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“ _____ ” _____ 2025

BACHELOR THESIS (EXPLANATORY NOTE)

Theme: «Analysis of the ecosystem sustainability for the city of Kyiv»

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KYIV 2025

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ДЕРЖАВНЕ НЕКОМЕРЦІЙНЕ ПІДПРИЄМСТВО
«ДЕРЖАВНИЙ УНІВЕРСИТЕТ «КИЇВСЬКИЙ АВІАЦІЙНИЙ ІНСТИТУТ»
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
_____ Тамара ДУДАР
« ____ » _____ 2025 р.

**КВАЛІФІКАЦІЙНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)**

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ «БАКАЛАВР»

Тема: «Аналіз стійкості екосистеми міста Києва»

Виконавець: здобувач групи Ба-101-21-1-ЕК Мирошник Сергій Сергійович

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2025

BACHELOR THESIS ASSIGNMENT

Serhii S. Myroshnyk

1. Theme: **«Analysis of the ecosystem sustainability for the city of Kyiv»**
approved by the Acting President on 28.04.2025 No 634/ct
2. Duration of work: from 28.04.2025 to 22.06.2025.
3. Output data of work: images of the research object, satellite images, air pollution level from the SaveEcoBot resource, noise level measured by a mobile application, data on the depth of groundwater
4. Content of explanatory note: Review of theoretical approaches to the concept of ecosystem and its sustainability in the context of urbanization. Identification of the main environmental indicators that characterize the state of the urban environment. Justification of the methodology for assessing ecosystem sustainability and calculation of the sustainability index based on open data and normalized indicators.
5. The list of mandatory graphic (illustrated) materials: photos, diagrams, tables

6. Schedule of thesis performance

| № з/п | Task | Term | Advisor's signature |
|----------|---|------------------|------------------------|
| 1 | Selecting a topic, agreeing with the manager | 30 April 2025 | |
| 2 | Collection and analysis of scientific literature on ecosystem resilience | 6 May 2025 | |
| 3 | Study of urban ecosystems and methods of construction impact assessment | 10 May 2025 | |
| 4 | visit to the building site, observation of the processes in practice | 23 May 2025 | |
| 5 | Gathering data from open sources, satellite images, and online monitoring services Visit the construction site, observe the processes in practice | 28 May 2025 | |
| 6 | Calculating the ecosystem sustainability index | 3 June 2025 | |
| 7 | Analyzing the results, drawing conclusions | 5 June 2025 | |

7. Date of task issue: «28» April 2025

Thesis supervisor: _____
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Task is taken to perform: _____
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МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
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«ДЕРЖАВНИЙ УНІВЕРСИТЕТ «КИЇВСЬКИЙ АВІАЦІЙНИЙ ІНСТИТУТ»

Факультет екологічної безпеки, інженерії та технологій

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Спеціальність, освітньо-професійна програма: спеціальність 101 «Екологія»,

ОПП «Екологія та охорона навколишнього середовища»

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« ____ » _____ 2025 р.

ЗАВДАННЯ

на виконання кваліфікаційної роботи

Мирошника Сергій Сергійовича

1. Тема: «**Аналіз стійкості екосистеми міста Києва**», затверджена розпорядженням в.о. Президента від 28.04.2025 № 634/ст
2. Тривалість робіт: з 28.04.2025 по 22.06.2025.
3. Вихідні дані роботи: зображення об'єкта дослідження, супутникові знімки, рівень забруднення повітря з ресурсу SaveEcoBot, рівень шуму, виміряний мобільним додатком, дані про глибину залягання ґрунтових вод
4. Зміст пояснювальної записки: Огляд теоретичних підходів до концепції екосистеми та її сталості в контексті урбанізації. Визначення основних екологічних показників, що характеризують стан міського середовища. Обґрунтування методології оцінки сталості екосистеми та розрахунку індексу сталості на основі відкритих даних та нормалізованих показників.
5. Перелік обов'язкових графічних (ілюстрованих) матеріалів: фотографії, схеми, таблиці

6. Графік виконання дисертацій

| № з/п | Завдання | Термін виконання | Підпис керівника |
|-------|---|------------------|------------------|
| 1 | Вибір теми, узгодження з керівником | 30 Квітня 2025 | |
| 2 | Збір та аналіз наукової літератури щодо стійкості екосистем | 6 Травня 2025 | |
| 3 | Вивчення міських екосистем та методи оцінки впливу будівництва | 10 Травня 2025 | |
| 4 | відвідування будівельного майданчика, спостереження за процесами на практиці | 23 Травня 2025 | |
| 5 | Збір даних з відкритих джерел, супутникових знімків та онлайн-сервісів моніторингу. Відвідування будівельного майданчика, спостереження за процесами на практиці. | 28 Травня 2025 | |
| 6 | Розрахунок індексу стійкості екосистеми | 3 Червня 2025 | |
| 7 | Аналіз результатів, формулювання висновків | 5 Червня 2025 | |

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ABSTRACT

Explanatory note to thesis «**Analysis of the ecosystem sustainability for the city of Kyiv**»: 45 pages, 13 figures, 2 tables, 15 references.

Object of research – Ecosystem sustainability of the city of Kyiv urban environment.

Aim of work – The aim of this study is to assess the environmental sustainability of urban ecosystems in the context of large-scale infrastructure construction, using the example of a new metro line in the Vinogradar district of Kyiv.

Methods of research: Since the thesis did not include full-fledged field monitoring, the main methodology was to use open sources of environmental information and analyze available data related to the construction area of the new metro line to Vynohradar.

First of all, we used air quality data from online resources such as SaveEcoBot. To analyze the noise load, we used acoustic mobile applications for approximate noise level measurement, which allow us to estimate its average values in dBA. Information on groundwater and soil conditions was collected from hydrogeological reports published as a part of the preparation for the subway construction. Satellite images and Google Earth maps were used to estimate the losses.

The paper investigates how the construction of a new subway line in the Vynohradar district affects the sustainability of the urban environment. Based on open sources, we analyzed the condition of soils, groundwater levels, the presence of green areas, and changes in biodiversity. Although the construction of the metro inevitably creates an environmental burden, the results showed that with proper control and consideration of the specifics of the territory, the ecosystem is able to maintain its functionality. The work demonstrates that even within a large infrastructure project, it is possible to find a balance between city development and preserving its natural potential.

ECOSYSTEM, SUSTAINABILITY, URBANIZATION, KYIV, VYNOHRADAR, METRO, ANTHROPOGENIC IMPACT, AIR QUALITY, NOISE POLLUTION, GROUNDWATER, GREEN AREAS, ENVIRONMENTAL INDICATORS, SATELLITE IMAGERY, SUSTAINABILITY INDEX, GIS ANALYSIS, ECOLOGICAL BALANCE

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INTRODUCTION

Relevance of the work. Nowadays, cities are growing faster than ever, and with this growth comes increasing pressure on the natural environment. Green areas are being replaced by buildings, underground infrastructure affects groundwater, and local ecosystems often don't have time to adapt. Kyiv is no exception. In places like the Vinogradar district — where construction of a new metro line is underway — these changes are especially noticeable, as they directly affect soil conditions, vegetation, and the overall ecological balance.

