

GREEN AREAS STATE ASSESSMENT WITHIN THE URBAN TERRITORIES

Oleksii Shestopalov✉

Department of Chemical Engineering and Industrial Ecology¹
pheonixalex@gmail.com

Tetyana Tykhomyrova

Department of Chemical Engineering and Industrial Ecology¹

Volodymyr Lebedev

Department of Plastics and Biologically Active Polymers Technology¹

Veronika Stadnik

Department of Chemical Engineering and Industrial Ecology¹

*¹National Technical University "Kharkiv Polytechnic Institute"
2 Kyrpychova str., Kharkiv, Ukraine, 61002*

✉Corresponding author

Abstract

The urbanized environment is a complex heterogeneous system that is constantly changing. In large cities, there is a complex stress effect on living organisms. Different areas of the city may be permanently or temporarily dominated by a certain stress factor. Vegetation is a component of urban landscapes, which are natural and artificial objects of various functional purposes. The ecological functions of green spaces include: environmental protection, environmental regulation and aesthetic functions. All these functions play an important role within residential buildings, especially in children's playgrounds. Various types of damage to green spaces negatively affect their main functions. The susceptibility to damage of woody plants by insects depends on anthropogenic factors of the environment, which lead to the weakening of plants and to the loss of resistance to these types of negative influences. The resistance of plants to diseases often decreases under the influence of transport and industrial pollution in the external environment. The purpose of the study is phytopathological analysis of the green areas state on children's playgrounds in Kharkiv. Green plantations state assessment methods of urban areas using various technical means are analyzed. Green plantings condition and morbidity analysis using one of the offered methods is carried out. According to the results of phytopathological analysis, it was determined that 100 % of the species *Aesculus hippocastanum* L., which grow on playgrounds in Kharkiv, are affected by *Cameraria ohridella*. Among the bushes, *Syringa vulgaris* L. and *Spiraea* L. are the most affected by diseases and pests.

Keywords: phytopathological analysis, GIS, playgrounds, urban territories, green spaces, monitoring methods, TreeTalker, WebGIS system, chlorosis, insects-phytophagous.

DOI: 10.21303/2504-5695.2022.002618

1. Introduction

The functioning of modern large cities is associated with the continuous accumulation of energy and matter, and from the suburbs to the center, the process intensity increases [1]. Urbanization and its consequences (soil compaction, waste accumulation and pollution) increase the adverse effects on the environment, including the thermal island effect formation, increased greenhouse gas emissions, hydrological cycle disruption, changes in organisms life medium and biodiversity loss. So, the cities growth and development leads to increased environmental risks and reduces the urban territories quality [2, 3].

Despite the decline in environmental safety, the process of urbanization does not stop, the urban population is growing rapidly, according to the United Nations forecast by 2030 more than 2/3 of the world's population will live in cities [4].

Thus, the urban ecosystems crucial role in providing the functions necessary for a high level of life quality in cities will continue to grow. Accordingly, the task of ecological sustainability of ecosystems is relevant.

It should be noted that the susceptibility to damage woody plants by sucking and leaf-eating insects to some extent depends on anthropogenic environmental factors that lead to plants weakening and resistance loss to these adverse effects. Plant resistance to disease often decreases under the transport influence and industrial pollution in the environment [5].

Long-term monitoring of urban green spaces makes it possible to assess the dynamics of their condition, to understand the reasons for the deterioration of any parameters and to take measures to improve them, as well as to prevent possible negative consequences.

An important tool for assessing urban ecosystems state and quality, as well as their social and economic significance, are ecosystem services – the ability of ecological systems to meet (directly or indirectly) human needs, support sustainable development and functioning of man and the environment [6].

The paper [7] identifies the main ecosystem services of urban green infrastructure are:

1. Thermoregulation. Green plantations are able to reduce air temperature by evaporating water and regulating the air masses flow.

2. Improving air quality. Plant contributes to the air quality improvement both directly (by reducing the level of pollution through the pollutants absorption and neutralization) and indirectly (by stabilizing the temperature and humidity). Dust retention and gas-absorbing function of plants depends on the initial pollutants concentration in the air, as well as on weather conditions, wind regime, type, germination place and plant condition.

3. Creating a stable water balance by reducing the number of waterproof surfaces (improving water permeability). Green infrastructure facilities increase the filtration share in the total amount of precipitation distribution and reduce the load on the city sewerage system.

4. Reduction of water pollution. Green plantations help to purify water in the filtration process and partial substances absorption by plant roots.

5. Recreational and decorative properties. Despite the fact that aesthetic, cultural and recreational functions are subjective and difficult to assess, there is a clear relationship between the positive physical and psychological state of man and its stay in green areas.

6. Carbon deposition and accumulation. The main carbon reserves in terrestrial ecosystems are concentrated in plant biomass and soils [8].

7. Providing food. In recent years, the number of projects for growing agricultural products directly in the city, such as urban farms and urban orchards, has increased significantly [9].

Thus, greenery, in particular, trees and bushes, provides a range of ecosystem services to the city and its inhabitants. It should be noted that the condition of greenery affects the properties level listed above. Therefore, monitoring the trees and bushes condition will help to improve the ecological condition of urban areas [10].

Now there are many methods for green areas condition studying (**Table 1**).

