Research of Nature-Based Solutions to Improve the Biocapacity of Cities and Increase Sustainable Development

Aleksandr Kononov[1], Elena Pavlova[2], Evgenii Iushkov[3]
ITMO University, Kronversky Avenue 49, Saint Petersburg, Russia
411558@niuitmo.ru, eapavlova@itmo.ru, Eevgeny1998@gmail.com

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Abstract: With the rapid growth of the urban environment and an increase in the number of citizens, the issues of environmental sustainability and conservation of the naturaleenvironment in cities are becoming increasingly relevant. The research of nature-oriented solutions to improve the bio-capacity of cities and increase sustainable development is an important topic that attracts the attention of researchers, urban architects, and the public. Nature-oriented approaches include the integration of green areas, the use of natural water resources, consideration of ecosystem needs in construction, as well as other innovative methods. The aim of these studies is to create sustainable urban development strategies that reduce the environmental impact, improve the quality of life of citizens and preserve biodiversity in the urban environment.

1 INTRODUCTION

In recent decades, humanity has faced growing environmental challenges, such as climate change, loss of biodiversity, environmental pollution, depletion of natural resources, and others. Solving these problems requires collective efforts and science-based decision-making. The current vector of urban development is to maintain a balance between bio-intensity and the ecological footprint of the population, these two indicators, that correlate with each other and are aimed at maintaining sustainable development, green transformation, and economic growth, as evidenced by the Sustainable Development Goals, adopted by the UN on September 25, 2015 (Gabbi, Matthias, Patrizi, Federico, Bastianoni, 2021).

Today, sustainable development is acquiring new trends related to the economy, ecology, and social institutions. To understand the whole picture of the world, we need a universal indicator that will reflect the relationship of many elements on the part of humanity and nature. This integral indicator can be biointensity.

2 BIO-CAPACITY AS AN INDICATOR OF SUSTAINABLE ECOSYSTEM DEVELOPMENT

The concept of bio-capacity is related to the assessment of the consumption of natural resources and the analysis of their sustainability. Bio-capacity determines the ability of an ecosystem to restore the resources needed to meet the needs of humanity and absorb the waste that human activities leave behind.

The use of natural resources and the production of waste that exceeds the bio-capacity of an ecosystem can lead to environmental degradation, resource depletion, and other environmental problems.

When we talk about bio-intensity, we mean several key types of land use, such as arable land, pastures, forest areas, built-up areas, and fishing areas. These territories are currently undergoing a global change, during уменьшается which the stock of bio-productive territories decreases, which in the future can lead to economic instability not only of the local territory, but also of a larger area (Sowińska-Świerkosz, García, 2022). To maintain and further

[1] https://orcid.org/0009-0001-2753-8180
[2] https://orcid.org/0000-0001-6492-7102
[3] https://orcid.org/0009-0005-2488-0422

increase the bio-intensity, it is necessary to properly manage the resources and the study area. To calculate the bio-intensity, there is a certain method, which implies that the bio-intensity (BC) of the study area is the total indicator of various types of land use:

$$BC = A * YF * EQF, \qquad (1)$$

where BC is the bio-capacity, A is the available area of the studied land use type, YF is the yield coefficient, and EQF is the equivalence coefficient for the considered land use type in the country.

The yield coefficient, in turn (YF) (2), is calculated as the ratio of the yield of the considered categories of land in the territory to the yield of this category of land in the world.

$$YF = \frac{\text{crop yields (territories)}}{\text{level culture (world)}} \qquad (2)$$

Equivalence Factor (EQF) - is a coefficient for converting the actual acreage for different categories of land in hectares to their global equivalent in global hectares. Equivalence factors for different types of surfaces were taken from the dissertation on the study of bio-productivity (Boev, Burenko, Shvartz, 2017) (Table 1).

Table 1: Equivalence factors for different types of bio-productive surfaces.

Type of bioproductive land surface	EF
Arable	2.51
Pasture	0.46
Forest	1.26
Fishing land	0.37
Built up land	2.51

Global hectare (gga) is a conventional unit that characterizes a hectare of bio-productive area or water area with an average global indicator of bio-productivity for a year of research. The global hectare is a composite unit for calculating the "ecological footprint" and bio-intensity (Boeva Shvartsev Knizhnikov Voropaev , 2014).

The global experience of using this methodology shows that this method has a number of limitations. The key indicator is the complexity of collecting reliable statistical information, which varies, differs, and sometimes even is not available in different sources. Such information is: the area of pasture and arable land, studied at the local level, data on the average yield of pastures and agricultural crops. crops, as well as information on fishing grounds.

An analysis of the consumption of natural resources and the impact of human activities on ecosystems allows you to determine the level of environmental sustainability and take measures to improve the situation. And the bio-capacity calculation can help determine the acceptable level of resource consumption and waste generation to support the sustainable functioning of the ecosystem.

