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Assessment of Model Grass Plots of the City of Kyiv in Eco-Conditions of Anthropogenic Load

Oleksandra Strashok^{1,2*}, Olena Kolesnichenko¹, Robert Kalbarczyk²,
Monika Ziemiańska², Dmytro Bidolakh³, Vitalii Strashok⁴

¹Education and Research Institute of Forestry and Landscape-Park Management
of the National University of Life and Environmental Sciences of Ukraine
03041, 19 Heneral Rodimtsev Str., Kyiv, Ukraine

²Department of Landscape Architecture,
Wroclaw University of Environmental and Life Sciences
50-357, 55 Grunwaldzka Str., Wroclaw, Poland

³SS of NULES of Ukraine “Berezhany Agrotechnical Institute”
47500, 20 Academic Str., Berezhany, Ukraine

⁴National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Abstract. Urban heat islands (UHI) and rapid urbanisation create new health risks for residents of urban territories. The authors consider lawns as an eco-stabilising factor of the urban environment and an element of ensuring the environmental safety of the capital. The purpose of this study was to determine the qualitative state of lawns to the factors of the urban ecosystem and their thermoregulatory function. To determine the impact of anthropogenic factors on research objects, the study assessed the amount of emissions into the atmospheric air from stationary and mobile sources, satellite maps of the intensity of nitrogen dioxide emissions (NO₂) and sulphur dioxide (SO₂) in the city's air basin, heat distribution, and normalised difference moisture index (NDMI). To assess the condition and quality of lawns, the methods of assessing the grasslands of A. A. Laptev (1983) and an unmanned aerial vehicle (UAV) were used. It was established that the results of the evaluation of lawn coenoses using the method of O.O. Laptev and UAV are correlated (r=0.87). Lawn areas that were rated as in “satisfactory condition” are characterised by a higher temperature on the heat map and lower NDMI values. Indicators of lawn cover that were rated as in “good condition” correlate with surface temperature and NDMI. The difference in surface temperatures over the area of the experimental sites reaches 5°C and depends on the objects surrounding the perimeter. It was established that lawn areas adjust the thermal mode of the urban system in the warm period of the year, and reduce the temperature of the asphalt surface by about 0.5°C, and together with flower and woody plants – by about 0.9°C. The study results improve the understanding of the physiological effects of heat stress on lawn areas, which allows developing practical strategies for managing urban green spaces with limited water resources and anthropogenic loads

Keywords: decorativeness, projective cover, heat island, urban ecosystem

Introduction

According to the “Strategy of Development of the City of Kyiv until 2025”, one of the priority goals is to ensure environmental safety in the capital and reduce the adverse environmental impact [1]. Green spaces, including lawn coverings, are eco-stabilising buffer components of the urban ecosystem, they constitute an inseparable component of

landscaping systems for any city [2-4]. Rapid urbanisation, technogenesis processes, and climate change are a prerequisite for environmental changes in species optimums, reduced biodiversity and ecosystem sustainability [5-7]. Lawn coenoses constitute the dominant elements of urban landscaping worldwide and account for up to 50-70% of urban

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*Corresponding author

green spaces, which does not directly depend on the climatic conditions of the region [8; 9]. New research also points to the social functions of green spaces in the context of COVID-19 [10; 11]. Lawn coverings are the easiest and fastest way of landscaping in cities [12]. The study of the influence of anthropogenic load factors on the city's lawn areas as the main elements of urban landscaping, including near roads, will allow investigating their eco-stabilising functions and improve the living conditions of citizens. In the context of irreversible large-scale global climate changes, technogenesis, and urbanisation, new factors are emerging in populated cities that directly or indirectly affect plants, including UHI and air pollution. It was found that the frequency, intensity, and duration of heat waves constitute unstable indicators that change and worsen over time due to global climate change [13]. It was recorded that an increase in vegetation cover by 10% reduces the temperature of the urban surface by about 1°C during the day [14]. Thus, scientists have found that urban lawns reduce the impact of UHI on the urban ecosystem [2; 12; 15]. The 20th century was described by the emergence of a new ecological factor due to the rapid development of Industry – anthropogenic environmental pollution. According to the data from [16], only in the 1920s – 1930s did the scientists begin to study the issues of plant resistance to aerotechnogenic emissions and only in the second half of the 20th century these studies became large-scale. Furthermore, air pollution of urban ecosystems with substances such as NO₂, SO₂, carbon monoxide (CO) is a problem affecting not only the quality of life of urban residents, but also the sustainability and functioning of the urban ecosystem in general [17-19]. Plants as producers of ecosystem services in the context of reducing the impact of air pollution as a new anthropogenic factor in cities began to be studied on a large scale in the 1990s [20-22].

According to their functional purpose, lawns are divided into decorative, special, and sports purposes, where each group has certain characteristics and requirements for creation and maintenance [23]. It is well-known that the quality indicators of lawns are influenced by soil and climatic conditions, agricultural techniques of maintenance and species composition, but the issue of the state and quality of lawns in territories with a considerable anthropogenic load, such as the city of Kyiv, is understudied and relevant at the same time in the context of investigating lawn coenoses in urban ecosystems. Likewise, it is well-known that increasing the quantitative and qualitative state of vegetation in the city reduces the temperature regime of the air and surface [24-26]. Studying the impact

of indicators of technogenic load of the urban ecosystem on plants allows reducing the complexity of the urban ecosystem to a manageable level in the context of making constructive decisions in the formation of green spaces [27-29]. Furthermore, to assess the state of lawn coenoses and decide on carrying out agrotechnical works, landscape industry workers need to seek innovative ways to monitor such objects that do not require prolonged time costs [30]. The purpose of this study was to assess the quality condition of lawns and their temperature-regulating properties, which grow localised near roads and transport interchanges. To perform this study, the authors identified the following tasks: 1) to identify model lawn areas with anthropogenic load near transport interchanges in the territory of Kyiv through the analysis of the amount of emissions into the atmosphere from stationary and mobile sources, satellite maps of the intensity of NO₂ and SO₂ emissions; 2) to analyse the distribution of NDMI indicators in experimental areas; 3) to assess the condition and quality of model lawn areas using various methods; 4) to analyse data and compare it with other international studies.