Visual assessment is the most traditional way of greenery condition analyzing in the city and is a determination by a specialist of the plant disease initial signs using methods of visual damage assessment. The method is characterized by high complexity, requires money and has some level of subjectivity. Large areas, high greenery spatial heterogeneity, as well as the diversity and dynamism of their functions limit the possibility of using ground-based observations in urban territories.

Sampling of roll by drill with the subsequent estimation of wood quality using portable fractometer allows estimating quality of wood biomass and a tree condition in whole.

Perspective, but quite expensive is TreeTalkers sensors using, which allow the analysis trees biometric and physiological parameters. Tree Talker (TT) – a modern technical tool for greenery monitoring, a new type of device, which principle is based on IoT (Internet of things) (**Fig. 1**).

TreeTalker technology is unique in its versatility while maintaining high accuracy in measuring individual parameters. Sensors of individual parameters can be compared with existing analogues in terms of measurement accuracy, cost of purchase and operation.

Table 1

Comparative characteristics of greenery monitoring methods

Method	Technology	Investigated parameters	Preferences	Imperfection
Direct ground-based and instrumental observations	Drilling with core sampling, gap test	Trunk wood quality, vertical stability	Accuracy, data security at the level of a specific tree. Identification of defects in the trunk condition and vertical stability analysis for risk assessment	Time costs, the need for Qualified personnel, restrictions on tests under external influence in conditions of dense development
	Visual assessment	The state of green spaces	No special equipment needed	Time costs, the need for qualified personnel
	Using monitoring sensors	Condition analysis, diameter increase, biomass increase	Accuracy, estimation of dynamics	The cost of equipment for each tree, the need for periodic monitoring
Remote and integral methods	Analysis of satellite images	Analysis of large areas. Assessment of crown condition (signs of diseases and stresses during the growing season). Terrestrial biomass (LiDAR)	Significant area provided by information	Errors in the analysis of vegetation indices for small objects. The high cost of high-resolution images for monitoring tasks
	UAVs (drones)			Restrictions on flights in the city
Database models	Allometric models, GIS	Biomass growth, the state of green spaces	Non-destructive method, visibility, reproducibility	The need for an array of empirical data with high resolution in time and space

Remote sensing technologies can provide a regular (possibly even continuous) flow of qualitative and quantitative spatially differentiated information about the nature of the Earth surface in any part. Most research in this area examines the relationship between the state of green areas (for example, according to visual assessment) with vegetation indices (VI), calculated on the basis of multispectral satellite data [11].



Fig. 1. Example of using a sensor TreeTalker: *a* – TreeTalker sensor on the tree; *b* – TreeTalker sensor

Index indicators are generated through satellite images of green mass, which absorbs electromagnetic waves in the visible red range and reflects them in the near infrared range.

The red region of the spectrum (0.62–0.75 μm) accounts for the maximum absorption of solar radiation by chlorophyll, and the near infrared zone (0.75–1.3 μm) has the maximum energy reflection by the leaf cell structure. That is, high photosynthetic activity leads to lower values of the reflection coefficients in the red region of the spectrum and large values in the near infrared region of the spectrum. The ratio of these indicators to each other allows to clearly separate the vegetation from other natural objects. As a result, it is possible to obtain a complete spectral analysis (Fig. 2).

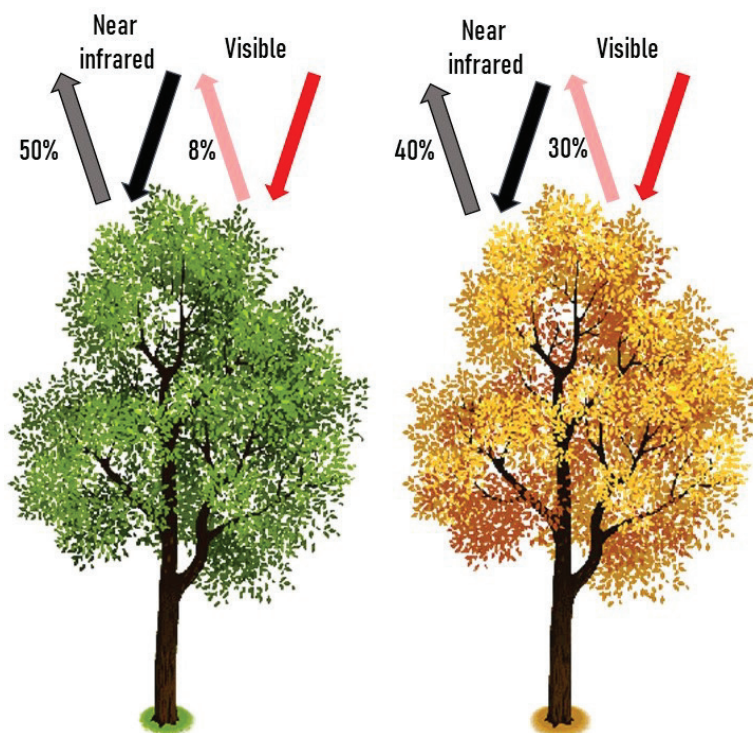


Fig. 2. Getting data for calculating indexes

Compared to forest areas, the potential of low-resolution multispectral space survey data (10–30 m) for urban vegetation research is severely limited due to high spatial diversity territory and, as a consequence, a numerous mixed pixels. Scientists [12] found out the presence of background (non-vegetation) values in the pixel, which reduces the reliability of index calculations.

