Folia Forestalia Polonica, Series A – Forestry, 2023, Vol. 65 (2), 104–116

ORIGINAL ARTICLE

DOI: 10.2478/ffp-2023-0011

Assessment and representation of Urban Trees Ecosystem Services: a case study in Pryzamkovyi park

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Abstract

The research was aimed at verification of the possibility and expediency of applying i-Tree Eco tools in order to assess the value of ecosystem trees and bushes by the example of one of the parks in Ukraine and representation of the obtained information on an interactive map. For this purpose, the inventory of 228 urban trees in Pryzamkovyi park was conducted and the possibility of its adjustment to the conditions in Ukraine was assessed. The obtained information was analysed and visualised, and the advantages and disadvantages of this process were determined. The scope of the provided ecosystem services for park spaces was specified and it was determined that urban trees in Pryzamkovyi park have a €12.38 million replacement value and the average indicator of annual usefulness of ecosystem services provided by one tree plant or one bush plant in the park is equal to €15.75 per year, according to i-Tree Eco assessment.

In order to improve the process of obtaining, processing and visualising materials, an orthophotomap based on unmanned aerial vehicle survey materials was applied. It allowed increasing the accuracy and improving the visualisation of the geolocation of trees and bushes. In order to familiarise a greater number of users with this information, electronic maps of vegetation that display the location of trees and bushes and their ecosystem services, both in quantity and monetary terms, were offered. The peculiarity and the scientific novelty of the approaches to solving the assigned task is the improvement of the process of informing the interested parties about the ecosystem services of a specific tree in the park and green plantations in the park as a whole. The suggested approaches to assessing the value of urban trees and their ecosystem services give ground to emphasise the value of these plants for urban ecosystems, to substantiate the expediency of implementing environmental measures as well as the need to increase the funding of these measures as a compensation for the services provided by trees and plants. At the same time, it is worth mentioning the expediency of conducting further research on this subject and the related issues, which requires follow-up studying.

Key words

inventory of park vegetation, urbanised landscape value, ecological benefits

Received 12 October 2022 / Accepted 23 February 2023

Introduction

It is common knowledge that the process of urbanisation constantly requires allocation of new territories for construction and infrastructure improvement. In this regard, there is often a choice to be faced as to the purpose of land plots, including the ones that contain trees and bushes, due to the unawareness of their value. The fact that protected and recreation territories may not generate rent in a monetary form but provide a great number of ecosystem services, which usually do not have a proper economic assessment, is often not taken into account when making such decisions. Thus, understanding ecological, economic and social usefulness that nature provides, namely by tree and bush species, should lead to better usage and designing of natural landscapes through the prism of environment optimisation and people's health improvement for the present and future generations (Nowak 2017).

The most commonly used definition of the term of ecosystem services can be considered the following one: "These are all the useful benefits that can be obtained from proper interaction with surrounding ecosystems" (Millennium Ecosystem Assessment 2005). It is worth taking into account that these benefits support a great part of our economics, culture, health and welfare and, thus, according to the conclusions made by Berghöfer and Schneider 2015 (p. 1), neglecting the requirements for supporting, protecting and enhancing the surrounding ecosystem functions is unacceptable.

Research on the approaches to assessing the value of ecosystem services is characterised by its relevance, which is proven by a constant increase in the number of scientific papers in this field (Nowak and Crane 2002; Nowak et al. 2007; Kiran and Kinnary 2011; Schomers and Matzdorf 2013; Rocha et al. 2015; Selmi et al. 2016; Steenberg et al. 2017; Nowak et al. 2018; Havrylenko and Tsyhanok 2019; Huang 2022). Here, the authors (Velasco-Muñoz et al. 2022) have investigated that "… inconsistency has been observed in the definition and classification of services provided by forests, as well as a lack of unanimity on the reference framework to be applied". Thus, it is important to study theoretical basis and practical principles of assessing the ecosystem services of urban plantations, taking into account the usefulness they provide for the environment and the society. This process requires the implementation of a scientifically sound approach built on regulatory legal basis, taking into account the social, ecological and economic roles of such services.

The main aim of this research is to verify the possibility and expediency of applying one of the tools for assessing the value of ecosystem services, namely i-Tree Eco, in order to obtain and interpret information about the ecological significance and the value of trees and bushes by the example of recreation plantations in the park located in the town of Berezhany. To achieve this goal, there was a task set to collect the parameters of trees and bushes in the process of their inventory, to test the methods of obtaining and processing information, to investigate the possibility of combining these methods with the ones typical for the inventory of green plantations in Ukraine, to analyse and visualise the obtained information and to determine the advantages and disadvantages of every stage of the process.

The peculiarity and the scientific novelty of the approaches to solving the assigned task is the improvement of the process of informing the interested parties about the ecosystem services of a specific tree in the park and green plantations in the park as a whole. For this purpose, a special publicly available map (https://www.google.com/maps/d/u/0/ edit?mid=1lG_HjOCTDEtJy9SrZXbeglc374rbJBc&usp=sharing) has been developed, showing the exact location of every tree, its indicators and the cost of ecosystem services. Following this map, everyone may obtain information about the usefulness of a specific tree on the spot standing next to it.