Materials and Methods

To conduct experimental studies of lawns assessment, the authors used the classical method of O. Laptev's assessment [23] and modern techniques of remote sensing of the Earth (remote sensing). To perform the tasks set, model grass plots were selected, which are located on the territory of four administrative districts of Kyiv with an anthropogenic load. The authors have identified four model lawns located on Odeska Square (50°22'12.0"N 30°27'31.0"E), Darnytska Square (50°26'32.0"N 30°37'33.0"E), along Heneral Almazov Street and L. Ukrainka Square (50°25'48.9"N 30°32'28.0"E), Kharkivska Square (50°24'08.0"N 30°40'59.0"E) and estimated during the growing season in June-August 2018. Using an UAV, the authors determined the areas of model lawns. All model lawns do not have an irrigation system, except for the plot located on the territory of L. Ukrainka square.

According to the Main Department of Statistics in Kyiv, mobile sources occupy a considerable place in the urban ecosystem, and therefore road transport is key in air pollution in the metropolis [31]. Furthermore, in 2018, emissions from mobile sources accounted for over 80% of the total amount of substances released. Results of the emission assessment in Figure 1 is presented by indicators of emissions from road transport and calculated based on data on the final use of fuel by road, given in the energy balance of Ukraine.

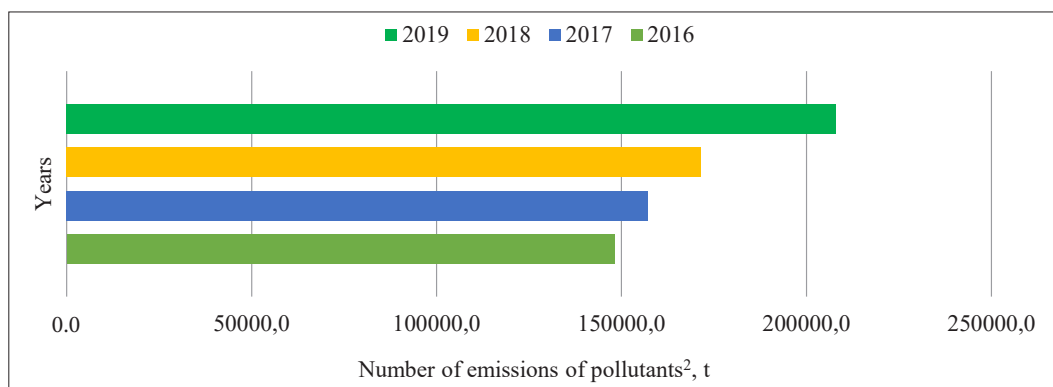


Figure 1. Emissions of pollutants into the atmosphere from mobile sources in Kyiv (2016-2019) [31]

Statistical data allow the districts of Kyiv to be divided by the amount of emissions of pollutants from stationary sources of pollution (Fig. 2). Thus, the leaders

in atmospheric air pollution from stationary sources are Pecherskyi, Holosiivskyi, Desnianskyi, and Darnytskyi districts, where research objects are located.

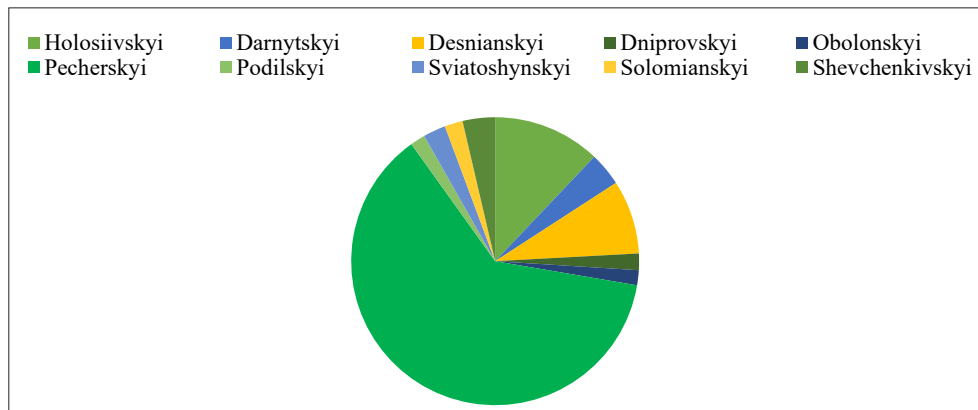


Figure 2. Emissions of pollutants into the atmosphere from stationary sources of pollution by district (2018, amount of emissions of pollutants², t) [31]

The heat map of Kyiv demonstrates a heterogeneous temperature distribution, where the temperature regime varies from 27°C to 38°C, which, for its part, forms UHIs mainly in the central part of the city (Fig. 3). The map was developed based on Landsat-8 satellite images

with a resolution of 30*30 m. A heat map of Kyiv was provided by the LUN.Misto.ua platform's employees to conduct this study [32]. All experimental lawn coverings are located in areas with a UHI with a temperature regime of 30°C.