Multispectral data obtained from drones and aerial photography (airborne data) with a resolution of 2–4 m and above, supplemented by LiDAR data (technology for obtaining and processing information about the distance to the object using active optical systems), allows to get accurate characteristics of the state of green plantations [13].

Available models that quantify the urban green areas biomass based on generalized equations of allometric biomass are presented in [14, 15]. The main problem of such models is the empirical data lack, as a result the direct classical models using without adaptation to the specifics of urban conditions is associated with a significant error, which can be up to 30%. The main mistakes include differences in the rate of plant growth in the urban environment compared to natural.

An example of web – GIS implementation for inventory and assessment of green spaces is WebGIS inventory of urban green areas in New York (USA) (Fig. 3).

The WebGIS system is related to the citizen's involvement in the municipal economy and is a means involving the population in the study, management and care of urban trees.

Technical capabilities and economical satiation in Ukraine limit the use of methods for assessing the green spaces condition. At present, only direct instrumental methods and visual assessment are available, which due to their complexity complicate research.

Assessment of the green plantations state by Ukrainians scientists is mainly carried out according to the generally accepted rating scale, which is subjective and does not take into account the analysis of individual diseases and pests that have different degrees of danger for a particular plant species [16–18].

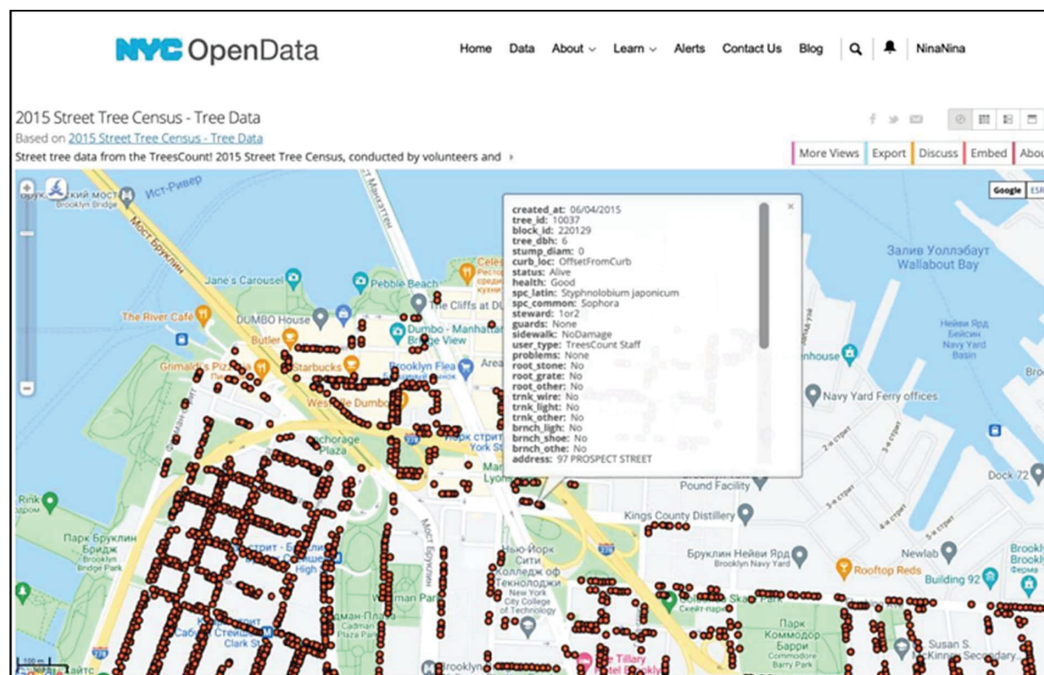


Fig. 3. WebGIS system of urban green spaces inventory in New York using data from citizens

2. Materials and Methods

In order to study the condition of green areas, phytopathological monitoring of plants on playgrounds (PG) in Kharkiv was made.

The selection of PG as areas for analysis is based on studies [19–21], which determine the role of these objects in the urban area. In the city, greenery is under constant stress of both natural and anthropogenic origin, which leads to the deterioration of their condition, reduced functionality and decorative. 540 children's playgrounds in 9 districts of the city (60 playgrounds in each) were studied. The selection of sites took into account the factor of anthropogenic impact: preference was given to sites located near the highway, within a radius of 1 km from the International Airport "Kharkiv" and industrial enterprises, as well as within a radius of 200 m from the new point building.

At the first stage, an inventory of green areas was conducted. The species composition of plantations was indicated by genus and species, the results were entered in the logbook. Permissible deviation in determining the species composition of plantations $\pm 3\%$.

6627 trees and bushes were studied, among which 59 species of greenery were identified, of which 37 species are the main ones. The most common species are: *Aesculus hippocastanum* L. (6.31%), *Betula pendula* Roth. (5.79%), *Syringa vulgaris* L. (4.89%), *Acer platanoides* L. (4.75%), *Tilia platyphyllos* Scop. (4.71%), *Buxus* L. (4.89%) [22].

The second stage is to examine each tree for pests, diseases or mechanical damage and assess the extent of the damage, which will allow to conclude about the potential threat to the plant. In the process of analysis, 9 main groups of damage to green areas were identified (Fig. 4).

