Journal of Vasyl Stefanyk Precarpathian National University. Biology
https://journals.pnu.edu.ua/index.php/jpnubio/
Vol. 11 (2024), P189-P194

JPNUBIO scientific journal

UDC 574.3: 581.52:504.058

URBAN GREENING IN IVANO-FRANKIVSK: ECOLOGICAL STATUS AND PROSPECTS FOR SUSTAINABLE DEVELOPMENT

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Abstract. The article provides an analytical assessment of the current state of urban greening in Ivano-Frankivsk (Ukraine) within the framework of ecological sustainability and climate change adaptation. Particular attention is devoted to the functional significance of green areas in regulating the urban microclimate, improving air quality, maintaining biodiversity, and contributing to the overall well-being of the urban population. The analysis emphasizes the role of green areas in shaping a favorable microclimate, improving air quality, preserving biodiversity, and enhancing overall well-being. Key challenges include rapid urbanization, climate-related risks, and insufficient maintenance of existing vegetation. Although the average green space per resident exceeds 18 m²—significantly higher than the World Health Organization's minimum recommendation of 9 m²—the spatial distribution of green infrastructure remains uneven, with central and peripheral districts experiencing significant deficits. The methodology combines a review of scientific literature and municipal reports, GIS-based spatial mapping of green zones, and a comparative analysis of national and international practices of green inventory. Findings reveal that urban green areas—including parks, river buffer strips, and small public gardens—deliver critical ecosystem services: mitigating the urban heat island effect, increasing humidity, filtering air pollutants, and supporting local biodiversity. At the same time, several issues were identified, such as unauthorized tree cutting, uncontrolled pruning, insufficient planting in high-density districts, and low climate adaptability of certain species. Special attention is given to the potential of digital tree cadastres, which are already operational in several European and Ukrainian cities. These systems enhance transparency in green space management, prevent illegal logging, optimize the selection of climate-resilient species, and promote community engagement. Strategic directions for sustainable development include creating ecological corridors between major parks, promoting vertical greening and green roofs, expanding the use of native tree species, and restoring riparian vegetation. The study concludes that combining digital innovation, adaptive planning, and participatory governance can significantly strengthen the ecological resilience of Ivano-Frankivsk and ensure effective adaptation to climate change.

Keywords: urban greening, urban environment, green infrastructure, sustainable development, biodiversity, climate change, woody plants, life form, systematic analysis.

1. INTRODUCTION

Climate change is one of the key challenges facing contemporary cities. According to UN projections, by 2050 approximately 68% of the world's population will reside in urban areas, substantially increasing risks to public health and well-being due to the rising frequency of heat waves and the formation of urban heat islands.

Ukrainian cities are already facing these threats. Research indicates that the number of heat waves during the period 1991 – 2025 has nearly doubled compared to the climatic norm. Medium-sized cities, such as Ivano-Frankivsk, are particularly vulnerable, where increasing building density coincides with a reduction in green spaces. Ukraine has already recorded a rise in the number of days with temperatures exceeding 30 °C, which is especially pronounced in medium-sized cities. In Ivano-Frankivsk, where intensive construction occurs alongside the shrinking of green areas, the issue of ecological resilience has acquired strategic importance.

Under these conditions, green areas become a critical component of ecological infrastructure. They reduce air temperature, regulate humidity, filter dust and harmful substances from the atmosphere, and contribute to enhancing the social comfort of urban residents (Fig. 1).

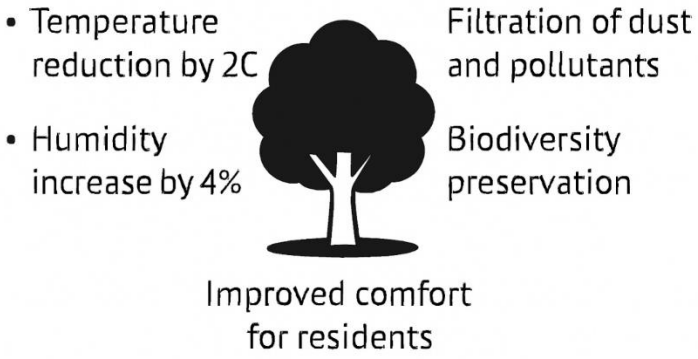

Fig. 1. Ecosystem Functions of Green Spaces.