Material and methods

The recreation plantations, which ecosystem services were assessed in the process of this research, are located on the territory of Pryzamkovyi park in the town of Berezhany, Ternopil oblast (Ukraine). The geographical location of the park can be described by such coordinates: the north latitude from 49.445429° to 49.447241°, the east longitude from 24.942631° to 24.946633°. The area of the object under study is equal to 3.6 hectares, the average height above the sea level is 343.7 metres. The park plantation is represented by 22 species, with *Aesculus hippocastanum* L. (17.8%), *Tilia cordata* Mill. (15.1%), *Fraxinus excelsior* L. (14.3%) and *Acer platanoides* L.

(7.8%) being the most numerous among them. Other species presented in the plantation account for 5% and less.

The inventory of green plantations in the park (collection of field materials) was conducted during the n-leaf season in order to have the possibility of assessing crown parameters and plant condition according to the United States Department of Agriculture (USDA Forest Service 2011, pp. 31–48) methodology, which involves measurement and recording of separate parameters of every plant (Tab. 1). The investigation was conducted with the involvement of volunteers during the implementation of the pilot project "Transparent and Participatory system of green area inventory in Ukraine: iTree4UA" under the guidance of the Department of Forestry and Park Gardening of SS NULES of Ukraine "Berezhany Agrotechnical Institute".

Table 1. Tree variables collected for ecosystem services analysis with description

Variable	Description
1	2
1. GPS Coordinates	The values of geographical longitude and latitude were determined by applying Garmin Etrex 22x and GPSMap64s receivers as well as using Samsung Galaxy M31 mobile phone geolocation function (GPS Point app) in order to compare the accuracy of the available methods of identifying the geographical coordinates of trees and bushes
2. Land use	It was determined by such categories: Agriculture, Cemetery Commercial/ industrial, Golf course, Institutional, Multi-family residential, Park, Residential Transportation, Utility, Vacant, Water/ wetland and Other. The land use variable is used to adjust model biomass and decomposition rates
3. Tree and shrub information	It was determined by the following indicators:
3.1. Tree ID	Unique tree number
3.2. Species	Scientific name
3.3. Total height	Height to top of tree (m)
3.4. Crown base	Height to crown base (m)
3.5. Crown top	Crown top height (m)
3.6. Crown width	Measured crown width (to nearest m) in two directions: north-south and east-west or as safety considerations or physical obstructions allow (m)
3.7. Percent canopy missing	Measured as percent of the crown volume that is not occupied by branches and leaves. Two perpendicular measures of missing leaf mass are made and the average result is recorded to nearest 5% (%)
3.8. Crown dieback	Percent dieback in crown area, does not include normal, natural branch dieback, i.e., self-pruning due to crown competition or shading in the lower portion of the crown. However, branch dieback on side(s) and top of crown area due to shading from a building or another tree was included (%)
3.9. Crown light exposure	Measured as number of sides of the tree receiving sunlight from above (maximum of five). Top of tree is counted as one side (1–5)
3.10. DBH	Measured as diameter at breast height (height at 1.37 metres or 4.5 feet)

In order to perform a flyover with remote area photographing, unmanned aerial vehicle (UAV) Phantom 4—a quadrotor of serial manufacturing with a built-in GPS (Global Positioning System) module, a stabilising control system and surveying equipment, which includes photographing devices of high optical properties and resolution, was applied. Before the beginning of photo surveying, UAV route planning was conducted, including the determination of a flight height, an execution time and the necessary specification. The information about the location of every tree was obtained with the help of three GPS receivers with further updating in geographic information system (GIS) (QGIS 3.16) based on the orthophotomap, which was obtained by means of a quadrotor Phantom 4. After this, a geo-information database of trees and bushes, which included the location of trees combined with the information about the species composition, phytosanitary and basic taxation characteristics of plants, was created (Lakyda et al. 2020).

Having performed all the necessary settings, UAV calibration and route planning, there was a flyover performed in order to investigate the object at heights 100 metres with orthogonal photographing of the park area. Here, every image was automatically connected to global coordinates and contained longitudinal and lateral overlaps for their further photogrammetric plotting and correction. During the data processing, an orthophotomap was created in Agisoft PhotoScan Professional program based on the obtained data with their orthotransformation in UTM coordinates on the ellipsoid WGS84. As a result, one-dimensional cartographic material on the castle park area was obtained, which is connected to the coordinates and can be used for further application in GIS.

A high-quality relevant cartographic basis, namely the obtained orthophotomap, made it possible to specify and adjust plant locations obtained by GPS receivers data in GIS. In its turn, that improved the accuracy of the obtained data on the geolocation of trees and bushes (Bidolakh et al. 2018). The suggested approach allows for mapping the location of a specific tree with high accuracy, which, in turn, enables users to easily find the information about every tree in the park standing next to it with their smartphones.