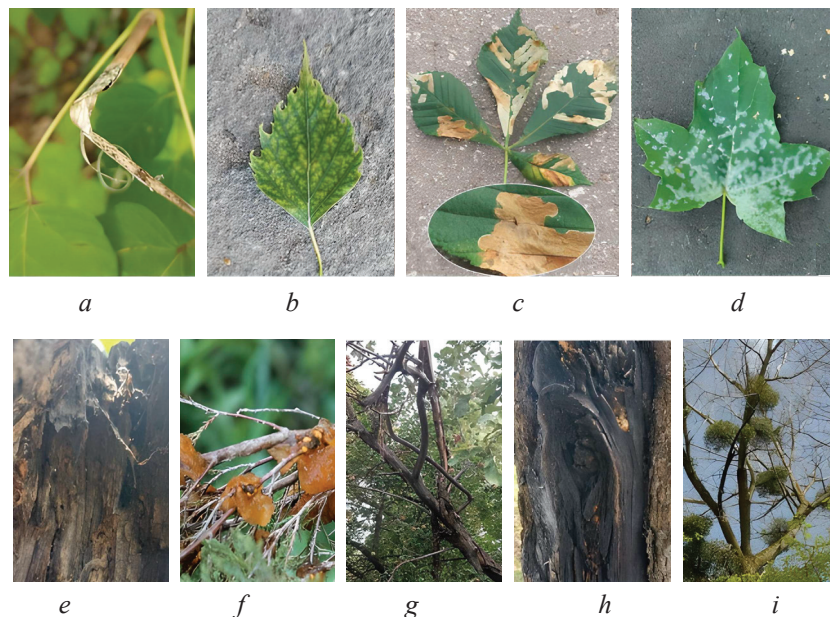


Fig. 4. The main types of damage to green plants: a – mechanical damage; b – chlorosis; c – insects-phytophagous; d – powdery mildew; e – stem decays; f – leaf rust; g – drying branches; h – canker diseases; i – mistletoe

3. Results and Discussions

The results of the study are presented in Fig. 5–13.

Mechanical damage Fig. 4, a to tree branches and shrubs occurs during commissioning, repair, construction work. In addition, accidental and intentional breakage of branches was considered mechanical damage. Among trees, mechanical damage is most characteristic of *Prunus armeniaca* L. and *Syringa vulgaris* L. among shrubs.

Due to the peculiarities of urban conditions affecting the development of plant organisms, a certain biological complex of pests of greenery has developed. In the course of research, various types of pests were identified: poplar moth, maple arrowhead, lilac moth, ringed silkworm, many species of aphids, leafhoppers and others. They were the most vulnerable at the research sites *Aesculus hippocastanum* L., *Prunus domestica* L, *Morus nigra* L, *Fraxinus excelsior* L.

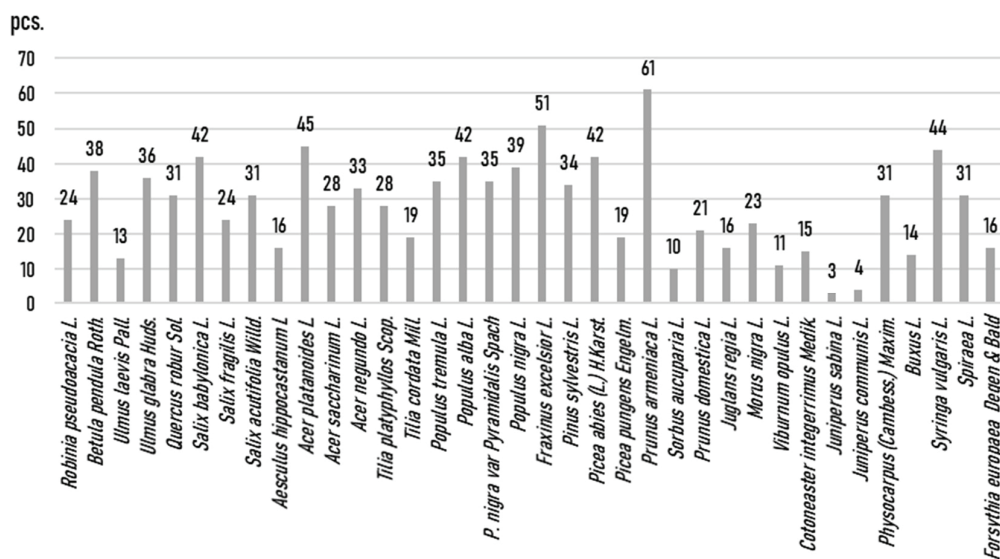


Fig. 5. Results of mechanical damage to trees and shrubs

Leaf rust (Fig. 4, f) is most common on *Sorbus aucuparia L.* and *Salix babylonica L.*

Chlorosis (Fig. 4, b) is a condition in which leaves produce insufficient chlorophyll. As chlorophyll is responsible for the green color of leaves, chlorotic leaves are pale, yellow, or yellow-white. Chlorosis of leaves was found in 13 species of greenery.

Powdery mildew diseases (Fig. 4, d) are caused by many species of fungi in the order Erysiphales. Powdery mildew is one of the easier plant diseases to identify, as its symptoms are quite distinctive – infected plants display white powdery spots on the leaves and stems.

