GeoTerrace-2024-056

Assessment of Green Space's State Along Highways: A Case Study of Kiltseva Road (Kyiv, Ukraine)

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SUMMARY

The types of green spaces within a 1 km radius of Kyiv's Kiltseva Road were identified using the buffering method in the QGIS geoinformation environment. GIS techniques were used to analyze the vegetation cover, specifically utilizing land use data from OpenStreetMap. Field observations in July 2024 focused on assessing leaf damage in the most abundant tree species (*Tilia cordata* Mill., *Populus nigra* L., *Acer platanoides* L., *A. negundo* L., and *Picea pungens* Engelm.) at 13 selected points along Kiltseva Road. The assessment includes leaf damage caused by pathogens and pests (including chlorosis, necrosis, pigmentation, pathogens and herbivore damage). Results show that the degree of leaf damage was medium to high, with 9.7% and 10.0% of the leaf area affected in the northwestern and southern parts of the highway, particularly near major transport interchanges. In contrast, the northern and western sections showed lower medium damage rates of 8.5% to 8.8%. Additionally, various amounts of solid dust particles (originating from soil and anthropogenic sources) were detected on the surface of tree leaves. Red-brown pigmentation, observed along the main veins of the leaves, can be the consequence of atmospheric pollution from NOx and SO2 emissions. The state of green spaces was further impacted by extreme weather conditions, including abnormally high temperatures (above 30°C) and prolonged drought periods during the summer.

Keywords: urban green space, spatial analysis, air pollution, urban heat island, climate change adaptation

Introduction

The rapid expansion of large cities leads to changes in land use, infrastructure development, and the replacement of natural vegetation with artificial materials. This process results in significant heat accumulation on the Earth's surface and infrastructure, creating notable differences in microclimatic conditions compared to adjacent suburban areas. This phenomenon, known as the "urban heat island" effect, impacts green spaces and microbiological conditions, and contributes to the spread of pests and pathogens (Desprez-Loustau et al., 2006; La Porta, 2008). Factors such as building density, wind direction and speed, air temperature and humidity, topography, and vegetation characteristics influence the extent of atmospheric pollution and heat load in urban areas (Boychenko et al., 2022). In large cities, especially in low-lying areas and near heavy traffic routes, photochemical smog often forms under anticyclonic conditions during summer. An effective strategy to mitigate the urban heat island effect is to conserve and expand urban green spaces. Vegetation contributes to cooling through shading and transpiration. As green spaces decrease, cities lose the cooling and shading effects provided by trees, and there is a reduction in carbon dioxide absorption and oxygen enrichment of the air (Mohan et al., 2022). For instance, one hectare of green space can absorb up to 8 liters of CO2 per hour, and one hectare of forest can produce enough oxygen to support the needs of 30 people (Silaydin Aydin and Çukur, 2012). Additionally, green spaces play a crucial role in air purification by removing dust and gases.

Climate change significantly impacts the health of green spaces. Recent decades have been the warmest on record in both Europe (Spinoni et al, 2016) and Ukraine (Boychenko and Maidanovych, 2024). During summer, even in northern and central Ukraine, periods of abnormally high temperatures exceeding 30°C have become common, and prolonged droughts have negatively affected urban green spaces.

This study aims to utilize satellite data and field observations to identify the main types of green spaces within a 1 km radius of Kiltseva Road in Kyiv and to evaluate the extent of damage of most abundant tree species from pathogens and pests along this route.

Method and Theory

To analyze the types of green spaces along Kiltseva Road in Kyiv, the area was divided into four sections. Using the buffering method in the geoinformation system QGIS, the study area was defined as a 1 km radius from the road. GIS techniques, particularly land use data from OpenStreetMap (source: http://download.geofabrik.de/europe/ukraine.html), were used to study the vegetation cover. In July 2024, samples were collected from 13 points along Kiltseva Road, focusing on 33 trees of the most abundant species: *Populus* spp. (mainly *Populus nigra* L.), *Acer platanoides* L., *Acer negundo* L., *Tilia cordata* Mill., and the less abundant but still present *Picea pungens* Engelm. For each tree, 10 leaves were sampled. The degree of leaf damage (chlorosis, necrosis, pigmentation, herbivores and pathogens damage) was assessed and summarized in Table 1. The severity of leaf damage was categorized as low (1.0-4.9%), medium (5.0-9.9%), high (10.0-14.9%), and very high (15% and above). Daily meteorological data, including average and maximum air temperatures, relative humidity, wind speed, and precipitation, were obtained from the Kyiv (Zhuliany) weather station for July 2024 (source: https://www.ncei.noaa.gov).

Results

Using maps from "The OpenStreetMap data files," five types of green zones were identified on both sides of Kyiv's Kiltseva Road: gardens, woodlands, grasses, meadows, and parks. These were further divided into four sections based on the rationale provided in (Khlobystov, 2024).