Once field data have been collected, they are transferred to the desktop and sent for processing using the version 6 of i-Tree Eco software. This computer program is an adaptation of the Urban Forest Effects model, which was cooperatively developed by US Forest Service Northern Research Station, the USDA State and Private Forestry's Urban and Community Forestry Program and Northeastern Area, the Davey Tree Expert Company, and SUNY College of Environmental Science and Forestry. More information can be found in the Manual I-Tree Eco Sample Inventories (i-Tree Eco 2006). According to the results obtained from processing the data entered in i-Tree Eco, a number of reports and results used for assessing certain ecosystem services of the plantations in Pryzamkovyi park in quality, quantity and monetary terms were obtained.

In the process of this research, the following software was applied: Agisoft PhotoScan for ortho-transformation of the images obtained from the survey of the park area using UAV and for orthophotomap generation; GIS (QGIS 3.16) for interpreting GPS inventory points of trees and bushes and creating a geo-information database of the vegetation; i-Tree Eco tools for investigating ecosystem services provided by trees and bushes in the park.

Results

The inventory of this object covered 228 trees and bushes and the parameters of every item were measured, which is shown in Table 1. The crowns of these plants cover the area of 2002 hectares, which is 55.6% of the total area of Pryzamkovyi park, and provide 16.33 hectares of leaf area. The most important species of trees are *Aesculus hippocastanum* L., *Fraxinus excelsior* L. and *Tilia cordata* Mill. (Tab. 2). High importance values do not mean that these trees should necessarily be encouraged in the future, rather these species currently dominate the park structure.

Table 2. Most important species in Pryzamkovyi park

No	Species name	Population (%)	Leaf area (%)	Importance values*
1	*Aesculus hippocastanum* L.	18.4	21.9	40.3
2	*Fraxinus excelsior* L.	15.8	20.9	36.7
3	*Tilia cordata* Mill.	13.2	15.5	28.7
4	*Acer platanoides* L.	7.9	13.3	21.1
5	*Acer pseudoplatanus* L.	4.8	7.2	12.1
6	*Betula pendula* Roth.	4.8	2.2	7.0
7	*Acer saccharinum* L.	2.6	4.3	6.9
8	*Thuja occidentalis* L.	5.7	0.8	6.5
9	*Prunus cerasus* L.	5.3	0.4	5.6
10	*Quercus robur* L.	2.6	2.6	5.2

* Importance values are calculated as the sum of percent population and percent leaf area.

The analysis of the structure of DBH distribution for the park trees (Fig. 1) shows that Pryzamkovyi park dendrocenosis is typical for similar parks and is presented by plants of various diameter with the prevailing class being 45.7–61 centimetres. The oldest tree of this park is *Quercus robur* L. being 136 centimetres in diameter.

The results of the statistical processing of geolocation measurements conducted by various devices (Tab. 3) show that the coefficient of variation in all the experiments is higher than 50% (I–60.6%, II–64.74%, III–57.70%), which testifies that the variation is significant, the connections between separate variables are absent and there is a certain disconnection in a statistical set structure. This can be explained by the complexity of performing geolocation under tree cover and the accuracy of the devices themselves, which is equal to 2–6 metres, according to their technical data.

The analysis of the statistical indicators shows that the accuracy of the third experiment is quite low ($p = 5.89$) and in case of the first and the second experi-

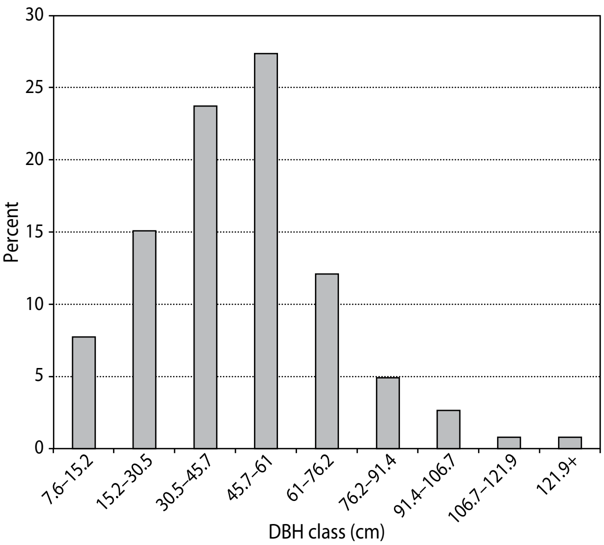

Figure 1. Percent of tree population by diameter class (DBH–stem diameter at 1.37 metres)

Table 3. Statistical indicators of the samples

Statistical indicators	I (Garmin 22)	II (GPS 64s)	III (GPS point mobile)
Average value (arithmetical mean), m	5.03	4.85	5.39
Variation indices			
Minimum value, m	0.43	0.76	1.27
Maximum value, m	15.14	18.19	16.60
Range of variation, m	14.71	17.43	15.33
Dispersion, m	9.28	9.86	9.70
Basic (standard) deviation, m	3.05	3.14	3.11
Coefficient of variation, %	60.60	64.74	57.70
Experiment accuracy, %	3.88	4.16	5.89

ments, it is satisfactory ($p < 5\%$). This gives ground to conclude that when carrying out data measurements, it is better to use tourist GPS receivers in comparison with smartphone geolocation apps due to the higher accuracy of their results and simpler and faster measurement process. However, on condition of adjusting the points according to remote sensing data, all the above-mentioned ways of performing geolocation can be applied. In addition, the obtained results indicate the need to clarify the coordinates obtained from GPS receivers. For this purpose, it has been suggested applying an orthophotomap based on UAV survey materials (Bidolakh et al. 2018; Lakyda et al. 2020).