This work is relevant because it explores how large infrastructure projects, even those considered environmentally friendly like the metro, can still create risks for local ecosystems during construction. At the same time, it shows that if we pay attention to data — even basic environmental indicators from open sources — we can better understand what's happening and respond in time. The study helps bridge the gap between urban development and environmental awareness, offering insights that can support more thoughtful and sustainable city planning.

Tasks of the diploma work

1. To explore the theoretical foundations of assessing the sustainability of urban ecosystems.
2. Determine the main environmental factors that influence ecosystem stability in the city of Kyiv
3. Assess the ecosystem sustainability in the area where the new metro line to Vinogradar is being constructed

Aim of the work – The aim of this study is to assess the environmental sustainability of urban ecosystems in the context of large-scale infrastructure construction, using the example of a new metro line in the Vinogradar district of Kyiv.

Object of the work: Ecosystem sustainability of the city of Kyiv urban environment.

Subject of research is sustainability of underground metro infrastructure. Using the example of a new metroline in the Vinogradar district of Kyiv.

Methods of research – Analysis of available environmental information, use of mobile applications, analysis of satellite images, application of a simplified methodology for calculating the ecosystem sustainability index

Personal contribution of the graduate: As part of this research, I independently carried out several key stages of data collection and analysis. I personally visited the construction area in the Vinogradar district and took photographs to document changes in the local landscape. Using a mobile application, I measured noise levels in different parts of the site. I also estimated the area of green spaces affected by the construction by analyzing satellite images. Finally, I calculated the urban ecosystem stability index based on normalized environmental indicators, combining both positive and negative factors to assess the overall resilience of the area.

CHAPTER 1

THEORETICAL FOUNDATIONS OF URBAN ECOSYSTEM SUSTAINABILITY RESEARCH

1.1 The concept of ecosystem and its components

In today's world, the concept of “ecosystem” is one of the most central in understanding the nature and interaction of humans with the environment. This term encompasses not only wildlife but also a complex system of connections between organisms and their habitats. The word “ecosystem” was first used in the scientific literature in 1935 by British ecologist Arthur Tansley, who proposed to consider nature not as a set of separate objects, but as an integral system where all elements are interconnected.

The term “ecosystem” usually refers to an integral natural system that includes living organisms - plants, animals, microorganisms - and non-living components such as water, soil, air, and minerals. All of these elements interact with each other within a certain area. An ecosystem is not just a habitat, but a complex functional system where metabolism, energy transfer, biomass formation, and the circulation of water and other substances are constantly taking place. Even small natural objects, such as a pond, a lawn or a city park, can act as separate ecosystems if they maintain a stable interaction between living and non-living nature.

Ecosystems can vary greatly in size and complexity, and are divided into natural and artificial. Natural ecosystems arise without human intervention - they include forests, rivers, lakes, swamps, steppes and other natural landscapes. Artificial ecosystems are created or significantly altered by humans. These can include agricultural fields, gardens, artificial reservoirs, and cities. The urban environment itself is an example of a particularly complex and dynamic ecosystem, where natural processes are closely intertwined with technical, social, and economic elements. Here, biological, engineering, and urban factors

form a multi-level system of interconnections that requires a separate approach to analysis and management.

Every ecosystem has a characteristic structure that includes several essential components. First, there are biotic components, i.e. living organisms. They are divided by their functions: producers (mostly plants), consumers (animals that consume other organisms), and reducers (organisms that decompose organic residues and return nutrients to the environment). All of these elements form the so-called trophic network, a food web where each component has a role.

Secondly, the ecosystem includes abiotic components - the non-living part of the environment. These include climate, temperature, humidity, light, air, water, relief, and soil composition. They determine which living organisms can exist in a certain area, how they will develop and interact.

It is worth emphasizing that an ecosystem is not something stable or immovable. It is constantly changing: the species composition changes, seasonal fluctuations occur, the number of populations fluctuates, and new life forms appear. However, in a healthy ecosystem, all these processes take place within a natural equilibrium that allows the system to maintain its functionality and sustainability.

Ecosystems are vulnerable to disturbance because of their complexity and interdependence. If one important element is changed or removed (for example, a certain species of animal or plant disappears), it can trigger a chain reaction and lead to serious changes or even destruction of the system. This principle illustrates the importance of preserving biodiversity - the greater the number of species, the more likely the ecosystem is to be able to adapt to change.

Understanding the structure and functioning of ecosystems is the basis for studying environmental sustainability, especially in the context of urbanization. Urban ecosystems are subjected to strong anthropogenic pressure, so researching their ability to self-regulate and recover is particularly important.

1.2. Ecosystem sustainability: definition, types and factors of influence

The Ecosystem sustainability is its ability to maintain its basic characteristics, structure and functions in the face of external or internal changes. In other words, we are talking about ecological stability: the extent to which an ecosystem is able to adapt to stressors, maintain its functions, and recover from disturbances.



Fig. 1.1. Illustration of ecosystem restoration

In the scientific literature, the concept of sustainability is interpreted in different contexts. One of the most common definitions is provided by Canadian ecologist C. Holling, who distinguished between two main aspects: resistance - the ability of an ecosystem to withstand change, and recovery - the ability to return to its original state after a disturbance.

For example, a forest ecosystem may be resilient to short-term drought, but at the same time, it will take a long time to recover from a forest fire.

The concept of sustainability is closely related to ecosystem balance. If external influences do not cause irreversible changes, and the system is able to maintain its internal structure, this indicates a high level of sustainability. However, in the face of constant anthropogenic pressure, especially in cities, this balance is often disturbed. This forces researchers to reconsider approaches to assessing resilience and look for new ways to determine the ability of ecosystems to recover.

In general, there are several types of sustainability:

- **Structural sustainability** — the ability to preserve species composition, spatial organization, and basic relationships between ecosystem components.
- **Functional sustainability** — is the preservation of key ecological processes, such as photosynthesis, the cycle of substances, and biological productivity.
- **Dynamic resilience** — is the ability of an ecosystem to change over time, but without losing its integrity.
- **Adaptive resilience** — includes the ability to adapt to new conditions, such as climate change or urbanization.

The sustainability of ecosystems is influenced by numerous factors that can be divided into natural and anthropogenic. Natural factors include climate, geographical location, terrain, soil type, availability of water resources, and species composition of flora and fauna. For example, ecosystems with high biodiversity tend to be more resilient, as the functions of one species can be partially compensated by other species in the event of changes. Anthropogenic factors are related to human activity. These include intensive land use, industrial pollution, deforestation, wetland drainage, land development, river channel changes, and climate change caused by greenhouse gas emissions. Urbanization, the process of urban growth accompanied by resource consumption and the transformation of natural landscapes into man-made ones, has a particularly strong impact.