Canker diseases (Fig. 4, h) are common, widespread, and destructive to a wide range of trees and shrubs. A canker is really a symptom of an injury often associated with an open wound that has become infected by a fungal or bacterial pathogen. Canker diseases frequently kill branches or structurally weaken a plant until the infected area breaks free. Among the studied plants in most cases, canker was found in *Acer negundo L.* and *Populus alba L.*

Stem decays (Fig. 4, e) are an important disease category leading to tree mortality. On developed sites and urban landscapes, stem decays are an important cause of tree hazard by creating tree defects that increase the likelihood of mechanical failure. Birches and poplars were the most affected in the studied areas.

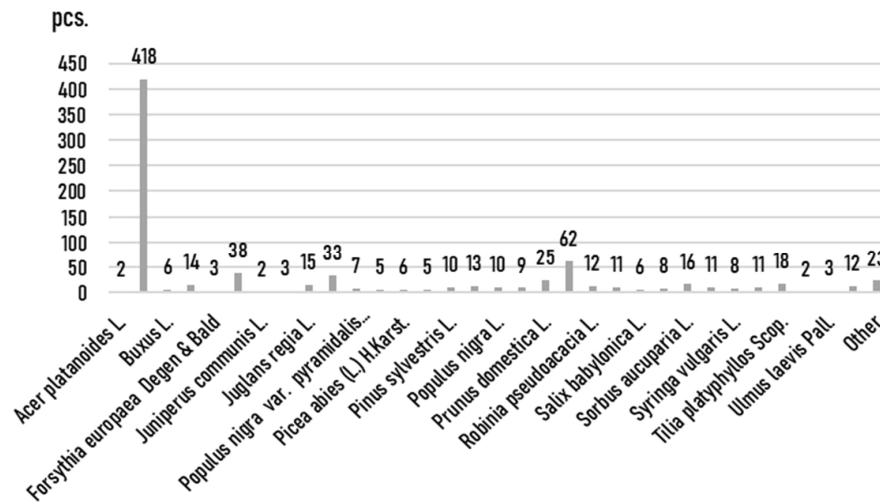


Fig. 6. The results of damage to trees and shrubs by insects-phytophagous

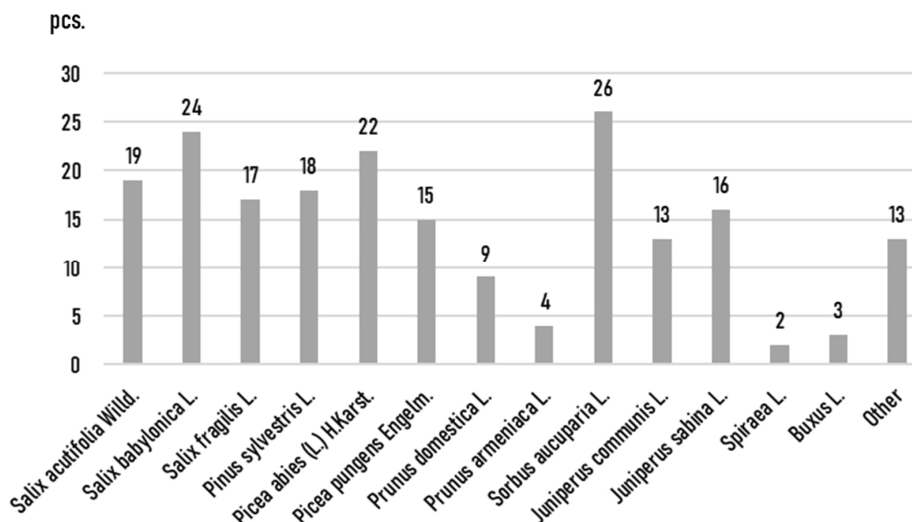


Fig. 7. The results of damage to trees and shrubs by leaf rust

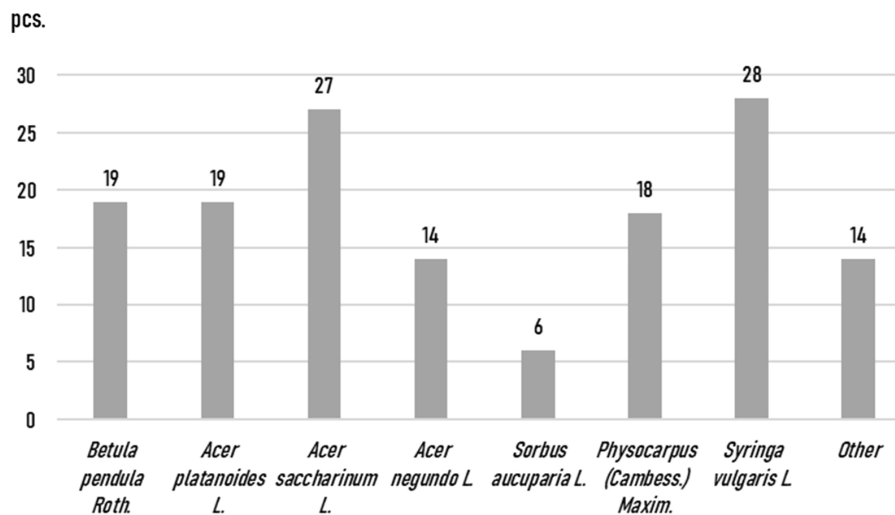


Fig. 8. The results of damage to trees and shrubs by chlorosis

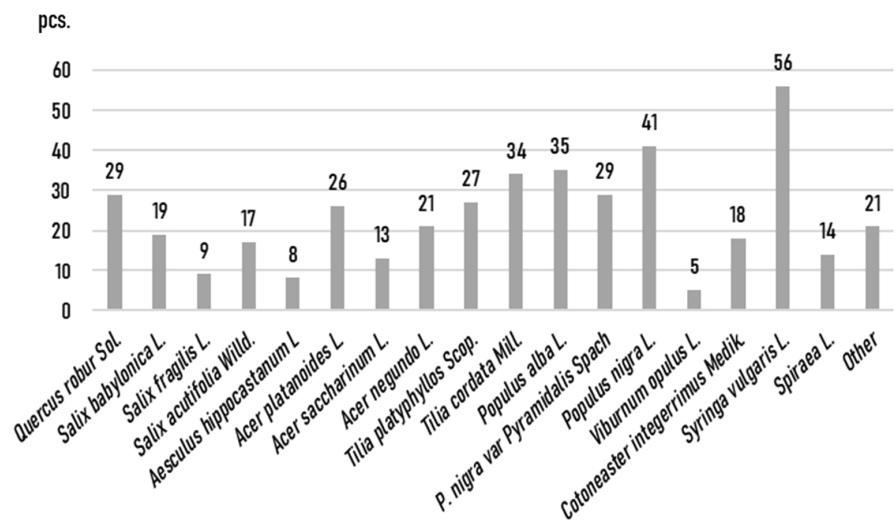


Fig. 9. The results of damage to trees and shrubs by powdery mildew