Air Pollution Removal by Urban Trees

Despite efforts conducted by European countries to reduce air pollutant emissions and improve air quality, urban populations are still exposed to high levels of pollutant concentrations (Selmi et al. 2016). Urban trees are a significant element to reduce air pollution; they remove this pollution by intercepting particulate matter on plant surfaces and absorbing gaseous pollutants through the leaf stomata (Nowak et al. 2018). Pollution removal by trees in Pryzamkovyj park is 481.4 kilograms per year and was estimated using field data, recent available pollution and weather data available. Pollution removal was greatest for sulfur dioxide (SO_2; Fig. 2). It is estimated that trees remove 481.4 kilograms of air pollution (ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10) and SO_2 per year with an associated value of €1965 per year.

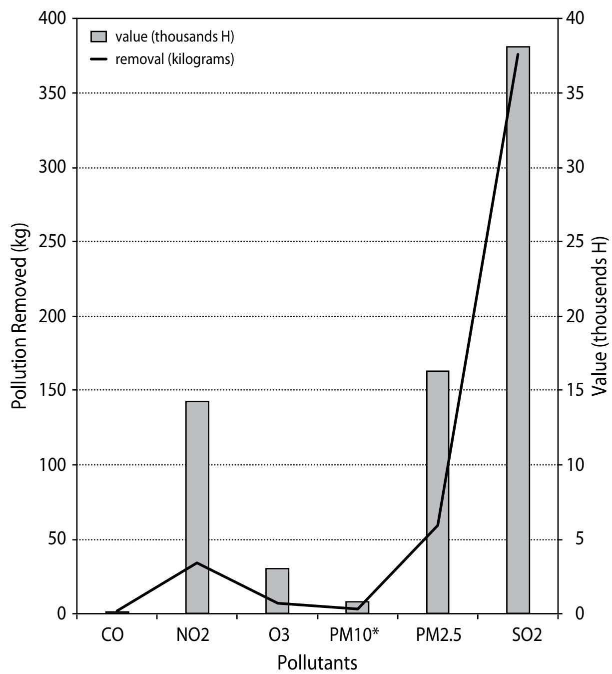

Figure 2. Annual pollution removal (points) and value (bars) by trees of park

In 2022, trees in Pryzamkovyi park emitted an estimated 22.21 kilograms of volatile organic compounds (VOCs) (7.297 kilograms of isoprene and 14.92 kilograms of monoterpenes). These VOCs are important precursors of photochemical ozone and secondary organic aerosol, namely precursor chemicals to ozone formation (Yang et al. 2021). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Forty-two percent of the urban forests' VOC emissions were from *Quercus robur* and *Acer platanoides*. Such observation is beneficial for the emitted control of VOCs and aids in the formulation of an emission control strategy in cities around the world (Yang et al. 2021).

Carbon Storage and Sequestration

Urban trees help to mitigate climate change by reducing the amount of carbon in the atmosphere. Some research shows that more than 50% of tree species are currently exceeding temperature and precipitation conditions experienced in their geographical range and respectively facing severe climate risks, undermining their roles in climate adaptation and other ecosystem services they provide (Huang 2022; Esperon-Rodriguez et al. 2022). Despite such evidence, the potential for urban green spaces to deliver regulating services, such as carbon storage, has received little attention in the world (McHugh et al. 2015). The amount of carbon annually sequestered is increased with the growth and health of the urban trees. The approximate sequestration of Pryzamkovyi park stands is about 4885 metric tons of carbon per year with an associated value of €731.7 (Fig. 3).

