at 5-10 minutes walk from the city centers. The attractiveness of forests as a recreational environment is also evident from the distance that people are willing to cover to visit a forest [28].

TABLE 2
Characteristics for provinces/counties including urban forests

	Unit	Min.	Max.	Mean
Population of province-county	persons	12 459	13 000 000	700 634
The ratio of forest area	%	0.5	68	38
Forest area per capita	m^2/person	0.01	36	4
The number of picnic area	number	1	165	21
Persons per picnic area	persons	655	698 887	45 616
Urbanization ratio	%	43	99	68

TABLE 3
General characteristics of urban forest

	Unit	Min.	Max.	Mean
Activity period	years	3	8	6.8
Distance	km	1	40	7.9
Urban forest area	ha	8	1 025	144

FIGURE 2
A view from Bartın Urban Forest

FIGURE 3
Artificial facilities in Kepez/Antalya Urban Forest

In Turkey, 28 (54%) of the considered urban forests are within walking distance (Figure 2). They can be reached either by municipal buses (for 19 urban forests) and/or by small buses (for 21 urban forests). However, 11 urban forests cannot be reached either by walking or public transport. These urban forests can only be reached by private vehicles of the visitors. Furthermore, Uslu ve Ayaşlıgil [29] stressed the importance that urban forests should be reachable by either private or public transport.

The size of urban forests studied varies from 8 to 1 025 ha, whereas the average is 144 ha. 34 out of 52 urban forests have smaller size than the mean value (Table 3). The large difference among the sizes of urban forests is due to the absence of standard sizes. In the Technical Prospectus for urban forests and resting areas, it is stated that the maximum area of urban forest should be 300 ha. In this case, only four out of 52 urban forests studied are larger than that value. In contrast, that prospectus does not mention the minimum limit for the size of urban forests. According to Gezer and Gül [12], the minimum size of urban forests in Turkey should be 45 ha. This implies that 13 out of 52 urban forests are below the minimum size (Table 3).

Urban Forest Infrastructure

Forest visitors often prefer open green areas such as urban forests including various types of water resources [12]. Variation is greatly appreciated, not only due to mixtures with other types of trees, but also the combination of trees with fields, meadows and, in particular, water bodies [30]. In Turkey, only 22 urban forests (42.3%) have a water resource such as a lake/pond, and stream (lake/ponds are found in 19 urban forests, streams are found in 2 urban forests, whereas both lake/ponds and streams are found in 1 urban forest). The other 30 urban forests include no water resource at all (Figure 3).

The origin of urban forests consists of 51.9% of afforestation (plantation) area, 36.5% of natural forest and 9.6% of picnic area (Figure 4). Most visitors appreciate the naturalness of an urban forest, and the importance of ecological management has increased during the past decade [31].

FIGURE 4
An urban forest in plantation area (Sandıklı/Afyon Urban Forest)

Urban Forest Management

Currently only five urban forests (9.6%) in Turkey have a management plan. Every urban forest virtually needs to have a management plan in order to provide a proper standard of urban forests services. Otherwise, urban forests may not develop in the desired direction. Çetiner et al. [32] stated that the municipality, forest management and the public have to participate to the administration to establish and manage an urban forest successfully and well. Therefore, there is a need for a proper management plan to be prepared by participation of interest groups.

Only 18 out of 52 urban forests are being managed by forestry organization. The rest of them have been managed by municipalities (29 urban forests), special provincial administrations (2 urban forests), private individuals (2 urban forests) and a village legal entity (1 urban forest). As understood from these results, forestry organizations prefer municipalities and the private sector to manage urban forests. However, municipalities and the private sector are often not able to manage the urban forest within the intended framework of the foundation purpose, because their main purpose is to gain income.

Some urban forests (9 urban forests) do not have even any personnel. The maximum number of personnel in an urban forest is 15, whereas the average is 4. Furthermore, the number of technical personnel, such as forest engineers and landscape architects is quite low. 18 urban forests have no technical personnel at all. The mean number of technical personnel working in urban forests is as low as 1.44.

Urban Forest Services

The number of tree species in urban forests of Turkey varies from 1 to 25 (Table 4). The Denizli Urban Forest consists of just one tree species only, while other urban forests have at least three different tree species. Two urban forests have no coniferous tree species, while six urban forests have no broadleaved tree species. Visitors often prefer urban forests with a higher diversity of tree species over natural forests with little variation [33, 34]. Oğuz [15] pointed out that in Europe, urban forests with deciduous tree species are relatively more common and the tree age is variable. Dirik and Ata [35] and Gezer and Gül [12] also stressed that deciduous tree species have to be used for recreation areas. In this sense, it may be indicated that the attractiveness of urban forests will lessen with the decreasing of tree species diversity.

The minimum and maximum numbers of animal species in urban forests varies from 1 to 12, and its mean value is only 5 (Table 4). The low number of animal species has resulted from the lack of animal inventory conducted in urban forests. Namely, the identification of animal species in urban forests has been done insufficiently. Actually, the real number is expected to be much higher.

TABLE 4
Information about urban forest composition

	Unit	Min.	Max.	Mean
The number of tree species	numbers	1	25	8
The number of coniferous tree sp.	numbers	0	9	3
The number of broad-leaved tree sp.	numbers	0	16	5
The number of animal species	numbers	1	12	5

Annual average number of visitors per urban forest in Turkey is 25 603. Sinop Urban Forest has the lowest number (500) of annual visitors (Table 5). Here the public opinion is lacking any knowledge about the urban forest. The annual number of visitors in four other urban forests is below 1 000. On the other end of the scale, İstanbul Urban Forest has the highest number of visitors (about 200 000). The average number of visitors can be affected by different variables such as distance, location, personnel number, presence of a manager or management plan and the number of functions that the urban forest provides [36]. But in some urban forests of Turkey, the number of visitors is pretty low. The reason is that service units in those urban forests have not been completed and are not introduced sufficiently yet.

The usage level has been calculated as the ratio of the number of visitors to the urban population. According to Table 5, it varies from 1% (in 14 urban forests) to 216.5% (Bilecik Urban Forest). Facilities such as casinos and wedding halls existing in Bilecik Urban Forest have increased the usage level of their urban forest considerably. Yet, these kinds of usages do not match the intended usage of urban forests. The average usage level of urban forests is 16.5% (Table 5).

Urban forest area per capita in some settlements is very low with 0.1 m^2 (Ankara Urban Forest), which is as high as 106 m^2 (Muğla Urban Forest) in other settlements. Its mean is 11 m^2 in Turkey (Table 5).

TABLE 5
Information about urban forest recreation services

	Unit	Min.	Max.	Mean
The annual urban forest visitors	persons	500	200 000	25 603
Usage level	%	1	216.5	16.5
Urban forest area per capita	m^2/person	0.1	106	11

In almost half of the urban forests, there are no car parking area lots and information centers. There are banks in 47 urban forests, viewpoints in 42, fountains in 40, and toilets in 37 (Table 6, Figure 5). Walking paths are the highest among the facilities presented in urban forests. There are walking paths in 49, sport areas in 34 and playgrounds in 45 urban forests (Table 6). In addition, there are no bicycle paths in the majority of the urban forests (94.2%). Çetiner et al. [32] pointed out that parking area lots are important for urban forests to attract visitors.

FIGURE 5
A Playground in Bartın Urban Forest

Recreation is important in 86% of the 52 urban forests in Turkey, various sport activities are possible in 75%, health facilities exist in 60% and flora-fauna wealth is found in 31% of the urban forests. The main aim of urban forests is to provide services, such as carbon emission reduction, mitigation of air pollution, amelioration of the microclimate and the supply of recreation areas [9]. Only recreation and sport activities out of these aims are intensively utilized in urban forests of Turkey.

CONCLUSIONS AND RECOMMENDATIONS

Based on this study the following results can be reached. These are given below and focus on general characteristics and prominent deficiencies of urban forests in Turkey.

The experience with urban forests in Turkey is short, where on average urban forests existed for 6.8 years only. In this short time span the society did not get to know urban forests sufficiently well. Moreover, forestry organizations have not given much importance to urban forests too. Although more than 100 urban forests have been established in a short period of time, there have been insufficient efforts to improve the

TABLE 6
Actually recreational facilities in urban forests

	Frequency		Percent	
	Existent	Absent	Existent	Absent
Sedile	47	5	90.4	9.6
Viewpoint	42	10	80.8	19.2
Fountain	40	12	76.9	23.1
Sport area	34	18	65.4	34.6
Walking	49	3	94.2	5.8
Playground	45	7	86.5	13.5
Toilet	37	15	71.2	28.8
Parking area	28	25	51.9	48.1
Bicycle road	3	49	5.8	94.2
Information center	28	24	53.8	46.2

quality of the established urban forests. Nevertheless the experiences with urban forestry have to be shared at the national or international level. For this purpose, forestry organization should collaborate with municipalities and non-governmental organizations and also an urban forestry congress at the national or international level can be held. With these efforts, not only the conceptual framework of urban forests can be evaluated, but also a model for urban forests in Turkey can be formed using experiences around the world. This will increase the quality of the existing urban forests and the recognition of the urban forests by the society. In addition, there is need for public relations to increase the number of visitors to urban forests.

This study has found that number of population, urbanization ratio and forest area per capita have no effect on the establishment of urban forests. In fact, these characteristics have to be taken into consideration in deciding on the establishment of urban forests and the selection of their locations. In addition, they guide the planner in many technical topics, such as defining the size of urban forests and the capacity of their facilities. Consequently, these characteristics should be considered in establishing the urban forests.

Some of the studied 52 urban forests were rather distant from urban settlements and only half of them were within walking distance. Moreover, the majority of urban forests can not been reached by public transport. However, easy access is one of the most important drivers for a city-dweller to adapt to urban forests and to increase their use. For these reasons, proximity of urban forests to the city and reachability by walking or public transport are important.

According to the recreation regulation of Turkey, the established urban forests should also have included purposes other than recreation. Yet, it was determined that the majority of urban forests in Turkey were used only for meeting the picnic and entertainment need of visitors. Besides these purposes, urban forests should be established to reduce carbon emission, to mitigate air pollution, to present social functions such as education, health, sport, aesthetic and culture to public, to introduce technical forestry activities and to give information about flora and fauna in urban forests.

The majority of urban forests in Turkey have no lake-pond or stream. The value of a recreation area increases with the presence of lake-pond or streams apart from plant and animal diversity. The demand of the society for urban forests will increase if water bodies such as a lake-pond or stream are available in urban forests.

Almost all urban forests had no management plan and the number of their managerial and technical personal was low. This is evidence that urban forests were not managed based on scientific and technical principles. However, the urban forests that have a management plan and enough managerial and technical personal can provide experience for formulating regulations. Therefore, management plans should be provided for each urban forest.

Service units in most urban forests have not been fulfilled, yet. Prominent facilities provided in urban forests were walking paths and playgrounds. Half of urban forests have no parking area and an information center. Actually, service units determining the visitor demand in urban forests have to be completed. Also recreational capacity definitely should be taken into account in the establishment of above mentioned units.

The number of tree and animal species in urban forests was low as inventory works for them were not done sufficiently. After inventory works are conducted in actual urban forests information points and signs have to be introduced for tree and other species. Moreover, tree species, plant and animal diversity should be considered in prospective urban forests.

Deficiencies in the legal and administrative infrastructure of urban forests in Turkey were not limited to the results of the present study only. All deficiencies of urban forest management need to be assessed by various scientific researchers. When following a participatory approach urban forests could serve the society more effectively. Finally, there is need for scientific studies to show legal and administrative aspects of urban forests.

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Thermic Attenuation on Concrete Sidewalk under Urban Trees. Case Study: Santa Marta – Colombia

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Abstract

Background and purpose: Urban trees provide a number of services including shade and thermal attenuation. This is related to morphological and physiological characteristics of trees and may vary between species and even between individuals of the same species. The aim of this work was to identify thermic attenuations on concrete sidewalks under six tropical urban trees with six different types of shadows.

Materials and methods: In Santa Marta City, Colombia (10º12´20" N, 74º13´33" W, 10 meters above sea level and 31ºC temperature), we selected six trees (species) with different types of shade, and they are evaluated for soil temperature and the temperature in the shade and off throughout the day for four different days of the year. ANOVA and t-tests were performed with R program in order to identify the influence of the specie, the day, the hour and the position (at the thermic comfort level, surface temperature) on the temperature results obtained.

*Results and conclusion: Some trees have the most translucent shadows most likely due to nictinastic movements and consequently less temperature attenuation. On the other hand, other trees have denser shadows and can generate more substantial thermic attenuations. Regarding temperature data, the hour of the day shows the greatest influence on the variability of air temperature and the species shows the greatest influence on the variability of surface temperature. Honey berry (*Meliccoca bijugatus*) and Malay almond (*Terminalia catappa*) trees have denser shadows and can generate more substantial thermic attenuations. Tree physiology can play an important role in temperature attenuation in cities as a result of shadow effects and can be applied as a criterion to select urban trees in tropical cities.*

Keywords: Tropical trees, temperature, shadow, heat islands, urban trees

INTRODUCTION

Urban trees provide a number of services including carbon and pollutants capture [1] shade, thermal attenuation and ultraviolet (UV) protection [2, 3] as well as hydric regulation [4].

Heat islands are a consequence of direct sun light effects over city structures. These structures take sun energy and convert it into heat, generating an increase of average city temperature in comparison with nearby rural areas [5]. Trees can reduce temperature by thermic attenuation depending on the shape of their shadows and other physiologic factors such evapotranspiration [6] and nastic movements [7]. Thermic attenuation by trees as an ecosystem service for whole city [8] can range from 0.5°C to 1.4ºC [9, 10]. These attenuations increase the service life of urban surface materials [11-13]. For example, asphalt roads can reach temperatures over 70ºC without shadow effect causing a reduction in the life cycle of this kind of surface and inducing other effects such as the release of toxic – mutagenic gases [14, 15].

The aim of this work was to identify thermic attenuations on concrete sidewalks under six tropical urban trees with six different types of shadows in Santa Marta city, Colombia.

MATERIALS AND METHODS

This research was developed in Santa Marta City, Colombia (10º12´20" N, 74º13´33" W, 10 SLM. (Figure 1), which has an average temperature of 32.6 ºC (Figure 2), and 443 mm of rain per year (Figure 3) [16].

FIGURE 1
Santa Marta Colombia location

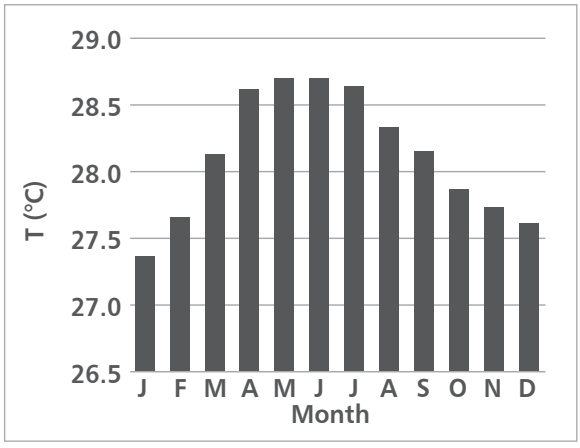

FIGURE 2
Medium temperature (°C)

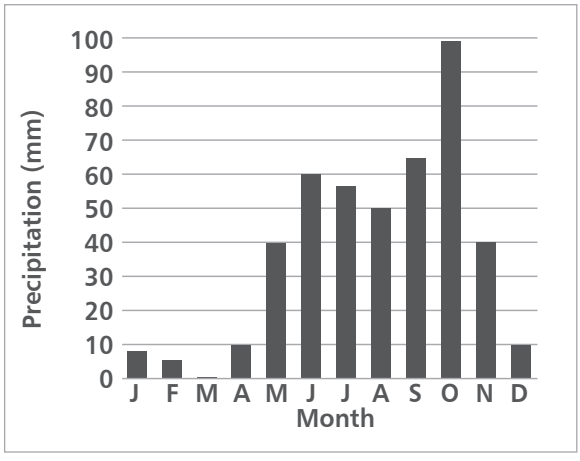

FIGURE 3
Precipitation value

We selected six different kinds of shadows – six trees (Figure 4–9) and five different species: Malay almond 1 and Malay almond 2 (*Terminalia catappa*), Honey mesquite (*Prosopis juliflora),* Honey berry (*Meliccoca bijuca*), Redwood tree (*Platysmincium pinatum*) and Rain tree (*Enterolobium ciclocarpum*).

The trees chosen have between 8 and 12 meters (high total), 21 and 45 cm diameter trunk and between 4 and 8 m diameter of crown (Table 1).

TABLE 1
Dendrometric information of selected trees

Tree	Total height (m)	Crown height (m)	Crown diameter (S-N direction) (m)	Crown diameter (W-E direction) (m)	Diameter at breast height (cm)
Malay almond 1	8.0	4.0	6.0	5.0	25
Honey mesquite	8.0	4.0	8.0	7.0	21
Malay almond 2	7.0	3.0	8.0	6.0	22
Honey berry	7.0	3.0	5.0	5.0	25
Redwood tree	6.0	3.0	4.0	4.0	25
Rain tree	12.0	5.0	8.0	7.0	45

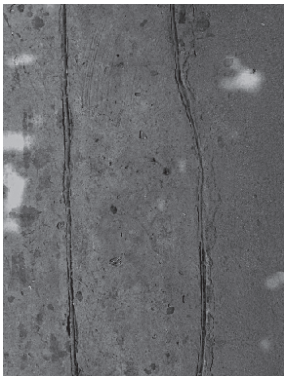

FIGURE 4
Malay almond´s shadow

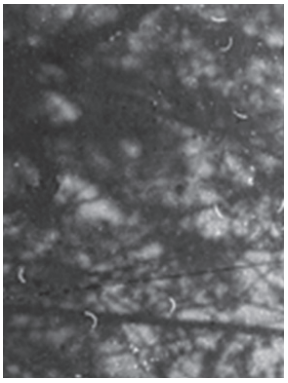

FIGURE 5
Honey mesquite´s shadow

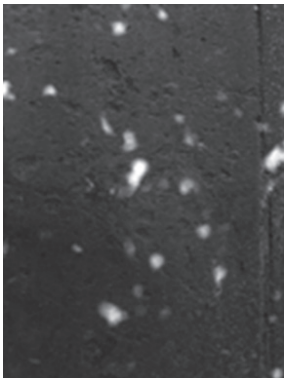

FIGURE 6
Malay almond´s 2 shadow

FIGURE 7
Honey berry´s shadow

FIGURE 8
Redwood tree´s shadow

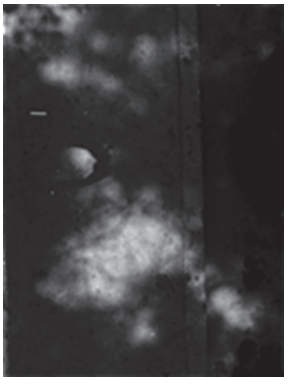

FIGURE 9
Rain tree´s shadow

Temperature data were collected at the thermic comfort level (1.5 m) beneath the trees and on the sidewalk at points affected and not affected by the tree's shadow, for day we took temperature with eleven measurements per hour (each 5 sec for a minute) between 8:00 a.m. and 5:00 p.m. over 4 days (March 13 and 26 and April 6 and 7), for a total of 5 720 values. For each tree we started with air temperature and in second place we took the surface temperature under the shadow. Finally we took the surface temperature in direct sun light. The value of temperature was taken with an air thermometer (*Sper Scientific Mini Environmental Quality Meter*), with a resolution of ±1.2°C ambient, and surface thermometer (*Extech® High Temperature IR Thermometer*), with a resolution of 0.1°F/°C.