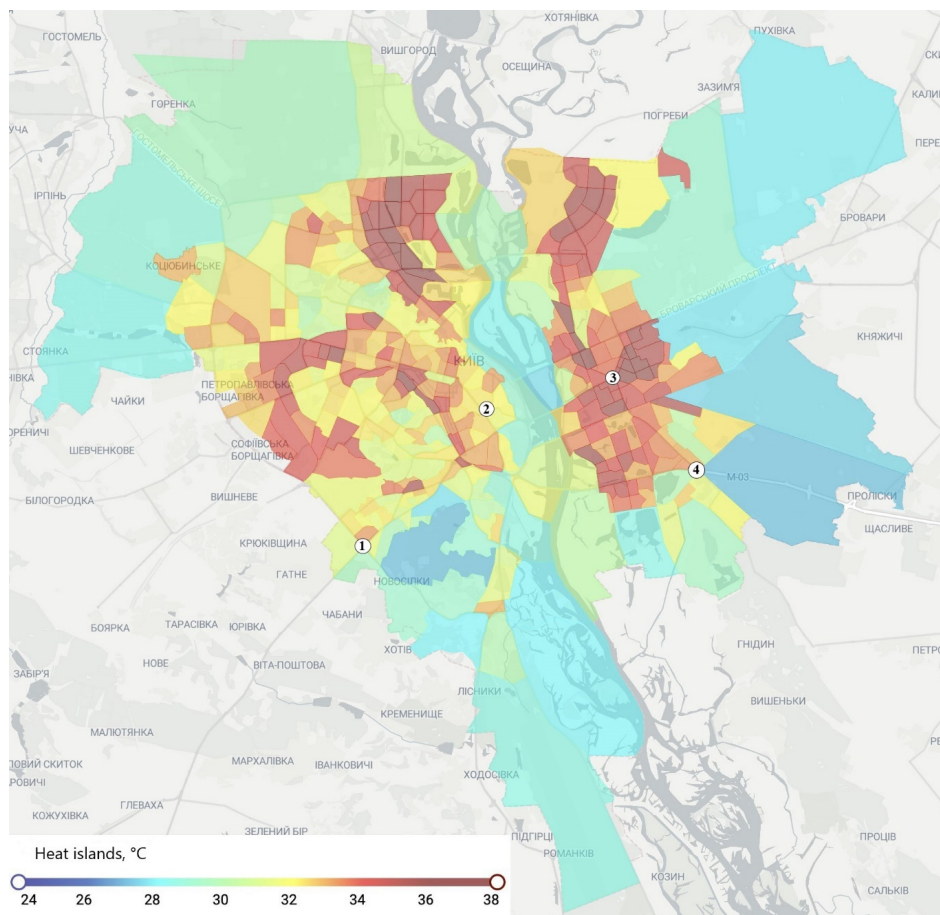


Figure 3. Heat map of Kyiv (2018) (Landsat-8, LUNMisto 2018) where: 1 – Odeska Square; 2 – Pecherska Square; 3 – Darnytska Square; 4 – Kharkivska Square

Qualitative assessment of the state of lawn coenosis was carried out on a 30-point scale of O.O. Laptev's comprehensive assessment of lawns [23], which includes

indicators of the quality of the structure of lawns and general decorative properties (Table 1).

Table 1. Thirty-point scale for comprehensive assessment of the quality of lawns

Assessment of the quality of the structure of lawns on a six-point scale	Assessment of the overall decorative effect of the lawn on a five-point scale	Overall maximum assessment of the grassland quality	Quality indicator of lawns
6	5	30	Top quality (superlawn)
5	5	25	Excellent
5	4	20	Good
4	4	16	Satisfactory
3	3	9	Mediocre
2	2	4	Bad

Source: developed by the author based on the study [23]

The overall decorative effect of the lawn cover was assessed on a five-point scale, determining the degree of soil closure by shortened vegetative and generative organs of plants [23]. At each experimental facility, the authors of this study selected 15 experimental sites and determined the average values. According to the chosen methodology, five points were assessed for the projective coverage of lawns with a closed-diffuse placement of plants and the degree of soil coverage within 90-100% of the total area. According to the closed-mosaic placement of shoots, the projective cover varied within 70-80%, which was estimated at four points. Lawn coenoses with mosaic-group placement of shoots within 50-60% were estimated at three points. Lawns with projective coverage indicators of less than 50% with separate-group placement of plants were estimated at two points and 15-20% with single-separate – one point.

The authors of this study evaluated the build quality of the lawn coenoses on a 6-point scale according to the number of shoots per 100 cm² and provided an evaluation according to the indicators of the climate zone [23].

To speed up the process of determining areas covered with lawns, flower beds, and hard surfaces, remote sensing methods were used involving UAV surveys and interpreting the survey results in the ArcGis 10.2 environment. Before the start of filming, the route of movement of the UAV was planned with the determination of the flight altitude, task completion time, based on the area of the landscape object, the focal length of the camera, and the necessary detail. When laying a route, adjacent images, according to the requirements of aerial photography, must have longitudinal (minimum value 56%) and transverse (30-40%) overlaps, which are achieved by setting the required filming interval and combining neighbouring routes [33]. After adjusting all the necessary settings and calibration of the quadcopter, a flyby of the research object was performed at an altitude of 100 m with orthogonal photographing of its territory. Orthotransformation of photographic material was performed in the UTM coordinate system on the WGS84 ellipsoid. Additionally, to improve the accuracy of the obtained materials, external orientation of images was carried out according to previously recorded points with known coordinates that are clearly visible in the images. Each pixel of the image provides information about the spectral characteristics of the lawn cover, its texture, viability, and general

condition of plants or the absence of lawn. Furthermore, processing the results of such studies using a geoinformation system allows classifying pixels or their spatial aggregates into diverse groups, which allows determining the condition of lawn coverings, their area, and the closeness of the lawn. The developed method for evaluating the lawns makes provision for three assessment scales, which, based on the results of photogrammetric processing of survey materials, allow distributing the lawns in three states: good, satisfactory, and unsatisfactory [34].

To analyse the factors affecting the research objects, maps of satellite surveys of the intensity of NO₂ and SO₂ emissions were analysed, which were obtained using the Sentinel-5P satellite system and the TROPOMI processing system for NO₂ and SO₂. The humidity index (NDMI) was obtained using the Sentinel-2 satellite system and calculated using the formula. The NDMI index is used to monitor the water content in the lawns at objects under study, where indicators from -0.2 to 0.4 indicate water stress in plants.

Statistical processing of the results and correlation analysis were performed using MS Excel software.