Currently, there is no single strategy for increasing bio-intensity in the world. Improving biological potential requires comprehensive measures, including effective management of natural resources, reduction of waste consumption and production, development of environmentally friendly technologies, conservation of biodiversity, and others. Environmental decision-making based on bio-intensity analysis can create a sustainable framework for development and ensure that the environment is preserved for future generations.

Thus, bio-intensity is an indicator that allows influencing decision-making in the field of sustainable development, allowing you to determine the level of ecosystem sustainability and develop strategies for improving the situation. Taking measures to improve bio-capacity is important for ensuring sustainable development and preserving the environment. Scientific research and an interdisciplinary approach are also important for developing effective strategies to improve biocapacity and make environmentally sound decisions.

3 NATURE-BASED SOLUTIONS TO INCREASE THE BIOLOGICAL POTENTIAL OF CITIES

Modern cities face a number of environmental challenges, including air pollution, deterioration of soil and water quality, and loss of biodiversity. These problems are caused by various factors, including urbanization, industrialization and climate change, and the loss of biocapacity (Luo, Cai, Zeng, Zheng, Lin, 2024). To address these issues, it is necessary to look for nature-oriented solutions that can help improve the biological potential of cities and increase sustainable development.

The concept of natural resource-based solutions (NBS) was first put forward in 2008 by the World Bank. The first research program on nature-based solutions was conducted in 2013 (Sowińska-Świerkosz, García, 2021). The concept solutions as a result of the search for innovative solutions for managing natural systems in such a way as to create a balance between nature and societyом. In other words, receiving from nature not only resources, but also its way of acting, using as many resources as necessary for life and making up for what was used. Thus, it turns out that human communities can develop and implement solutions for a sustainable, resource-efficient, and green economy. For many years, the scientific community could not come to a single consensus on what NBS is. According to the EU report on NBSследует, "the concept of natural solutions embodies new ways of approaching socio-ecological adaptation and sustainability, equally relying on social, environmental and economic areas" (Dumitru, Wendling, 2021). To clarify the conceptual nature of NBS, the IUCN global Standard includes eight criteria that can be used to form a cluster of economically green interventions as NBS actions. These criteria are based on the principles of the concept and on feedback, received from public authorities involved in green policy: (1) solving social problems; (2) scale of intervention in the natural landscape; (3) increased biodiversity; (4) economic viability; (5) ability to manage; (6) equitable ecological and economic balance; (7) adaptive management; (8) relevance in the relevant jurisdictional context.

In practice, e- solutions include such aspects as the creation of green zones, reservoirs, sustainable use of natural resources, the development of environmentally friendly modes of transport and public space (Sowińska-Świerkosz, García, 2022).

One of the most important aspects is the development of urban parks and green areas. Their creation and maintenance contribute to improving air quality, preserving water resources, creating places for recreation and entertainment, and also contributes to the formation of an ecological infrastructure of the city.

In addition, sustainable water resources management is also a key issue. The introduction of methods for collecting and cleaning rainwater, the creation of reservoirs, recreational areas and systems for water reuse allows cities to ensure sustainable use of water resources and improve the environmental situation.

The integration of eco-friendly modes of transport and the development of infrastructure for pedestrians and cyclists also play an important role in improving the biocapacity of cities (Bressane, Hashimoto, 2024). The creation of hiking areas and bike paths will reduce air pollution and create favorable conditions for an active lifestyle of citizens.

To study natureoriented solutions to improve the biointensity of cities, an analysis of existing research and practices in this area was conducted. The main principles and approaches that can contribute to achieving these growth points to improve the bio-intensity of cities were identified.

Today, there are various natural solutions, but for each location where NBS will be implemented, it is necessary to take into account local climatic, economic, and social factors and determine the adaptability of innovations. The territories of many countries may include different climatic zones and urban conditions, and it is impossible not to take into account the fact that a large number of natural solutions are more adaptable to countries with mild climates, where the weather is warmer most of the year and there are more sunny days, based on this, in the opinion of scientific communities, it is necessary to take into account the following features (Hossein, Zarfeshani, Arast, 2024). Local adaptation of environmental solutions in each research area and the possibility of implementing such solutions in relation to the specifics of climatic conditions.

One of the most effective natural solutions for the territories of most countries of the world, and first of all, urban settlements, can be the concept of vertical gardening, which consists in creating and hydroponic vertical gardens aimed at absorbing carbon dioxide, street noise, creating a new format of park areas within the city, and also serve as an important catalyst for improving the quality of urban biodiversity. This approach includes the following ecosystem services (Maksimova, 2020):

- mitigates the effects of global climate change;
- creates conditions for recreation of citizens;
- forms the cultural identity of the city and its individual districts;
- reduces the city's "heat island".
- manages rainwater runoff.
- adjusts the wind speed.
- cleans the air from dust.
- absorbs carbon dioxide and releases oxygen.
- supports the biodiversity of urban animals and plants.