ANOVA and t-tests were performed with R program in order to identify the influence of the specie, the day, the hour and the position (at the thermic comfort level, surface temperature) on the temperature results obtained.

RESULTS AND DISCUSSION

The average comfort level temperature was 30.3ºC and ranged from 30.1ºC to 34ºC. For the temperature measured at the sidewalk, the average value with shadow effect was 29.8ºC and ranged from 26.0ºC and 40.7ºC, while the average value without shadow effect was 40.8ºC and ranged from 40.3ºC to 77.2ºC. (Table 2, Figures 10 to 21).

TABLE 2
Temperature Data

Species - Position	Temperature (°C)		
	min	aver	max
Malay almond 1 (air)	30.1	30.0	34.5
Malay almond 1 (surface)	29.1	29.9	38.1
Honey mesquite (air)	31.3	30.4	34.7
Honey mesquite (surface)	30.0	30.8	40.7
Malay almond 2 (air)	30.9	29.9	34.7
Malay almond 2 (surface)	26.0	29.1	36.4
Honey berry (air)	31.2	30.8	34.1
Honey berry (surface)	28.8	28.1	36.5
Redwood tree (air)	31.2	29.2	34.7
Redwood tree (surface)	29.2	31.6	40.1
Rain tree (air)	31.3	31.4	34.7
Rain tree (surface)	27.4	29.2	36.6
Direct sunlight (surface)	40.3	40.8	77.2
Total value tree (air)	30.1	30.3	34.7
Total value (surface)	26.0	29.8	40.7

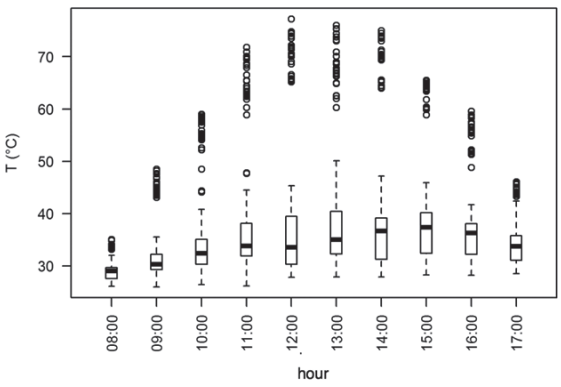

FIGURE 10
Temperature variation along of the day (total values)

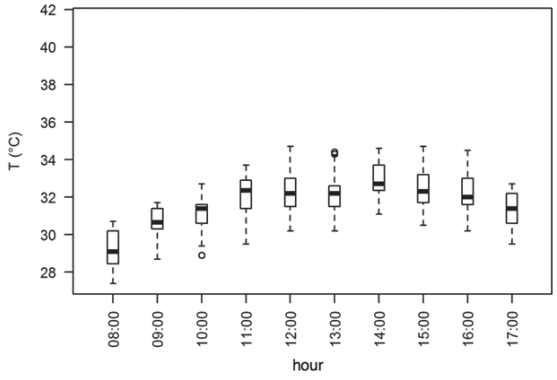

FIGURE 11
Temperature variation along of the day (air values)

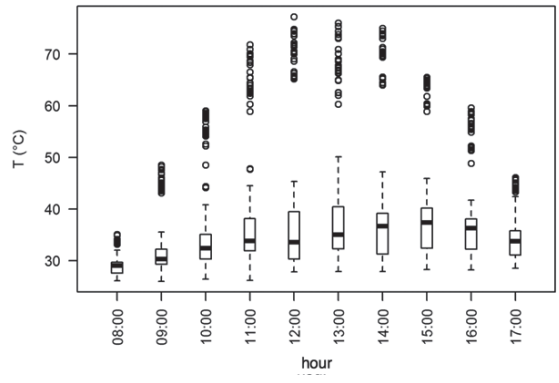

FIGURE 12
Temperature variation along of the day (surface values)

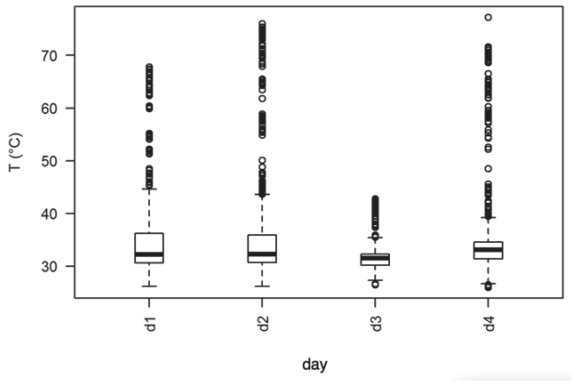

FIGURE 13
Temperature hourly variation (total values)

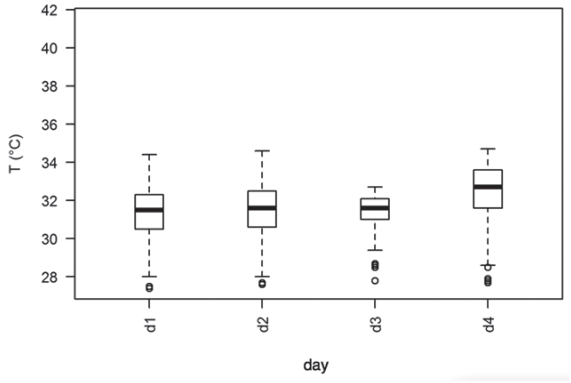

FIGURE 14
Temperature hourly variation (air values)

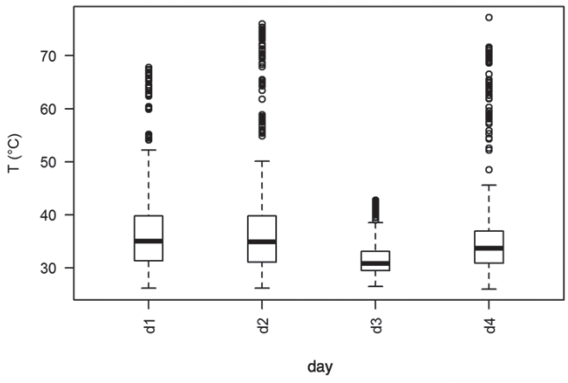

FIGURE 15
Temperature hourly variation (surface values)

For temperature collected we applied ANOVA and t-test. ANOVA results indicated that ***the species*** (kind of shadow) show the greatest influence on entire temperature variability, followed by the hour of the day, the date and the position (with or without shadow) (Figure 19). The kind of shadow is a primary factor for tree services associated with thermic attenuation. Regarding temperature data, ***the hour*** of the day shows the greatest influence on the variability of air temperature (Figure 19) and the species shows the greatest influence on the variability of surface temperature (Figure 20). These results are of the same magnitude as those reported in the literature for Mediterranean climate

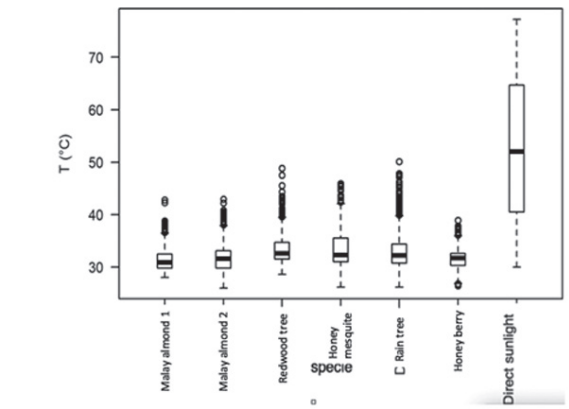

FIGURE 16
Thermic variation by specie (total value)

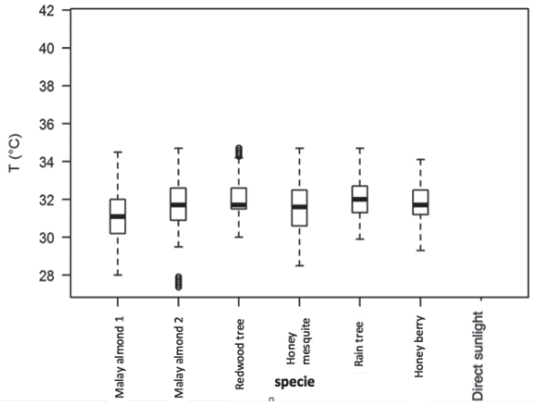

FIGURE 17
Thermic variation by specie (air values)

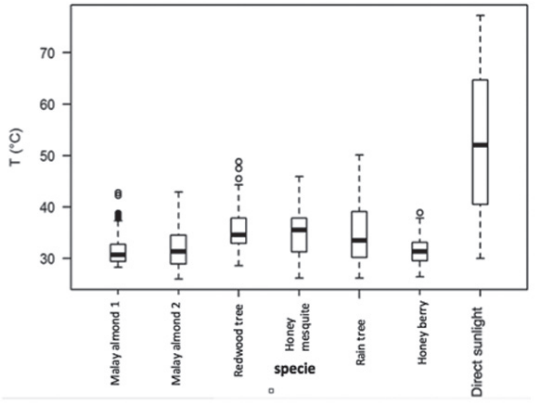

FIGURE 18
Thermic variation by specie (surface values)

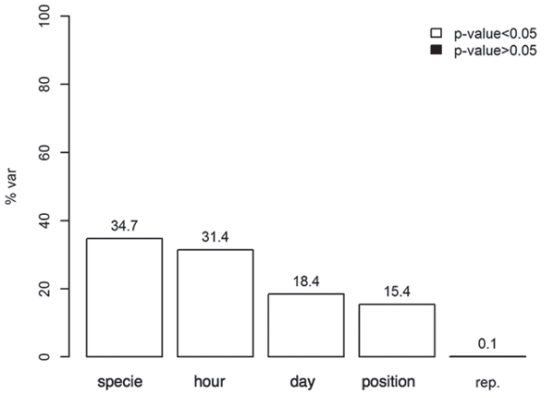

FIGURE 19
Total variance (total values)

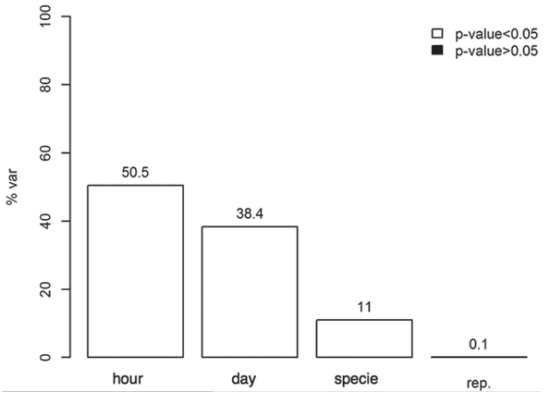

FIGURE 20
Total variance (air values)

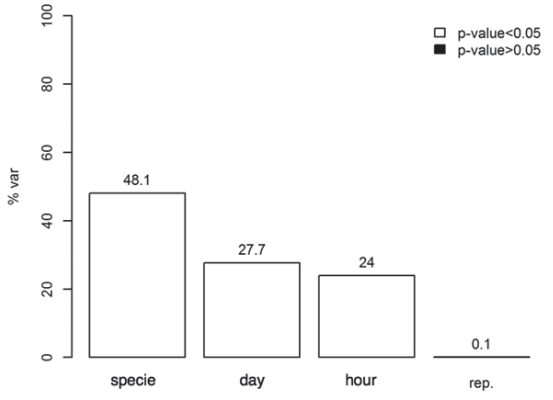

FIGURE 21
Total variance (surface values)

(41.3 ºC surface under tree and 63.6ºC surface direct sun light) [16]. T-test results indicated that the air temperature under the shadow of Malay almond 1 tree vary significantly (p-value < 0.05) from the air temperature results under the shadows of the other trees studied, including Malay almond 2. No significant differences between air temperatures under the shadow of Malay almond 2 tree and air temperature related to the other trees were detected (with exception of Malay almond 1) and Honey berry

TABLE 3
p-values from t-test species, air temperature

	Malay almond 1	Malay almond 2	Redwood tree	Honey mesquite	Rain tree
Malay almond 2	9.88E-17	NA	NA	NA	NA
Redwood tree	1.51E-24	0.837962096	NA	NA	NA
Honey mesquite	8.02E-09	0.214090457	0.00019813	NA	NA
Rain tree	2.38E-28	0.093276126	1	3.39E-06	NA
Honey berry	2.68E-16	1	0.63659583	0.294487039	0.064964105

TABLE 4
p-values from t-test species, surface temperature

	Malay almond 1	Malay almond 2	Redwood tree	Honey mesquite	Rain tree	Honey berry
Malay almond 2	4.47E-07	NA	NA	NA	NA	NA
Redwood tree	2.75E-69	1.44E-33	NA	NA	NA	NA
Honey mesquite	1.31E-42	1.07E-15	0.001378591	NA	NA	NA
Rain tree	2.85E-38	4.59E-13	4.46E-05	1	NA	NA
Honey berry	6.67E-06	1	3.20E-36	1.49E-36	9.13E-15	NA
Surface	2.82E-260	7.50E-204	2.39E-99	1.35E-129	1.14E-135	1.31E-208

TABLE 5
p-values from t-test especies, hour air temperature

	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
9:00	2.04E17	NA	NA	NA	NA	NA	NA	NA	NA
10:00	6.33E-54	5.51E-09	NA	NA	NA	NA	NA	NA	NA
11:00	7.65E-90	2.43E-28	3.02E-06	NA	NA	NA	NA	NA	NA
12:00	1.06E-82	3.27E-24	0.000342336	1	NA	NA	NA	NA	NA
13:00	1.75E-110	4.29E-41	1.23E-13	0.596434889	0.032186769	NA	NA	NA	NA
14:00	1.36E-110	3.64E-41	1.11E-13	0.575694756	0.030741969	1	NA	NA	NA
15:00	6.59E-124	6.05E-50	1.95E-19	0.002970047	4.43-05	1	1	NA	NA
16:00	2.36E-108	9.97E-40	8.77E-13	1	0.076710664	1	1	1	NA
17:00	7.34E-69	1.02E-16	0.439815179	0.25604151	1	7.49E-06	7.00E-06	7.26E-10	2.75E-05

offer not significantly difference for other species, the species of Redwood tree and Rain tree significantly similar, the Malay almond 1 tree was significantly different about other trees; the Malay almond 2 tree was not similar to Redwood tree and at the same time significantly different about other trees, however the Redwood tree was significantly different about other trees; Honey mesquite tree was significantly different about other trees as such the Rain tree (Table 3). The Honey mesquite, Redwood tree and Rain tree trees have nictinastic movements and consequently less temperature attenuation. About the surface temperature only the Malay almond 2 and Honey berry give same significant of similar conditions (Table 4). The values of air temperature are significant similar for 13:00 and 16:00 hours, 12:00 and 17:00 hours and between 13:00 and 15:00 hours (Table 5). The values of surface temperature are similar significantly between 11:00 to 13:00 hours and between 13:00 and 16:00 hours (Table 6).

Finally about the surface temperature, all trees are significantly different in refer to surface with shadow (direct sunlight).

TABLE 6
p-values from t-test especies, hour surface temperature

	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
9:00	4.86E-35	NA	NA	NA	NA	NA	NA	NA	NA
10:00	3.31E-102	7.94E-16	NA	NA	NA	NA	NA	NA	NA
11:00	1.95E-199	6.40E-69	4.10E-22	NA	NA	NA	NA	NA	NA
12:00	4.23E-192	2.10E-64	2.19E-19	1	NA	NA	NA	NA	NA
13:00	6.55E-217	5.69E-80	4.04E-29	1	1	NA	NA	NA	NA
14:00	8.26E-264	2.09E-111	4.75E-51	7.95E-06	2.17E-07	0.007869	NA	NA	NA
15:00	1.15E-248	5.37E-101	1.64E-43	0.002392	0.000134	0.457822	1	NA	NA
16:00	2.40-228	2.07E-87	4.55E-34	0.711183	0.10442	1	0.220402	1	NA
17:00	2.87E-138	6.61E-34	0.000591	9.34E-07	2.94E-05	6.91E-11	1.79E-25	3.01E-20	5.39E-14

CONCLUSIONS

For urban surfaces (sidewalks) we found a range of 50ºC between the lowest value (26ºC under shadow effect) and the highest value (77.2ºC under direct sunlight), conditions that can generate positive effects on heat islands and, in the case of asphalt pavements, even a control of toxic vapours and increase in life cycle durability.

Honey mesquite (*Prosopis juliflora)*, Redwood tree (*Platysmincium pinatum*) and Rain tree (*Enterolobium ciclocarpum*) trees have the most translucent shadows most likely due to nictinastic movements and conse-quently less temperature attenuation. On the other hand, Honey berry (*Meliccoca bijugatus*) and Malay almond (*Terminalia catappa*) trees have denser shadows and can generate more substantial thermic attenuations. Finally found that there are significant differences between the shadow temperature control (sun light direct) and any temperature under the surface shadow tree.

This information suggests that tree physiology can play an important role in temperature attenuation in cities as a result of shadow effects and can be applied as a criterion to select urban trees in tropical cities.

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Original scientific paper

Perception of the Local Population toward Urban Forests in Municipality of Aerodrom

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Abstract

Background and purpose: With the development of both society and economy, environmental issues have become a more popular topic. In recent decades both the role and perception of urban forests have changed regarding recreational and environmental aspects on both a local and global level. This coupled with urbanization places great importance on how people see and value the forests in an urban and peri-urban setting. Visitors are not a homogeneous category and hence have different needs and perceptions of urban and peri-urban green spaces. The study aims to understand the visitors` perception from municipality Aerodrom towards urban forests and their recreational use, benefits, preferences and perception regarding management activities of urban forests.

Materials and methods: The method used for the research is qualitative with semi-structured questionnaire which was conducted face to face. Gathered data were analyzed by Excel and after that were presented in tables and graphs for better review of the results. The study area was municipality of Aerodrom which has the biggest space under urban forests per capita in Skopje.

Results and conclusions: Results have shown that all respondents have permanent residence in the municipality of Aerodrom, located in different settlements and with the length of stay mainly between 5 to 40 years. There is a dominance of female population and respondent's age over 40 in the research. Results also showed that the average number of visit in urban forests by respondents during the week is three times. Regarding the meaning and association of term urban forests, results showed that majority of respondents have a clear and concise perception, and mainly this term for them is association on park and greenery, a nice decorated environment and place for walk. When it comes to the way how current situation with urban forest can be improved almost all of the respondents highlighted it can be through the following things: maintenance of the urban forests by the public enterprises to be set on a much higher level, more trees and flowers to be planted, more toilets and playgrounds to be built, and local government to forbid companies of building apartments and houses close to the urban forests.

Keywords: urban forests, perception, local population, municipality, urban green space, peri-urban green space

INTRODUCTION

With the development of both society and economy, environmental issues have become a more popular topic. In recent decades both the role and perception of urban forests have changed regarding recreational and environmental aspects on both a local and global level. This coupled with urbanization places great importance on how people see and value the forests in an urban and peri-urban setting [1].