The northern section (Part 1, sampling points 2, 3, 4, 5) is characterized by extensive mixed and pine forests, which are recognized as public green spaces and forest parks, including the Sviatoshynsko-Bilychansky forest and Vinogradar Park. Within the Vynogradar residential area, there are areas with deciduous tree plantations, primarily garden vegetation, as well as the "Kin Grust" park and public squares along Lytovsky Avenue. The mixed forests are predominantly composed of deciduous species, such as *A. platanoides, P. nigra*, and the invasive *A. negundo*. Conifers present include *P. pungens* and *Pinus sylvestris* L. The trees in this area show moderate damage by herbivores and pathogens, with various types of leaf browning observed, including marginal browning, browning at the base, and along the veins. The general degree of leaf damage is medium, averaging 8.5±2.0%. The green areas in **the northwestern section** (Part 2, sampling points 1, 6, 13) partly belong to the Sviatoshynsko-Bilychansky forest and are also represented by several squares, gardens, and grass lawns near Beresteysky Avenue and Akademik Vernadskyi Boulevard. The vegetation here is dominated exclusively by deciduous tree species, including *Populus* spp., *A. platanoides*, and *T. cordata*, with the invasive *A. negundo* being much less common. Aerosol pollution from dust particles (originating from soil and anthropogenic sources, mainly PM10 particles) is present in this area. Leaf damage is predominantly characterized by chlorosis, necrosis, and pigmentation in the form of browning, though less severe than in other parts of the road. Herbivores and pathogens damage is observed but remains at a low level. The overall degree of leaf damage is above medium, at 9.7±1.7%. In **the western section** (Part 3, sampling points 7, 12, 8), grassy vegetation predominates, with woody vegetation found primarily around Lesia Kurbas Avenue, Zodchikh Street, and along the road near "Sovki" Park and remnants of garden settlements. The typical tree species in this area include *Populus* sp. and *A. platanoides*, with *T. cordata* and *A. negundo* being less common. Coniferous trees are scarcely represented. The leaves in this area show dust contamination, primarily from PM2.5 particles. The trees along the road exhibit moderate levels of pathogens and herbivores damage and a significant incidence of chlorosis. Isolated cases of browning and pigmentation along the veins were also observed. The overall degree of leaf damage is medium, averaging 8.8±1.9%.

The southern section (Part 4, sampling points 9, 10, 11) is primarily characterized by grassy vegetation along the border of the South-Borshchagivka residential area and parts of Akademik Glushkov Avenue. In the area of the former village of Zhulyany, gardens are concentrated, while woodlands are represented by narrow plantations along certain sections of the road. Among the deciduous species, *Populus* spp. and *A. platanoides* predominate, with *P. pungens* being widespread in some locations. This area is heavily contaminated with dust from anthropogenic sources. The trees are moderate damaged by pathogens and herbivores, with frequent occurrences of necrosis, chlorosis, and red-brown pigmentation. The overall degree of leaf damage is high, at 10.0±2.6%.

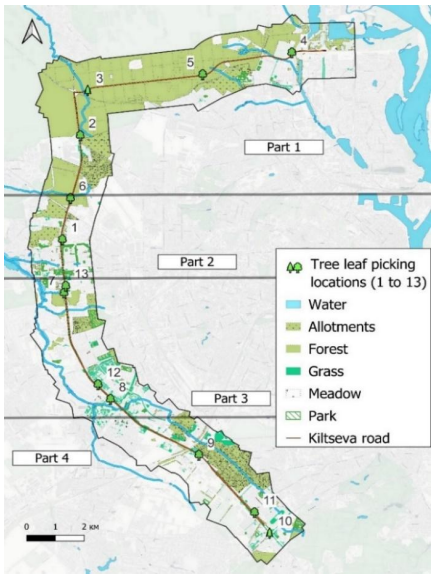

Figure 1. *Types of green spaces within a 1-kilometer area of the Kiltseva Road in Kyiv and locations of tree leaf sampling for damage analysis (points 1-13).*

Table 1 presents the degree of leaf damage for the most abundant tree species at 13 points along Kyiv's Kiltseva Road in July 2024, with summarized estimates illustrated in Fig. 2. Chlorosis and necrosis were the most common types of leaf damage observed, while pigmentation was less frequent. Among the species studied, *T. cordata* leaves exhibited the least damage, whereas *A. negundo* leaves were the most severely affected.

Table 1. *The degree of different type of leaf damages of trees selected at 13 points along the Kyiv's Kiltseva Road in July 2024*