Results and Discussion

In 2017, it was recorded that the annual limit values of NO₂, which are established by the European Commission Directive 2008/50/EC were exceeded in almost 20 European countries [35]. Furthermore, the highest rates of NO₂ are recorded in 86% of cases at road stations [36]. The results of the analysis of the intensity of NO₂ emissions into the air basin of the city of Kyiv demonstrate the heterogeneity of its distribution on the territory of the city, which became one of the decisive factors in the selection of experimental objects (Fig. 4). Notably, NO₂ is found in automobile transport exhaust gases and fumes from thermal power plants. Considering that the lawns under study are located directly near roads and road transport interchanges with heavy automobile traffic, even in conditions of different directions of movement of air masses on different days of assessment, satellite maps clearly demonstrate a tendency to accumulate NO₂ over research areas, especially in the central part of the metropolis. The highest rates were recorded in July on the territory of Darnytska Square (9.0 E-5 mol/m²), Heneral Almazov Str. and L. Ukrainka Square (6.25 E-5 mol/m²).

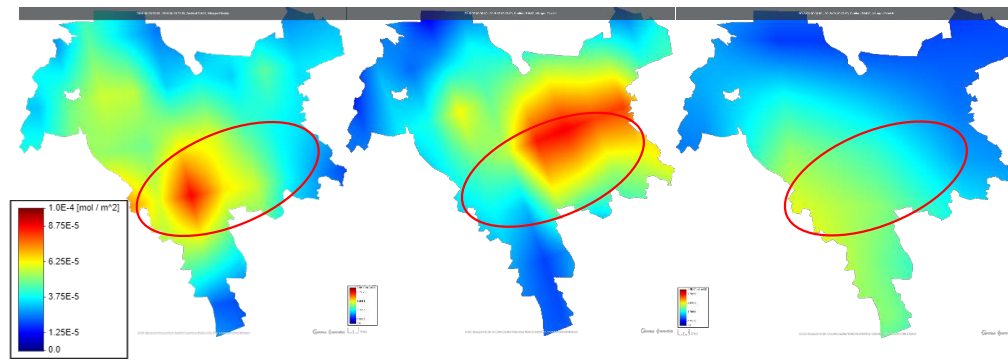


Figure 4. Intensity of NO₂ emissions into the air in the territory of Kyiv (Sentinel-5P 2018-06-29; 2018-07-06; 2018-08-30)

SO₂ can enter the air both naturally and anthropogenically, but approx. 70% is of anthropogenic origin [37]. Sulphur-containing compounds play a crucial role in growth processes, and therefore, in lesser amounts, are absolutely harmless to the plant and, conversely, are characterised by a positive effect. However, in conditions of long-term excess of SO₂ content in plants, processes

of decreasing physiological activity begin [38]. The results of the analysis of maps of the intensity of emissions of SO₂ into the air on the territory of objects under study show that in July 2018 alone, on the territory of Darnytska Square, there was a slight excess of SO₂ emissions (0.1 E-5 mol/m²) in comparison with other areas under study (Fig. 5).

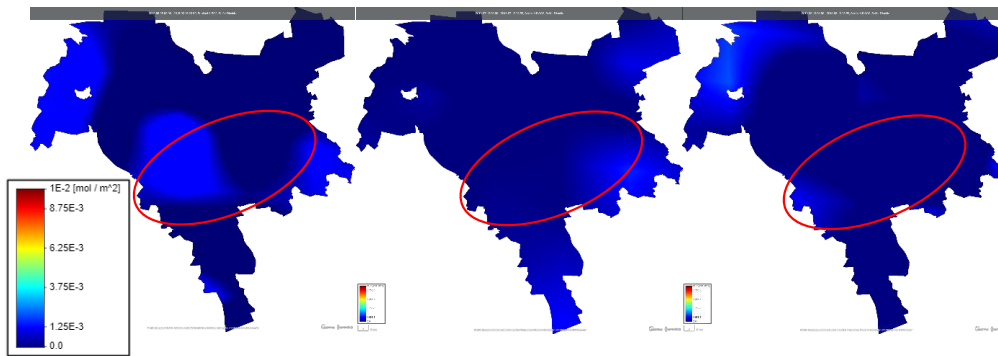


Figure 5. Intensity of SO₂ emissions into the air in the territory of Kyiv (Sentinel-5P 2018-06-26; 2018-07-12; 2018-08-13)

The results of assessing the overall decorative effect of lawns show low indicators of the quality of lawn coenoses near roads (14-18 points). Notably, all objects under study lack an irrigation system, which also directly affects the indicators of decorative properties, condition, and quality of lawns. Photo examination revealed areas where the vegetative organs of herbaceous plants did not cover the surface, the lawn changed colour from green to yellow. This is primarily conditioned upon high-temperature stress and anthropogenic loads on the territory of objects under study. Analysis of research data using UAVs indicated that

the lawn on Odeska Square occupies an area of 36,312 m². The average lawn quality indicator is rated as “mediocre” and is 14 points according to the integrated lawn assessment scale. It was found that 75% of the area of the lawn coenosis in terms of the quality of the structure of lawns varied from 2 to 4 points, and only 25% was estimated at 5 points (Fig. 6). The average indicators of projective coverage were 3.6 points and approx. 13% was estimated at 5 points as closed-mosaic, which indicates low indicators of closure of the lawn, which is probably also caused by anthropogenic load on plants.

