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ROLE OF GREEN-BLUE INFRASTRUCTURE IN THE FORMATION OF AN ECO-ORIENTED CITY ON THE EXAMPLE OF KAMIANKA-BUZKA CITY

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Abstract. Ecological and economic consequences of a full-scale Russian invasion of Ukraine are difficult to define, outline and quantify because the destructive war continues. For the post-war period, there will be a need to rebuild cities that were destroyed as a result of Russian aggression; at the design stage, it will be relevant to make proposals for the formation of green-blue infrastructure and implementation of eco-oriented solutions in all settlements of Ukraine, in particular, in Kamianka-Buzka city. The analysis of scientific publications on the formation of green-blue infrastructure was carried out and its functional potential was determined; based on the list of basic eco-oriented solutions, a number of proposals were made for the implementation of eco-oriented solutions in the city of Kamianka-Buzka. Given the current environmental situation, priority measures for the implementation of eco-oriented solutions in the city are: increasing the number and density of green areas, placing forest strips along roads, cleaning water surface runoff, modernizing parks, water supply and drainage systems, setting up a river embankment. Strengthening the role of green and blue infrastructure is a growth point that will help Ukrainian cities become more sustainable, progressive, comfortable and developed in the future.

Keywords: green-blue infrastructure, green spaces, greening, urbanization, city.

1. Introduction

The purpose of the study is a comprehensive analysis of international and national experience in the formation of green-blue infrastructure in cities and determination of the functional role of green-blue infrastructure at the stage of reconstruction and restoration of cities in the post-war period. The object of the study is the green-blue infrastructure of Kamianka-Buzka city, whereas the subject is natural-geographic and socio-economic conditions as a prerequisite for improving existing or forming new elements of this infrastructure.

In the conditions of globalization, urbanization and climate change, this topic is particularly relevant and requires a thorough research by the scientific community. The ecological and economic consequences of a full-scale Russian invasion of Ukraine are difficult to define, outline and quantify because the destructive war continues. After the end of the war, Ukraine will need to rebuild and restore not only those cities that were destroyed as a result of Russian aggression, but also those that were partially affected because they did not have proper economic development due to the lack of funding because of the war. It is relevant at the design stage of work to make proposals regarding the formation of green-blue infrastructure and introduction of eco-oriented solutions in urban development, which would significantly help to minimize anthropogenic impact and provide residents with more ecosystem services, while performing functions of a balancing framework between the urban environment and the natural environment. Green-blue infrastructure can help solve a number of environmental problems and provide high-quality ecosystem services in cities that are designed for a comfortable and safe life of citizens.

We have analyzed scientific publications on the formation of green-blue infrastructure and determined

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its functional potential, proposed a list of basic optimization measures and eco-oriented solutions that will be available for implementation in the city of Kamianka-Buzka.

The priority for the community is to increase the number and density of green spaces; greening is one of the main tools for solving environmental problems in the urban environment.

2. Theoretical part

The study uses a number of methods and techniques, including: the method of observation and field research, synthesis and analysis, forecasting, generalization, a descriptive method, a comparative method and others. A number of foreign (Arizona, Beijing) and national scientific schools (Lviv, Kharkiv, Ternopil, Dnipro and others) are engaged in the study of green-blue infrastructure. In particular, scientists of Kharkiv National University named after V. N. Karazin, together with foreign scientists, were engaged in the implementation the International Visegrad Foundation project and jointly published a monograph: "Green and blue infrastructure in the cities of post-Soviet space: studying the heritage and sharing the experience of V4 countries". This monograph most fully discloses the concept and contains a comprehensive analysis of development and maintenance problems of green-blue infrastructure, which are related to aspects of policy, management, technology and gives examples of effective solutions (Maksymenko, Shkaruba, 2022).

The experience and advantages of using green roofs as an element of green infrastructure are revealed in the study of A. Grechko (Grechko, 2022). The process of interaction between urban environment and nature on the example of transformations and development of historical parks and landscapes in Lviv city was studied in the scientific work of Professor M. Nazaruk (Nazaruk, 2010).

With the financial support from Swedish International Development Agency (SIDA), members of Ukrainian climate network (NGO "Plato", NGO "Center for Environmental Initiatives "Ekodiya", "World Wild Fund for Nature of Ukraine" (WWF-Ukraine)) and a number of other public organizations developed a catalog of eco-oriented solutions. The catalog is a guide with 25 proposed solutions that help to solve environmental problems of communities and adapt urban space to the consequences of climate change (Riabyka et al., 2021).