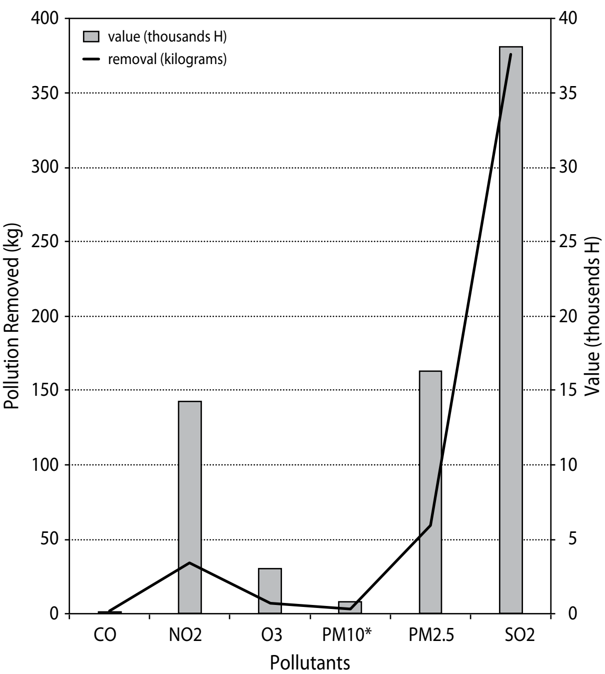

Figure 2. Annual pollution removal (points) and value (bars) by trees of park

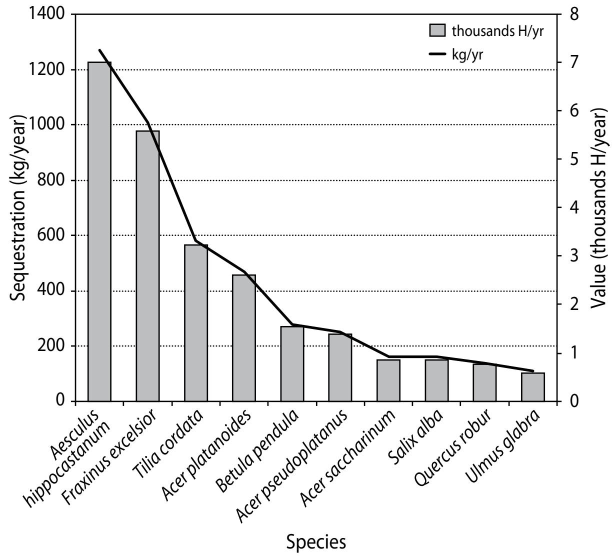

Figure 3. Estimated gross carbon sequestration (points) and value (bars) for trees with the greatest sequestration, Pryzamkovyi park

Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban vegetation, particularly trees (Nowak et al. 2007). The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass. Trees remove (sequester) carbon from the atmosphere through photosynthesis, extracting carbon dioxide from the air, separating the carbon atom from the oxygen atoms and returning oxygen to the atmosphere (Kiran and Kinnary 2011). Trees in Pryzamkovyi park are estimated to produce 13.03 metric tons of oxygen per year. However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems (Nowak et al. 2007).

According to the data presented in Table 4, it may be remarked that the production of oxygen is directly proportional to a plant leaf area, which in its turn correlates with the size and the vitality of trees. Trees store a tremendous amount of carbon in their structures, and annual growth increases the carbon stored within the structure (Kiran and Kinnary 2011).

Table 4. The top 10 oxygen production species

No	Species	Oxygen (kg)	Gross carbon sequestration (kg/yr)	Number of trees	Leaf area (ha)
1	*Aesculus hippocastanum* L.	3380.40	1267.65	42	3.58
2	*Fraxinus excelsior* L.	2697.65	1011.62	36	3.41
3	*Tilia cordata* Mill.	1555.54	583.33	30	2.53
4	*Acer platanoides* L.	1258.02	471.76	18	2.16
5	*Betula pendula* Roth.	745.95	279.73	11	0.35
6	*Acer pseudoplatanus* L.	668.65	250.74	11	1.18
7	*Acer saccharinum* L.	414.34	155.38	6	0.70
8	*Salix alba* L.	413.68	155.13	6	0.28
9	*Quercus robur* L.	372.17	139.56	6	0.43
10	*Thuja occidentalis* L.	180.75	67.78	13	0.13

Avoided Runoff

Surface runoff can be a cause for concern in every urban area. A nature-based solution is to plant trees because they intercept precipitation and help to reduce water reaching the ground, forming surface runoff (Zabret and Šraj 2019). The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Koirala et al. 2014). In urban forests, the large extent of leaf surfaces is beneficial in reducing surface runoff.

The trees and shrubs of Pryzamkovyi park help to reduce runoff by an estimated 480 cubic metres a year (Fig. 4) with an associated value of 33 000 Ukrainian hryvnia (UAH) or €894.3. Avoided runoff is estimated based on local weather from the user-designated weather station. In Pryzamkovyi park, the total annual precipitation in 2019 was 91.9 centimetres.

Summarising the above, it should be mentioned that the total cost of ecosystem services provided by trees and bushes in Pryzamkovyi park was determined to be €3591 per year. Besides, as of today, trees and bushes in the park under study store carbon, which is worth €42 751 in its biomass.

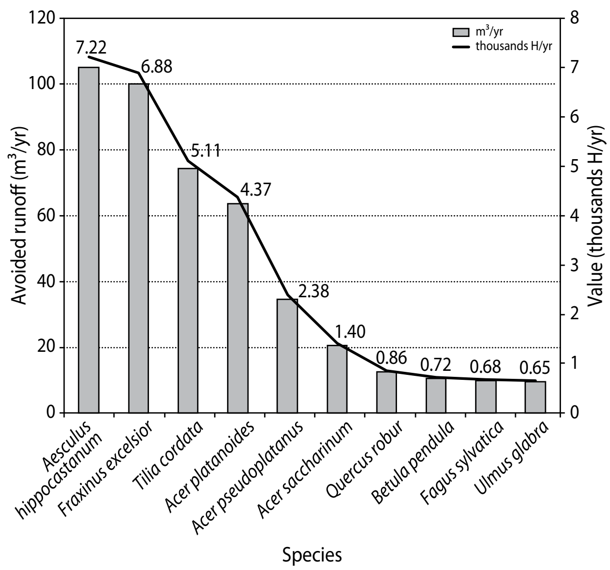

Figure 4. Avoided runoff and value for species with greatest overall impact on runoff

Discussion

According to the scientists (Steenberg et al. 2017), in order to provide constant and regular support of ecosystem services, the process of their quantitative determination is important. Here, the assessment of the value of these services can be conducted in various measurement units, for example, the amount of labour, energy, materials and other resources spent. However, in order to integrate it into the practice of making substantiated decisions, it is necessary to carry out monetisation. In the absence of direct financial expression of the value of ecosystem services provided by urban trees, there is underestimation and unawareness of their great value observed.