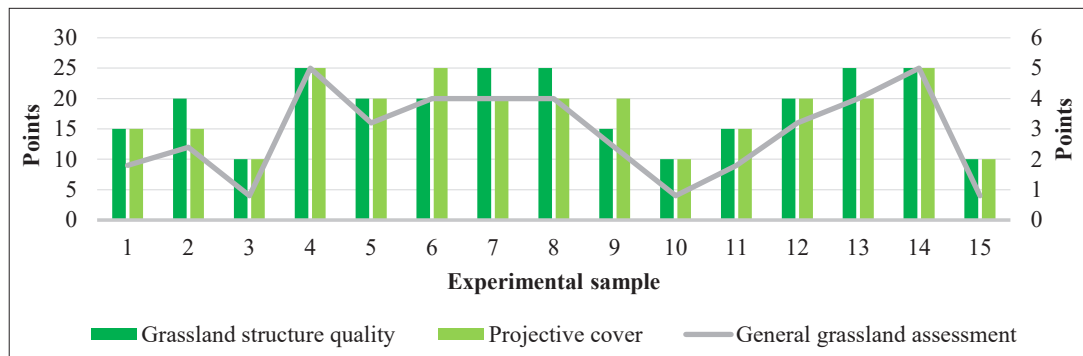


Figure 6. Results of evaluating lawn surface indicators on the territory of Odeska Square

According to the results of field studies, it was revealed that the lawn on the territory of Heneral Almazov Street and L. Ukrainka Square is in satisfactory condition (Fig. 7). Indicators of the quality of the structure of the lawn were characterised mainly by 4-5 points, and the projective

cover varied from 2 to 6 points. Analysis of the research results indicated that only one sample was rated at 6 points, where the number of shoots was 124 pcs. per 100 cm². Projective cover was mainly evaluated as closed-mosaic and mosaic-group, which corresponds to 3 and 4 points on a 5-point scale.

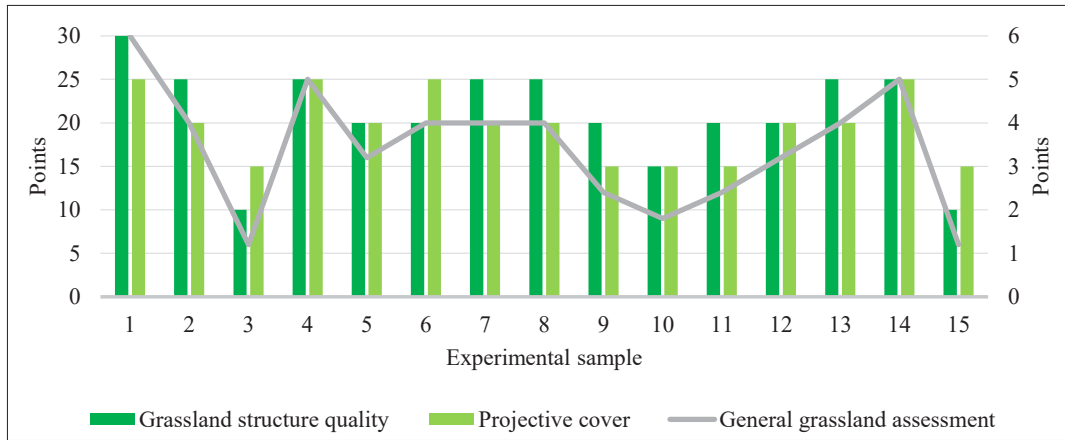


Figure 7. Results of assessment of lawn covering indicators on the territory of Heneral Almazov Street and L. Ukrainka Square

According to the results of the study, the lawn on the territory of Darnytska Square is described by the highest indicators of lawn quality and amounts to 17.5 points, which is equivalent to a satisfactory indicator (Fig. 8). The

area of lawn coenosis is 10,347 m², where 75% in terms of the quality of the lawn structure and 50% in terms of the overall decorative effect of the projective cover were estimated at 4 points.

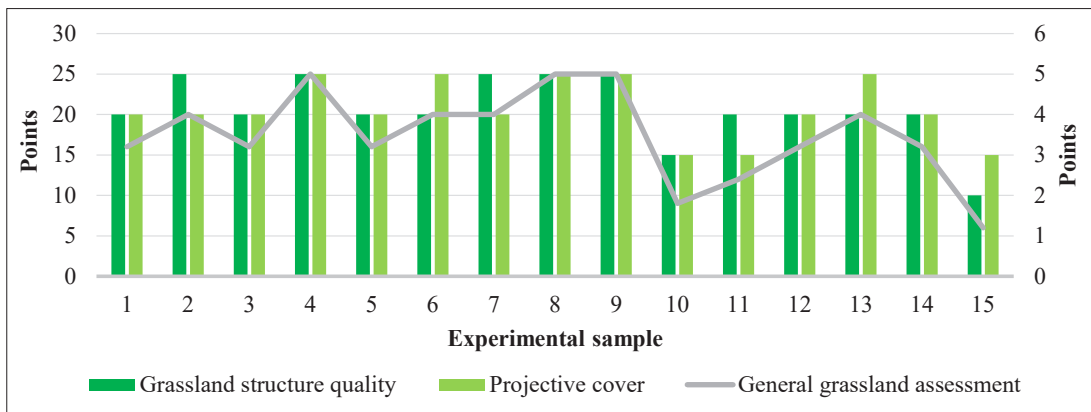


Figure 8. Results of assessment of lawn indicators on the territory of Darnytska Square

The lawn on the territory of Kharkiv Square was described by rather low indicators of the quality of the structure of the lawn and approx. 27% was rated at the lowest score, where there were less than 20 pcs. of shoots

per 100 cm² (Fig. 9). Almost 50% of the experimental lawn coenosis was described by a closed-mosaic nature of the composition of the lawn and was estimated at 4 points.