Urban sites are often harsh, characterized by many pressures and threats, from limited growing space to adverse climatic conditions and air pollution [2]. As a result of urbanization attention is being given to green areas in and around cities. Need for on-site recreation, place for passive and active refreshment from daily stresses is increasing thus, easy accessible nearby green areas in and around cities are good opportunity for recreational and refreshment activities of citizens. Urban forestry is one of the most used terms in relation to trees in or near the urban environment. An urban forest can be defined by its placement in or near urban areas and by its multi-functional aspects given shade,

amenity values, etc. Therefore, urban forestry can be defined as: planning, design, establishment and management of trees and forest stands with amenity values, situated in or near urban areas [3].

Although there is no commonly accepted definition for urban forestry, a working definition may be "an integrated approach to the planting, care and management of trees and forests in and around the city to secure multiple environmental and social benefits for urban dwellers" [4]. Current thinking leans toward considering the urban forest as all trees and related vegetation in and around towns and cities [5].

"Near-town forests have high value because of recreational demand, familiarity of the forest to the people..." [6]. Most of the values attached to urban forests are non-priced environmental benefits that include e.g. pleasant landscape, ecological balance, pollution control, climatic and physical benefits, peace and quiet and potential recreation opportunities [7].

Urban forestry is a new concept in SEE region. Relatively little has been written about urban forestry, so there is need for more comparative information on what modes of urban forest governance exist and how they work [8]. Definitions of the (peri-) urban forest (hereafter referred to as the 'urban forest' for reasons of simplicity) itself include all the trees and woodland in - and around - urban areas [9]. "Urban Forestry means planning, establishing, protecting, and managing of trees and associated plants, individually, in small groups, or under forest conditions within cities, their suburbs, and towns" [4]. USDA Forest Service guidance amplifies this, defining the management of the urban forest as the "planning for and management of a community's forest resources to enhance the quality of life. The process integrates economical, environmental, political and social values of the community to develop comprehensive management plan for the Urban Forest"[4].

Trees and forests are, because of seasonal changes and their size, shape, and color, the most prominent elements of urban nature. Their benefits and uses range from intangible psychological and aesthetic benefits to amelioration of urban climate and mitigation of air pollution. Historically the main benefits of urban trees and forests relate to health, aesthetic and recreational benefits in industrialized cities. Moreover, green areas have provided people with subsistence by providing food, fodder, fuel, wood and timber for construction [10].

While these benefits of urban woodland, other tree stands and individual trees are not new they are still insufficiently recognized in urban planning and development processes. There is need to provide more knowledge on the role of urban woodland and trees in improvement of the environment and relate this to their social functions such as fostering mental and physical health. Urban forests, trees and other green spaces are thought to contribute significantly to certain psychophysical and social needs of urban dwellers. Recent studies on citizens' perceptions and behavior toward urban green areas have shown the complexity and the multidimensional character of the man-nature relationship in the city; inhabitants' use of green spaces appears to be motivated by the need for psychological health with relevant social implications [11].

PROBLEM STATEMENT

Visitors are not a homogeneous category and hence have different needs and perceptions of urban and peri-urban green spaces. In the recent years, South Eastern Europe (SEE) countries are facing with dynamic changes. Transition from socialism to democratic governance, fast growth of the population in the cities, urbanization and industrialization leads to changes in social and cultural lifestyle of citizens. Urbanization is ongoing process throughout the world especially in developing countries. The human population has lived a rural lifestyle through most of history. The world's population is quickly becoming urbanized as people migrate to the cities. In 1950, less than 30% of the world's population lived in cities. This number grew to 47% in the year 2000 (2.8 billion people), and it is expected to grow to 60% by the year 2025 [12].

Skopje, the capital city of Macedonia has a very long history as a main settlement in the Balkan region. Over the years, and influenced by many different and shifting regimes and cultures, the town has turned into a multi-faceted and vibrant city, where a mixture of ethnic and socio-economic groups gives the city a specific character. Population increase in parity with the global urbanization trend and the simultaneous growth and shifts in the economy of the area has put a pressure on the socio-economic and environmental conditions under which the people live. According to last Census (2002), City of Skopje has 506 926 inhabitants and this number rapidly grow. It is estimated that nowadays Skopje has around 1 million citizens [13].

With the high level of urbanization in Skopje, green areas in and around city are of great importance as recreational settings for urban dwellers. Environment in and around Skopje has become more and more polluted, life in the City become more stressed. It makes working people feel exhausted; nervous thus need more clean air, peace and recreation. Hence, parks, green spaces and trees are more than the "lungs

of the city" or air pollution cleaners. They affect human health in a variety of ways such as active lifestyles, improved wellbeing, activities and emotional and physical health.

Study or research toward perception of the local population of municipality Aerodrom toward urban forests is not done yet, thus this research will provide (answers) information's on what are the visitors perception towards this area which will be helpful for the future development of the area. For many people, direct and indirect contact with nature is an essential aspect of their quality of life. Failures to understand how people experience and value nature can lead to misunderstanding between managers and public. Hence this research will help managers to understand and take into account the less tangible values that people derive from contact with nature. Taken into account above mentioned, it is necessary to know who, why and how use the urban forests - park in order to meet needs of the visitors.

Aerodrom is a municipality with the highest percentage on green space per capita, data from municipality show that it has 28 m^2 of green space per capita, while according to the European standards this green space should be at 8.5 m^2 per capita [14]. Currently the municipality builds new green spaces and parks in settlements Micurin, Lisice and regional centre of Aerodrom. For the maintenance of the green space, municipality use the services of public enterprise in Skopje - PE "Communal Hygiene" and PE "Parks and Greenery". In addition to better hygiene and maintenance of the green spaces, municipality hires seasonal workers [15]. Also, the municipality has purchased machinery (lawn mowers) tools and other equipment needed for that purpose. Maintaining hygiene of the green spaces municipality is conducting with the help of the public enterprises, with certain omissions, through its points. Local government is also working intensively on their urban documentation as a condition for sustainable development, quality of life and attracting investment [15]. All this is very important for the local population, science, public undertakings, parks and greenery.

OBJECTIVE OF THE RESEARCH

Research is focused on visitor's perception of urban forests in municipality of Aerodrom in everyday life – how local population, as direct users of the area, perceives urban forests in Aerodrom. The goal of research is to explore and describe opinions of the local population on the benefits of urban forest, variations in preferences and perceptions, recreational use of urban forest, perception and level of satisfaction of maintenance and management activities in the urban forests to policy makers who may be able to make changes to preserve and improve those areas.

In order to achieve the goal of the research, *general objective of the study is to understand the perception of local population toward urban forests*, though setting overall research question:

- What is the perception of the local population in municipality of Aerodrom toward urban forest in their place of living?
- What should be done in order to be improved management of urban forests in the municipality of Aerodrom?

THEORETICAL FRAMEWORK

In recent years, urban forest managers have been caught between the increasing demand for aesthetic and recreational use of urban forest resources and the decreasing budgets for managing those resources. This dilemma has created a need for more efficient ways to manage urban forests for the benefit of urban residents. In response to this need, the social science and design disciplines have undertaken studies of the human perceptual and behavioral aspects of the urban forests [16].

Perceptions and preferences from urban forests by Schroeder [16] are derived into following aspects:

- Benefits of urban forest vegetation,
- Preferences and perceptions,
- Safety,
- Variation in perceptions and preferences,
- Recreational use of urban forests,
- Applications of research.

Benefits of urban forest: Vegetation can have beneficial effects on people's moods and emotional states. The perceived benefits of urban forests generally fall into two main categories: benefits involving aesthetic enjoyment and relaxation; and benefits involving sports and social contact [2]. Coles and Bussey [17] recorded that 80% of visitors felt "close to nature", "relaxed" and/or "happy" when in the forest. Very few in their study felt anxious or insecure although Schmithusen and Wild-Eck [18] reported figures as high as 15% of all visitors feeling "unsafe" in other forests.

Preferences: Environmental perception studies seek to identify the characteristics and features that enhance the perceived quality of urban forests. In general, natural elements such as trees and water in landscapes are highly preferred over artificial elements. Trees and forested areas, water, good maintenance, and peace and quiet were among the most preferred features of urban parks and forests in several studies. The most

widely preferred kind of park environment seems to be a well-maintained open stand of large trees with evenly mowed grass and water. Features that detract from the attractiveness of a park include manufactured objects (e.g. buildings, fences, and parking lots), poor condition of vegetation, urban surroundings adjoining the park, litter, graffiti, crowding, and large, monotonous fields. Either too many or too few trees in a park can reduce visual preference. Sounds that are incongruous with the character of the setting can also make a forest or park less attractive [19].

Safety: The probability of being a victim of crime is higher in cities than in non-urban areas. Despite large variations between regions, countries and cities, recent years show a widespread increase in urban violence worldwide, including homicide, assault, rape, sexual abuse and domestic violence [20]. Some urban parks, according to Wekerle and Whitzman [21] have become 'hot spots' of crime and other criminal activities like drug dealing, bashing and sexual violence. Crime and social conflict are a serious concern in some urban parks and forests. "Many park users are unwilling to use areas of a park they perceive as unsafe and many potential park users are deterred from using parks at all due to fears for personal safety" [22]. Social conflict includes a wide range of behaviors, from violent crimes to "nonviolent" offenses such as drug use, to behaviors that, although not illegal, may be threatening or offensive to other users [23].

Variation in preferences: Not everyone likes the same kind of places. There are variations in urbanites' perceptions of urban forest settings, especially with respect to the degree of naturalness versus development. Schroeder and Anderson [24] found that most of the participants in their research thought that natural-appearing parks with dense vegetation were the most attractive, but a few people preferred highly developed, "manicured" parks.

Recreation use: People's preferences for urban forest environments are expressed in their choices of which sites to visit and how to use those sites. Konijnendijk's study [25] showed that urban forests are highly valued and appreciated for their recreational potential. Some recreational activities seem to be popular in almost all urban forests, such as going for a short walk, jogging and walking the dog. These mostly concern daily, short-time use by people living nearby. In Britain, for example, urban forests often include golf courses, while cycling is very popular in the Netherlands and Denmark. In the Nordic and Eastern European countries in particular, skiing is a main use in winter, and the collection of berries and mushrooms in summer and autumn. In former East-Berlin, overnight stays in tents in the forests used to be very popular and is still practised, even after the reunification of the city and being illegal. Nature-oriented forms of recreation seem to be preferred, although this trend is stronger in some countries than in others. Another general development is the emergence of more active forms of recreational use, such as mountain biking [26].

Applications of research: Research on urban forests is useful only to the extent that it can contribute to the planning and management of vegetation in cities. In this section, research can provide information on how visitors perceive the importance of management objectives and the performance of the manager in meeting those objectives. Research will be used to document the importance of Park Forest to citizens, what services should be provided, and to reveal sources of dissatisfaction with tree management programs.

METHODOLOGY

When social research is conducted, certain methods and methodologies for producing scientifically based results have to be applied. The method used for conducting the research is qualitative. In order to explore and describe social and aesthetic benefits of urban forests and discuss how local population perceive these benefits, urban forests in municipality Aerodrom are used as a case study. Aim of the research is to gain insight in perception, preferences and demands/needs of local population in municipality of Aerodrom toward urban forests as well as their habits and motivation related to visiting urban forests (e.g. sports, relaxation, etc.). Deductive approach is applied beginning with abstract thinking, logically connecting ideas in theory to concrete evidence and testing the ideas against evidence. Surveys have been conducted in-person contact by the `next-to-pass' technique [27], the sequential interview of a person or a group passing by. If a group was approached, the researcher attempted to make eye contact and responded to those who made eye contact.

The research was focused on fix settlements in the municipality of Aerodrom or in the larger parks in the municipality. Municipality of Aerodrom covers an area of 21.85 km^2 and population of 98 382 inhabitants. The whole area of the municipality or about 804 519 m^2 are green space [14].

The method of data collection were interviews "face to face" with half- structured questionnaire, which consisted of six closed and nine open-ended questions. In collection of data were interviewed 65 respondents, who were meet directly in the urban forests and were chosen by the method next to pass. The interviews were done over two days during the week, in the morning and in the evening during the day, in October 2012. Data have been analyzed in Excel and then presented in graphs and tables.

RESULTS

After completion of survey and analysis of the primary data, in order to be examined and evaluated perception on the local population from municipality of Aerodrom toward urban forests following results has been obtained.

All (100 %) of the interviewed respondents (Figure 1) that took part in survey had a permanent residence in the municipality Aerodrom. Regarding in which part of municipality Aerodrom respondents are living (Figure 2), results showed that 29.6% were located in settlement Aerodrom, 27.6% are living in Novo Lisice, 18.4% of respondents answered that they live in settlement Lisice, after them with 13.8% follow respondents from Micurin, while 7.6% from respondents live in settlement Ostrovo, and only 3.0% of respondents are located in settlement Old Aerodrom.

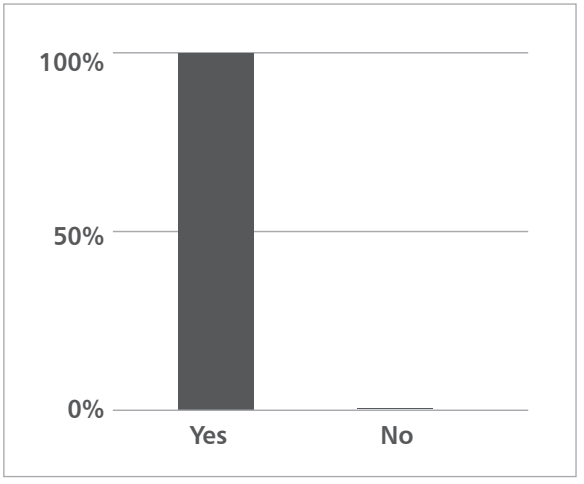

FIGURE 1
Q1: Is this your place of living?

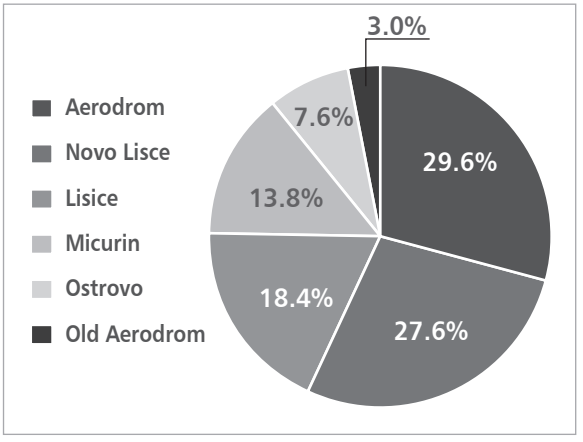

FIGURE 2
Q2: In which part of municipality do you live?

In terms of how long respondents live in their settlements (Figure 3), results gained from the research showed that nearly half or 41.5% from respondents answered that duration of their stay in that settlement is between 21 – 40 years, close to this percentage or around 36.9% of respondents are with period of living between 5 – 20 years, with 16.9% are respondents which period is more than 41 years , while only small % or around 4.7% belongs to the respondents which period of living is less than 5 years.

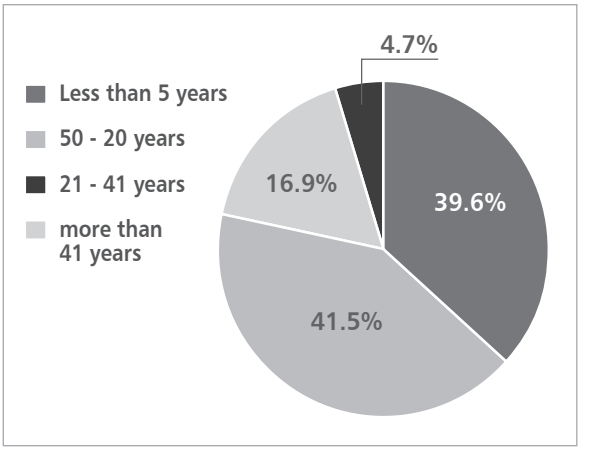

FIGURE 3
Q3: How long do you live here?

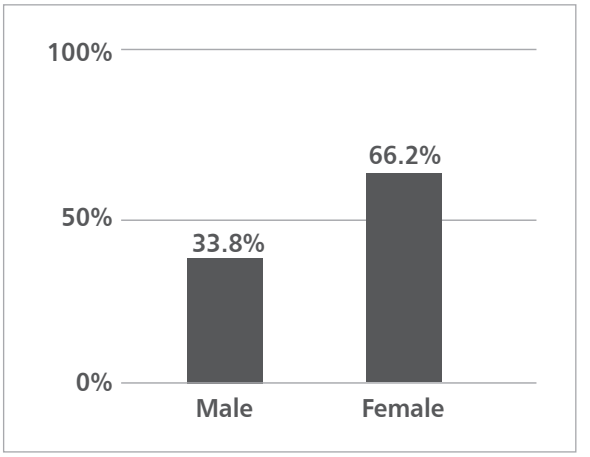

FIGURE 4
Q4: What is your gender?

Regarding the gender of respondents that took part in research, results showed (Figure 4) that involvement of both genders is not the same or female population with 66.2% is dominating over the male population which participated in the research with only 33.8%. When it comes to maturity or age structure of respondents that were included and participated in the survey according

to the obtained results, the age structure of respondents was divided into four categories. First category includes all respondents younger than twenty years, the second is between twenty one and forty years, the third class is from forty one to sixty while in the fourth class are respondents older than sixty one. As it can be seen and concluded from the (Figure 5), the biggest share (50.7%) in the survey has respondents from forty one to sixty years, while the respondents over sixty one have only 12.3%. It means that 73% of the respondents involved in the survey belong to the category over forty years. While only 27.7% of the interviewed respondents belong to the category from twenty one to forty, and 9.3% goes to the age under twenty. Hence the average maturity of respondents is 44.5 years.

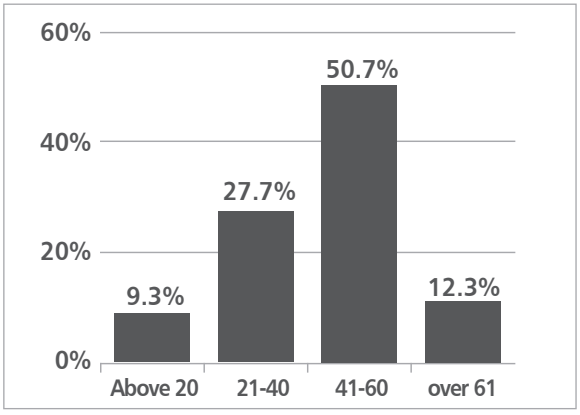

FIGURE 5
Q5: How old are you?

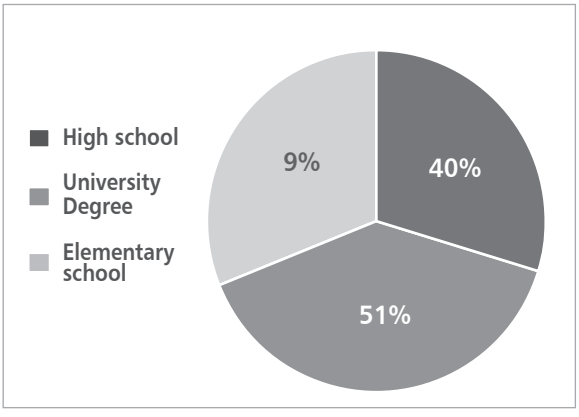

FIGURE 6
Q6: What is your education?