Urbanized areas often lose their environmental sustainability due to excessive building density, isolation of natural areas, and reduction of green areas. At the same time, cities as complex socio-ecological and economic systems require a scientific approach to analyzing their sustainability. Assessment of ecosystem sustainability in urban environments is becoming critical, first and foremost, for making effective management decisions aimed at developing a sustainable urban environment.

Thus, resilience is an integral indicator that allows us to understand how a certain ecosystem is able to maintain its viability in changing conditions. This concept is particularly relevant for cities where the natural environment functions under the constant pressure of urbanization processes.

1.3. Features of urbanized ecosystems

Urbanized ecosystems are special types of environments formed as a result of active human activity that transforms natural space into urban space. They differ significantly from natural ecosystems both in their structure and functioning. Urban ecosystems consist of various elements: residential and industrial buildings, parks, water bodies, transportation networks, green areas - and all these components are interconnected into a single system.

One of the characteristics of urbanized ecosystems is their high fragmentation. Natural landscapes are broken up into numerous isolated areas, which complicates the migration of species, the exchange of genetic material and the maintenance of biodiversity. This isolation often leads to a decrease in the number of individual species and even local extinction.

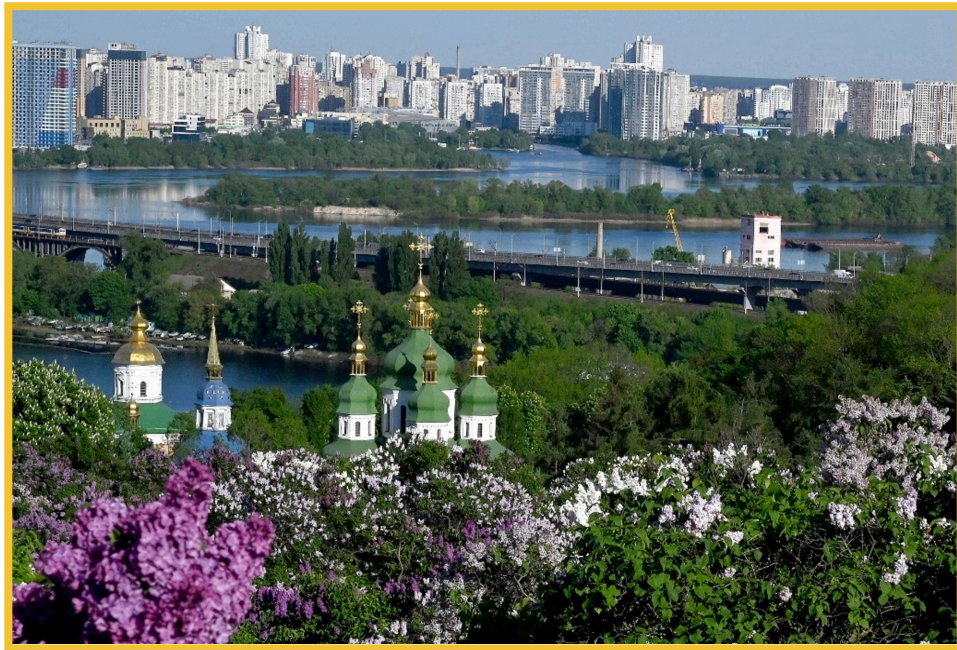


Fig. 1.2. urbanized ecosystem, Kyiv

Another important factor is the change in the physical characteristics of the environment. The urban landscape is filled with artificial surfaces - asphalt, concrete, metal, which significantly changes the heat and water balance. For example, the urban heat island phenomenon - an increase in air temperature within the city compared to the surrounding rural areas - is a consequence of the concentration of heat absorbed by buildings, roads and industrial facilities. This creates an additional load on the ecosystem, especially in summer, and affects the comfort of people's living.

Urbanized ecosystems have their own peculiarities, including a significant anthropogenic impact. Human activity leads to excessive use of natural resources, air, water, and soil pollution, and creates noise and light pollution. All these factors significantly complicate the living conditions for living organisms, causing stress, changing their habitual behavior, and affecting their ability to reproduce and survive.

At the same time, humans, being an integral part of the urban environment, play a dual role as both destroyers and creators. It is human decisions that determine what the urban environment will look like: whether green spaces will be preserved, how nature protection measures will be organized, and what the city's environmental policy will be. Responsible

attitude to nature allows not only to reduce damage but also to create favorable conditions for living in harmony with the environment.

Another important aspect is the ecological role of the city as a complex system in which social, environmental and economic elements are closely intertwined. The urbanized environment combines natural components with man-made elements, and also includes social structures that constantly interact with each other. This interaction generates new types of ecological processes that are not found in natural ecosystems. These include changes in the cycle of substances, specific energy flows, and the formation of unique biocenoses adapted to the artificial environment.

The study of urban ecosystems allows us to better understand these processes and, on this basis, to create effective approaches to biodiversity conservation in cities, the development of green areas, environmental monitoring, and the rational management of urban space. This is important not only for maintaining the ecological balance, but also directly affects the comfort and quality of life of people in the city.

1.4. General characteristics of the natural environment of Kyiv

The city of Kyiv, located in the northwestern Forest-Steppe zone of Ukraine, is one of the largest and oldest cities in the country. Its natural environment is shaped by a unique combination of geographical, climatic, hydrological and biological factors that create a special ecological context for the functioning of the urban ecosystem.

Geographically, Kyiv is located on the slopes of the Dnieper Plateau, along the banks of the Dnieper River, one of the largest waterways in Ukraine. The Dnieper River is a key element of the city's natural environment, shaping not only the landscape, but also the climatic conditions, water resources and biodiversity of the region. A significant area of the city is located on the right bank of the river, where rolling hills and forests stretch,

while the left bank is a flatter area with a predominance of agricultural lands and green areas.



Fig. 1.3. landscape of kyiv

The climate of Kyiv is moderately continental, with moderately cold winters and warm summers. The average annual temperature fluctuates around $+7-8^{\circ}\text{C}$, and the average amount of precipitation is around 600–700 mm. This climate contributes to the development of mixed forests, which dominate the natural landscapes of Kyiv region.

The soil cover of the city is represented mainly by sod-podzolic soils, which were formed on loess and loess-like deposits. These soils have average fertility and are the basis for natural vegetation, as well as for agricultural use in the city's surroundings.

Despite its high level of urbanization, Kyiv retains a significant amount of biodiversity. Many types of trees and shrubs can be found in the city. The most common are pine, oak, birch, ash, maple, and linden. The capital's green areas - parks, gardens, and protected

areas - occupy a significant part of the city's space and play a key role in maintaining the ecological balance.