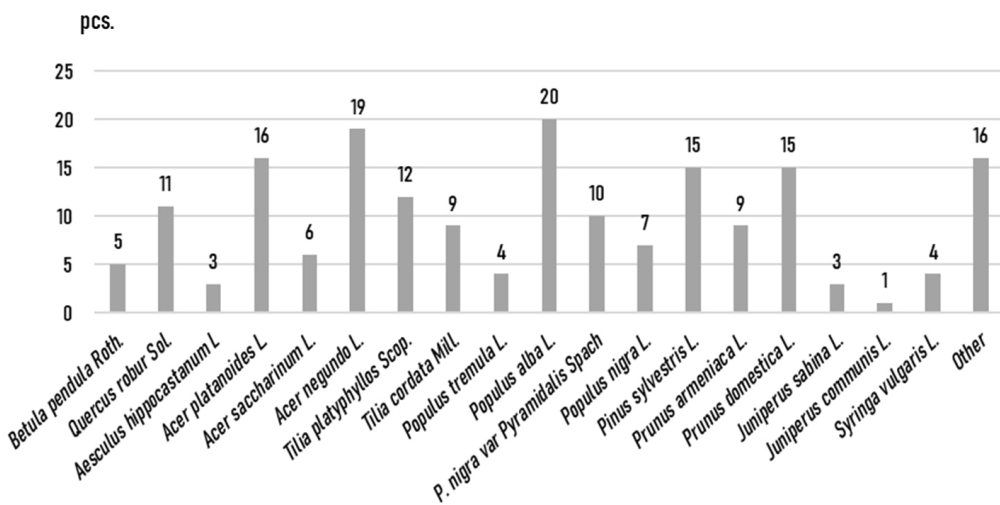


Fig. 10. The results of damage to trees and shrubs by canker diseases

There are many reasons for the drying of plant branches. During the study, it was found that of all the presented plants, poplar branches (*P. nigra* var *Pyramidalis* Spach, *Populus nigra* L.) turned out to be the most susceptible to drying out.

Mistletoe species grow on a wide range of host trees, some of which experience side effects including reduced growth, stunting, and loss of infested outer branches. They are attached to their host tree or shrub by a structure called the haustorium, through which they extract water and nutrients from the host plant. Mistletoe infestation is one of the serious problems for greenery in Kharkiv region.

A large number (3108) of affected greenery indicates poor plant care, as well as stressful conditions that affect growth, development and resistance to anthropogenic factors. Some plants are affected by more than one disease or pest (Fig. 14).

Fig. 14, a shows an example of damage to the leaves of one tree by three pests and diseases, and Fig. 14, b shows an example of damage to one *Acer platanoides* leaf by three types of pests and diseases.