It is certainly impossible to assess the entire list of ecosystem services, because currently there are no clear procedures of determining the value of aesthetic, hygienic, recreation, educational and other intangible functions of urban trees. However, even the assessment of the ecosystem services that are available for evaluation makes it possible to demonstrate some value of trees and bushes in monetary terms to local authorities, organisations involved in urban forest management, activists and other interested parties. A significant change in the approach to financing environmental measures is a positive tendency of the economic development in the countries that pay considerable attention to the implementation of sustainability principles. According to the research results (Sattler et al. 2013), such category of funding is determined by various terminologies but corresponds to the same concept, which is summarised under the name PES in foreign literature sources.

The concept of payment for the cost of ecosystem services is of considerable international interest (Schomers and Matzdorf 2013) in terms of being an economically effective way to improve ecological management by means of applying financial incentives to increase the efforts aimed at providing these services. The prospect of this kind of ecological payments (Wunder and Wertz-Kanounnikoff 2009) is the possibility of substantiating the expediency of financing environmental measures based on economic calculation of the usefulness that a country obtains from ecosystems.

In Ukraine, there have also been discussions on the expediency of a more detailed study of ecosystem services (Havrylenko and Tsyhanok 2019) in order to assess the usefulness that a society obtains in the process of its vital activity without even being aware of its cost. The expediency of creating a separate State Agency of Ecosystem Services has been discussed since 2013. However, there are practically no developments related to the peculiarities of assessing ecosystem services in urban ecosystems in our country and the ones that have been published are mostly of conceptual nature.

Thus, the conducted research enabled testing the possibility and the expediency of applying one of the leading and available tools for assessing the cost of ecosystem services, that is to say i-Tree Eco, in order to obtain information about the ecological assessment and the value of tree and bush plants by the example of a park in the town of Berezhany. In the course of conducting the research, it was determined that the suggested methodology (USDA Forest Service 2011, pp. 31–48) is similar to the typical methods of green plantation inventory in Ukraine (State Committee of Construction 2001). At the same time, in order to improve the accuracy of determining biomass, a number of additional indices, such as 2 and 3.4–3.9 (Tab. 1), were measured. That is to say, this methodology can be integrated into National System of Urban Forest Inventory by means of conducting a number of additional measurements.

The analysis of the possibility of adjusting the i-Tree Eco tool to the economic conditions of Ukraine showed that this programme uses certain input national parameters, such as: climate data from local meteorological stations, a number of residents in the area, local cost of the main energy resources, current exchange rate and others. This provides the possibility of not only obtaining the results of monetisation of ecosystem services in national currency, but also adjusting them to local economic conditions to a certain extent.

The possibility of obtaining results both for the research object in general (for all trees and bushes in the park) and for every separate plant opens up new opportunities for interpreting the obtained results. Namely, there is a possibility of presenting the usefulness of every tree or bush both in a unit of production of ecosystem services and in a monetary form. If we apply the suggested high-quality cartographic base for this purpose, all the interested parties will be familiarised with this information on the spot standing next to the tree.

The conducted research shows that the greatest number of the ecosystem services under study in Pryzamkovyi park was provided by a tree No. 97 being 66 centimetres in diameter and 18 metres in height, which gave the total annual benefit for the ecosystem worth €91.60. At the same time, the average value of annual usefulness of the park trees and bushes was equal to €15.75 per year without taking into account their replacement and carbon storage value.

The urban forest in Pryzamkovyi park provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared with estimates of average municipal carbon emissions, average passenger automobile emissions and average household emissions methodology (Nowak and Crane 2002). Carbon storage is equivalent to amount of carbon emitted in Pryzamkovyi park in 1 day, annual carbon emissions from 163 automobiles and annual carbon emissions from 67 single-family houses. NO_2 removal is equivalent to annual NO_2 emissions from five automobiles or from two single-family houses. SO_2 removal is equivalent to annual SO_2 emissions from 4460 automobiles or from 12 single-family houses.

The analysis of the cost of creating ecosystem services conducted by various scientists in the world and local levels gives ground to conclude that a proper quantitative and economic assessment of the usefulness provided by ecosystems will create conditions for focusing on the value of urban forests for urban ecosystems and will make it possible to substantiate the expediency of applying and financing regular environmental measures. Some scientists (Nowak 2017; Rocha et al. 2015; Schomers and Matzdorf 2013; and others) suggest using and practising various information systems for demonstrating tree locations including information about their value.