Numerous species of animals find refuge in these natural areas. They are home to various birds, small mammals, insects, and representatives of aquatic fauna. Kyiv's river system creates a favorable environment for aquatic organisms. Thanks to the harmonious combination of nature and the urban environment, Kyiv remains a center of wildlife in a metropolitan environment.

Of particular value are the natural complexes preserved within the city or on its outskirts - these are forests, river floodplains, reserves and parks. They provide ecological functions: air purification, microclimate regulation, water balance, biodiversity support, and also serve as places of rest and recreation for residents.

At the same time, Kyiv's environment is undergoing significant anthropogenic pressure. Intensive construction, traffic, industrial pollution, changes in river channels and destruction of natural landscapes pose threats to the city's ecological state. This necessitates comprehensive monitoring and implementation of sustainable approaches to planning and managing natural resources.

To summarize, the natural environment of Kyiv is a dynamic system that is shaped by natural factors and human activity. A deep understanding of its features is the basis for further studying the sustainability of the urban ecosystem, as it determines the effectiveness of environmental protection measures and the quality of life of the urban population.

1.5 Conclusion to the section

This chapter has laid the theoretical foundation for understanding what an ecosystem is in the modern sense and why its sustainability is crucial in the context of urbanization. An ecosystem is not just a collection of elements, but a living,

interconnected system in which each component - from a microorganism to a river - plays a role. Its ability to self-regulate, adapt and recover from external changes is what we call resilience.

Consideration of different types of resilience - structural, functional, dynamic, and adaptive - has allowed us to better understand how ecosystems respond to challenges, including those related to human activity. In the urban environment, where there is an intense load per square meter - construction, noise, soil change, and the reduction of green areas - these processes are particularly acute.

So, knowledge about the structure, types of sustainability, and factors that influence ecosystems is of practical importance: it is the basis for making informed decisions in the field of urban environmental management. Only with this approach is it possible to preserve the living environment in the city - not as a remnant of nature, but as a full-fledged part of it.

CHAPTER 2

ANALYSIS OF THE ECOSYSTEM SUSTAINABILITY FOR THE CITY OF KYIV

2.1 Anthropogenic impact on the city's ecosystem

In modern conditions, the urban ecosystem is a complex and unstable structure that exists on the border of the natural and artificial environment. In such an environment, anthropogenic impact becomes the main factor of changes that are sometimes irreversible.

What is anthropogenic impact?

Anthropogenic impact is the sum of all changes in the environment caused by human activity. Unlike natural factors (such as climate fluctuations, floods or erosion), anthropogenic factors arise as a result of deliberate or indirect human intervention in natural processes. In a city, this impact becomes not just permanent, but all-encompassing.

Anthropogenic load manifests itself in various forms:

- **physical disturbance** of the natural environment (development, cutting down of green spaces, change in relief);
- **chemical pollution** (emissions into the atmosphere, wastewater, accumulation of garbage);
- **biological changes** (displacement of native species, emergence of invasive organisms);
- **acoustic and vibration loading**, which is particularly characteristic of transport infrastructure.

All this changes the ecological balance: some ecosystem functions are lost (for example, the ability to absorb carbon dioxide), others are overloaded or distorted (for example, the local climate becomes more arid due to a lack of vegetation).

Anthropogenic impact in the context of metro construction in Vynohradar

The construction of a new subway line is a typical example of a large-scale infrastructure project that is accompanied by a significant anthropogenic impact on the environment. Although the subway is generally considered one of the most environmentally sound forms of public transportation, the process of its construction poses a serious environmental threat. It is at this stage that the area experiences the highest level of environmental vulnerability.

2.1.1 Physical disturbance of the natural environment

First of all, construction is accompanied by the removal of soil cover, clearing the area for pits, and laying of auxiliary infrastructure (temporary roads, construction sites).

In the Vynohradar district, such actions are of particular importance, as there are fragments of slightly disturbed green areas, such as the Krysterova Hirka park and parts of the Syretsky Hai forest park. Damage to the root system of trees, soil compaction by heavy machinery, and pollution of the top layer all lead to degradation of the natural landscape, even if some areas are later re-landscaped.

In the Vynohradar district of Kyiv, gray forest soils, which are characteristic of the forest-steppe zone, prevail. These soils have average fertility and are formed under deciduous forests. They contain a moderate amount of humus and have good water permeability.



Fig. 2.1. photo of the soil section in the area of metro construction

Risks

Soil instability when moistened

- Gray forest soils have moderate density and permeability, but with excessive moisture (for example, due to rain, pipe bursts, or groundwater) they can lose their bearing capacity.
- This can cause subsidence or landslides, especially when digging tunnels.



Fig. 2.2. Landslide near the construction of a metro tunnel

Risk of cavities

Due to the presence of loose layers or a porous structure, karst-like cavities can form in certain areas.

- This could pose a risk of collapse or make it difficult to concretize tunnels.

Drainage problems

- Metro construction changes the natural water regime, and if the drainage system is not properly designed, flooding or water accumulation in the tunnels may occur.
- This is especially critical in the area of gray forest soils, which do not always hold their shape well when moistened.



Fig. 2.3 groundwater infiltration into the metro tunnel

Difficulties with soil consolidation

- When laying tunnels, it is necessary to use special strengthening methods (for example, freezing, injection of concrete mixtures), which increases the costs and complexity of the work.

2.1.2 Hydrological changes and interference with groundwater

Tunneling, especially in deep areas, disrupts the hydrological balance, changing the conditions of groundwater movement. In Vynohradar, which is dominated by gray forest soils with relatively shallow water storage depths, this means the risk of flooding neighboring areas or, conversely, moisture depletion in green spaces.

Such changes, although not always immediately noticeable, gradually alter vegetation types, cause landslides or the appearance of cracks on the surface, especially in built-up areas.

2.1.3 Acoustic, vibration and airborne loads

Although the metro itself is a low-noise form of transport, the construction phase includes the operation of heavy equipment, drilling rigs, and freight transport. For the densely populated areas of Vynohradiv, this means the constant presence of noise, dust, and diesel emissions. All this puts pressure not only on the residents, but also on the flora and fauna that have adapted to the urban environment. It is often in such places that residual populations of small mammals or birds live, which are the first to react to disturbances and changes in the microclimate.



Fig. 2.4. drilling rig

2.1.4 Ecosystem fragmentation and loss of connectivity

Construction disrupts the spatial unity of the natural environment. For example, green areas that used to form a continuous “green axis” often turn into disconnected fragments after the construction of technical subway lines. As a result, the migration routes of animals and insects are disrupted, and the natural process of vegetation renewal is interrupted.

This is especially true for the Vynohradar district, where even individual tree stands play an important ecosystem role. Their damage or destruction can have a significant impact on the ecological balance and sustainability of local natural conditions.