Vertical gardening has been known to the population for a long time, but now this environmentally oriented method is gaining a new trend among architects, environmentalists, and managers of nature-oriented areas. Vertical gardening is becoming more popular every year and is being introduced into urban planning, being a leading trend in urbanization and sustainable development based on natural solutions. For its active implementation in the urban environment, it is necessary to popularize this concept at various hierarchical levels, from local initiative to communicating this idea to the level where urban decisions are made on planning the environmental strategy of regions. The creation of green walls will develop the ecological framework of cities, increase the biodiversity of urban areas, improve the ecological situation, thereby contributing to the increase in the city's bio-potential.

Turning to historical chronicles, we can recall how in ancient times people collected rainwater in various containers, but today, in the context of the increasing influence of climate change and sustainable development, effective water resources management is becoming an increasingly important task. In this regard, the use of rainwater and snow as one of the options for nature-based solutions is an important innovative approach to sustainable water use. Collecting rainwater or snow can be relevant at different times of the year and in many cities due to the country's climatic features. Naturally collected sediments in special containers can be used as a backup water source in case of emergencies оря when water is turned off to the building.

Collecting, storing, and using rainwater and snow has several advantages. First, it helps to reduce the consumption of groundwater and surface water bodies, which helps to conserve water resources and prevent water scarcity. Second, it promotes more efficient use of water for agriculture, industry, and urban water supply systems. Finally, collecting rainwater and snow can reduce the risk of flooding and erosion, which increases the sustainability of water systems.

Successful projects for using rainwater and snow as one of the NBS systems are already underway in various parts of the world. Many countries in Africa and South Asia actively use rainwater collection and storage to provide drinking water and irrigate agricultural land. Similar projects are also being implemented in other regions, including North America and Europe, where combined with solar energy, in particular with solar panels, water is heated in containers with precipitation, such a symbiosis of natural solutions allows you to effectively use natural sources without harming the environment.

When talking about green solutions for cities, we should not forget that historically, many of the cities are located either on rivers or near large bodies of water. Destruction of coastlines is one of the major challenges faced by many countries due to climate change and overexploitation of coastal areas (Souliotis, Voulvoulis, 2024). Nature-based solutions, including the use of live coastlines, have been widely used to address this problem.

Living shorelines are morphological forms created and maintained by vegetation and biological processes. This includes measures such as the restoration of mangroves (for warm countries), the creation of natural coastal formations from vegetation, plant fencing and other natural ways to strengthen the coastline.

Using live coastlines as an NBS can bring a number of benefits. First, they contribute to the conservation of coastal zones and prevent erosion, which threatens biodiversity and economic infrastructure in coastal areas. Second, living shorelines are a natural means of filtering out pollution and depositing salt, which contributes to improving water quality and maintaining ecosystems in the tidal zone (Waylen, Wilkinson, Blackstock, Bourke, 2024). Finally, they provide coastal residents with protection from floods and hurricanes.

Projects to create living coastlines are being successfully implemented in various parts of the world. For example, in some regions of Asia and Africa, mangroves are being actively restored, and green belts and park areas are being laid out in urban suburbs and coastal settlements to protect against natural disasters.

And the use of live shorelines as one of the NBS options demonstrates the potential of this strategy for preserving coastal zones and improving the sustainability of coastal communities. However, to scale this approach and successfully implement it, it is necessary to continue research, develop regulatory standards, and implement appropriate technologies.

4 CONCLUSIONS

Nature-Based Solutions (NBS) is an innovative approach to sustainable development that aims to use natural processes and biodiversity to address the various challenges facing humanity and ecosystems. In recent years, NBS has attracted a lot of attention as an effective way to adapt to climate change, ensure environmental sustainability, increase biological potential and human well-being.

Based on various studies, projects, and experiences with NBS applications in various regions of the world, several conclusions can be drawn about their effectiveness and potential:

1. Improving ecosystem resilience: Biodiversity and natural processes, using NBS, can offer solutions for restoring and strengthening vulnerable ecosystems. For example, restoring mangroves, creating plant baskets to control erosion, and other

methods help prevent ecosystem degradation and preserve their value.

2. Climate change adaptation: The NBS can serve as an effective tool for climate change adaptation. For example, the use of natural reservoirs and green spaces to reduce the risk of flooding and conserve water resources, as well as the creation of residential zones and parks to regulate the temperature in cities.

3. Cost effectiveness: NBSS can offer additional benefits in the form of cost-effectiveness. For example, green spaces and natural filters can help reduce infrastructure maintenance costs, as well as improve public health and environmental quality.

4. Community approach: It is important to note that NBSS can encourage public participation and an opportunity to engage local communities in nature conservation and improving the quality of life.

In general, it can be concluded that nature-based solutions represent an effective and promising approach to solving various environmental and social problems, and also have a positive impact on increasing the bio-intensity of cities, especially where flora and fauna are in a depressed state. Some of these methods are highly adaptable even to the climate features of the Nordic countries, although many of the green solutions are easier to implement in countries with more pleasant and warmer climates. However, for their successful scaling and integration in various fields of activity, it is necessary to continue research, develop regulatory mechanisms, and share international experience to ensure their sustainable implementation in practice.

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