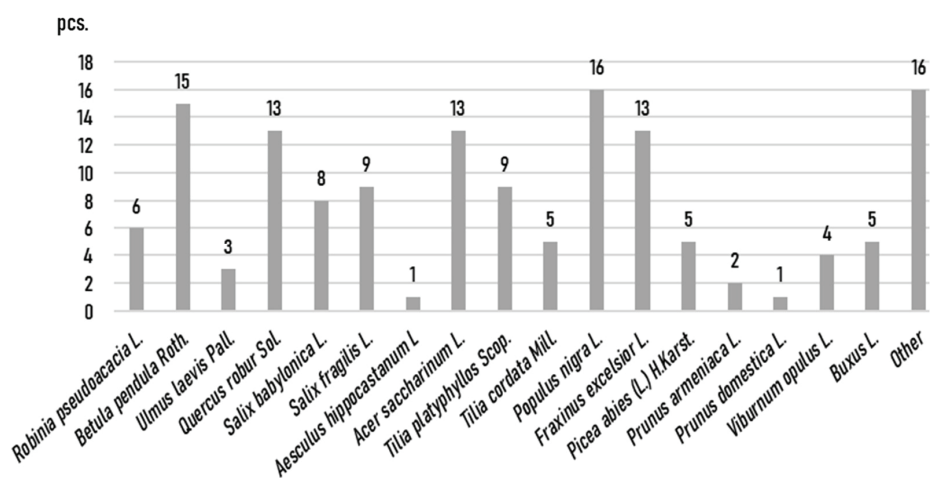


Fig. 11. The results of damage to trees and shrubs by stem decays

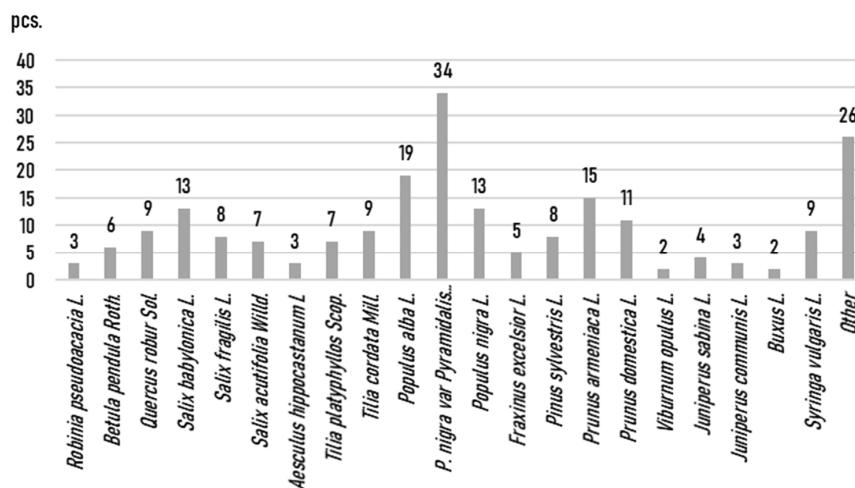


Fig. 12. Results of the study of drying branches on trees and shrubs

For better understanding the reasons of such plants damage it is necessary to carried out same studying in other Ukrainian big cities and industrial regions as well as in different cities all over the world. Than it is possible to find correlation between ecological situation in city and plant's damage. Studying trees only in Kharkiv it is not exactly possible to say, that only air and water pollution influence trees damage. Other factors can be: bad sanitary care of plants, treatment absence of all

green areas in the city from pests and diseases, impact of invasive species, the loss of biodiversity, which leads to the absence of natural predators to neutralize pests.

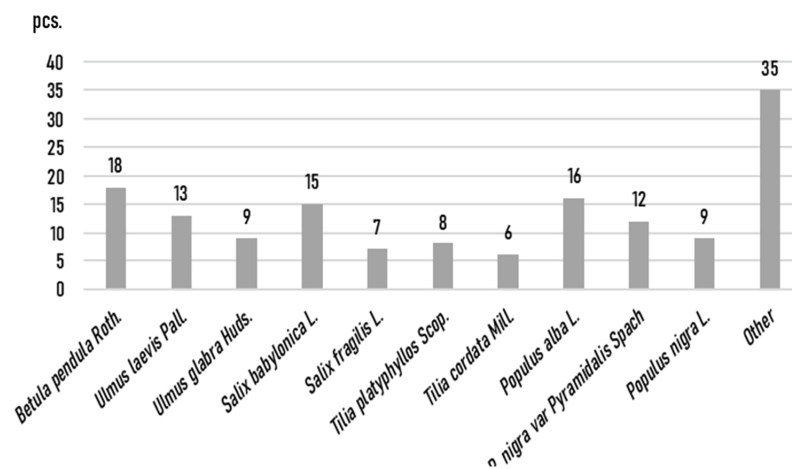


Fig. 13. The results of damage to trees and shrubs by mistletoe



Fig. 14. Damage to plants by several types of diseases and pests: a – leaves of one tree (insects, powdery mildew and *Rhytisma acerinum*); b – damage to one leaf by insects and *Rhytisma acerinum*

4. Conclusions

The analysis of modern methods the green areas condition assessing in the urban territories has shown the limited use of these methods in Ukraine. The use of GIS technologies on the example of WebGIS, which is used in the USA, is perspective in terms of available technical means, cost and other indicators. Such a system will simplify the activities of public utilities, timely record the suppression or emergence of diseases or pests. The introduction of such a system at the playground will allow to involve children in the study of the world around them and being the part of hand-on-science training.

The results of phytopathological monitoring at the sites confirm the need for regular surveys of green areas and pest and disease control. 100 % of *Aesculus hippocastanum* L. affected by *Cameraria ohridella*. The obtained results can be used in further research and to develop recommendations for plant care.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

References

- [1] Roman, L., Campbell, L., Jordan, R. (2018). Civic Science in Urban Forestry: An Introduction. *Arboriculture & Urban Forestry*, 44 (2). doi: <https://doi.org/10.48044/jauf.2018.004>