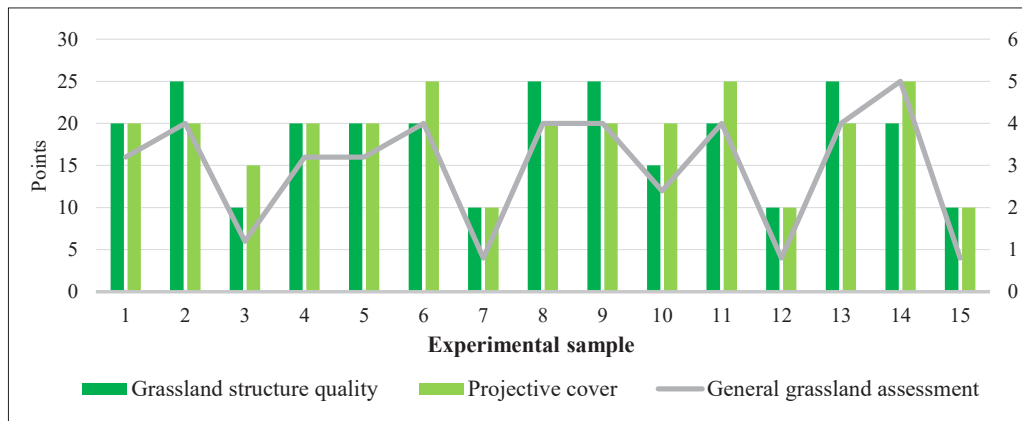
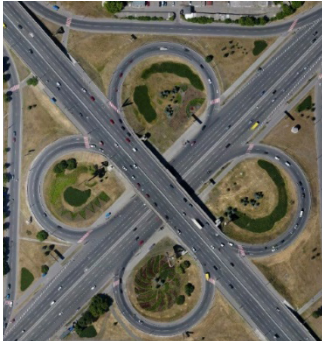









Figure 9. Results of assessment of lawn indicators on the territory of Kharkivska Square




The first stage of assessing the state of coenoses on the territory of objects under study was the differentiation of contours and areas of research lawns and other garden and park elements (Table 2). All experimental



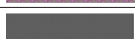
lawns do not have an irrigation system, except for the model lawn plot, which is located on the territory of L. Ukrainka Square, which certainly affects their quality indicators.

Table 2. Differentiation of elements of objects under study using a UAV (2018)

Output orthophotoplane	Classification results
Odeska square	
	
Darnytska square	
	
Heneral Almazov St. and L. Ukrainka Square	
	
Kharkivska square	
	

Note: colour symbols for the following elements:

	Remote filming materials
	Lawn (good condition)
	Lawn (satisfactory condition)

	Lawn (unsatisfactory condition)
	Flower beds
	Hard surface

When assessing the lawn coenosis by projective coverage indicators, it was found that most of the grass species that formed the lawn were described by drying of the aboveground part. The authors of this study believe that this

may have been caused by high-temperature stress. Table 3 presents the results of evaluating lawn coenoses with a division into quality states – unsatisfactory, satisfactory, and good.

Table 3. Results of determining the areas of research objects based on remote sensing materials

Seq. No.	Name	Area, m ²						
		Lawns (condition), m ² / %				Flower beds	Hard surface	General area
		good	satisf.	unsatisf.	total			
1	Odeska square	2,197 / 6.1	8,362 / 23	25,753 / 70.9	36,312 / 100	6,960	46,035	89,307
2	Darnytska square	199 / 1.9	3,962 / 38.3	6,186 / 59.8	10,347 / 100	245	19,758	30,350
3	General Almazov Street and L. Ukrainka Square	2,862 / 21.8	1,460 / 11.2	8,770 / 67.0	13,092 / 100	735	41,112	54,939
4	Kharkivska square	3,167 / 5.8	12,979 / 23.8	38,396 / 70.4	54,542 / 100	4,688	47,472	106,702

Thus, data on the qualitative state of lawns in urbanised areas of the city were obtained using various assessment methods [23; 34] and compared using correlation analysis. A correlation was established with $r=0.87$ upon comparing the total indicators of satisfactory and good condition of the indicators of experimental lawns with the indicators of the overall assessment of the grass plots in points. A low correlation of $r=0.3$ was found when comparing only the indicators of “good condition” with the indicators of the overall assessment of the lawns. Such results demonstrate the effectiveness of the method of assessing the lawn surface using UAVs, which, apart from assessing the qualitative state of the coenosis, allows differentiating the site according to the quality state.

To determine the causes of low-quality indicators of lawns in the areas under study, the features of the formation of a UHI and the humidity index were additionally analysed. The decisive factor affecting the condition and quality of a lawn coenosis is heat stress. There are three strategies for plant drought endurance (escape, avoidance,

and tolerance), but the same species can combine them when adapting to drought stress [39; 40]. Scientists note that the relative importance of each adaptation mechanism depends on the duration of the drought, the severity of the drought, and the grass species specificity [41]. The heat map shows the heterogeneity of the temperature regime of city surfaces and a decrease in temperature indicators in the presence of vegetation or water bodies (see Fig. 3). When comparing the heat map and the NDMI content, a pattern is established – with an increase in the temperature regime, there is a tendency to decrease the NDMI, as well as indicators of the quality of the lawn surface. Thus, the lowest indicators according to the results of the UAV assessment were obtained by the lawn covering located on Darnytska Square (good condition – 1.9%). The results of satellite surveys show the accumulation of the highest temperatures in this area compared to other research objects, where the lowest surface temperature was 34°C, and the highest – 38°C and the presence of a temperature difference on the surface is approx. 4°C (see Fig. 10).

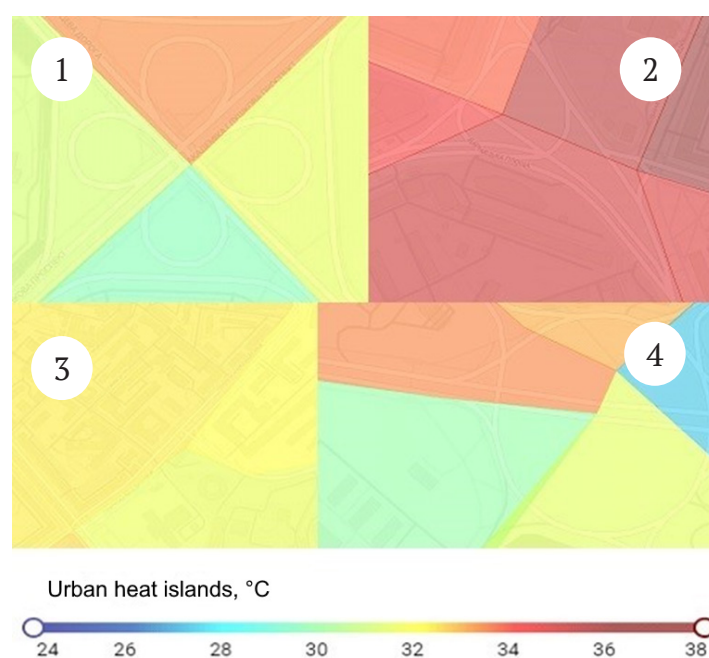


Figure 10. Heat islands on the territory of research objects, where: 1 – Odeska Square, 2 – Darnytska Square, 3 – Henerala Almazova St. and L. Ukrainka Square, 4 – Kharkiv Square (Landsaft-8, LUNMisto 2018)