№ point	Address	Coordinates		Tree species	Chlorosis	Necrosis	Pigmentation	Herbivores and pathogens	General damage
		Longitude	Latitude						
1	Akademika Palladina Ave, 34	50.4669980	30.3563350	*Populus nigra*	3	2.6	1.1	2.2	8.9
				Acer platanoides	3.8	2.9	1.1	1.4	9.2
				Tilia cordata	2.8	2.8	0.7	1.3	7.6
2	Synoozerna St, 2B	50.5012955	30.3650737	*Populus nigra*	3.7	3.1	0.6	3.5	10.9
				Acer platanoides	2.9	2.6	0.4	1.6	7.5
				Tilia cordata	2.4	2.1	0.9	3.6	9
3	Miska St, 1/1	50.5160990	30.3686720	*Populus nigra*	2.2	1.8	0	1.1	5.1
				Acer negundo	2.4	2.6	0.2	2.8	8
				Picea pungens			1.6		
4	Yuriya Kondratyuka St, 16	50.5285639	30.4682891	*Populus nigra*	5.1	3	1.7	1.8	11.6
				Acer negundo	3.6	2.8	0.6	2.9	9.8
5	Kosenka St, 57	50.5213883	30.4247817	*Populus nigra*	3.3	2.1	1.5	0.9	7.8
				Acer platanoides	1.9	2.5	0.6	2.1	7.1
6	Akademika Palladina Ave, 46A	50.4806427	30.3603001	*Populus nigra*	3.4	3	1	2.3	9.7
				Acer platanoides	3.3	3.3	1	2.5	10.1
				Acer negundo	4	2.8	1	1.8	9.6
7	Velyka Okruzhna Road, 22	50.4494499	30.3571729	*Populus nigra*	3.1	1.7	0	2.2	7
				Acer platanoides	4	1.6	0.5	2.5	8.6
				Acer negundo	3.4	1.8	0.9	2.7	8.8
8	Velyka Okruzhna Road, 54	50.4143851	30.3797876	*Populus nigra*	3.5	3.5	0.8	2.6	10.4
				Acer platanoides	2.1	2	1	3.1	8.2
				Tilia cordata	1.8	1.7	0.2	1.2	4.9
9	Velyka Okruzhna Road, 11	50.3959905	30.4229534	*Populus nigra*	4.1	2.5	2.7	3	12.3
				Acer negundo	4.4	2.3	0.5	3.3	10.5
10	Teremkivska St, 1	50.3701688	30.4573330	*Picea pungens*			3		
11	Lyatoshyns'koho St, 9A	50.3770020	30.4500628	*Populus nigra*	2.3	2	0.5	1.5	6.3
				Acer platanoides	3.7	3.5	3.3	1.9	12.4
				Acer negundo	2.9	4	0.2	1.4	8.5
12	Zodchykh St, 30/6	50.4192417	30.3737446	*Populus nigra*	4.6	3.4	0.4	2.7	11.1
				Acer platanoides	3.7	2.8	1.1	2.4	10
				Tilia cordata	3.6	2.5	1.1	2.7	9.9
13	Verkhovynna St, 69	50.4517278	30.3580349	*Acer platanoides*	3.1	4.3	1.5	2.4	11.3
				Acer negundo	3	3.2	1.2	3.4	10.8

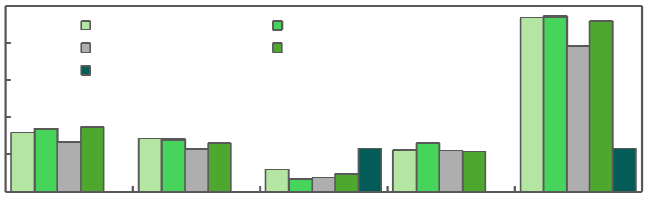

Figure 2. *Total percentage of tree leaves damage along Kyiv's Kiltseva Road, July 2024*

In addition to air and soil pollution, the condition of green spaces is also influenced by weather conditions. In July 2024, the weather was dominated by blocking anticyclones, which typically bring anomaly high air temperatures of 30°C and above to Ukraine, along with prolonged dry periods, low air humidity, and light winds. According to data from the weather station Kyiv (Zhulyany), maximum daily air temperatures reached 35–36°C, with daytime air humidity ranging from 35–45% during the period of July 11–18. Throughout the month, surface temperatures averaged 24.8-32.9°C, with approximately 54 mm/month of precipitation recorded. It is worth noting that anomaly high summer temperatures have become characteristic of Europe in recent decades (Spinoni et al., 2016; Boychenko et al., 2023; Boychenko and Maidanovych, 2024). The hot and dry conditions during summer can lead to outbreaks of pathogens affecting tree plantations (Desprez-Loustau et al., 2006; La Porta, 2008), which underscores the need for long-term monitoring to ensure the sustainable management of urban green spaces.

Conclusions

It was found that the overall degree of leaf damage in the five studied tree species along Kyiv's Kiltseva Road is between high and medium damage in the northwestern and southern sections, with rates of 9.7% and 10% respectively, particularly in areas with concentrated traffic intersections. In the northern and western sections, the damage was moderate, ranging from 8.5% to 8.8%. The most common types of leaf damage observed were chlorosis and necrosis, suggesting the cumulative impact of various stressors. Additionally, varying amounts of hard dust particles, originating from both soil and man-made sources, were detected on the leaf surfaces. Red-brown pigmentation was also noted on the main veins of the leaves, indicating atmospheric pollution from NOx and SO2 emissions. Among the species studied, A. negundo leaves were the most affected, while T. cordata demonstrated the greatest resistance. Summer weather conditions, characterized by abnormally high temperatures of 30°C and above, along with prolonged dry periods, also negatively impacted the condition of green spaces.

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