In terms of education level of the respondents that participated in research results showed that the largest percentage (51%) from respondents are with university degree, with high school have around 40% and only 9% of respondents answered that they have other education level (Figure 6).

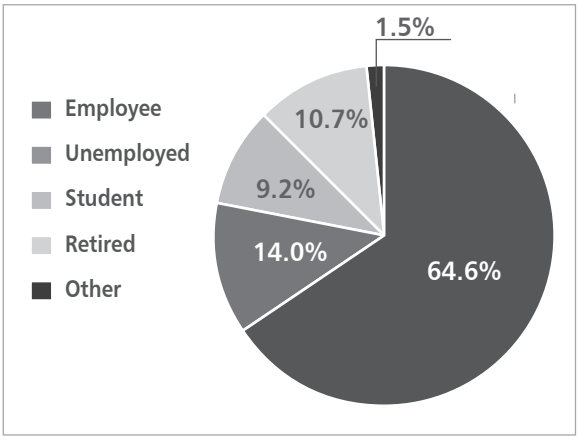

FIGURE 7
Q7: What is your occupation?

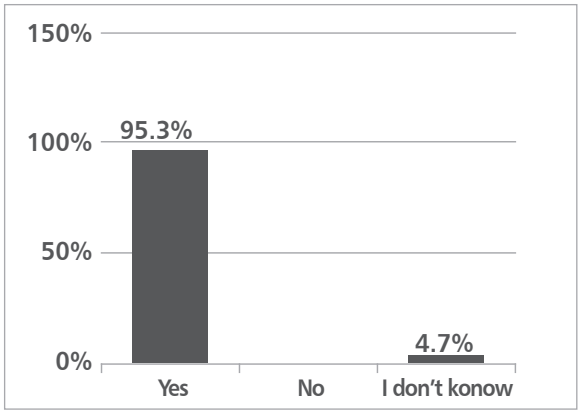

FIGURE 8
Q8:Are you familiar with the term urban forests?

The biggest part (64.1%) in the research took respondents (Figure 7) who are employed, after that following were unemployed respondents with 14.0%, while retired people participated with 10.7%, with a slightly lower percentage (9.2%) were students, and only 1.5% of the participants belong to the group of others. Regarding familiarity of respondents with the term urban forests, research obtained following results. Interesting is to highlight the fact that almost all (95.3%) of respondents are familiar with the term urban forests, while only 4.7% dont know right meaning of this term, and what makes things really interesting is that not even one of respondents answered that is not familiar.

When all respondents that took part in the research were asked to explain on what associate them the term urban forests, almost half of them (47.6%) pointed out that is park and greenery. Around 15.3% of respondents stressed that this term associate them on a nice decorated environment, while for about 10.7% this term mean a

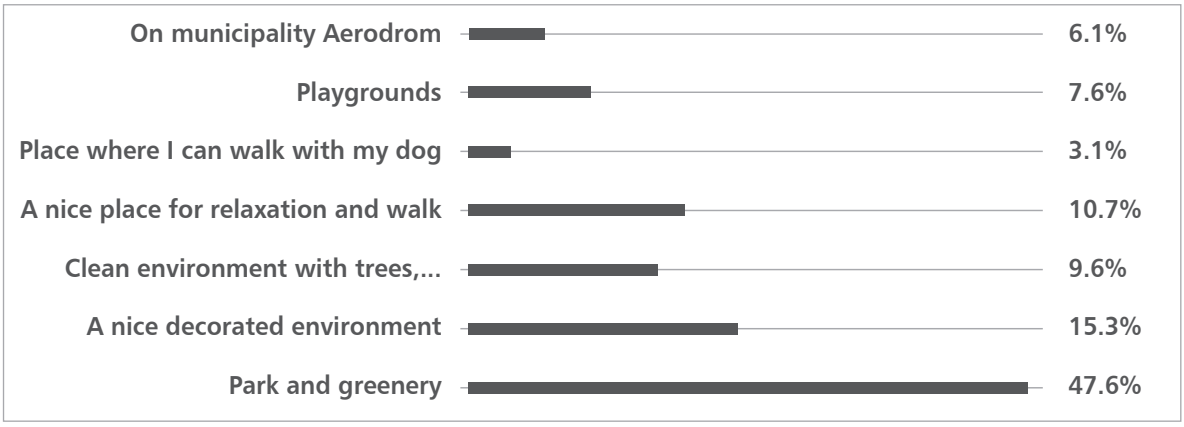

FIGURE 9
Q9: On what you become associated with the term urban forests?

nice place for relaxation and walk. For 9.6% this term is association of a clean environment with trees, grass and flowers, while for smaller percentage or for about 7.6% the term associate them on a playgrounds, some (6.1%) are associated with the municipality Aerodorm and for the smalest percentage of respondents (3.1%) this term associate them on a place where they can take a walk with their dog. Results from the research also showed that number of visits in the urban forests among respondents vary greatly starting from once per a week till seven times per a week. Hence average number of visit on local population to the urban forests is three time per a week.

Regarding the main reasons why respondents visit urban forests, according to the gained results more than a half of respondents (53.8%) highlight because these places offer them relaxation,piece, and walk, while 18.6 % visit urban forests because of aestethic reasons. Around 13.8% visit urban forests in order to socialize with their friends, some (6.1%) of respondents state that they visit them because of the fresh air and health, while for a small percentage of them (4.6%) reason is their walk with the kids and for (3.1%) is walk with the dog.

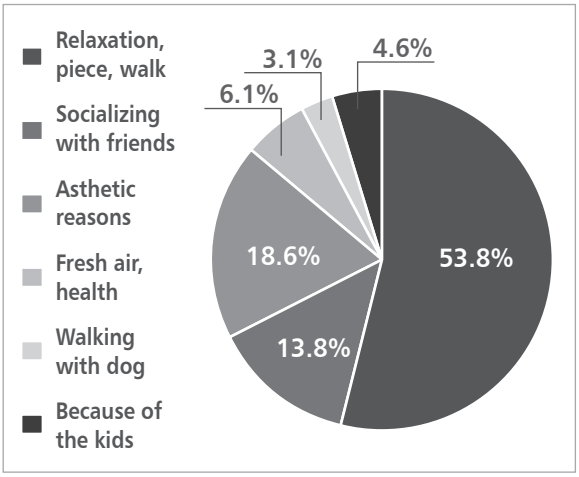

FIGURE 10
Q10: What are the reasons why you visit urban forests?

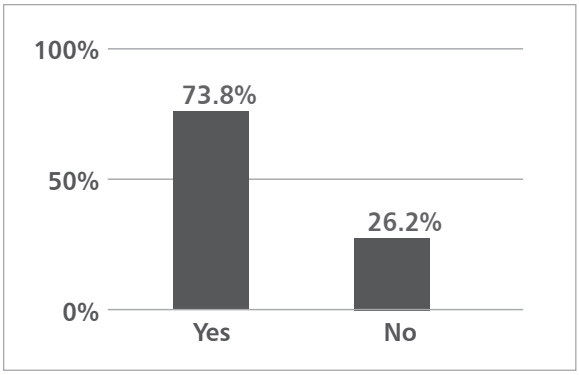

FIGURE 11
Q11: Are you satisfy with the current

When it comes to how respondents are satisfy with the current situation of urban forests in their place of living (Figure 11) according to the results majority of respondents (73.8%) are satisfy while only 22.2 % think that situation should be better and is not on a satisfactory level. Regarding the needs of new urban forests at their place of living (Figure 12) results showed that according to the opinion of majority of respondents (80%) there is a need for new urban forests, while 20 % don't share the same opinion so they stressed that those surface under urban forests are enough to meet the needs of the local population from municipality Aerodrom.

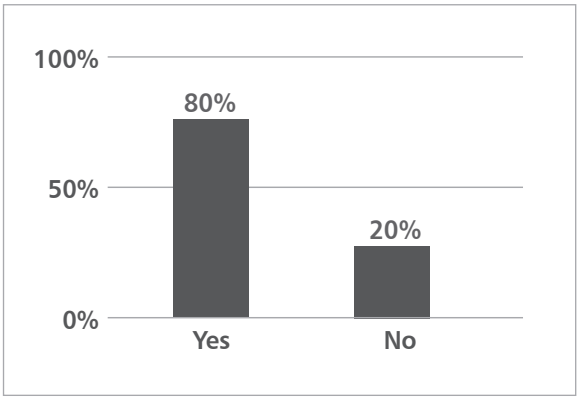

FIGURE 12
Q12: Do you think there is a need for new situation of urban forests?

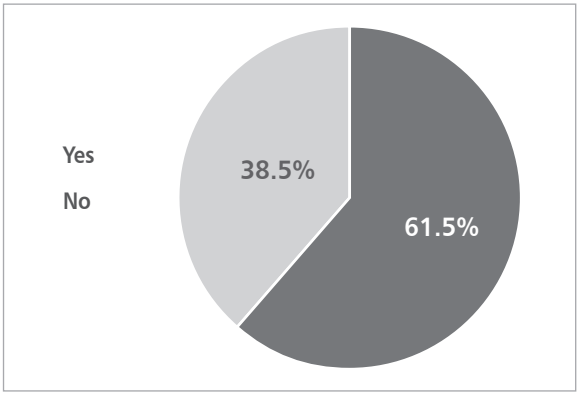

FIGURE 13
Q13:Do you think something should be improved regarding the urban forests in your area?

Opinion among respondents in terms of whether something should be change or not in terms of urban forests in their region differs (Figure 13). Thus 61.5% of respondents said that according to them there are many things that should be changed in urban forests in their region, while 38.5% do not share same opinion because according to them there is no need for any change at all. According to the respondents perception following things should be done in order the complete situation with urban forests to be improved in their place of living. Thus as one of the most important or with 26.3% is maintenance of the urban forests to be on a much higher level than it is the moment. While 24.6% from respondents think that situation will be improved if there will be planted more flowers and trees, and at the same time to be built more toilets and plagrounds. Contrary to those respondents 18.4% stressed that according to them nothing should be changes or improved for now because everything is ok. But for 13.8% there is a space and needs for more urban

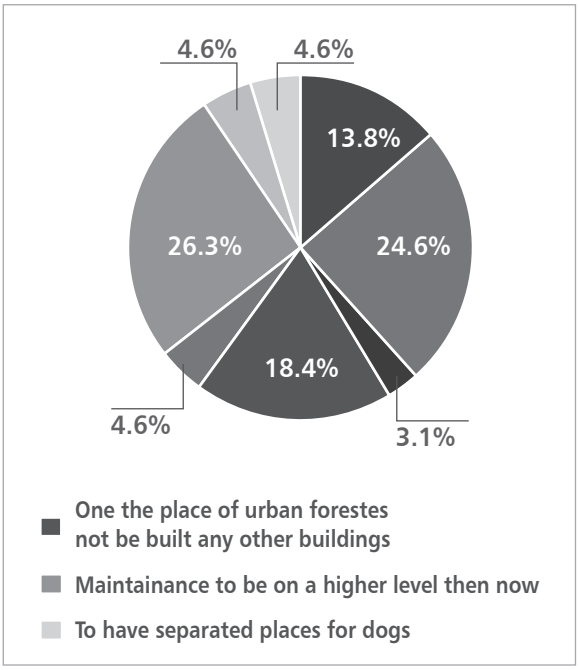

FIGURE 14
Q14:What should be done and improved regarding the urban forests in your area?

forests in this municipality and that can help a lot in improvement of the current situation.While according to 4.6% of respondents there is a need for more space for kids, on the place of the urban forests to not be built any other facilities, and to have separated place for dogs. And at the end only 3.1% pointed out that according to them urban forests should be set on a higher distance from the traffic.

DISCUSSION AND CONCLUSSIONS

This research gives an general understanding on perception of the local population toward urban forests in municipality Aerodrom. With alteration on lyfestyles of local population and modernazation of the world, needs and demands for urban forests had changed a lot and become more diverse. Although urban forests often can be places which bring people with different social and cultural background to socialize together, still many of the residents are seeing urban forests as a pieceful and quite place for their relaxation. However awarness of the importance on ecology, preserving and improving the urban forests benefits is constantly increasing among local population. For many people, their direct or indirect contact with nature play very important role for the quality of their life. Inability to precisely understand how people perceive and value urban forests might lead to misunderstandings between managers and users [10].

Obtained results from the research clearly indicate that all of respondents have a permanent residence in the municipality of Aerodrom, but located in different settlements and parts. Length of the stay in their place of residence for majority of respondents (78%) that took part in the research is between 5 to 40 years, while a smaller percentage refers to those respondents who have either less than 5 or more than 41 years. When it refer to gender involvement in the research, results shown that there is a significant predominance of female over male population, and also a predominance of respondents (73%) over 40 years. Taking into account the educational level of respondents (90%) which have either high school or university degree than its not suprising the result that almost all (95.3%) of respondents are familiar with the term urban forests. On top of this if is add the fact that average number of visit by local population is three times per a week according to the results from the research than its not suprising again very high percentage of local population with the familiarity of the term urban forests. Regarding on which things are associated with the term urban forests, results from the research showed that majority of respondents (74%) stressed that these things are: park and greenery, a nice decorated environment and a place for relaxation and walk. Although opinions among respondents vary about the reasons why they visit urban forests, yet majority of the respondents (73%) pointed out that the main reasons why they visit urban forests are: relaxation, piece, walk and also aestethic. Its intresting to highlight that majority (73.8%) of respondents are satisfy with the current situation of the urban forests in their municipality, and only small percentage express their dissatisfaction regarding the current situation. Although majority (80%) of respondents are satisfied with the current state of urban forests, yet they think that there is a space and need for new urban forests in their place of living. Intresting is to highlighgt that although majority (73.8%) of respondents are satisfy with the urban forests in their municipality still for more than a half something should be done regarding this areas. As some of the things that have been mentioned and pointed out by the respondents which can help in improvements of the current situation with urban forests are: maintenance of the urban forests to be on a much higher level, to be planted more trees and flowers, to be built more toilets and plagrounds, as well as to not be built any other buildings close at the place where are located urban forests.

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Contingency Valuation of Croatian Arboretum Opeka

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Abstract

Background and purpose: Social aspects of forestry have always been an important factor of forest usage and management, and therefore have significant influence on its sustainability. Non-wood forest functions such as recreation, tourism, aesthetic and educational factors influence development of rural areas. Contingent valuation method has rarely been used for evaluation of protected forest areas. The aim of the article is to estimate the amount of money visitors are willing to pay for nature's resources preservation in the arboretum Opeka in the North-West Croatia.

Material and methods: Opeka Arboretum is situated in the Vinica municipality in northern Croatia. Located in a large park surrounding a manor, Opeka arboretum, with its 65 hectares is the largest of the three arboretums existing in Croatia today. The arboretum was founded in 1860 by the Count Marko Bombelles. Contingent valuation is a survey-based economic technique for the non-market valuation of resources, such as environmental preservation or the impact of contamination. It is also the approach that can generally be used to include what is usually referred to as the passive use component of the economic value of environmental goods.

Results and conclusion: Willingness to pay for visitor's use of the arboretum has been investigated using the survey and contingency valuation method on a sample of 53 respondents. Research results present high preference for arboretum benefits such as beauty of landscape, cultural and historical significance, recreation and health but low willingness to pay.

Keywords: contingency valuation, environmental economics, willingness to pay, arboretum, Opeka

INTRODUCTION

Forest Economics is a discipline that studies production, distribution, and consumption of forest products and services. It characterizes mental calculus of a decision maker, whether a private landowner or a policy maker, by focusing on the relationship between ends and scarce means (resources) that have alternative uses [1]. In other words, forest economics is a study of choices relating to forest conservation and management.

Natural resources are considered unique input factors; out of which many have features that make them similar to capital factors. Foremost, in order to be used for consumption or in the production process, the majority of natural resources must be separated [2]. Time is also an important precondition in analysis of natural resources use. It helps in distinguishing different types of resources.

Determining the total economic forest value, as well as the value of a particular function is needed for effective management of natural resources and better making of investment decisions in forestry [3]. Classical forest evaluation methods are based on calculation of growing stock value (stand) and land value. Quantitative inventory is conducted on stand level (forest unit), due to the heterogeneous characteristics based on stand quality, coverage, tree species etc. Some stands have different biological parameters and evaluation methods because of their different location [4].

The contingent valuation method (CV) approach uses surveys to directly measure people's willingness to pay (WTP) for nonmarket goods. The early CV studies focused on developing empirical estimates of theoretical welfare measures. Particularly concentrated on measuring the benefits of air quality regulations, although various methodological experiments were also undertaken [5-7]. According to Boyle, [8] the CV method is consistent with welfare economic theory and provides an empirical method that can capture nonuse values of environmental goods. A recent

meta-analysis by Barrio et al. [9] examines how characteristics of the survey instrument, the sample, and the study area tend to influence CV estimates for forest services.

There is a lack of research regarding estimation of forest values with CV method in Croatia. Different environmental valuation methods were used to estimate the aesthetic value of coastal forests in Croatia to tourists. Results from a Contingent Valuation (CV) study of tourists´ willingness-to-pay (WTP) for a hotel room with a view of coastal forests were compared to a Hedonic Price (HP) analysis of hotel room prices, and an Expert Assessment (EA) by hotel managers providing their best guess of the added value to a hotel room from a coastal forest view [10].

An economic analysis of a Coastal Forest Reconstruction and Protection Project in Croatia reveals the significance of environmental amenities provided by the forests to economic and social sectors. The assessment conducted in this study was carried out for fourteen sites that are proposed for the restoration. Estimates for the landscape values of restoration are based on the visitors' willingness to pay for the forested landscape (derived from contingent valuation studies) estimated at $1.50 per visitor per day. Benefits from each site are then determined from the number of hotels beds which would benefit from the restoration. The results are adjusted for site specific factors, e.g. attractiveness of the locality [11].

Detailed review of the forest valuation literature provided different authors like Krieger et al. [12], Holgen et al. [13], and Mogas et al. [14] by approaching sources of value separately, some of which are dominated by the CV method. Methods which are today often used for environment valuation are classified as monetary methods [3].

The aim of the paper is to explore values of nature's resources provided to environmental service users by using the contingency valuation method. The research tries to identify arboretum visitor's preferences and attitudes towards the condition and appearance of arboretum.

The obtained results will help future development and protection of this cultural good and horticultural monument, which is in decay owing to insufficient investments.

The study investigated the determinants of stated WTP for access to forests for outdoor recreation and similar purposes.

Arboretum Opeka is an important biological and cultural-historical facility ruined because of the financing issues. Despite of the bad condition, arboretum attracts many visitors every year, which is one of the reasons for exploring the arboretum's social values. The paper was prepared in cooperation with Public Service for Management of Protected Nature's Resources of Varaždin County. The research results could be used for future management and investments in Arboretum.

MATERIAL AND METHODS

Study area

Arboretum Opeka is on the NW part of the Croatia, close to the city of Varaždin, at the area of 65 hectares. It is divided in two parts, lower plain land shaped in English style and upper, shaped like park-forest consisted of sessile oak (*Quercus petraea* (Matt.) Liebl.) and chestnut (*Castanea sativa* Mill.). On arboretum is also baroque castle Opeka which together with gardens and park-forest form three independent zones. The lake created during the soil digging for production of terracotta in former factory, is on the lower part of the Arboretum. The small island connected with the wooden bridge is in the middle of the lake. According to Potočić [15], arboretum is an independent space or part of the botanical garden where trees and coppice are cultivated for scientific, ornamental or silvicultural purposes.