The NDMI index was used to monitor the water content in the lawns at objects under study, where indicators from -0.2 to 0.4 indicate water stress [42]. It was found that the lowest indicators are typical for the Darnytska Square, where the condition of lawn coverings is estimated as good only approx. 2% and the NDMI did not exceed 0.18. The highest rates of lawns among the objects under study were on Heneral Almazov Street and L. Ukrainka Square, where 21.8% of area was rated as good condition. Such indicators are explained by the presence of lawns with proper agrotechnical care on the experimental territory, which are located near the Administrative

Services Centre “Hotovo” and the Central Election Commission of Ukraine. Notably, in places where a lawn at the above-mentioned objects was in good condition, the NDMI indicator was approx. 0.4, and the surface temperature was lower by about 0.5°C (near the Administrative Services Centre “Hotovo”, Fig. 11). However, at the object under study on the territory of the Central Election Commission of Ukraine with lawns grow flower and woody plant species, which in the complex also act as an eco-stabilising factor, which allows regulating the thermal mode of the urban ecosystem and reducing the temperature regime of the paved surface by about 0.9°C.

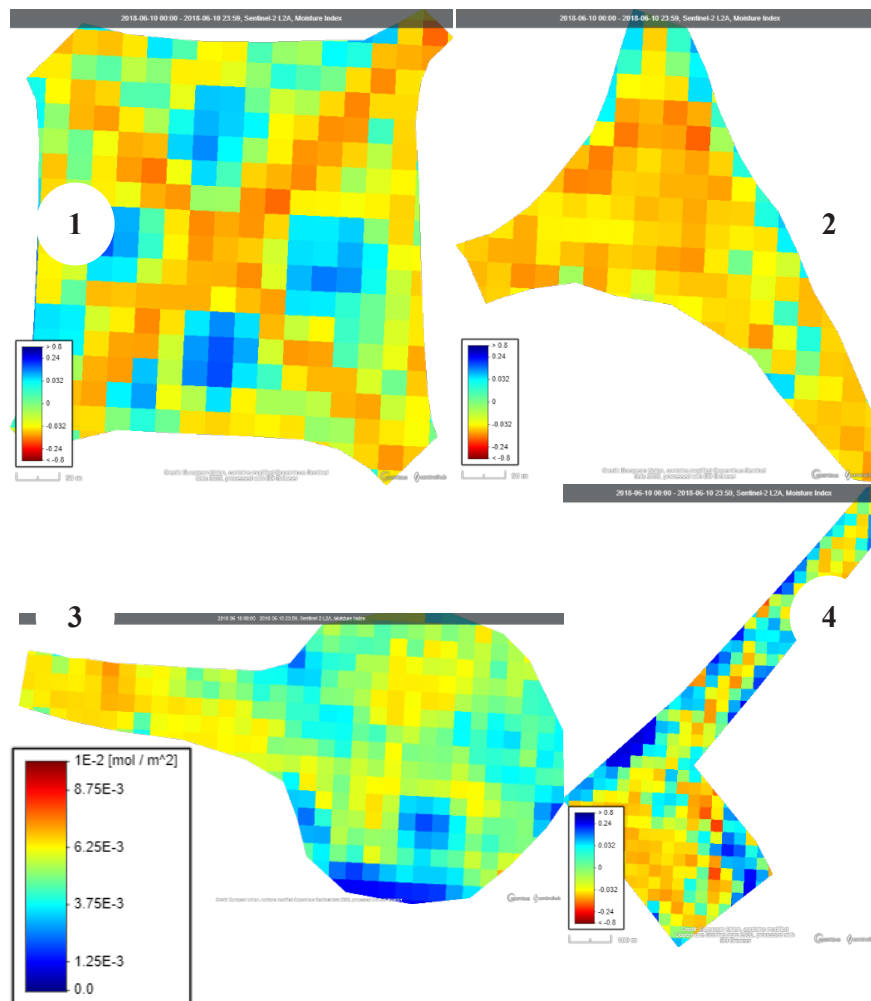


Figure 11. NDMI index on the territory of objects under study, where: 1 – Odeska Square, 2 – Darnytska Square, 3 – Heneral Almazov Street and L. Ukrainka square, 4 – Kharkivska Square (Sentinel-2, 2018-08-11)

Analysis of satellite maps of the NDMI Indicator shows that most of the vegetation on the territory of the research objects was under high-temperature stress. Thus, scientists determine the latent heat of the surface according to the main hydrological process that combines the surface with lawn vegetation and the atmosphere [43]. Notably, on the Odeska and Kharkivska squares a considerable part of the territory is occupied by flower beds – 6,960 m² and 4,688 m², respectively, which are located in areas with the highest NDMI values (≥0.7) (see Table 3 and Fig. 11). Interestingly, the largest area of lawns in unsatisfactory condition was found on Odeska and Kharkivska squares. Herbaceous plants that form the lawns under study grow under chronic drought stress due to the lack of an irrigation system (except for L. Ukrainka Square) and the presence of