In this direction, we have used the possibilities of creating a geographical information database, which is able to store information about the location of objects as well as certain information about them. Namely, the i-Tree Eco tool is able to store information about the location of park trees and bushes, their parameters and their ecosystem services in common data formats, such as .CSV and .KML, which enables the possibility of displaying these data on a cartographic base and interpret them (Fig. 5).

Such an approach opens up possibilities of automated data processing in various GIS as well as importing the obtained data in common formats to other electronic resources including those that operate online. The created database, together with a cartographic base, makes it possible to build an electronic map of green plantations, which becomes available due to open web resources. Such an approach to mapping in order to represent the results obtained from i-Tree Eco tools has already been tested in the park by the users of this information who have been able to get the information about the ecosystem services of a specific tree on the spot using their smartphones.

The conducted analysis of the possibilities provided by free-of-charge Internet resources shows that there is a great number of them available. At the time of study, the most widely spread and functional resources were determined to be the following ones: Click 2 Map (http://www.click2map.com/); GMapGIS (https://gmapgis.com/); Google MyMaps (https://www.google.com/maps/d/); Map Tiler (https://www.maptiler.com/); Mapbox (https://account.mapbox.com/); Mindmeister (https://www.mindmeister.com/ru); Scribble Maps (https://www.scribblemaps.com/); uMap (https://umap.openstreetmap.fr/ru/); Zee Maps (https://www.zeemaps.com/) and others.

The study of the possibility of visualisation of the created geographical information database of urban

Figure 5. A way of displaying a geographical information database of Pryzamkovyi park dendrocenosis on an orthophotomap

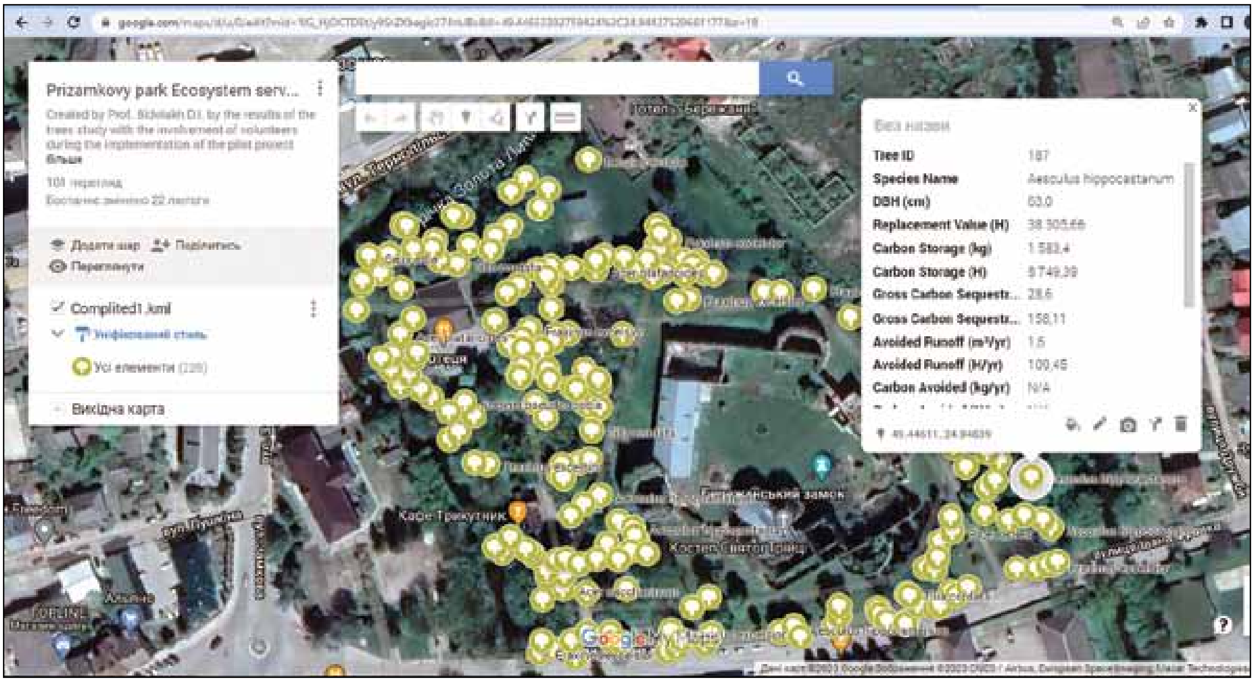

Figure 6. A way of displaying a geographical information database of Pryzamkovyi park dendrocenosis in the system of Google MyMaps

trees by means of creating online maps (the example shown in Fig. 6) shows that their advantage is the simplicity and speed of data entering by means of importing, the availability of free information placement and storing on respective resource servers, the availability of users' access by following the link and the possibility of using free space images and topographic maps as a raster basis. At the same time, these resources are limited in terms of the amount of information that can be entered. Thus, in order to fully perform the task of familiarising the largest possible number of users with an ecosystem plant value, it is to the point of applying specialised electronic maps, such as NYC street tree map (2019) and others.

Besides, the use of an orthophotomap created according to a UAV survey as a raster basis for a geo-base of trees and bushes makes it possible to avoid errors when determining plant location by means of GPS receivers since the location points of trees and bushes can be clearly seen on such a basis and this makes it possible to adjust GPS points. In addition, such an approach can improve the accuracy of geolocating vegetation.