Because of its artistic, scientific, educational, cultural-historical and other values arboretum was protected by Law of nature protection [16] in 1961 (in category of park architecture monument – arboretum). That monument of park architecture is defined as an artificially created space, individual tree or a group of trees that have aesthetical, artistic, cultural-historical, ecological or scientific value. Any kind of activities that could harm or change the protected values are not allowed (on the monument or in the nearest area). The complex was announced as protected cultural good in 2007. Because of favourable ecological conditions there are many protected species from Europe and other countries collected in the arboretum. There are more than 800 different tree species, scrubs, lianas and flowers [17].

Contingency valuation

The CV approach uses surveys to directly measure people's willingness to pay (WTP) for nonmarket goods. Contingent valuation is a survey-based economic technique for the valuation of non-market resources, such as environmental preservation or the impact of contamination. While these resources do give people

utility, certain aspects do not have a market price as they are not directly sold – for example, people receive benefit from a beautiful view of a mountain, but it would be tough to evaluate it using price-based models. Contingent valuation survey is a technique used to measure these aspects. Contingent valuation is often referred to as a stated preference model, in contrast to a price-based revealed preference model. Both models are utility-based. Typically the survey asks how much money people would be willing to pay (or willing to accept) to maintain the existence of (or be compensated for the loss of) an environmental feature, such as biodiversity.

Visitors Survey

The studied group consisted of visitors of arboretum Opeka of all age groups. Face to face interviews were carried out in April and May 2012 during the weekends, working days (afternoon) and holidays. The assumption was that at those times the arboretum has the most visitors. In the survey the visitors were asked about a range of issues related to their visit to the arboretum Opeka and their willingness to pay.

Before asking the questions it was explained to the respondents that the research is being conducted by the Faculty of Forestry University of Zagreb with the aim of sociological valuation of Opeka arboretum. This was supported by a short text on history and significance of arboretum.

In the first part of the questionnaire were questions about motivation for visiting the arboretum and experience of the visit. The respondents evaluated separately the condition of the gardens, castle and the entire complex. The second part of the questionnaire contained specific questions related to contingent method, i.e. how much the visitors are ready to pay for the improvement of the services. The third part was related to the socio-demographics of the respondents. The sample size was 53 respondents.

Statistical methods

All the data in the research were first summarized by descriptive statistics, frequency distributions, and selected measures of location and dispersion (mean and standard deviation). The crosstabulation was used to assess the relationship between willingness to pay for complete protection and management of arboretum Opeka and visitor's income as the crosstabulation display in table the relationship between two categorical variables. The chi-square test (95% significance interval) was used to determine whether there is a relationship between the variables WTP and income. Data analyses were conducted in SPSS 18.0.

RESULTS AND DISCUSSION

The largest part of respondents was in the age group 45 – 54. Of the 53 visitors interviewed, 43.4% were male and 56.6% female distributed through all age groups. The majority of respondents (69.8%) work in the services industry or in public service. More than half of the respondents (59%) have a monthly income lower than 800€.

Motivation for visiting the arboretum

Motivation for visiting the arboretum is connected to visitor's experiences of previous visits, frequency of those visits and services offered by the arboretum.

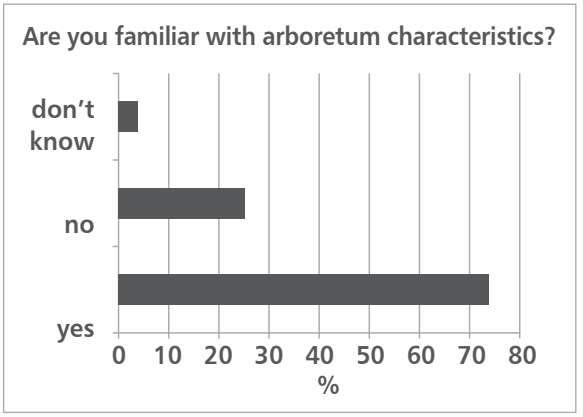

FIGURE 1
Familiarity with arboretum conditions

Visitor's familiarity with Arboretum is mostly based on previous visits to Opeka. Results show that 72% of respondents are familiar with conditions/ circumstances of Arboretum Opeka, while 25% are not familiar with those conditions. Furthermore, 4% of respondents don't know arboretum well so they did not give an answer. The majority of respondents (78%) answered that they visit arboretum once in a few months. Only 2% of visitors come to Opeka every day. Beauty of landscape is the most common reason for visiting arboretum. Almost half (48.5%) of arboretum's visitors come mostly for enjoyment in the landscape, while other reasons include recreation, cultural and historical significance of the site. Only 8% of visitors use arboretum for health reasons.

TABLE 1
How visitors evaluate the arboretum's condition

	Park	Castle	Together
Average	2.75	1.17	2.28

Rating (1- very bad, 4-very good)

Because of its cultural importance and biodiversity the park was awarded the highest value. As it can be seen from the table 1, Opeka arboretum presents a negative image to its visitors, the reasons for which are of financial nature, as there are insufficient funds for investing in the arboretums maintenance and forest management.

Contingent valuation

On average, the visitors are willing to pay 10.6 € for the complete protection and management of the arboretum. The cross tabulation showed (Table 2) that the visitors with lower income (less than 800 €) are not willing to pay for arboretum's maintenance (43.5%). While the visitors with higher income (more that 800 €) are more willing to pay. 37.5% of visitors are willing to pay up to 10€ and 43.8% more than 10 €.

TABLE 2
Willingness to pay for protection and management of arboretum

		Income		Total (%)
		Less than 800 € (%)	More than 800 € (%)	
Willingness to pay	0 €	43.5	18.7	33.3
	0.1-10 €	26.1	37.5	30.8
	More than 10 €	30.4	43.8	35.9
	Total	100.0	100.0	100.0

The Pearson chi-square test shows that there is no statistically significant relationship between variables (χ^2=2.596, p=0.273).

TABLE 3
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.596[a]	2	.273
Likelihood Ratio	2.713	2	.258
Linear-by-Linear Association	1.924	1	.165
N of Valid Cases	39		

By asking the question about WTP in order to prevent conversion of the arboretum into a building site, the intention was to find out whether the visitors are willing to pay higher price in order to preserve this environmental good. On average they are willing to pay an 15 €. The most of visitors (87%) are against the conversion of arboretum to building site.

The most efficient method of collecting financial means would be through introduction of an entrance fee, as the visitors showed significant interest in this form of financial support to the arboretum. The visitors are willing to pay 2.6 € for the daily ticket.

The results show that the value of arboretum increases with the satisfaction of its visitors which is encouragement and guideline towards its future management, maintenance and adjustment of its offer to the needs of the visitors.

CONCLUSIONS

Through the research of social values of Opeka arboretum by using the contingency valuation method, useful results were obtained which could be of aid to the Public Service for Management of Protected Nature's Resources of Varaždin County in decision making processes regarding its maintenance and management. Besides identification of the reasons for visiting arboretum, the profile of its visitors and their evaluation of its condition, significant information was obtained on the visitors' willingness to pay 10.6 € on the annual basis in order to provide for the protection and maintenance of the arboretum. It has been made clear that the visitors are not satisfied with the current condition and management of this protected area, and that there is demand for social forest services such as recreational activities, aesthetic and educational values which this forest is able to provide.

The contingency valuation method enables identification of environmental values which are difficult to measure as was shown in this research even on a small sample of respondents. The methods flexibility enables its wide application and adjustment to variety of problems connected to environmental services. Although this method has its limitations, it has been widely applied in many studies [18]. However, the method is rarely used in Croatia and mainly for evaluation of services tourists are willing to pay for a hotel visit or a protected nature site [19, 20].

Even though the data in this research was obtained from a relatively small sample, the results imply the need for further research of this area of forestry.

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Original scientific paper

Identification of Key Indicators for Drinking Water Protection Services in the Urban Forests of Ljubljana

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Abstract

Background and purpose: The importance of forest ecosystem services, related to provisioning of fresh water and water purification are of increasing importance, especially in urbanized areas. This study investigates key indicators for ecosystem services, related to drinking water protection, provided by urban and peri-urban forests.

Materials and methods: Seven different monitoring programs, projects or directives, assessing water quality variables were analysed. We determined which indicators, describing the drinking water protection services in forest ecosystems, can be applied to urban forests. A list of core indicators sensitive to the specifics of the drinking water supply and urban forest ecosystems in Ljubljana were suggested.

Results and conclusions: Analysis included over 86 potential indicators related to nutrient regulation, storage capacity and water purification in forest canopies, forest soils, surface streams, lakes and groundwater. Through scientific review and the application of "necessary" and "feasible" criteria to urban forests the number of indicators was reduced to 62. According to the specifics of drinking water supply and urban forest in Ljubljana 52 core indicators have been selected. Due to the influence of urbanization on water bodies, special emphasis should be given to indicators for storage capacity and water purification capacity of urban forest ecosystems for hazardous substances. This might increase the willingness of decision and policy makers to acknowledge the water protection capacity of urban forests.

Keywords: urban forests, ecosystem services, drinking water protection, Ljubljana, Slovenia

INTRODUCTION

Forests are identified as the key landscape element for the provision of pristine surface and groundwater resources. Influence of forest cover on total runoff from a catchment [1-3] and water quality in rivers is increasing according to increasing share of forest cover in the basin [4, 5]. Nitrogen and phosphorous concentrations are lower in water bodies from forested catchment compared to a catchment with prevailing agriculture land [5, 6]. Forest ecosystem services of provisioning fresh water and water purification are of particular importance in those urbanized areas, where a great share of water sources (mainly for drinking use) comes from forested water catchments and drainage basins.

Urban forests are generally defined as tree stands or individual trees in and around urban community ecosystems, special due to their physiological, sociological, economic, and aesthetical benefits trees provide society [7]. Relative to natural ecosystems, urban ecosystems seem to possess similar climate, soils, vegetation, soil dynamics, and flows of energy as a result of natural ecological patterns and processes [8]. However, urban ecosystems differ from natural ecosystems in the importance and prevalence of certain disturbances (*ibid*.). Urbanization can negatively impact stream and drinking water quality by increasing loads of nutrients, metals and organic pollutants to surface and ground water [9]. Urban runoff and sewage releases were found to have a strong influence on the river geochemistry, including trace metal contamination [10]. Urbanization increases runoff frequency and duration due to increasing imperviousness [9].

A large amount of environmental monitoring and evaluation data is collected in various formats throughout the research community, which has the potential to inform practice, decision and policy making [11]. However, information about the extent of how urban and peri-urban forests fulfill

their ecosystem services, related to drinking water protection and purification, is very limited. In order to increase the willingness of public entities [12] and private societies [13] to acknowledge the water protection capacity of urban forests, indicators and their benchmark definitions should be identified. Identification and systematic monitoring of indicators, related to drinking water protection services would help to link the decision making incorporated in urban planning system with the relevant scientific knowledge and environmental information, models and data, (e.g. water protection areas, human health exposure and risk by air pollutants, ecosystem exposure to exceedance of critical levels and loads, etc.) [11, 14, 15].

Indicators are numerical values that describe the state of a phenomenon or environment and are used as tools to summarize information about the condition of an ecosystem [16, 17]. Ecological indicators are communication tools that facilitate a simplification of the high complexity in human-environmental systems [18]. They reduce dimensionality of data, simplify interpretations, and facilitate communication between experts and non-experts [19]. Therefore, indicators could be used as metrics for key information concerning ecosystem structure, function and services [8].

This study investigates key indicators for ecosystem services, related to drinking water protection, provided by urban and peri-urban forests. A set of indicators was composed, based on a review of existing or proposed water quality variables from different programs, projects and directives. The specific hypotheses addressed in this study were to: 1) determine which indicators, describing the drinking water protection services in forest ecosystems, can be applied to urban and peri-urban forests and 2) suggest a list of core indicators, sensitive to the specifics of drinking water supply and urban forest ecosystems in Ljubljana.

Results could be used as part of a framework that uses indicators to assess the effects of urbanization and policies on urban forest structure and subsequent provision of its ecosystem services, related to drinking water protection.

MATERIAL AND METHODS

Study area

The City of Ljubljana has a population of 280 140 inhabitants. It is located at 46°03'20'' N and 14°30'30'' E in central part of Slovenia (South Eastern Europe) and covers an area of 275 km^2 (http://www.ljubljana.si/si/ljubljana/). The climate is oceanic, with average monthly temperature of -1.1 °C in January and 17.8 °C in June [20] and mean annual precipitation is 1393 mm in the reference period 1961 – 1990 [21].

Prevailing soils are diverse sorts of dystric soils on non-carbonate rocks: dystric regosols, dystric rankers and dystric cambisols [22]. Natural vegetation is mesic forest vegetation, characterized by Acidophilic, Submontane and (Alti-) montane *Fagus sylvatica* forests [23]. Due to anthropogenic influences the natural forest vegetation is altered in many urban and peri-urban forests. Therefore in some areas secondary forests of *Pinus sylvestris* and *Vaccinium myrtillus* or *Picea abies* monocultures prevail [22].

Urban and peri-urban forests

Forests cover an area of 11 651 ha, which is approximately 41 % of the total area of the City of Ljubljana [24]. The most forested is E part where forests cover 74 % of the area. In the central, more urbanized part, forest cover is 24 % [24]. 91 % of the forests are private, 7 % of the forests are state forests and the City of Ljubljana owns 2 % of the forests. Realization of forest management plans has been hindered by a high number of private forest owners in combination with the small average size of their forest land, often fragmented into a number of dislocated cadastral plots [24].

Forests in the City of Ljubljana belong to two forest management units of Slovenian Forestry Service which makes sylvicultural plans and hunting management plans every 10-years for all the forests regardless of the ownership. Fundamental principles of forest treatment and management are sustainability, close-to-nature management and multi-purpose management [25]. Compared to natural forests, urban and peri-urban forests in Ljubljana possess several specific social or environmental characteristics:

- deforestation due to infrastructure, urbanization and agriculture [24],
- pollution of air, soil, surface waters and groundwater [26]
- higher frequency of visitors and their use of forest infrastructure (e.g. recreational activities, transportation),
- illegal waste dumps, quarries and sandpits [24],
- different species composition (e.g. lower biodiversity compared to natural forests and higher occurrence of invasive species) [27],
- smaller importance of wood production and higher use of externalities [24],
- altered horizontal and vertical forest structure (e.g. intensive litter gathering in the past) [27],
- different population dynamics of pests and diseases compared to natural forests [27].

Water resources in the urban and peri-urban forests

Most of the water supply for the Citiy of Ljubljana (pumping around 100 Ml d^{-1}) is abstracted from groundwater of aquifer Ljubljansko polje and Ljubljansko Barje aquifer system [28]. The "Vodovod – kanalizacija" Public Utility provides, manages and maintains all water supply, sewerage, wastewater treatment and drainage services in Ljubljana (http://www.jhl.si/vo-ka). The natural features of the groundwater aquifers allow the exploitation of drinking water that does not require additional treatment, but the city's activities put tremendous pressure on the soil and water reservoirs below it [29]. Hydrogeological survey of the available renewable water resources reports on 102 active and potential water resources (e.g. pumping stations, catchments and springs) in Ljubljana [28]. 36 of them are located in the forests, 61 in the forest edge and only 5 are located outside of the forest [30].

Water protection areas for water resources are regulated by national decrees on water protection areas for the water body of the Ljubljansko polje [31] and Ljubljansko Barje [32], which are in accordance to the European Community framework in the field of water policy [33]. The forest management measures formally correspond to the Water protection decrees, as reported by Vilhar et al. [30] in an assessment of implementation of the water protection regulations in the forest management planning.

Key indicators for drinking water protection services

Key indicators for drinking water protection services in urban and peri-urban forests were selected based on a review of seven different monitoring programs, projects or directives, assessing water quality variables, which differ according to their objectives:

1. LTER-Europe, European Long-Term Ecosystem Research Network (http://www.lter-europe.net/);
2. EnvEurope Project, Life Environment Project LIFE08 ENV/IT/000339 (http://www.enveurope.eu/);
3. International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) (http://icp-forests.net/);
4. International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM) (http://www.ymparisto.fi/default.asp?node=6412&lan=en);
5. Directive of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. Water Frame Directive 2000/60/EC [33];
6. European Environmental Agency (EEA) core set of indicators [15];
7. World meteorological organization (WMO) - Guide to hydrological practices [34].

LTER-Europe and EnvEurope Project propose the design of environmental quality monitoring and the establishing of common parameter sets collected across a large network of long-term ecological research sites in Europe. Focusing on three types of ecosystems (terrestrial, freshwater and coastal/marine) they aim at defining measures relevant to different scales of investigation, with specific monitoring intensities and with methods adjusted to the respective assessment intensity, implementing a multi-level and multi-functional approach [35]. We focused on water quality indicators for terrestrial and freshwater ecosystems.

The objectives of ICP Forests are to provide: 1) a periodic overview on the spatial and temporal variation of forest condition in relation to anthropogenic and natural stress factors (in particular air pollution) by means of European-wide and national large-scale representative monitoring on a systematic network and 2) a better understanding of the cause-effect relationships between the condition of forest ecosystems and anthropogenic as well as natural stress factors (in particular air pollution) by means of intensive monitoring on a number of selected permanent observation plots spread over Europe and to study the development of important forest ecosystems in Europe [36]. In this study we focused on Intensive monitoring (Level II) of ICP Forests which is carried out on plots installed in important forest ecosystems and are dedicated to in-depth investigation of the interactive effects of anthropogenic and natural stress factors on the condition of forest ecosystems. Special emphasis was given to the manuals on "Sampling and Analysis of Deposition" [37], "Sampling and Analysis of Soil" [38] and "Soil Solution Collection and Analysis" [39].

The overall aim of International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM) allows the ecological effects of tropospheric ozone, heavy metals and persistent organic substances to be determined [40]. Implementation of the ICP IM provides a major contribution to the international data requirements for examining the ecosystem impacts of climatic change, changes in biodiversity and depletion of stratospheric ozone. In this study we focused on subprograms, related to Precipitation chemistry, Throughfall, Soil chemistry, Soil water chemistry, Runoff water chemistry, Stemflow, Groundwater che-

mistry, Lake water chemistry, Hydrobiology of streams and Hydrobiology of lakes [40].

Water Frame Directive of the European Parliament and of the Council [33] establishes a legal framework to protect and restore water across Europe and ensure its long-term, sustainable use. The directive establishes an innovative approach for water management based on river basins, the natural geographical and hydrological units, and sets specific deadlines for member states to protect aquatic ecosystems. The directive addresses inland surface waters, transitional waters, coastal waters and groundwater and targets at the achievement of an Ecological Quality Status (EQS) of all freshwater and coastal systems as well as a good ecological potential of heavily modified or artificial water bodies in the European Union until 2015. The directive requires from EU member states characterization of water bodies, monitoring and classifying the status of each water body in each river basin district and controlling pollution of surface waters by compliance with standards for priority substances and other substances discharged into surface water. We reviewed the environmental standards specifies for specific pollutants, priority substances and other pollutants and substances, the biological element status boundary values to water bodies, groundwater chemical status [41], etc.

European Environmental Agency (EEA) [15] has given higher priority to the development and publication of EEA core set of policy-relevant indicators for six environmental issues (air pollution, climate change, water, waste and material flows, biodiversity and terrestrial environment) and five sectors (transport, energy, agriculture, tourism and fisheries). We focused on indicators, related to water and terrestrial environment issues, mainly in agriculture sector.