- [2] Foster, J. B. (2007). The Ecology of Destruction. *Monthly Review*, 58 (9), 1. doi: https://doi.org/10.14452/mr-058-09-2007-02_1
- [3] Odum, H. T. (2007). *Environment, power, and society for the twenty-first century: The Hierarchy of Energy*. Columbia University Press, 432.
- [4] Luo, X., Bing, H., Luo, Z., Wang, Y., Jin, L. (2019). Impacts of atmospheric particulate matter pollution on environmental biogeochemistry of trace metals in soil-plant system: A review. *Environmental Pollution*, 255, 113138. doi: <https://doi.org/10.1016/j.envpol.2019.113138>
- [5] Rai, P. K. (2016). Impacts of particulate matter pollution on plants: Implications for environmental biomonitoring. *Ecotoxicology and Environmental Safety*, 129, 120–136. doi: <https://doi.org/10.1016/j.ecoenv.2016.03.012>
- [6] Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B. et. al. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387 (6630), 253–260. doi: <https://doi.org/10.1038/387253a0>
- [7] Smiley, E. T., Matheny, N., Lilly, S. (2017). BMP best management practices: tree risk assessment. *BMP best management practices: tree risk assessment*.
- [8] Edmondson, J. L., Davies, Z. G., McHugh, N., Gaston, K. J., Leake, J. R. (2012). Organic carbon hidden in urban ecosystems. *Scientific Reports*, 2 (1). doi: <https://doi.org/10.1038/srep00963>
- [9] Russo, A., Escobedo, F. J., Cirella, G. T., Zerbe, S. (2017). Edible green infrastructure: An approach and review of provisioning ecosystem services and disservices in urban environments. *Agriculture, Ecosystems & Environment*, 242, 53–66. doi: <https://doi.org/10.1016/j.agee.2017.03.026>
- [10] Nowak, D. J., Hoehn, R. E., Bodine, A. R., Greenfield, E. J., O'Neil-Dunne, J. (2013). Urban forest structure, ecosystem services and change in Syracuse, NY. *Urban Ecosystems*, 19 (4), 1455–1477. doi: <https://doi.org/10.1007/s11252-013-0326-z>
- [11] Van de Voorde, T., Vlaeminck, J., Canters, F. (2008). Comparing Different Approaches for Mapping Urban Vegetation Cover from Landsat ETM+ Data: A Case Study on Brussels. *Sensors*, 8 (6), 3880–3902. doi: <https://doi.org/10.3390/s8063880>
- [12] Van Beek, J., Tits, L., Somers, B., Deckers, T., Janssens, P., Coppin, P. (2015). Reducing background effects in orchards through spectral vegetation index correction. *International Journal of Applied Earth Observation and Geoinformation*, 34, 167–177. doi: <https://doi.org/10.1016/j.jag.2014.08.009>
- [13] Zhen, Z., Quackenbush, L., Zhang, L. (2016). Trends in Automatic Individual Tree Crown Detection and Delineation – Evolution of LiDAR Data. *Remote Sensing*, 8 (4), 333. doi: <https://doi.org/10.3390/rs8040333>
- [14] Escobedo, F., Varela, S., Zhao, M., Wagner, J. E., Zipperer, W. (2010). Analyzing the efficacy of subtropical urban forests in offsetting carbon emissions from cities. *Environmental Science & Policy*, 13 (5), 362–372. doi: <https://doi.org/10.1016/j.envsci.2010.03.009>
- [15] Nowak, D. J., Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*, 116 (3), 381–389. doi: [https://doi.org/10.1016/s0269-7491\(01\)00214-7](https://doi.org/10.1016/s0269-7491(01)00214-7)
- [16] Suslova, Y. P. (2018). The current condition of woody parkland in the town of Slavyansk. *Scientific Bulletin of UNFU*, 28 (5), 57–60. doi: <https://doi.org/10.15421/40280512>
- [17] Marno-Kutsa, O. M. (2014). Comprehensive Assessment of Parklands in Uman. *Scientific Bulletin of UNFU*, 24 (9), 75–80. Available at: https://nv.nltu.edu.ua/Archive/2014/24_9/15.pdf
- [18] Marno-Kutsa, O. M. (2013). The wood-shrubby vegetation in the park “Dytyachuy” today in Uman. *Scientific Bulletin of UNFU*, 23 (5), 242–246. Available at: https://nv.nltu.edu.ua/Archive/2013/23_5/242_Mar.pdf
- [19] Stadnik, V. (2021). Efficiency of using flowering herbaceous plants for landscaping children's playgrounds in urban areas. *Problems of Chemistry and Sustainable Development*, 3, 57–62. doi: <https://doi.org/10.32782/pcsd-2021-3-9>
- [20] Stadnik, V. Yu., Tikhomyrova, T. S. (2017). Noise load at the children's playgrounds of the Kharkov city. *Young Scientist*, 10 (50), 24–27. Available at: <http://molodyvcheny.in.ua/files/journal/2017/10/7.pdf>
- [21] Stadnik, V. (2021). Analysis of environmental hazards in the system «children's playground – urbanized area». *Technology Transfer: Fundamental Principles and Innovative Technical Solutions*, 28–30. doi: <https://doi.org/10.21303/2585-6847.2021.002163>
- [22] Stadnik, V. (2021). Assessment of the qualitative and quantitative characteristics of greenery on the territory of the children's playgrounds in Kharkiv. *Transactions of Kremenchuk Mykhailo Ostrohradskyi National University*, 6 (131), 48–53. doi: <https://doi.org/10.30929/1995-0519.2021.6.48-53>

Received date 05.05.2022

Accepted date 15.07.2022

Published date 31.07.2022

© The Author(s) 2022

This is an open access article
under the Creative Commons CC BY license

How to cite: Shestopalov, O., Tykhomyrova, T., Lebedev, V., Stadnik, V. (2022). Green areas state assessment within the urban territories. *EUREKA: Life Sciences*, 4, 10–20. doi: <https://doi.org/10.21303/2504-5695.2022.002618>