An important result of similar investigations is the determination of the total value of trees and bushes themselves, which can serve as a prototype of forming a replacement value parameter. Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values based on the functions the trees perform (Nowak and Crane 2002). The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees, and annual functional values also tend to increase with increased number and size of healthy trees (Nowak 2010). Through proper management, urban forest values can be increased.

Urban trees in Pryzamkovyi park have €12.38 million replacement values, based on the i-Tree Eco assessment. Currently, plants of this object deposit carbon worth €42 751 in their biomass. That is to say, an average replacement value of one park plant is approximately equal to €54 500. In addition to this value, an average annual cost of ecosystem services provided by one tree or bush plant worth €15.75 per year should be added. Here, it is worth mentioning that these are monetisation results of only a certain part of the usefulness of trees and bushes in Pryzamkovyi park for the urban ecosystem, which were obtained in this research.

Summarising the above, it is worth paying attention to the fact that the given approaches to assessing the value of urban trees and their provided ecosystem services give ground to focus on the value of these plants for urban ecosystems by substantiating the expediency of introducing measures to preserve and expand landscaping territories in order to improve the ecological safety and increase the funding of these measures to compensate for the services provided by trees and bushes. The suggested precise mapping of the park plants, together with representing the information about their ecosystem services, creates conditions for raising the validity of the decisions about protection, treatment, replacement or removal of every specific tree or bush.

At the same time, it is worth mentioning the expediency of conducting further research on this subject since there are certain issues that require further consideration. They include the following:

– investigation of the possibilities of extending the list of tools for assessing ecosystem services provided by urban trees (recreation, aesthetic, sanitary-hygienic, educational and other intangible functions of urban trees);
– definition of the information content of the obtained indicator of a plant replacement value and the possibility of its further adjustment to national standards;
– possibility of applying these tools in order to assess ecosystem services provided by other plant species in urban landscapes (lawns, flower beds, etc.);
– thorough research on the "weak points" of the process performance and the possibility of improving the accuracy of the obtained data (including the influence of the peculiarities of public inventory of urban trees);
– continuation of the adjustment of the methodology to the conditions of different countries and the compliance of cost-based ecosystem service parameters to their economic conditions.

Conclusions

The development and the practical implementation of the method of assessing the volume and the value of ecosystem services provided by urban trees is an important area of research for the scientists worldwide. Obtaining and presenting the results of assessing the usefulness of trees and bushes for urban ecosystems to the public will inevitably lead to the awareness of the important role of urban trees, increasing the responsibility for their preservation and raising additional funds for the environment facility. These funds should be allocated to cover the needs of improving urban forests and supporting sustainable development requirements in the field of providing ecosystem services.

The conducted research has made it possible to validate the application of one of the advanced tools for assessing the value of ecosystem services, namely i-Tree Eco, by the example of trees and bushes in one of the parks in Ukraine. The expediency of applying this tool for obtaining information about the ecological importance and the value of tree and bush plants lies in its availability for a wide circle of scientists and other users, its functionality and convenience when presenting results. The methodology of collecting field data with their further processing in the above-mentioned programme can be adjusted to national systems of urban forest inventory by means of conducting additional measurements. The adjustability of i-Tree Eco to local economic and climatic conditions makes it possible to obtain the results of monetisation of ecosystem services in national currency and adjust the results to local conditions. It is better to use tourist GPS receivers in comparison with smartphone geolocation apps due to the higher accuracy of their results and simpler and faster measurement process. The application of an orthophotomap based on a UAV survey makes it possible to avoid the errors when determining plant location with the help of GPS receivers and improve the accuracy of determining the geolocation of vegetation. Visualisation of the value parameters of green plantations, including their ecosystem services, by applying interactive electronic maps and an electronic system of green plantation arrangement will contribute to general awareness of the value of urban landscapes and their preservation.

Overall, the given approaches to assessing ecosystem services provided by urban forests give ground to focus on their value, substantiate the need of increasing their funding as a compensation for the services provided by trees and plants. At the same time, it is worth mentioning the expediency of carrying out additional theoretical and practical investigations on this subject and the existence of certain issues that require further research.

Acknowledgements and information concerning research grants

The inventory of trees and bushes was conducted within the framework of the implementation of the pilot project "Transparent and Participatory system of green area inventory in Ukraine: iTree4UA" under the guidance of the Department of Forestry and Park Gardening of SS NULES of Ukraine "Berezhany Agrotechnical Institute". The iTree4UA project is aimed at creating analytical and technological preconditions for implementing an interactive and transparent inventory system for urban trees in Ukraine based on i-Tree technologies in order to obtain the advantages for local communities and the environment under the threat of climate change. The project is being implemented with the financial support of US Forestry Service International Programs in partnership with Davey Tree Expert Company (i-Tree product developer in the USA) and Ukrainian ecological club "Zelena Khvylia". The authors would like to express their gratitude to the volunteers involved in the process of conducting the research, namely activists, teachers and students, pupils and their mentors.

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