World meteorological organization (WMO) in its Guide to hydrological practices [34] promotes the standardization of meteorological and hydrological observations describing in details the practices and procedures that members are requested or invited to follow, respectively, in monitoring and assessing their respective water resources. We focused on water quality related variables described in this Guide [34].

We defined a hierarchical indicator system, including the following components (Figure 1):

1. Ecosystem function or process considering specific environmental conditions (e.g. the storage capacity, referring to the nutrient, energy and water budgets of the ecosystem and the capacity of the ecosystem to store them when available and release them when needed [35]);
2. Provision of ecosystem service (e.g. drinking water protection) [42];
3. Indicator: a variable which provides aggregated information on a certain phenomenon [35];
4. Parameter: data/numbers used to quantify the respective indicator. Parameters can originate directly from measurements, from modeling or they can be calculated based on further parameters (e.g. efficiency measures) [35].

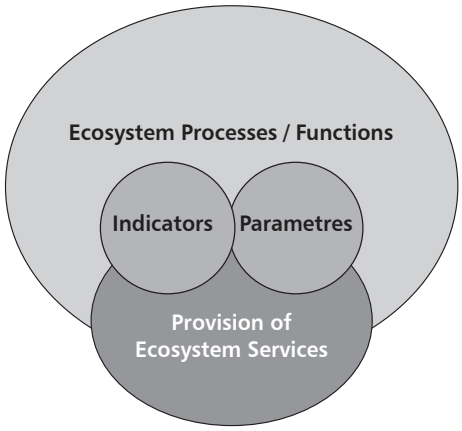

FIGURE 1
Linking ecosystem functions or processes and provision of ecosystem services to indicators and parameters

Political relevance, analytical soundness and measurability should be taken into account when selecting criteria for indicators [16]. Therefore the primary criteria were for each indicator to be necessary - contributing a unique perspective of an ecosystem component, and feasible - practical and able to be implemented [43]. We determined which indicators, describing the drinking water protection services in forest ecosystems, can be applied to urban and peri-urban forests and suggested a list of core indicators due to the specifics of drinking water supply and urban forest ecosystems in Ljubljana.

RESULTS

Selected indicators, sensitive to specifics of urban and peri-urban forest ecosystems

In the review of different monitoring programs, projects and directives, related to monitoring of forest or water resources we focused on environmental indicators, related to nutrient regulation, storage capacity and water purification in forest canopies, forest soils, surface streams, lakes and groundwater. Analysis included over 86 potential indicators. Through scientific review and the application of "necessary" and "feasible" criteria to urban forests the number of indicators was reduced to 62 (Table 1).

TABLE 1
A review of key indicators for drinking water protection

No	Ecosystem function or process	Indicator	Monitoring program or project						
			LTER[1]	EnvEurope[2]	ICP Forests[3]	ICP IM[4]	WFD[5]	EEA[6]	WMO[7]
1	Canopy interactions	Precipitation quantity	x	x	x	x			
2		Throughfall quantity	x	x	x	x			
3		Stemflow quantity	x		x	x			
4		Snowpack (amount / duration)	x	x	x	x			
5		Bulk deposition	x	x	x	x			
6		Throughfall deposition	x	x	x	x			
7		Stemflow deposition	x		x	x			
8		Snow deposition	x	x	x	x			
9		Total atmospheric deposition	x	x	x	x		x	
10	Soil interactions	Soil chemical characteristics	x	x	x	x			
11		Parent material type	x	x	x	x			
12		Soil carbon and nitrogen	x	x	x	x			
13		Nutrients	x	x	x	x		x	
14		Acidity, exchange characteristics	x	x	x	x			
15		Heavy metals	x		x			x	
16		Soil contamination by pesticides						x	
17		Soil physical characteristics	x	x	x				
18		Organic layer mass			x	x		x	
19		Bulk density	x	x	x	x			
20		Stone content	x	x	x	x			
21		Leaching by the runoff		x					
22		Lateral emissions		x					
23		Soil erosion		x				x	
24		Soil temperature		x	x				
25		Soil water chemistry	x	x	x	x			
26		Soil water content	x	x	x				
27		Soil water retention		x		x			
28	Surface streams	Water discharge/level		x		x	x		
29		Chemical properties	x	x		x	x	x	x
30		Physical properties	x	x		x	x		x
31		Optical properties	x						
32		Total suspended solids	x	x					x
33		Organic matter							x

No	Ecosystem function or process	Indicator	Monitoring program or project						
			LTER[1]	EnvEurope[2]	ICP Forests[3]	ICP IM[4]	WFD[5]	EEA[6]	WMO[7]
34		Fluoride	x			x			
35		Color	x			x			
36		Hydrobiology of streams	x			x	x	x	x
37		Specific pollutants*					x	x	
38		Priority substances*					x		
39		Other substances*					x		
40	Lakes	Instantaneous discharge							x
41		Physical properties	x	x		x	x		x
42		Chemical properties	x	x		x	x	x	
43		Oxygen saturation, concentration (profile)		x					
44		Metals	x			x			
45		Fluoride	x			x			
46		Transparency (L)							x
47		Water color	x	x		x			
48		Hydrobiology of lakes	x			x	x	x	x
49		Organic matter							x
50		Ice cover		x					
51		Specific pollutants*					x	x	
52		Priority substances*					x		
53		Other substances*					x		
54	Groundwater	Groundwater chemistry	x			x		x	x
55		Groundwater level	x	x		x		x	x
56		Groundwater recharge	x	x		x			x
57		Groundwater physical properties							x
58		Organic matter							x
59		Microbiology							x
60		Pesticides in groundwater						x	
61		Other hazardous substances						x	x
62		Risks of contamination of surface and groundwater from contaminated sites						x	

* according to Water Frame Directive 2000/60/EC [33]
[1]LTER-Europe: European Long-Term Ecosystem Research Network (http://www.lter-europe.net/)
[2]EnvEurope Project, Life Environment Project LIFE08 ENV/IT/000339 (http://www.enveurope.eu/)
[3]International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) (http://icp-forests.net/)
[4]International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM) (http://www.ymparisto.fi/default.asp?node=6412&lan=en)
[5]Directive of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. Water Frame Directive 2000/60/EC [33]
[6]European Environmental Agency (EEA) core set of indicators [15]
[7]World meteorological organization (WMO) - Guide to hydrological practices [34].

The purpose of selected indicators for canopy interactions is to quantify the input of energy, nutrients and water to the urban forest area by deposition. In forests part of the precipitation falls through gaps in the canopy without being intercepted and part is intercepted during its passage through the canopy. Together the parts are called (crown) throughfall. The part of the precipitation running down the tree trunk is called stemflow. Together, throughfall and stemflow are called total throughfall or stand precipitation and enables us to estimate the total deposition input to the soil under the forest canopy and forest vegetation. In forested areas, throughfall and bulk deposition from an open area are both needed to estimate the total deposition input to forested sites. This is done by comparing total throughfall with bulk deposition from an open area, to assess canopy interception and the interaction and internal cycling of nutrients. For some types of forest stands, also stemflow amount is important. At sites frequently influenced by fog and clouds, a significant fraction of the deposition input may deposit by fog (occult deposition) and throughfall sampling may serve as an indicator of the amount of the fog deposition.

Indicators for soil interactions aim at describing cause/effect relationships within forest soils and soil water. Soil water percolating through the soil dissolves and weathers minerals, releasing base cations for nutrient uptake by microbes and roots alike, for seepage to deeper layers and ground water, and ultimately for outflow to rivers and lakes. Soil water is intimately coupled with the chemical and biological processes in the upper soil layers and is sensitive to both acidification and nitrogen pollution.

Surface streams (or runoff) are the main output of solutes from a catchment area. The amount of element loss can be calculated by measuring the runoff and analyzing the concentrations of the runoff water [40]. The biotic composition and biomass of streams react differently to acidification due to different species tolerance. Therefore hydrobiology of streams is considered a good indicator of acidification and the frequency of acid shocks to stream water, however universal indicators cannot be identified due to differences in geographical distribution [40].

Lakes intercept the flow (and fluxes) in an area. The chemistry of lake water thus gives an integrated picture of the fluxes from atmospheric and terrestrial environments [40]. Processes occurring in lakes, like net sedimentation, turnover and freeze-over may change the concentrations in the water. Thus the retention of fluxes in lakes might affect the values in the output to some degree.

Groundwater is defined as subsurface water, which occurs in the water saturated zone of ground [40]. It may lie near surface or deep in the bedrock. Groundwater is present everywhere and is, hence, one of the output media for elements in the terrestrial ecosystem. The monitoring of groundwater chemistry is dependent on the definition of the hydrological area. Usually it is monitored in open wells and observation tubes penetrating the loose overburden covering the bedrock. Monitoring may also take place in springs.

Water Frame Directive 2000/60/EC [33] defines environmental standards in surface streams, lakes and groundwater for specific pollutants (2,4-Dichlorophenoxyacetic acid, 2,4-Dichlorophenol, un-ionised ammonia as nitrogen, arsenic, chlorine(a), chromium VI, chromium III, copper, cyanide, cypermethin, diazinon, domethoate, iron, linuron, mecoprop, permethrin, phenol, toluene, zinc, total ammonia, etc.), priority substances (alachlor, atrazine, cadmium and its compounds, DDT total, lead and its compounds, mercury and its compounds, etc.) and other substances (3-chloro-3-methyl-phenol, bentazone, fenitrothion, 2-chlorophenol, biphenyl, malathion, 1,1,1-tichloroethane, chloronitrotoluenes, triphenyltin and its derivatives, 1,1,2-trichloroethane, dichlorvos, xylene).

Proposal of core indicators for drinking water protection in urban forests of Ljubljana

Most of the water supply for the City of Ljubljana is abstracted from groundwater [28]. The groundwater exhibits certain local characteristics as a result of land use and features of the natural supply of the aquifers [44]. Two recharging components of the groundwater, i.e. the local precipitation and infiltrated Sava river, are exposed to different sources of contamination because they originate from different parts of hydrological cycle [44]:

a. pollution from direct (dry/wet) deposition,
b. pollution of Sava river.

According to the specifics of drinking water supply and urban forest 52 core indicators have been selected (Table 2). Each core indicator was marked according to the indication of the two main sources of contamination. 17 of core indicators may indicate water purification services according to both main sources of contamination: pollution from direct deposition and pollution of Sava river.

TABLE 2
Core indicators for drinking water protection in urban forests of Ljubljana

No	Ecosystem function or process	Indicator	Sources of contamination	
			Pollution from direct deposition	Pollution of Sava river
1	Canopy interactions	Precipitation quantity	x	
2		Throughfall quantity	x	
3		Stemflow quantity	x	
4		Snowpack (amount / duration)	x	
5		Bulk deposition	x	
6		Throughfall deposition	x	
7		Stemflow deposition	x	
8		Snow deposition	x	
9		Total atmospheric deposition	x	x
10	Soil interactions	Soil chemical characteristics	x	x
11		Parent material type	x	x
12		Soil carbon and nitrogen	x	x
13		Nutrients	x	x
14		Acidity, exchange characteristics	x	x
15		Heavy metals	x	x
16		Soil contamination by pesticides	x	x
17		Soil physical characteristics	x	x
18		Organic matter content	x	x
19		Bulk density	x	x
20		Stone content	x	x
21		Leaching by the runoff	x	
22		Lateral emissions	x	
23		Soil erosion	x	x
24		Soil temperature	x	x
25		Soil water chemistry	x	x
26		Soil water content	x	x
27		Soil water retention characteristic	x	x
28	Surface streams	Water discharge/level		x
29		Chemical properties		x
30		Physical properties		x
31		Optical properties		x
32		Total suspended solids		x
33		Organic matter		x
34		Fluoride		x
35		Color		x
36		Hydrobiology of streams		x
37		Specific pollutants		x
38		Priority substances		x
39		Other substances		x
40		Instantaneous discharge		x
41		Physical properties		x
42		Chemical properties		x
43		Oxygen saturation, concentration (profile)		x
44		Metals		x
45		Fluoride		x
46		Transparency		x
47		Water color		x
48		Hydrobiology of lakes		x
49		Organic matter		x
50		Ice cover		x
51		Specific pollutants		x
52		Priority substances		x

Pollution from direct deposition

Direct infiltration of precipitation makes the aquifer vulnerable to contamination by pollutants flushed through soils [44]. Deposition interception of forest canopies and buffering capacity of forest soils, e.g. the ability of soils to resist change [22], are therefore of major importance.

Infiltration of pollutants to the Sava river

Agricultural activities with excessive use of fertilizers and pesticides as well as other human activities (e.g. leakage from the sewer system, road accidents, industrial zones with insufficient emission control, expansion of existing physical planning areas, illegal waste deposit sites, excavation of gravel, etc.) and the resulting decreasing depth of the unsaturated zones may be a serious threat towards a safe drinking water supply [45]. Most frequent source of pesticides in freshwaters is neighboring agricultural land [5]. Strips of riverside vegetation can reduce or even prevent the input of pesticides into freshwaters significantly (*ibid*.). Living and detrital biomass in a riparian buffer zones ameliorate diffuse-source pollution originating from adjacent landscapes [46]. Pollution removal is mediated by sediment trapping and uptake of nitrogen by plants and by denitrification by microbial communities in root zones using organic matter and root exudates as energy sources (*ibid*.).

DISCUSSION

Recent years have seen increasing focus on many environmental services provided by urban forests, such as flood regulation [47], moderation of the urban climate [48] and air pollution reduction [49]. Provisioning of fresh water, water purification, regulating water runoff and erosion in urban and peri-urban forests are important ecosystem services, closely related to human well-being [42].

A review of seven different monitoring actions, assessing water quality variables, showed that a large number of different environmental indicators could be applied to monitor drinking water protection services of urban and peri-urban forests. As stated by Segnestam [8], two types of indicators are needed to quantify the capacity of urban forests: (1) State indicators describing which ecosystem function is providing a service and (2) How much of that service can be used in a sustainable way. This information could provide decision-makers with an evaluation tool for establishing baselines and developing management and maintenance strategies aimed at conserving urban and peri-urban forests (*ibid*.).

According to the specifics of drinking water supply and urban forests in Ljubljana the core set of indicators reflects urban forest ecosystem functions or processes, related to local (wet / dry) deposition and river Sava quality. The highlighted ecosystem functions or processes include [35]:

- The canopy interactions and soil interactions, referring to the storage capacity of the forest ecosystem;
- Nutrient regulation, the capacity of the forest ecosystem to carry out the (re) cycling of nutrients;
- Water purification, referring to the capacity of the forest ecosystem to purify water.

Canopy interactions refer to the deposition of pollutants to the ecosystems by precipitation, which is assumed to be a major factor affecting the natural processes in the environment, with particular emphasis on the acidifying compounds and on nutrients [40]. Selected indicators for soil interactions 1) represent soil quality per se (e.g. the acidity, carbon and N status of the soil); 2) allow to estimate soil chemistry pools/ amounts (e.g. bulk density, stone content) and 3) refer to sulphate adsorption, nitrification rates and soil water retention characteristics [40]. In urban forest soils special emphasis should be given to heavy metal accumulation in soil and soil contamination by pesticides [15]. Surface streams and lakes as intermediate pools of element fluxes are important bodies for compound changes, which in turn might cause reactions in their hydrobiological nature. If surface streams or lakes exist within an urban forest area, their water chemistry should be monitored for the understanding of the effect of internal fluxes [41]. Groundwater is present everywhere and is, hence, one of the output media for elements in the terrestrial ecosystem [40].

Due to the specific influence of urbanization on water bodies, such as increasing loads of nutrients, metals and organic pollutants to surface and ground water [9], special emphasis should be given to indicators for priority substances and other substances in urban forest ecosystems, as defined in Water Frame Directive of the European Parliament and of the Council [33]. Deposition of hazardous substances to water [15] is one of the main concerns of European Environmental Agency (EEA). Hazardous substances are substances or groups of substances that are toxic, persistent and liable to bio-accumulate. Elevated concentrations of hazardous substances have been found in many of water bodies such as pesticides in groundwater and heavy metals in river, in particular near point sources of pollution. Information about storage capacity and water purification capacity of urban forest ecosystems for hazardous substances would increase the willingness of practice, decision and policy makers to acknowledge the importance of water protection capacity of urban forests.

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Professional paper

Inventory of Green Spaces and Woody Plants in the Urban Landscape in Ariogala

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Abstract

Background and purpose: Regulation of urban greenery design, management and protection was approved in 2008 in Lithuania after the Green Space Law was passed, allowing protection of public green spaces and woody plants. Protection of these resources first requires an inventory, and we have created a digital database that will help in management of urban green spaces.

Materials and methods: An inventory of green spaces and woody plants was conducted in the public urban territory of Ariogala, using GIS technology. A digital cartographic database was created using ArcGis 9.1 software.

Results and conclusions: Most of the woody plants in the survey area are deciduous trees, and the survey results highlighted the major green space management problems. Often, planted trees grow under power lines, and their crowns touch the power cables. Near blocks of flats, trees are often in the wrong place-planted too close to buildings, trees shade windows and their roots heave pavers and penetrate building foundations. According to the inventory, street trees sustain the most damage, most commonly showing injuries on their trunks and roots. Leaves of Aesculus hipocastanum *L. show massive damage from* Cameraria ohridella *Deschka & Dimić, and* Tilia cordata *Mill. are damaged by Cercospora microsora Sacc.* T. cordata *is a favourite city tree, but is susceptible to infestation and when damaged appears unsightly, ending its vegetation period very early. The inventory of green spaces also showed that there are sufficient public parks.*

Keywords: street trees, GIS, parks, condition, green spaces

INTRODUCTION

Regulation of urban greenery design, management and protection in Lithuania was approved in 2008 after the Green Space Law was passed [1]. This law regulates monitoring of the condition of urban greenery [2]. The first survey of green space conditions was conducted in Alytus [3] and focused on application of methodology. V. Stravinskienė assessed the condition of green spaces in the city of Kaunas [4]. The Green Space Law requires conducting inventories of green spaces and woody plants. In performing the inventories, we are planning means of woody plant protection, management and design and building a digital database for green space accounting [5]. The aims of greenery inventory are to identify green space land boundaries, to catalogue species and dimensions of trees and shrubs, to evaluate the qualitative condition of woody plants, to develop accounting data for effective management of the green spaces, to provide information about the environmental condition of the green spaces and to ensure that the size of the green spaces conforms to valid standards [1].

The inventory of green spaces in Lithuanian towns using GIS technology was launched in 2005. An upgraded methodology of forest inventory, which is more appropriate for individual trees, small tree groups and alleys, was used for inventory of green spaces in towns.

This article analyses the results of the green space inventory of the town of Ariogala.

MATERIALS AND METHODS

Study Area

The inventory was conducted in Ariogala, which is located in the central part of Lithuania (55° 15′ 54.06″ N, 23° 28′ 06.21″ E).

The town of Ariogala covers an area of 480.5 ha, and has a population of 3692 (2001). The inventory encompassed 3436 individuals and 397 groups of woody plants that grow in public areas. Plants on private residential land were not included.

Inventory

The green space inventory was conducted in July–August 2008, when vegetation is most abundant and can fully reveal the phenological characteristics of the plants, and their condition can accurately be determined. In performing the inventory, we collected the following data: botanical name (species, cultivar) [6]; height (1-metre accuracy); diameter (2-centimetre accuracy); health condition (4-point scale: 1 - good; 2 - fair; 3 - bad; 4 - deadwood).