Fig. 2.5. Syretskyi Hai Park as of 2018

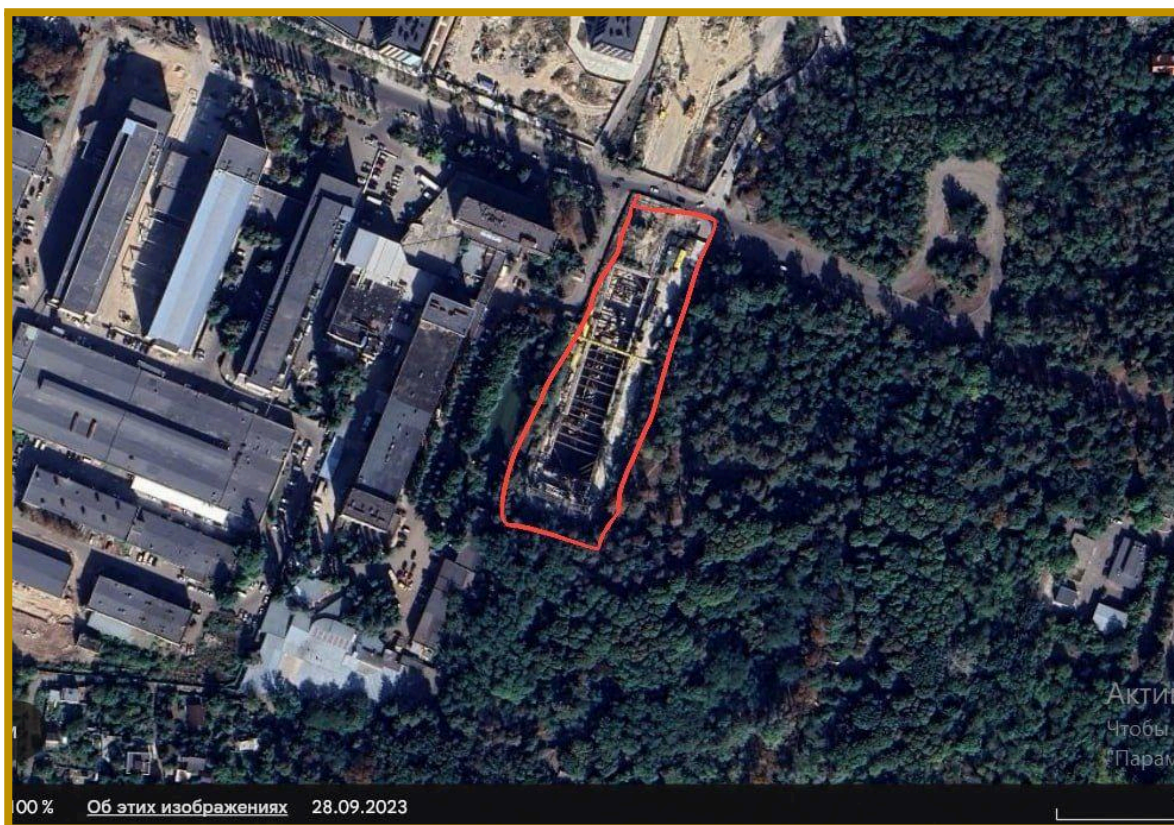


Fig. 2.6. Laying of the metro through Syretskyi Hai in 2025

2.1.5 Social and environmental impact

The construction of large infrastructure, in particular the new metro line in the Vynohradar district, affects not only the physical characteristics of the environment - soil, air, green spaces or noise levels. No less important is the socio-ecological effect - that is, how changes in the ecosystem are felt, perceived and experienced by the residents themselves.

In the case of Vynohradar, this is especially relevant. The district has long been associated with the "green suburbs" of the capital, where fragments of forest-park zones, a calm atmosphere and access to nature have been preserved. For many residents, the presence of green spaces was not just a pleasant bonus, but a part of their everyday life: a place for

walks, relaxation, informal communication. That is why large-scale construction has caused an ambiguous reaction.

On the one hand, residents understand the importance of developing public transport, especially in conditions of constantly increasing load on ground infrastructure. The metro is an environmentally friendly, fast and convenient way of transportation. But on the other hand, the construction process is accompanied by a number of inconveniences: noise, dust, partial closure of streets, felling of trees, change of landscape. These changes have not only physical, but also emotional impact: there is a feeling of loss of familiar environment, a decrease in the quality of life, especially among those who valued the silence, greenery and stability of the area.

Such an effect can be called ecological stress - internal tension caused by the violation of the usual natural and visual space. In some cases, it can transform into public discontent, local resistance initiatives, petitions or demands for compensatory greening.

The socio-ecological effect also has a long-term dimension. If construction is not accompanied by a clear information policy, transparency of decisions and community involvement, the level of distrust in projects may increase. On the contrary, when residents' opinions are taken into account and compensatory measures are implemented (e.g., planting new trees, creating new parks or recreational areas), this helps to maintain a balance between infrastructure development and maintaining the local ecological climate.

Thus, the socio-ecological effect is a kind of "community mood indicator", which directly depends on how technical progress is combined with respect for the natural environment and people's interests. Its consideration is a necessary condition for sustainable urban development, where the comfort of residents and the preservation of the ecosystem are considered as parts of a single whole.

2.2. Methodology for assessing ecosystem sustainability

In urban environments, where there is active man-made intervention, there is a need for a clear methodology for environmental impact assessment. The construction of a new subway line in Kyiv, particularly in the Vynohradar district, is a good example of this need. This is a complex infrastructure process that not only changes space but also affects local ecosystems - soil, water regime, green spaces, and microclimate.

At the first stage of the assessment, a general ecological audit of the territory is applied. It includes an analysis of natural conditions - soil types, groundwater levels, the presence of green areas, sources of surface runoff. In the case of Vynohradar, the presence of gray forest soils, which are sensitive to mechanical disturbances and changes in humidity, is recorded. In such cases, it is important not only to record the initial state, but also to predict possible scenarios of changes.

Further, the methodology provides for an indicative approach - identifying key indicators that can be measured on a regular basis. For example, during the construction of a subway, such indicators may include the depth of groundwater, soil moisture, noise and vibration levels, and the concentration of pollutants in the air. All of these parameters are assessed before the start of work, during construction, and after its completion. This allows us not only to assess the damage but also to identify critical areas that need protection or compensation.

A special place is occupied by spatial analysis, which is carried out using geographic information systems (GIS). A digital model of the territory is created on the basis of satellite images, topographic maps and engineering schemes. It allows you to simulate future changes - for example, how the drainage structure will change, how soil subsidence or changes in watercourses may affect adjacent areas. In the case of laying the metro underground, this is critically important to prevent flooding or sinkholes.

The next component of the methodology is an environmental and engineering assessment - a comparison of technical solutions with environmental risks. For example, if tunnels are

laid at depths where damage to aquifers is possible, engineers must provide insulation solutions or change the route. In the case of the Kyiv metro, this may mean switching to trenchless technologies or adjusting the depth of the tunnel.