Urban greening is one of the key factors shaping ecological resilience and the comfort of urban environments. In response to rising temperatures, increasing frequency of heat waves, and the reduction of natural landscapes, cities are required to develop adaptive and ecologically balanced spatial development strategies. Ivano-Frankivsk, as a dynamic city experiencing active construction and population growth, also faces challenges in preserving and expanding its green areas.

2. RESEARCH OBJECTIVE, METHODOLOGY AND DATA

The aim of the study is to analyze the current state of urban greening in Ivano-Frankivsk, to identify the main ecological challenges, and to define pathways for improving green infrastructure as a tool for climate adaptation.

Main objectives:

To analyze the current state of green areas in Ivano-Frankivsk;

To identify potential risks posed by heat waves for the city;

To assess the experience of other Ukrainian cities in digital inventorying of green spaces;

To propose practical measures for implementing similar solutions in Ivano-Frankivsk.

The issue of heat waves in Europe and Ukraine has been extensively studied in the scientific literature. It has been established that green spaces reduce the average temperature in parks by 2 °C compared to urban built-up areas, while relative humidity in such zones is 4% higher (Kabisch, 2016).

European experience demonstrates the effectiveness of interactive tree inventory systems, which are operational in cities in Poland, Germany, and Sweden. In Ukraine, similar projects have been implemented in Kyiv, Odesa, Lviv, Lutsk, Bila Tserkva, and Kropyvnytskyi.

For Ivano-Frankivsk, which is actively developing but has unique green infrastructure (Taras Shevchenko Park, squares along Nezalezhnosti Street, and the riparian zones of the Bystrytsia Solotvynska and Bystrytsia Nadvirnyanska rivers), the experience of digital inventory is particularly relevant (Kavchuk, 2022).

This study analyzes reports and recommendations from the NGO "Ukrainian Ecological Club 'Green Wave'"; it compares practices of green space inventory in Ukrainian cities. A cartographic analysis of Ivano-Frankivsk's territory was conducted using open data and published sources, and potential approaches for implementing a local inventory system were summarized.

The study was based on the analysis of open statistical data and reports of the Ivano-Frankivsk City Council (United Nations, Department of Economic and Social Affairs, 2019; US EPA, 2008); the use of Geographic Information Systems (GIS) for cartographic analysis of the distribution of green areas (Östberg 2013); the comparison of experiences in digital inventorying of green spaces in Ukrainian and European cities (Khalaim 2021; Inspectree 2019); and the review of scientific literature and recommendations of international organizations (WHO, ICLEI, European Commission).

The methods included comparative analysis, spatial modeling, and ecological assessment of the functional role of green spaces in the urban environment.

3. RESULTS AND DISCUSSION

Ivano-Frankivsk is characterized by a well-developed network of green areas, the largest of which include Taras Shevchenko Park, the Memorial Square, the International Soldiers' Park, the "Youth Park", and the riverside zones along the rivers Bystrytsia Solotvynska and Bystrytsia Nadvirnianska. However, processes of intensive residential development contribute to the gradual reduction of green spaces, particularly in the central districts of the city. The most problematic remain the inner courtyard areas, which largely lack proper registration and systematic maintenance.

Green spaces perform a critically important ecological function within the structure of the urban environment. They reduce air temperature by an average of 2 °C, increase relative humidity, lower the concentration of particulate matter in the air and the level of noise pollution, and also create conditions for the preservation of biodiversity. According to recent studies, the city has about 18 m² of green space per capita, which exceeds the minimum standard of the World Health Organization (9 m² per person). However, the spatial distribution of these areas is uneven: a denser network of greenery is observed in the central part of the city, while the peripheral neighborhoods, particularly "Kaskad," experience a shortage of green zones.