The condition of woody plants was estimated using the following indicators: pruning intensity, defoliation level, disease and pest damage level, tree trunk (bark) mechanical damage intensity and flagging intensity. Pruning intensity was divided in three groups: 1 - crown reduction to 1/3 of tree head; 2 - crown reduction to 1/2–2/3 of tree head; 3 - tree lopping (a trunk with a few branches is left). Tree (shrubs) defoliation was divided in three levels: 1 - healthy or faintly affected (defoliation 0%-25%); 2 - moderately affected (defoliation 26%-60%); 3 - intensely affected (defoliation >60%). Disease intensity, pest abundance and level of damage was grouped: 1 - healthy or faintly damaged by pests and diseases (leaves or needles are healthy or disease or pest damage affects less than 1/3 of their number); 2 - moderately damaged (disease or pest damage between 1/3 and 2/3 of leaves or needles); 3 - intensely damaged (disease or pest damage to more than 2/3 of leaves or needles or they are completely destroyed). Tree trunk (bark) mechanical damage intensity groups: 1 - healthy or faintly damaged (no wounds or bark is freshly affected (in the current year) in a small area, less than 30 cm^2); 2 - moderately damaged (there are one or more wounds a few years old in the affected area (50-300 cm^2) of bark, which may already be infected by wood-destroying fungi); 3 - intensely damaged (there are one or more wounds a few years old, affecting a large area (more than 300 cm^2) of bark, trunk of tree is being eroded intensively by wood-destroying fungi).

When plants show different levels of damage in different categories, the lowest score is used to estimate the plant's condition.

Once a plant's condition was estimated, we determined its possible deleterious effects and aesthetic importance [7].

Plants were visually estimated to have a destructive effect whtrees are growing under power cables or in power line protection zones:

- trees and shrubs are close to underground systems (particularly close to drainage lines);
- trees are growing too close to buildings and darkening building windows;
- woody plants isolate small, polluted areas (parking lots of apartment house courtyards and so on) and worsen ventilation;
- surface roots of trees and shrubs destroy hard ground surface (asphalt, precast or tile paving).

When estimating the aesthetic importance of woody plants, their positive and negative impacts on the aesthetics of the environment are determined. Woody plants that improve the environmental aesthetics have the following characteristics: the trees have uniquely shaped or coloured crowns, stems or leaves; the plants have unique characteristics or age; the trees hide objects that are not aesthetically pleasing. Woody plants which have negative impacts on the environmental aesthetics hide artistic buildings or sculptures, cultural or natural heritage objects or valuable landscapes.

After plant condition was estimated and their possible negative impacts and aesthetic importance had been determined, the necessary management measures were planned (pruning, cutting down or removal of plants, rejuvenating shrubs, thinning, cutting deadwood) (Figure 1).

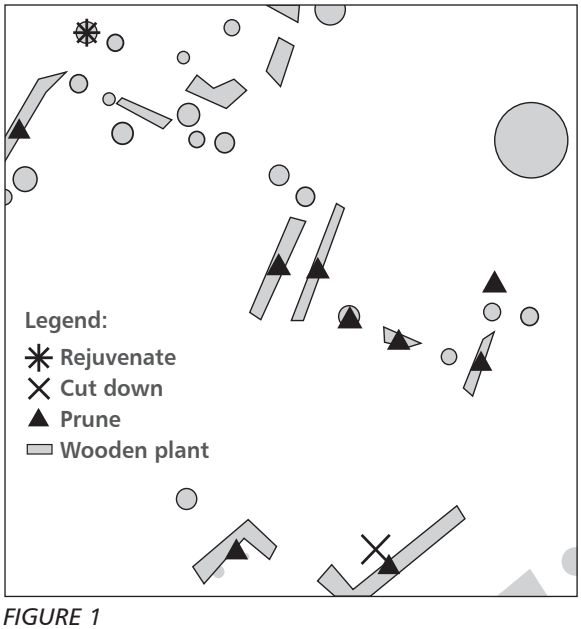

FIGURE 1
Woody plant management map

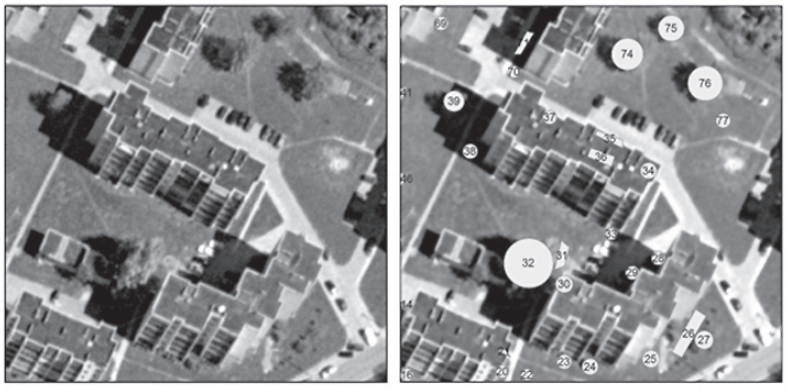

FIGURE 2
Creation of a woody plants layer

Creation of digital databases

Cartographic material was prepared using ArcGIS 9.1 software. Aerial photographs at 1:2000 scale (in which all green spaces could be seen) were used. After collecting the necessary data for each plant, its location was noted in the photo, and it was given a number. Plant locations, including the canopy, were drawn in a polygon layer. In groups of plants where the canopies of the trees are touching and the location of individual trees could not be distinguished, the location of the entire group was noted. Data were submitted to the Lithuanian coordinate system LKS-94. For plants near tower blocks, location was estimated to scale, because building shadows can hide the plants (Figure 2).

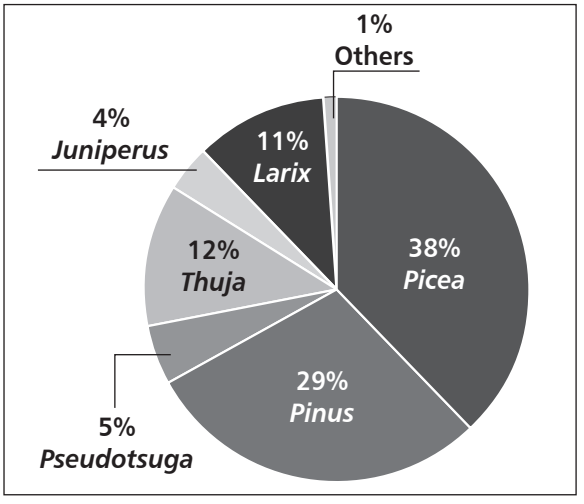

FIGURE 3
Composition of coniferous plants

RESULTS

These results report the woody plant inventory data for the town of Ariogala. Ariogala has 26 taxa of woody street plants, including 7 conifer taxa and 19 broadleaf taxa. In the nearby town of Raseiniai, which is twice as big as Ariogala, 55 taxa of woody street plants grow [8]. In other public urban green spaces, 37 conifer taxa and 94 broadleaf taxa grow (Table 1).

TABLE 1
Distribution of woody plant taxa in Ariog

Area	Conifers				Broadleaves				Total	Total
	genus	species	cultivars	taxa	genus	species	cultivars	taxa	genus	taxa
Street	3	5	2	7	15	19	0	19	18	26
Urban	9	25	12	37	53	81	13	94	62	131

The most common genus of conifers is *Picea*. Spruces account for 38% of the conifer population and pines account for 29% (Figure 3).

Conifers with maximum trunk diameter (60, 52 cm) and tree height (21, 19 m) of conifers are spruces and pines (Table 2).

TABLE 2
Composition of the highest and thickest conifers by genus

Genus	Taxa	H_{max}(m)	D_{max}(cm)
Taxus L.	1	2.5	4
Picea A.Dietr.	5	19	52
Abies Mill.	4	10	18
Larix Mill.	4	19	42
Pseudotsuga Carr.	3	16	40
Pinus L.	6	21	60
Juniperus L.	6	10	10
Chamaecyparis Spach.	2	1.5	2
Thuja L.	6	12	36

TABLE 3
Composition of the highest and thickest broadleaves by genus

Genus	Taxa	H_{max}(m)	D_{max}(cm)
Acer L.	9	21	68
Aesculus L.	1	16	70
Betula L.	2	26	56
Fraxinus L.	3	20	58
Populus L.	4	30	118
Quercus L.	2	23	64
Tilia L.	2	20	72

The thickest tree in the city is *Populus balsamifera* L. (118 cm), and the highest are *P.* x *canadensis* Moench and *P. nigra* 'Italica' (30 m). Table 3 lists the highest and thickest deciduous trees, which mostly grow in town.

The most common species of native deciduous trees are *Tilia cordata* Mill, *Acer platanoides* L., *Betula pendula* Roth, *Quercus robur* L., *Fraxinus excelsior* L. In outlying scrubby areas, street woody plant tree stands often included alien species, such as *Spiraea chamaedryfolia* L. hedges (in 6 places); in town, the alien species *Syringa vulgaris* L was most common. Of the native shrub species, *Prunus padus* L., *Crataegus monogyna* Jacq. were most common.

The largest proportion of the woody plant population is composed of urban plants. In Ariogala, street trees comprise only about 5% of the city's woody plant population (Figure 4). Conifers comprise even less, only 2.2%. In Chicago, street trees comprise about 10% [9].

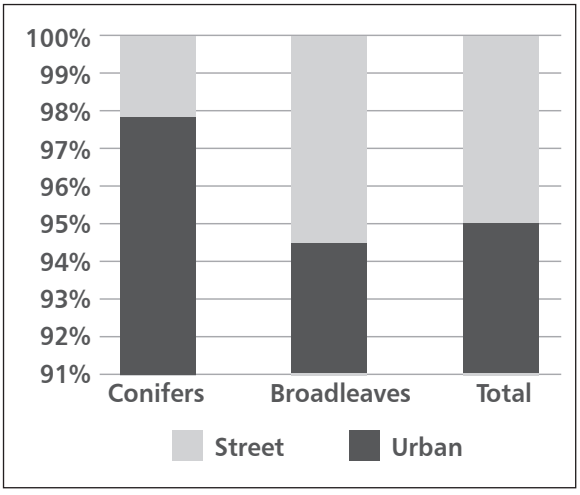

FIGURE 4
Distribution of conifers and broadleaves in different green spaces

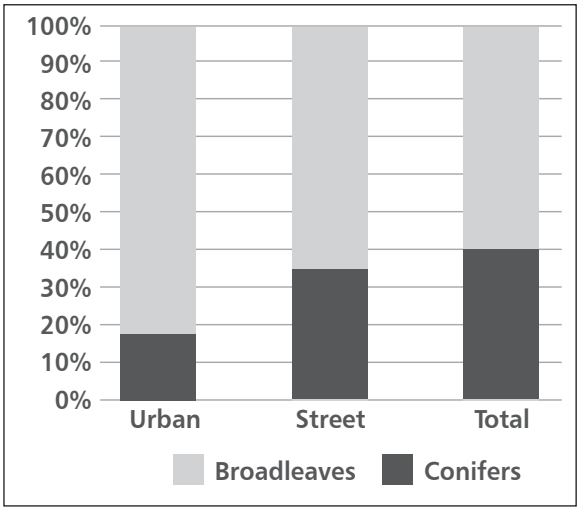

FIGURE 5
Distribution of urban and street woody plants by division

Broadleaves represent 84% of all woody plants in green spaces (Figure 5). Conifers are more common in urban green spaces than in street tree stands.

Condition

Of the estimated 3436 individual woody plants and 397 groups in Ariogala, 88% are in good or excellent condition (Figure 6).

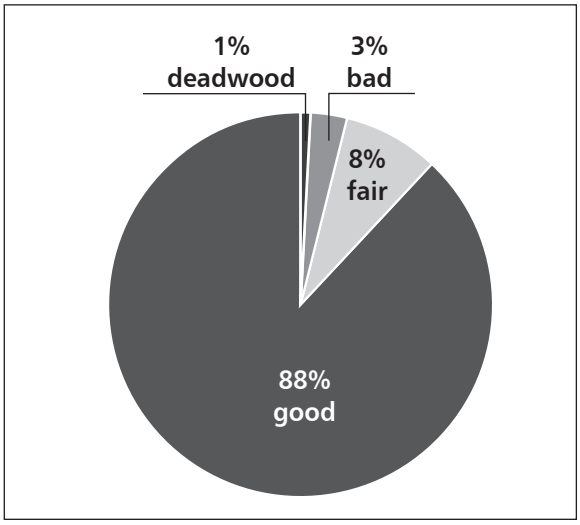

FIGURE 6
Distribution of woody plants by condition

Trees showing the most damage are street trees. The most common injuries are found on tree stems and roots. *Aesculus hipocastanum* L. leaves were massively damaged by *Cameraria ohridella* Deschka

& Dimić *and* those of *T. cordata* Mill. by *Cercospora microsora* Sacc.

In neighbourhoods of multifamily households, trees are often found in the wrong place: trees planted too close to buildings shade windows, and their roots heave pavers and penetrate foundations.

Green space inventory

Using aerial photographs, we created a layer that notes all territories and the town green space, in which individual plants and groups of plants growing in the canopy could be hidden (Figure 7).

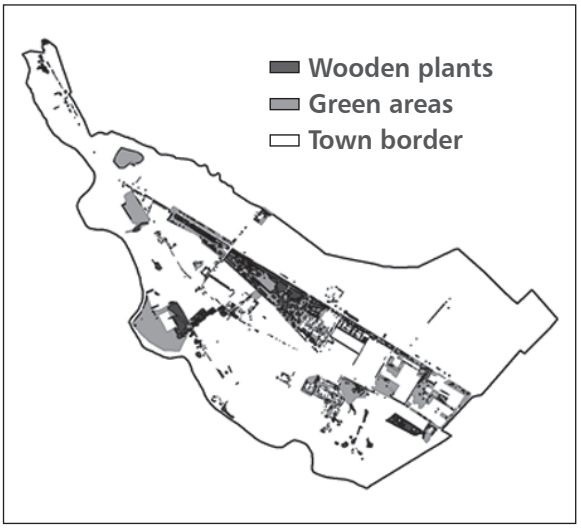

FIGURE 7
Green space and woody plant cover in Ariogala

Once the digital database inventorying the woody plants was created and the green spaces were mapped, additional information about the canopy cover areas occupied by woody plants was obtained (Table 4).

Once the green spaces were mapped, information about the park green spaces, the cemetery green spaces, the protective green spaces and the integrated green spaces was provided, by area and units (Table 5). Sizes of cemeteries and parks are regulated, while those of other categories of green spaces are not.

DISCUSSION AND CONCLUSIONS

The main aim of the present study was to collect tree inventory data, including measuring dendrometric parameters and evaluating plant condition. The data collected allow evaluation of the diversity and condition of the dendroflora. Recent tree inventories have revealed which species are most common or rare in Raseiniai [8] and Ariogala [4]. Unfortunately, these methods could not be used to give an accurate estimate of the number of woody plants because woody plants growing in large groups are not counted separately (a group consists of more than 20 woody plants). According to this method of counting woody plants, sums of individual plants and groups are estimated, and therefore, tree inventory data presents only an approximate number of woody plants.

J. Backaitis [10] points out that in some municipalities (Pasvalys), there are specific problems encountered when conducting tree inventories, such as lack of digital databases on city infrastructure. The law and the post-legal acts define that tree inventory work must be conducted by qualified specialists who are able to recognise woody plants and accurately identify their species and cultivar. Unfortunately, the tree inventory is not always performed by forestry professionals, but by individuals who do not know the rare species of trees and shrubs. In this case, inaccurate information about the city's dendroflora is catalogued.

Tree inventory data has highlighted some errors in street tree care and species selection. In the streets of

TABLE 4
Canopy cover area of street and urban woody plants

Urban trees		Street trees	
Canopy cover area (ha)	Site (unit)	Canopy cover area (ha)	Site (unit)
18.2	1197	0.47	68

TABLE 5
The distribution, by area and units, of different categories of green space

Integrated		Protective		Parks		Cemetery	
Area (ha)	Site (unit)	Area (ha)	Site (unit)	Area (ha)	Site (unit)	Area (ha)	Site (unit)
17	62	3.7	9	34.3	8	5.1	2

Ariogala, 80% [11] of the woody plants are healthy, but the figure is 8% less in town. Often planted trees grow under power lines, and their crowns start to seek the power cables. Rows of woody plants should instead be planted near streets. The same species or cultivars should be selected for rows of trees. Plant cultivars with narrow and low crowns, and those that need infrequent cutting should be chosen, especially if they grow under power cables. *T. cordata* is a favourite tree, but this species is susceptible to infestation and appears unappealing when damaged; it also ends its vegetation period very early in the year.

In large cities (Vilnius, Kaunas, Klaipėda), where land has great commercial value, it is common to find trees that have been artificially damaged, probably with the purpose of killing them to create space for installing parking spaces. In smaller towns, where land has no significant commercial value and enough there are sufficient parking spaces for cars, such cases do not often occur.

The green space system was created in order to preserve the landscape's structure, biodiversity and historic value, to maintain its ecological stability and to improve people's living and working conditions [12, 13]. It offered two types of green spaces: green spaces for general use (parks, town gardens, squares, etc.), and green spaces integrated for various purposes (dwelling, industrial and commercial activities, learning, etc.) [14]. In urban planning divisions green space has already attracted criticism and proposals for classification according to the prevailing greenery [15].

During the tree inventory, the easiest way to distinguish the boundaries of city parks, squares and cemeteries was found. These boundaries are easily seen in aerial photography, often framed with roads, sidewalks and fences. Other green space boundaries cannot visually be distinguished accurately if the area is not fenced. It is extremely difficult to determine even the preliminary green space boundaries in community areas composed of blocks of flats. Due to the absence of a layer showing planted trees during the inventory process, visual determination of the boundaries caused many errors, and the boundaries could not be identified if the planted territories did not comply with the relevant standards.

The minimal proportion of green area for recreational purposes should be 20 m^2 per inhabitant [16] in order to improve people's living and working conditions, to maintain the ecological stability of the area and to meet the recreational needs of society. There are 73 m^2 of green space per habitant for recreational purposes in Ariogala. The city parks form natural oases in the environment [17], and we recommend that there should be a sufficient quantity of benches. Unfortunately, this survey revealed that there is a lack of benches in the parks.

- Survey results highlighted the major green space management problems. Trees had often been planted under power lines, and their crowns had started to seek the power cables. In blocks of flats, planted trees were often found in the wrong places: trees planted too close to buildings shade windows and their roots heave pavers and penetrate foundations.

- Ariogala contains many recreational green spaces. The area of parks is 5 times bigger than recommended. Recreational parks are evenly distributed throughout the city and are easily reached by inhabitants.

- There are not enough woody plant rows in the streets, and some rows contain too many different species. It is advisable to plant rows with the same plants species at equal planting intervals.

Acknowledgement

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FIGURE 8
Visible square boundaries (left) and non-visible boundaries (right) of housing block sites.