No less important is a social and environmental survey. Community involvement allows collecting data on the perception of risks by local residents: for them, not only the state of the environment may be critical, but also the comfort of life during construction - noise, dust, traffic restrictions. The results of such studies allow adapting the work schedule or providing additional protective measures.

The assessment methodology is completed by forming an integrated map of risks and vulnerabilities, where the most vulnerable zones are determined based on all the collected data - for example, areas where aquifers lie close together, or areas with high recreational value, such as green spaces along Pravdy Street.

In conclusion, the methodology for assessing the environmental consequences of metro construction is not just a set of technical procedures, but a whole system of interconnected steps. It allows not only to record damage, but also to manage risks, maintaining a balance between infrastructure development and preservation of the urban environment. In the context of Kyiv, where dense construction is intertwined with fragments of the natural landscape, such a methodology is of crucial importance.

2.3. Assessment of the ecosystem sustainability of the Syretsky Forest and Vynohradar area in the context of subway tunnels

To assess the sustainability of the ecosystem of this area, I chose an indicative approach.

2.3.1 Selection of key environmental indicators for assessment

Assessing ecosystem sustainability during the implementation of infrastructure projects, such as the construction of a metro, requires the identification of a number of key environmental indicators. These indicators should be relevant to the nature of the impact, easy to monitor, and capable of reflecting both direct and indirect changes in the state of the ecosystem.

In the case of the construction of a new metro line in Kyiv (Vynohradar district), the following indicators are most appropriate for assessment:

1) Air quality

Construction machinery, dust from earthworks, transportation of materials and lack of green barriers lead to deterioration of air quality. Main substances to be monitored:

- particulate matter (TSP, PM10, PM2.5),
- nitrogen dioxide (NO₂),
- carbon monoxide (CO),
- volatile organic compounds (VOC),
- total pollution level (AQI or AQI - air quality index).

2) Noise Load

The noise level during active construction significantly exceeds the natural background level of the urban environment. The impact of noise is felt not only by people, but also by animals. Monitored:

- average daily noise level (dBA),
- peak values (during peak hours),
- compliance with sanitary standards (60 dB during the day, 45 dB at night - according to DSP 173-96).

3) Soil and groundwater condition

The rupture of natural horizons and a change in the hydrodynamic regime can cause a decrease in the groundwater level or its contamination. Important indicators:

- groundwater depth (m),
- change in pH and mineralization of water,
- humidity and density of soils in the development area.

4) Green spaces

Cutting down trees, destroying lawns, and destroying soil cover reduces the absorption capacity of the ecosystem. They are defined as:

- area of lost green areas (ha or m²),
- number of trees, bushes removed,

duration of biomass recovery (estimate from satellite images or GIS data).

2.3.2 Methods of environmental data collection

Since the thesis did not include full-fledged field monitoring, the main methodology was to use open sources of environmental information and analyze available data related to the construction area of the new metro line to Vynohradar.

First of all, we used air quality data from online resources such as SaveEcoBot, which provides up-to-date pollution indicators in different districts of Kyiv. This resource allows to track the level of fine dust (PM_{2.5}, PM₁₀), which is the main indicator of construction impact on the air.

To analyze the noise load, we used acoustic mobile applications for approximate noise level measurements, which allow us to estimate its average values in dBA. Although these

measurements are not certified, they provide a general idea of the situation within the construction area.

Information on groundwater and soil conditions was collected from hydrogeological reports published as part of the preparation for the subway construction. These documents contain data on the depth of groundwater, soil moisture levels, and other characteristics that are difficult to assess independently without special equipment. In some cases, additional information was found in the public domain.

As for green spaces, satellite imagery and Google Earth maps were used to assess the losses, allowing for a comparison of the site before and after construction. We also analyzed publicly available decisions of the Kyiv City Council on tree removal.

In general, the data collection method in this paper focused on analyzing available, mostly public sources of information. This approach is appropriate in conditions of limited resources and allows for a basic assessment of the environmental condition of the area affected by the infrastructure project.

Application values (Vynogradar district, 2025)

1) Air quality

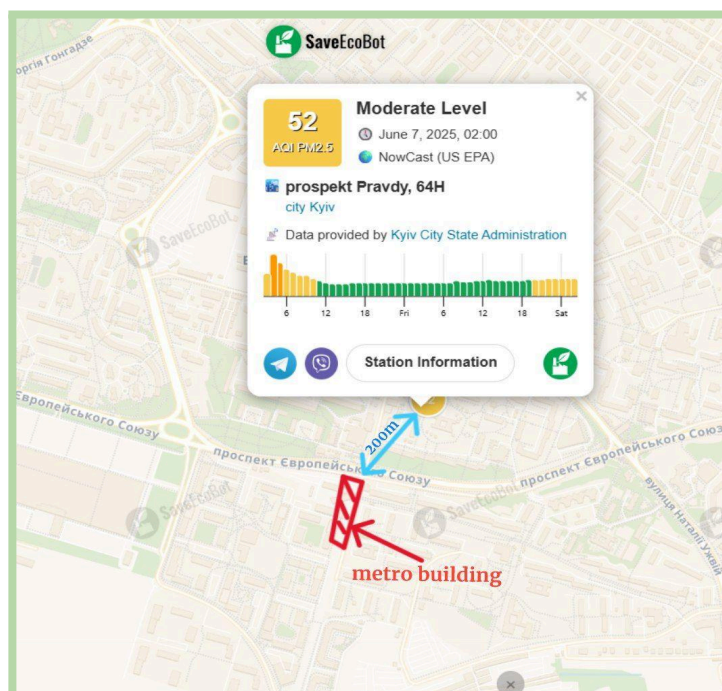


Fig. 2.7 AQI PM2.5 indicator in the vinogradar district

During observations in the area of construction of a new metro line on Vynohradar, according to the SaveEcoBot platform, the PM2.5 indicator was recorded at an AQI level of 52. This level belongs to the category of "moderate pollution" - it is not yet critical, but indicates a noticeable presence of fine dust in the air.

For most people, this indicator does not pose a serious threat, however, people with increased sensitivity, including children, elderly residents, and people with respiratory diseases, may experience mild discomfort.

This result is another reminder that even when environmentally friendly transport such as the metro is built, environmental pressures still arise. That is why it is important not only to react to already noticeable changes, but also to monitor indicators in real time - so that the urban environment remains safe and comfortable for all its inhabitants.

2) Noise load

During my own visit to the construction site at Vynohradar, I conducted an approximate measurement of the noise level using a mobile application. In the daytime, the indicator reached 81 dB, which is significantly higher than the recommended norm for the urban environment (60 dB during the day according to sanitary standards).

This noise level is typical for the active construction phase: heavy machinery is in operation, excavation work is underway, and traffic is moving. However, for residents of nearby buildings, this creates a significant acoustic load, which over time can cause fatigue, headaches or decreased concentration, as well as negatively affect their psycho-emotional state.