Climate change intensifies ecological challenges for urbanized areas. In Ivano-Frankivsk, periods of heatwaves are increasingly recorded, with average daily values exceeding +30 °C. The most vulnerable are areas with high building density and insufficient green spaces, which worsens the comfort and safety of living conditions for the population. Under these circumstances, tree species traditionally common to the region demonstrate reduced resilience, which necessitates a shift toward planting autochthonous and climate-adapted species.

Woody plants form the basis of all green areas in the city. In total, 106 species were identified in Ivano-Frankivsk. Among them, in terms of life forms, trees predominate: deciduous trees account for 48%, while evergreen species make up 10%. Deciduous shrubs account for 37%, evergreen shrubs for 3%, and deciduous lianas are also present in the study area (2% of the total number of species) (tabl. 1).

Table 1. Distribution of woody plants by life forms in Ivano-Frankivsk

Item No.	Life form	**Percentage (%)**
1.	Deciduous trees	48,0
2.	Evergreen trees	10,0
3.	Deciduous shrubs	37,0
4.	Evergreen shrubs	3,00
5.	Lianas	2,00

According to a systematic analysis, the most numerous family in terms of representatives is *Rosaceae*, comprising 24 species. The families Aceraceae and Pinaceae each include 7 species, while the families *Oleaceae* and *Cupressaceae* comprise 6 species each. The families *Caprifoliaceae*, *Fabaceae*, *Betulaceae*, and *Salicaceae* each account for 5 woody plant species. Meanwhile, two families – *Fagaceae* and *Magnoliaceae* – include 3 species each. The remaining 10 families comprise 1 or 2 species each (Fig. 2).

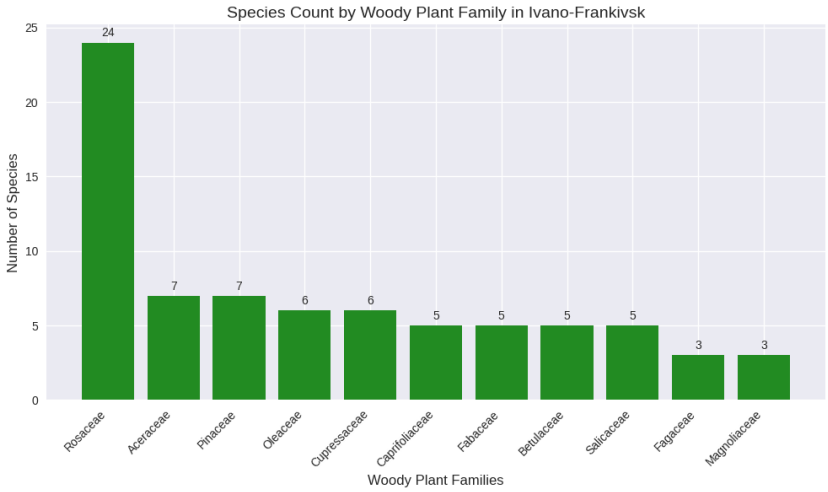

Fig. 2. Most Numerous Woody Plant Families in the City of Ivano-Frankivsk.

A key instrument for the sustainable management of green infrastructure is the development of a digital cadastre using geographic information systems (GIS). Such a system would allow for systematic monitoring of vegetation health, help prevent illegal logging, support the planning of greening initiatives in response to climate-related challenges, and facilitate public participation in decision-making processes. Examples from other Ukrainian cities demonstrate the effectiveness of digital solutions in this area. In particular, Lviv and Lutsk have implemented the "Inspectree" system for tree inventory, Kyiv has developed an open interactive map of green areas with access to object passports, and Odesa has introduced a mechanism for public data contribution to the public registry of woody plants.