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Professional paper

Horse Chestnut (*Aesculus hippocastanum* L.) Urban Habitat - Pollution Influence on Some Phenotypic and Morphological Characteristics

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Abstract

*Background and purpose: Horse chestnut (*Aesculus hippocastanum *L.) may be found in most urban areas in Croatia. Over the years it showed to be resistant to various negative urban influences. In this research we tested trees on randomly selected streets with intense traffic in smaller towns. The main goal of this research was to establish the link between pollution and tree growth and to analyze to what extent pollution influences the increase in the measured parameters.*

Materials and methods: The research was done in 7 settlements, in towns with the population of up to 75 000 inhabitants. The measured parameters were the morphological characteristics of trees, shoots, leaves and nuts. From the selected branches we measured the annual shoot (thickness and length), leaves, the number of flowers and nuts. The crown transparency was assessed according to the ICP Forest method.

Results and conclusions: The phenotype of the urban Horse chestnut significantly differs from its natural phenotype, and it is transformed by multiple radical pruning, what may be seen in the following ratios: the diameter at breast height - tree height, trunk height - tree height, crown height – tree height, crown width – crown height. The most significant characteristic of the tree is the vitality expressed by crown-damage classes. On the selected trees the worst crown damage class was "3b" and the best was "0". The measured parameters of yearly shoot characteristics were defined. All measured parameters (trees, shoots, leafs and nuts) show significant differences from the given average values.

Keywords: Horse chestnut, phenotype, crown transparency, shoot, leaf and nut morphological characteristics

INTRODUCTION

Common, Horse chestnut's (*Aesculus hippocastanum* L.) natural habitat is Central Europe - from Bulgaria to Greece [1]. The tree grows up to 25 m in height and 100 cm in diameter at breast height (DBH) during its two-hundred-years life cycle. The species has intense juvenile height growth. It is very sensitive and highly demanding to chemical, physical and biological stand parameters, such as the soil parameters, especially humus, while less demanding to insolation and temperature [2].

In Croatia, Horse chestnut trees may be found in urban areas, parks and alleys in all three regions: the Pannonian, Dinaric and the Mediterranean [3]. The reason for planting horse chestnuts as one of the main urban species lies in the exceptional aesthetics and management characteristics. Although the tree is very tolerant to environmental factors, it is exposed to new pressures of technological advancement, which is especially evident in urban areas.

Horse chestnut is very sensitive to soil quality, especially its chemical, biological and physical characteristics. Horse chestnut physiology is greatly affected by humus as one of the main influences on growth and development (stand devastation may decrease development up to 50%) [4, 5].

That was the reason why we analyzed the link to environment pollution, its influence on Horse chestnut growth and we attempted to determine the effects on annual shoot, leaf and nut growth. The main goal of this research was to establish the link between pollution and tree growth and to analyze to what extent pollution influences the increase in the measured parameters.

MATERIALS AND METHODS

In the research of annual shoot and leaf morphological characteristics the following criteria for tree selection were applied:

- Trees from all three regions: Pannonian, Dinaric and Mediterranean towns with populations of up to 75 000 inhabitants;
- Trees near heavy traffic junctions;
- Trees more than 30 years old and not pruned for 5 years (to avoid tree reactions after pruning and the influence of stress on the increase of the measured tree parameters).

In this analysis of air, soil, leaves and nuts, facts that would give us a more complete picture of the devastation and environmental pressure, were not considered due to high costs, so this research should be taken as a preliminary study.

The selected Horse chestnut trees were wider than 25 cm and the analyzed branches were taken from the crowns' southern exposure. The sampling was done from the crowns' southern exposure, so that equable samples may provide us with representative results, with data free of various physiological reactions / morphological adjustments (e.g. bigger shaded leaves, lesser number of buts due to flower devastation caused by high amounts of sun and ultraviolet radiation). Other measured parameters were trunk diameter (DBH), trunk height, trunk length, crown height, crown width, the crown degree of defoliation and stand microenvironment characteristics. From the selected branches we measured the annual shoot (thickness and length), leaves, number of flowers and nuts.

Crown transparency was assessed according to the ICP Forest method (International Co-operative Programme in Assessment and Monitoring of Air Pollution Effects on Forests) [6].

Research was done in 7 settlements:

- the Pannonian region: Ilok, Vinkovci, Varaždin, Jastrebarsko and Karlovac;
- the Dinaric region: Razloge;
- the Mediterranean region: Imotski.

Ilok (45°10′ N, 19° 28′ E) is a small and the farthest eastern Croatian town. It is situated at approximately 150 meters above the sea level (MAMSL) in the Pannonian lowlands, has a population of around 8 300 inhabitants. One tree near the main road was selected for testing.

Vinkovci (45°17′ N, 18°48′ E) is a town situated in the eastern part of Croatia in the Pannonian lowlands at approximately 100 MAMSL. It has around 35 000 inhabitants and lies on the important traffic corridor that connects Western Europe with the Middle East and Central Europe with the Adriatic Sea. One tree was selected near the main street in Vinkovci.

Varaždin (46°18′ N, 16°20′ E) is a city at the edge of the Pannonian lowlands in the northern part of Croatia, at approximately 170 MAMSL. It has around 41 000 inhabitants. Two trees that were selected for this study are situated in the town's central park.

Jastrebarsko (45°42′ N, 15°40′ E) is a small town near Zagreb, the capital of Croatia, in the North-Western part of Croatia at the edge of the Pannonian lowlands at 154 MAMSL. The Jastrebarsko municipality has around 17 000 inhabitants and lies on the strategic corridor connecting the country's inland with the seaside. In our research we included two horse chestnut trees that grow beside the main road on the very compacted and devastated grounds because the space in the vicinity is used as a parking zone.

Karlovac (45°29′ N, 15°32′ E) is a city that lies at approximately 112 MAMSL at the border between the Dinaric region and the Pannonian lowlands. The city of Karlovac houses around 60 000 inhabitants and lies on the strategic corridor connecting the country's inland with the seaside. Three horse chestnut trees were selected from the city's central park.

Razloge (45°29′ N, 14°45′ E) is a small settlement situated in the Dinaric region and a part of the Croatian National Park "Risnjak". This village has 10 permanent inhabitants and lies at approximately 450 MAMSL. One horse chestnut tree from the edge of the village was selected.

Imotski (43°26′ N, 17°10′ E) is a small town situated in Dalmatinska zagora at approximately 412 MAMSL. It has around 10 500 inhabitants. In our research we included five trees in the main street avenue.

Between the selected settlements there are significant climate differences [7] in cloudiness, precipitation and temperature quoted in Table 1.

RESULTS AND DISCUSSION

The most significant characteristic of trees is the vitality expressed by tree crown-damage classes, known as crown transparency. The average crown damage class on the tested trees (defoliation) was "1.35", the worst "3 b" and the best "0".

Horse chestnut trees significantly differ, not only in the habitat's climate characteristics but also regarding the tree measuring parameters (Table 2).

TABLE 1
Climate parameters in the settlements included in the research

Climate parameter	Imotski	Razloge	Karlovac	Jastrebarsko	Varaždin	Vinkovci	Ilok
avg. annual T (°C)	13.8	7.7	11.0	11.0	10.0	11.2	11.7
avg. T spring (°C)	12.4	6.5	11.0	11.0	10.0	11.2	10.5
avg. T summer (°C)	22.7	16.0	20.4	20.4	21.2	20.8	21.0
avg. T autumn (°C)	14.6	8.1	11.3	11.3	10.3	11.6	12.4
avg. T winter (°C)	5.7	-0.2	1.5	1.5	0.5	1.2	2.0
abs. annual max. (°C)	38.0	34.0	42.4	42.4	39.3	39.0	39.8
abs. annual min. (°C)	-12.0	-25.0	-25.2	-25.2	-28.0	-28.8	-22.0
avg. N icy days	0.3	17.3	8.6	8.6	14.1	11.0	8.0
avg. N chill days	2.4	31.2	15.6	15.6	19.6	15.8	18.2
avg. N cold days	28.1	116.8	82.8	82.8	97.1	74.9	67.2
avg. N warm days	103.7	22.8	84.8	84.8	68.9	93.3	92.3
avg. N hot days	46.4	1.8	23.9	23.9	12.6	27.8	26.8
avg. annual RH (%)	60	86	77	77	77	77	71
avg. annual precipitation (mm)	1310	2486	1121	1121	888	687	764
avg. annual precipitation - spring (mm)	265	518	248	248	190	171	188
avg. annual precipitation - summer (mm)	147	428	284	284	302	203	240
avg. annual precipitation - autumn (mm)	443	744	311	311	239	153	171
avg. annual precipitation - winter (mm)	455	786	278	278	160	157	165
avg. N day precipitation >20 (mm)	19.9	46.5	13.9	13.9	10.9	6.8	8.2
avg. N day snow >0,1 (mm)	7.7	45.7	25.7	25.7	25.0	21.7	23.8
avg. N day snow on ground >1 (cm)	8.6	82.8	39.8	39.8	43.3	26.4	29.1
avg. annual cloudiness	5.1	6.6	6.2	6.2	6.2	5.2	6.0
avg. N cloudy days	105.7	171.9	135.0	135.0	131.7	110.3	141.2
avg. N clear days	103.4	56.4	54.7	54.7	51.9	99.3	64.4

avg. - average; abs. – absolute; T – temperature; N - number

TABLE 2
The selected Horse chestnut tree measurement parameters

Tree measurement parameter	Ilok	Vinkovci	Varaždin	Jastrebarsko	Karlovac	Razloge	Imotski	Average
Diameter at breast height "DBH" (cm)	48	47	41	41	58	52	35	46
Tree height „h" (m)	15.5	11.5	12.5	9.5	25.5	18.5	9.8	14.6
Trunk length „hd" (m)	5.0	4.8	5.0	2.5	7.0	4.5	3.4	4.6
Crown height „L" (m)	10.5	6.7	7.5	7.0	18.5	14.0	3.7	9.7
Crown width „S" (m)	5.8	7.9	8.1	7.2	8.7	8.6	7.7	7.7
Defoliation	1b	1b	1b	3b	1b	0	1a	1.35
Ratio DBH/h	0.031	0.041	0.033	0.043	0.023	0.028	0.036	0.034
Ratio hd/h	0.322	0.417	0.400	0.263	0.275	0.243	0.347	0.324
Ratio L/h	0.677	0.583	0.600	0.737	0.725	0.757	0.378	0.637
Ratio S/L	0.552	1.179	1.080	1.029	0.470	0.614	2.081	1.001

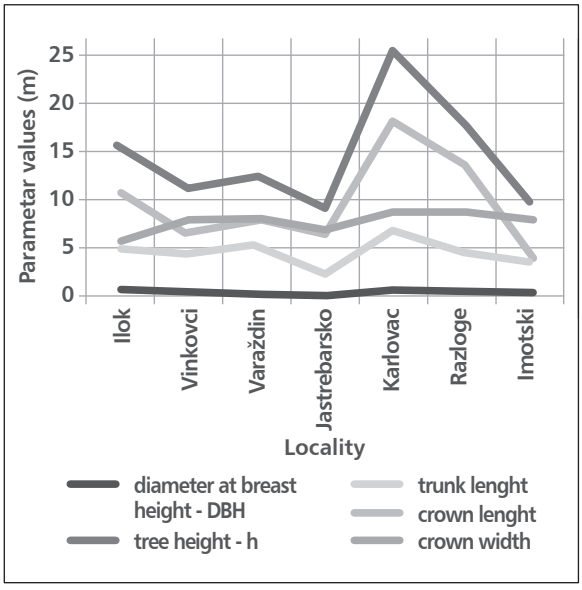

FIGURE 1
Important tree measuring parameters of the selected Horse chestnut trees

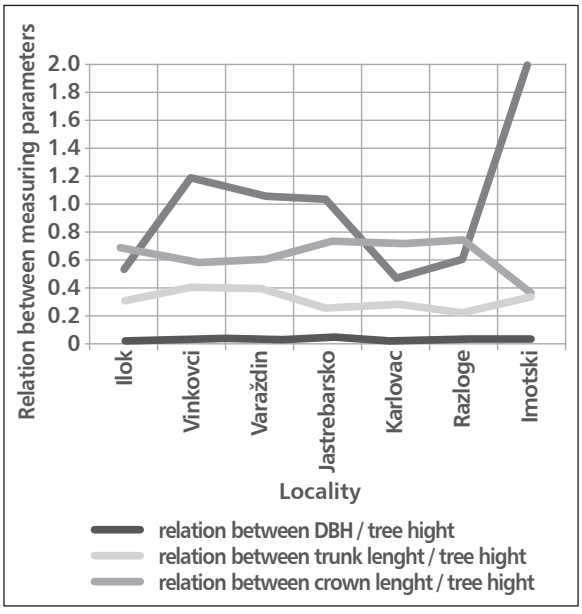

FIGURE 2
Relations of the Horse chestnut tree measuring parameters

The selected trees differed mostly in tree height while the least differences were found in crown width (Graph 1). Differences were evident also in the relation between crown width and crown length, the least differences in the DBH/ tree height ratio (Graph 2).

The results of the measured annual shoot parameters are displayed in Table 3. The greatest difference was recorded in the number of leaves and the least difference in the annual shoot diameter (Graph 3).

The measured leaf parameters are displayed in Table 4, the longest leaf was recorded in Razloge and the shortest in Jastrebarsko. Also the leaves in Jastrebarsko

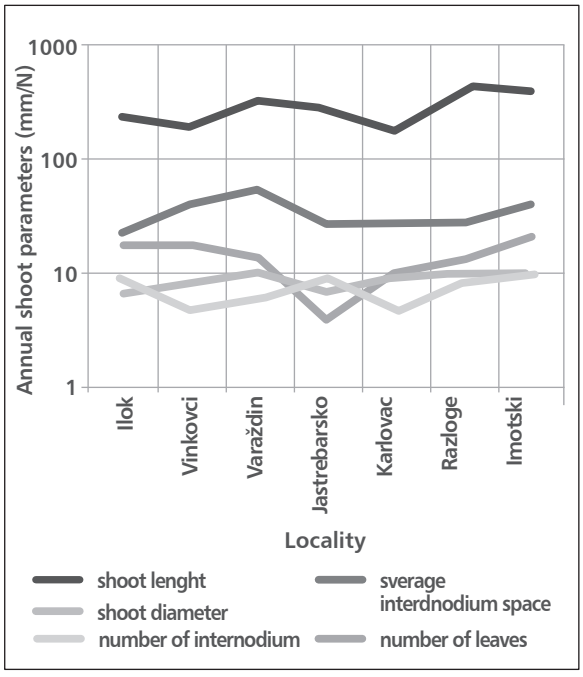

FIGURE 3
Horse chestnut annual shoot parameters

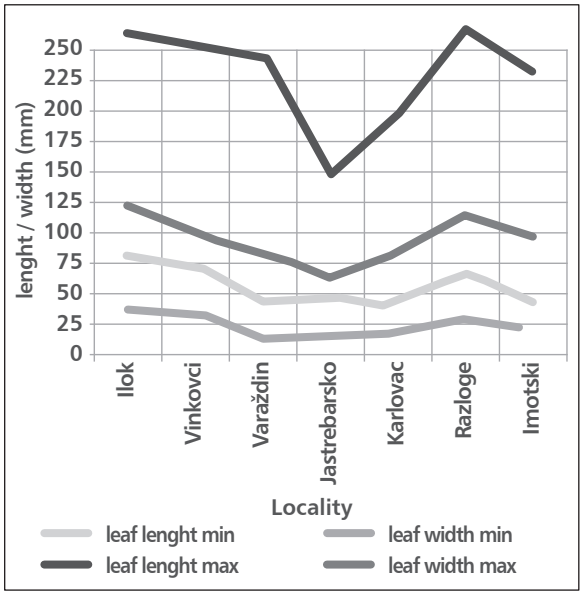

FIGURE 4
Horse chestnut leaf parameters

TABLE 3
Horse chestnut annual shoot parameters

Settlement	Shoot (mm)		Number of internodium	Internodium space (mm)	Number of leaves	Number of flowers
	length	diameter				
Ilok	229.50	6.54	9	22.62	18	0.5
Vinkovci	204.50	8.66	5	40.80	18	-
Varaždin	339.10	10.50	6	56.51	14	-
Jastrebarsko	279.70	7.17	9	27.25	4	1
Karlovac	191.17	9.23	5	29.17	10	1
Razloge	412.10	10.20	9	28.81	14	1
Imotski	410.05	10.08	10	41.70	22	0.5
Average	315.86	9.03	8.43	38.25	14.57	0.75

had the least width while the leaves measured in Ilok were the widest (Graph 4). The longest petiole was measured in Imotski and the shortest in Jastrebarsko.

The phenotype of the urban horse chestnut tree significantly differs from its natural phenotype, and it is transformed with multiple radical pruning - what may be seen in the following ratios: (I) DBH - tree height (average 0.034), (II) trunk height – tree height (average 0.324), (III) crown height – tree height (average 0.637), (IV) crown width – crown height (average 1.001).

Horse chestnut is a species found in forests of Central Europe, but it has adapted very well to urban environment. In Croatia it may be found in all 3 regions, but it prefers the mild climate in the continental part of the country.

The urban soil devastation and destruction, especially of its humus layer, has been present and ongoing for more than half a century [8], and negatively influencing the growth and tree development - up to 50% growth reduction [5]. The global and local pollution (soil, water and air), especially the continuous traffic and transportation pollution (for more than half a century), has a negative influence on tree growth [5].

Those chestnuts in Jastrebarsko grow near the main road, in the town's centre and represent trees mostly influenced by traffic pollution pressure and stand devastation, with the class "3b" crown damage, while the tree in Razloge is least influenced by pollution pressure. It has class "0" crown defoliation damage, evident from the tree measurement parameters and the morphological parameters analyzed in this research.

The research showed that in a relatively unpolluted habitat the leaf and annual shoot size are greater than in the habitat with intense pollution, where annual shoot and leaves are significantly lesser.

TABLE 4
Horse chestnut leaf parameters

Settlement	Leaf				Petiole			
	length		width		length		diameter	
	min	max	min	max	min	max	min	max
	mm	mm	mm	mm	mm	mm	mm	mm
Ilok	82.36	263.35	34.86	121.41	27.65	169.95	1.53	6.36
Vinkovci	72.81	252.35	35.21	99.22	40.05	238.25	1.98	7.82
Varaždin	44.50	244.15	14.70	84.25	17.95	204.80	0.75	3.30
Jastrebars	48.15	148.70	14.20	64.25	18.30	117.75	0.66	1.85
Karlovac	41.98	198.48	16.60	82.18	13.13	157.28	0.63	3.05
Razloge	68.17	269.25	29.30	114.20	34.73	188.65	2.13	5.64
Imotski	46.24	233.25	22.52	99.18	27.84	289.30	1.36	3.43
Average	74.89	232.79	31.06	94.96	37.09	196.60	1.56	4.46

CONCLUSIONS

Based on the research done on annual horse chestnut shoots, the following conclusions may be made:

- The sampled horse chestnut tree locations differ in basic meteorological parameters;
- The selected trees immediate environment differs significantly regarding the traffic intensity from the lowest intensity in Razloge to the most intense traffic in Jastrebarsko;
- The sampled horse chestnut trees, differ significantly based on the basic measuring tree parameters. Those differences are evident in crown transparency, that is, the tree in Razloge has the best, class "0", crown damage and the trees in Jastrebarsko the worst crown damage, class "3b";
- The traffic pollution pressure on the environment is the highest in Jastrebarsko, and that is reflected in the reduced horse chestnut tree morphological and tree measuring parameters, while on the other hand the horse chestnut tree in Razloge has the best morphological and tree measuring parameters.

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