Noise is not only a side effect of development, but also part of the environmental context in which people live. And if its level remains high for a long time, it is important to take measures: restricting work at night, installing noise barriers, or reviewing the schedule of active construction activities in densely populated areas.

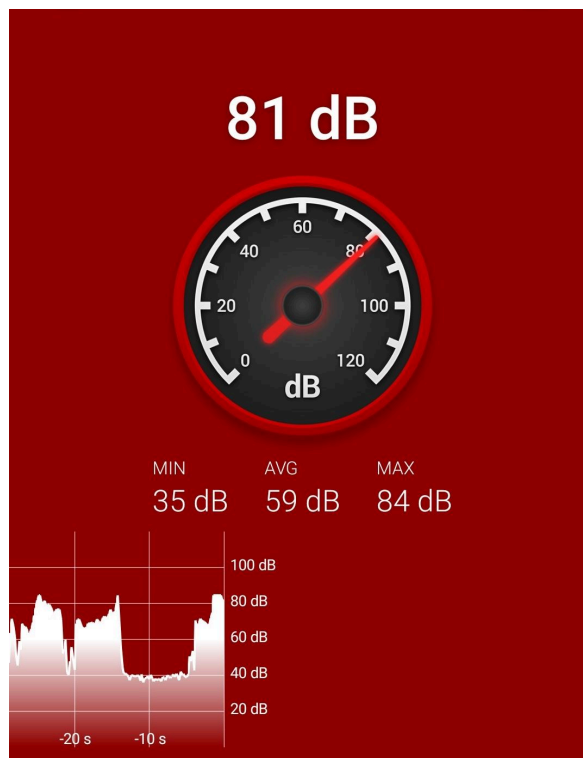


Fig. 2.8. noise level

3) **Soil and groundwater condition**

One of the important environmental parameters that was taken into account when assessing the sustainability of the Vynohradar metro construction area is the depth of groundwater. According to available hydrogeological information, this area is located on the Jurassic aquifer — one of the deepest and most stable layers within Kyiv. It is thanks to this geological feature that the depth of groundwater here is on average about 120 meters, and in some areas — even more.

This gives a certain natural advantage: water at such a depth is largely protected from surface pollution, seasonal fluctuations in humidity, and ordinary household interventions. However, at the same time, this does not mean complete environmental safety. Large-scale construction — especially with active drilling, vibrations, and changes in the soil profile — can disrupt the hydrological balance even at such a depth.

If the aquifer receives additional load or partially loses its tightness, changes in pressure, leaks, or even shifts of deep rocks are possible, which will negatively affect not only the natural environment, but also the stability of built-up areas. It should also be borne in mind that any violation of the water regime may have delayed consequences - for example, gradual drying or, conversely, flooding of individual areas. Therefore, knowledge of the geological structure and origin of groundwater is not just background information, but a critically important factor that must be taken into account at all stages of design and implementation of construction works. In the case of Vynohradar, this is especially relevant, since underground processes here are closely related to the long-term natural regime, which is easy to disrupt but difficult to restore.

4) Green spaces

To assess how the metro construction will affect the environment in the Vynohradar district, I conducted my own analysis using satellite imagery. First, I outlined the boundaries of the area that would be most affected by the construction — an area of about 8 km², which includes not only the site itself, but also nearby streets, temporary infrastructure, traffic zones, etc.



Fig. 2.9. the territory for the study is defined

Next, based on the image, I calculated the area of the main green spaces within this territory. Only large areas were taken into account - forest parks, dense groups of trees, squares and other noticeable green areas, that is, those that are clearly visible from the satellite. Grass, single bushes or landscaping in yards were not included in the calculation. The results showed that green spaces occupy about 1.73 km², or 21.6% of the total area of the impact zone.

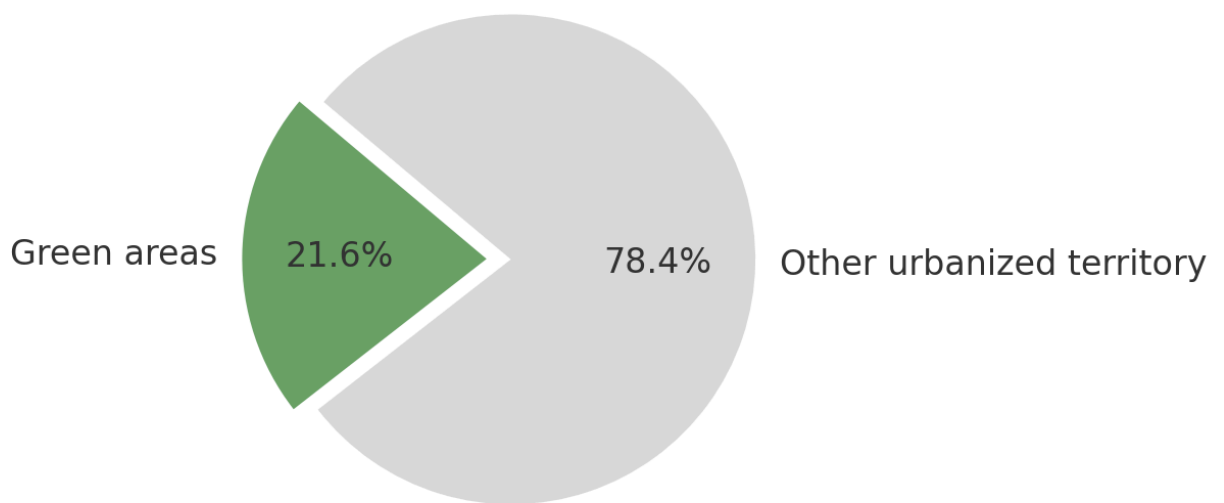


Fig. 2.10. Land cover within the metro construction impact zone

This means that the vast majority of the space around the construction site is already urbanized or has been significantly altered. In this context, green areas are islands of natural environment that play an important role: they soften the microclimate, purify the air, reduce noise, and create a visually pleasing space. However, in construction conditions, these areas are the most vulnerable to changes due to dust, soil compaction, and limited access to light and moisture.

Thus, even if green areas formally remain in place, their environmental quality can be significantly reduced. This once again confirms the importance of a cautious approach to

development and the need not only to preserve green areas but also to maintain their actual environmental condition in the course of urban development.

Table 2.1.

Measuring results

| Indicator | Measured Value | Interpretation |
|---------------------|------------------------------|--|
| Air Quality (PM2.5) | 52 AQI | Moderate air pollution; may affect sensitive groups |
| Noise Level | 81 dB | Above recommended limit; potentially harmful with long exposure |
| Groundwater Depth | ≈120 m | Relatively deep due to Jurassic aquifer; stable but not immune to disruption |
| Green Area Coverage | 1.73 km ² (21.6%) | Limited green coverage; vulnerable to urban pressure |

The table summarizes four key environmental indicators that give a general idea of the state of the natural environment in the Vynohradar metro construction area. Each of them reflects a certain aspect of the impact on the ecosystem, from air quality to soil and vegetation conditions.