an amount of water below the level of evapotranspiration (ET) [44; 45]. This can be explained by the species composition of the lawns of these areas, where most cereals are represented in comparison with other experimental sites. The aboveground mass of plants under the influence of anthropogenic factors and heat stress is damaged, and the underground mass levels the surface temperature regime due to its high regenerative capacity [46]. Using the example of common meadow-grass, it was found that maintaining transpiration cooling is an essential factor of adaptation in combined conditions of hot temperature and drought due to increased rooting [47]. Perennial ryegrass cultivars show high regenerative capacity after severe drought stress after just 6 weeks [44]. Thus, conclusions can be drawn regarding the specific features of adaptive reactions and adaptations

of cereals to conditions of high-temperature stress and anthropogenic factors. ET is characterised by the rate of water use by plants and is expressed as the rate of evaporation. It is established that the evaporation of the upper soil layer increases with a decrease in the density of sod [48]. The data are consistent with the results of studies where the ET of lawns in a humid environment is approximately 40-60% lower than for the same variety in an arid environment [49]. Presumably, the ET processes in cereals under conditions of high-temperature stress increase, which leads to a rapid loss of water depletion in the soil, which is confirmed by the results of tests using UAVs, where the experimental areas of the lawn surface with lower indicators of satisfactory condition correspond to locations on the heat map with higher temperature parameters and lower NDMI. Furthermore, such mechanisms of adaptation to high-temperature stress are manifested in closed stomata [50]. The results of this study on this mechanism of adaptation of lawns are also consistent with experimental data from other researchers [51].

Conclusions

Results of assessing the qualitative condition of model grass plots that grow localised near roads and transport interchanges show low scores from 14 to 18 points out of 30. A correlation ($r=0.87$) was established upon comparing the total indicators of satisfactory and good condition of the indicators of experimental lawns with the indicators of the overall assessment of the grass plots in points. The statistical data demonstrate the effectiveness of the method of assessing the lawn surface using UAVs, which, apart from assessing the qualitative state of the lawn coenosis, allows differentiating the site according to the quality state. The use of UAVs in the assessment of lawns can serve as an express method for landscape industry workers, which allows

quickly and efficiently classifying and identifying areas requiring complex restoration or added agrotechnical works. When comparing the heat map and the NDMI, a pattern was established – with an increase in the temperature regime, there is a tendency to decrease the NDMI, as well as indicators of the quality of the lawn surface.

Thus, the lowest indicators according to the results of the UAV assessment were obtained by the lawn covering located on Darnytska Square (good condition – 1.9%) and was described by the accumulation of the highest surface temperatures among the objects under study. It was recorded that the difference in surface temperatures at the experimental sites was up to 5°C and depend on the presence of buildings, vegetation, water bodies, and the intensity of automobile traffic. The results of the research showed that model lawns are described by temperature-regulating properties in the warm period of the year, reduce the temperature of the asphalt surface by about 0.5°C, together with flowering and woody plants – by about 0.9°C. Such artificially created UHIs, given the temporary loss of plant vitality due to drying out, block the dispersion and neutralisation of toxic substances and require the development of separate recommendations for available methods for restoring vegetation cover and cooling the surface.

The study of the thermoregulatory role of lawns in the city serves as the basis for creating a comfortable city for residents in the centres of UHIs and technogenesis. The question of the influence of anthropogenic factors on the growth and development of herbaceous plants is still understudied and needs to be clarified.

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Оцінювання модельних трав'яних ділянок міста Києва в екоумовах техногенного навантаження

Олександра Юрїївна Страшок^{1,2}, Олена Валеріївна Колесніченко¹, Роберт Кальбарчик²,
Моніка Жемянська², Дмитро Ілліч Бідолах³, Віталій Васильович Страшок⁴

¹Навчально-науковий інститут лісового і садово-паркового господарства
Національного університету біоресурсів і природокористування України
03041, вул. Генерала Родімцева, 19, м. Київ, Україна

²Вроцлавський природничий університет
50-357, вул. Грюнвальдська, 55, м. Вроцлав, Республіка Польща

³ВП НУБіП України «Бережанський агротехнічний інститут»
47500, вул. Академічна, 20, м. Бережани, Україна

⁴Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Анотація. Міські острови тепла і швидка урбанізація формують нові ризики для здоров'я мешканців урботериторій. Автори розглядають газонні покриття як екостабілізуючий чинник міського середовища й елемент забезпечення екологічної безпеки столиці. Метою досліджень було визначення якісного стану газонних покриттів до чинників урбоекосистеми та їх терморегулюючої функції. З метою визначення впливу техногенних чинників на дослідні об'єкти проаналізовано кількість викидів у атмосферне повітря від стаціонарних і пересувних джерел, карти супутникових зйомок інтенсивності викидів діоксиду азоту (NO_2) і діоксиду сірки (SO_2) у повітряний басейн міста, розподілу тепла й індексу вологості (NDMI). Для проведення оцінки стану та якості газонних покриттів використано методики оцінки травостою О.О. Лаптева (1983) і безпілотного літального апарата. Встановлено, що результати оцінки культурфітоценозів за допомогою методики О.О. Лаптева та безпілотного літального апарата корелюють ($r=0,87$). Трав'яні ділянки, які було оцінено як «задовільний стан» характеризуються вищою температурою на тепловій карті та нижчими показниками NDMI. Показники трав'яного покриття, які було оцінено як «добрий стан» корелюють з температурою поверхні та NDMI. Різниця температур поверхонь на площі дослідних ділянках сягає $5\text{ }^\circ\text{C}$ і залежать від оточуючих по периметру об'єктів. Встановлено, що трав'яні ділянки регулюють терморезим урбоекосистеми у теплий період року і знижують температуру асфальтованого покриття близько на $0,5\text{ }^\circ\text{C}$, а разом із квітниковими і деревними рослинами – близько на $0,9\text{ }^\circ\text{C}$. Результати досліджень вдосконалюють розуміння фізіологічних наслідків впливу теплового стресу на трав'яні ділянки, що дозволяє сформулювати практичні стратегії управління міськими зеленими насадженнями за обмежених водних ресурсів і техногенного навантаження

Ключові слова: декоративність, проективне покриття, тепловий острів, урбоекосистема