The integration of such tools in Ivano-Frankivsk would contribute to enhancing the city's ecological resilience and the more efficient use of natural resources. Promising directions for development include the expansion of greening in central districts through vertical structures and green roofs, the creation of ecological corridors between existing parks and squares, and the establishment of favorable conditions for public participation in the monitoring and maintenance of green areas. Thus, a comprehensive approach that combines spatial planning, digital technologies, and community engagement can ensure the sustainable development of Ivano-Frankivsk's green infrastructure under climate change conditions.

4. CONCLUSIONS

Green zones in Ivano-Frankivsk play a crucial role in mitigating the effects of heat waves and enhancing residents' quality of life. The implementation of an interactive inventory of green areas would: facilitate efficient management of urban greenery; improve transparency in decision-making processes; foster community engagement in the development of green infrastructure; support the city's adaptation to climate change. Accordingly, a digital inventory of green zones could serve as a key element of Ivano-Frankivsk's environmental development strategy. Greening in Ivano-Frankivsk is a key factor for ecological resilience and the improvement of residents' quality of life. Despite an overall sufficient level of green zones, the city faces challenges related to the uneven distribution of green areas, illegal logging, and climate-related pressures. The implementation of an interactive green zone inventory system, the development of vertical greening, and active community engagement in green infrastructure management will enable the city to adapt to climate change and maintain ecological balance. Greening in Ivano-Frankivsk is not solely the responsibility of municipal services but a shared responsibility of the authorities, businesses, and the community. Only a comprehensive approach can preserve ecological balance, improve quality of life, and create a more resilient and comfortable city under changing climate conditions. Greening is an important component of the city's environmental strategy. Despite positive indicators regarding the quantity of green areas, challenges remain related to uneven access, climate change, and urban development. The development of green infrastructure should be based on the principles of sustainable development, adaptive planning, and public participation.

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Василь Бойчук, Надія Різничук. Озеленення міського середовища в Івано-Франківську: екологічний стан та перспективи сталого розвитку. Журнал Прикарпатського національного університету імені Василя Стефаника. Біологія, 11 (2024), С189–С194.

Анотація. У статті проведено аналіз сучасного стану озеленення міста Івано-Франківськ у контексті екологічної стійкості та адаптації до змін клімату. Акцент зроблено на ролі зелених зон у формуванні сприятливого мікроклімату, покращенні якості повітря, підтримці біорізноманіття та підвищенні добробуту населення. Визначено ключові виклики, пов'язані з урбанізацією, кліматичними ризиками та недостатнім доглядом за зеленими насадженнями. Попри середній рівень озеленення понад 18 м² на мешканця, що перевищує мінімальну норму ВООЗ, розподіл зелених територій залишається нерівномірним, особливо у центральних і периферійних районах міста. Методологія ґрунтується на аналізі наукових джерел, муніципальної звітності та використанні геоінформаційних систем для просторового картографування зелених зон, а також порівнянні національних і міжнародних практик інвентаризації. Результати показують, що зелені насадження — парки, сквери, прибережні смуги — виконують важливі екосистемні функції: зменшують ефект теплових островів, підвищують вологість, очищують повітря від забруднювачів та підтримують локальне біорізноманіття. Водночас виявлено проблеми: несанкціоновані вирубки, неконтрольована обрізка, нестача нових посадок у районах щільної забудови та низька стійкість деяких видів до кліматичних змін. Особливу увагу приділено перспективам цифрової інвентаризації зелених насаджень, що забезпечує прозорість управління, оптимізацію видового складу та залучення громади до співуправління. Серед стратегічних напрямів розвитку виділено створення

зелених коридорів, розвиток вертикального озеленення й зелених дахів, використання автохтонних видів дерев та відновлення прибережних територій. Поєднання інноваційних технологій, адаптивного планування та громадської участі визначається як ключ до підвищення екологічної стійкості міста.

Ключові слова: озеленення, міське середовище, зелена інфраструктура, сталий розвиток, біорізноманіття, зміни клімату, деревні рослини, життєва форма, систематичний аналіз.