In particular, the level of air pollution (52 AQI) is within moderate limits, but it can already affect sensitive groups of people. The noise level (81 dB) recorded during the daytime exceeds sanitary standards and creates a real burden on residents. The deep occurrence of groundwater (approximately 120 meters) indicates a certain hydrogeological stability, but even this can be disrupted by intensive anthropogenic impact. Of particular concern is the proportion of green spaces - only 21.6% of the area of the zone, which indicates a high level of fragmentation of the natural environment and the need for its preservation.

Thus, each of these parameters carries important information about the overall ecological balance of the area and emphasizes the need for a cautious and responsible approach to urban development.

2.3.3 Calculation of sustainability indices normalization results

In this study, for the final assessment of ecosystem sustainability, I use a simplified but visual methodology based on the ratio of positive environmental characteristics to anthropogenic pressures: $S = P / A$. This approach allows to integrate various indicators into a single index that reflects the general state of the ecosystem under the influence of urban development. The formula is an adapted model based on the logic of ecological balance: the higher the values of positive parameters (e.g. soil moisture, groundwater depth, green space) compared to man-made factors (noise, pollution), the higher the sustainability of the territory. The method was chosen for its simplicity, accessibility for practical application, and ability to reflect the overall dynamics of the environmental state even in the case of limited field data.

Process:

Identification of indicators: Key environmental indicators that characterize the state of the ecosystem, such as the level of greenery, soil moisture, pollution, etc., are identified.

Data normalization: Each indicator is converted to a dimensionless scale from 0 to 1, where 1 corresponds to the best condition for positive factors and the worst for negative factors, using the formula - $A_i = 1 - (X - X_{min}) / (X_{max} - X_{min})$

Calculation of the sustainability index (S): The S index is calculated as the ratio of the sum of normalized positive indicators to the sum of normalized negative ones:

$S=P/A$, where P is positive environmental parameters (green spaces, groundwater), and A is anthropogenic load (pollution, noise, etc.).

1) Air quality:

The actual value of the air quality index in the area of the construction of the metro on Vynohradar is:

AQI = 52

$$A_i = 1 - (X - X_{\min}) / (X_{\max} - X_{\min}) \quad (2.1)$$

де: X — the actual value of the indicator (in our case, 52),

$X_{\min} = 0$ — the best possible value (ideal)

$X_{\max} = 100$ — the worst permissible value (the limit level of pollution according to the European AQI scale).

$$A_i = 1 - (52 - 0) / (100 - 0) = 1 - 0.52 = 0.48$$

2) Noise Load:

The actual noise level in the Vynohradar metro construction area is:

Noise level = 81 dB

where:

- X = 81 — actual noise level value (in dB),
- $X_{\min} = 30$ — optimal noise level for the natural environment (background),

- $X_{\max} = 100$ — critical noise level (harmful to human health and fauna, accepted as the upper limit of what is permissible in urban conditions).

$$A_i = 1 - (81 - 30) / (100 - 30) = 1 - (51 / 70) \approx 1 - 0.73 = 0.27$$

3) Groundwater:

X (fact) — depth of the aquifer in the Vynohradar area: 120 m

X_{\min} — minimum safe depth at which water is not yet exposed to anthropogenic factors: 30 m (conditionally — close to the surface, vulnerable).

X_{\max} — ideal, fully protected depth (e.g., deep artesian horizon): 350 m (maximum from the source).

$$A_i = (120 - 30) / (350 - 30) = 90 / 320 = 0.28$$

This is considered a low level of sustainability in terms of this indicator, meaning that the water is not deep enough and can potentially be affected from the surface in the context of metro construction (vibrations, changes in soil structure, etc.).

4) Green spaces

X — percentage of green spaces in the selected area that is affected by the metro construction 21.6%

X_{\min} — Less than 10–12% — already indicates environmental vulnerability, especially if green areas are fragmented and do not form a single network.

Xmax - 40-63% - is considered to be the ideal ratio between buildings and nature. Such indicators are typical for environmentally friendly cities.

$$A_i = (21.6 - 10) / (63 - 10) = 11,6 / = 0,22$$

Table 2.2.

Normalization results

| Indicator | Value | Normalisation index |
|-------------------|--------|---------------------|
| Air quality | 52 AQI | 0.48 |
| Groundwater depth | 170 m | 0.44 |
| Noise load | 81 dB | 0.27 |
| Green spaces | 21,6% | 0.39 |

Calculation of the sustainability index

Behind the formula $S=P/A$, where P - positive environmental parameters (green spaces, groundwater) and A - anthropogenic load (pollution, noise, etc.).

S - sustainability index -?

P1 (Groundwater depth)- 0.44

P2 (Green spaces) - 0.22

A1 (Air quality) - 0.48

A2 (Noise load) - 0.27

$$S = (P1+P2)/(A1+A2)$$

$$S = (0.44+0.22)/(0.48+0.27) = 0.66/0.75 = \underline{\mathbf{0.88}}$$

The main environmental indicators that affect the sustainability of the Vynohradar district ecosystem were calculated using the ecosystem sustainability index (S), which is defined as the ratio of the sum of normalized positive environmental indicators to the sum of negative (anthropogenic) impacts. The obtained value of the sustainability index $S = 0.88$ indicates a relatively unfavorable state of the environment in the area of construction of the new metro line to Vynohradar. This means that negative anthropogenic factors currently prevail over positive natural impacts, although the latter are also quite significant. At the same time, it should be noted that the result is indicative and analytical in nature - it demonstrates the correlation, but is not a full-fledged environmental assessment.

CONCLUSIONS

This paper investigated how large-scale construction, such as the construction of a new metro line in the Vynohradar district, affects local urban ecosystems. The study covered key aspects such as the structure of the urban environment, the impact of anthropogenic factors, and the potential of ecosystems to remain resilient in the face of change. Particular attention was paid to assessing the sustainability of ecosystems using a set of environmental indicators. The calculated index $S = 0.88$ allows us to draw a preliminary conclusion about the relatively unfavorable current state of the natural components of the study area. At the same time, it should be emphasized that the calculation itself is conditional and does not provide grounds for accurate forecasting. Rather, it performs an analytical function, allowing us to orient ourselves in the ratio of positive and negative environmental impacts. The paper does not claim to be a full-fledged environmental assessment, but demonstrates the possibilities of a basic assessment of the urban environment based on open data, logical analysis, and simple calculations. The conclusions drawn can be useful as a starting point for further research or in-depth monitoring. An important result is also the understanding that the urban environment is extremely complex and vulnerable, so any construction should be accompanied by not only technical but also environmental considerations. Even a conditional assessment based on public indicators can reveal potential negative impacts on local ecosystems.

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