Professor R. Paraniak notes that components of ecological infrastructure, including green-blue infrastructure, are artificial (anthropogenic) and natural ones. An important feature that allows to include an element into the composition of green-blue infrastructure is the availability of an ecological function or provision of ecosystem services (Paraniak et al., 2022).

The Beijing Scientific School defines green-blue infrastructure as an organic integration of blue (water-based), green (vegetation) and gray inanimate landscapes in an ecosystem (Urban ecological infrastructure: an integrated network for ecosystem services and sustainable urban systems, 2016). According to the Arizona School of Science, "Green-Blue Infrastructure (GBI)" is a component of "Urban Ecological Infrastructure (UEI)". Ecosystem services provided by UEI directly affect city well-being and form an important interaction between nature in cities and people living in cities (Urban ecological infrastructure: an inclusive concept for the non-bilt urban environment, 2019).

It is important to distinguish between concepts of "ecological infrastructure" and "green-blue infrastructure". Ecological infrastructure includes administrative, behavioral, biological (reservoirs and green spaces), informational and material components. "Ecological infrastructure" is a broader concept that includes "green and blue infrastructure". "Green-blue infrastructure" is a component of "ecological infrastructure".

Green-blue infrastructure performs a number of important functions, including:

– ecological (mitigation of the effect of heat islands, restoration of biodiversity, creation of a favorable microclimate, purification of atmospheric air and production of oxygen, reduction of noise pollution, absorption and retention of precipitation, etc.);

– economic (attraction of investments for the implementation of nature protection projects, which relate to the development of the green and blue economy, the provision of ecosystem services that can be monetized);

– healthy (supporting physical and mental health);

– recreational (creation of rest areas and places for walks, embankments, etc.);

– decorative (Scherba, Pylypovych, 2023).

Natural and anthropogenic elements are distinguished in the structure of the green-blue infrastructure. Natural elements include rivers, lakes, seas, ponds, oceans, lagoons, water springs, forests, nature parks, herb areas, nature reserves, meadows etc.

Anthropogenic elements include: green roofs, greenhouses, drainage systems, green bus stops,

community composting, green tunnels and bridges, fountains, city gardes, botanical gardens, orangeries, green parking, forest strips, tiered and vertical gardening. Natural elements are of natural origin and formed by air, water and geological environment. Anthropogenic elements are linked with human activity.

We offer a basic list of eco-oriented solutions, which we have divided into three categories (simple, medium-term, and long-term and high cost) in terms of implementation by communities. Each of these solutions implies reducing the effects of heat islands, noise pollution, atmospheric air pollution, flooding, abnormal heat, etc. (Nazaruk et al., 2020). These solutions include restoration of green areas in cities, optimal urban planning, restoration of biodiversity, change in consumer habits and adaptation of communities to the consequences of global climate change.

Examples of simple and affordable eco-oriented solutions are:

1) planting green spaces and arrangement of flower beds, placement of vegetation in flower beds, pots, barrels, etc. This is an example of quick and affordable improvement of streets that does not involve significant financial costs or excessive efforts (Fig. 1);

a b c d

Fig. 1. Examples of simple and affordable eco-oriented solutions: a – planting climate trees on Svobody Avenue in Lviv city; b – tulip flower beds in Stryisky Park, Lviv; c – “eco-hotel” for insects in Stryisky Park, Lviv; d – greening of the facade in the courtyard of the pharmacy museum on Stavropigiyska street, Lviv

2) placement of feeders (special constructions for feeding wild birds) on trees or other spaces of biodiversity (biotechnical structures). Urban fauna provide a number of ecosystem services: insects pollinate flowers, birds regulate insect pests, urban fauna regulate rodent populations, etc.;

3) greening of facades and walls, which, under conditions of constant growth of urbanization, serve as an additional green solution for more efficient use of vertical areas. In addition to the ecological function, green walls perform a decorative and aesthetic function, in particular, such a facade or wall can serve as an art object. Usually, wild grapes, hedges or ivy are used for greening facades and walls (Fig. 1);

4) popularization of eco-oriented solutions and green-blue infrastructure, activity in social networks, awareness raising of environmental education and culture, creation of environmental clubs in educational institutions.

The category of eco-oriented solutions of medium term and cost includes:

1) creation of urban gardens and backyard gardens. These are public spaces created to promote eco-oriented solutions and cultivation of vegetables and fruits. For example, in Lviv city, in the park “Zalizna Voda”, there is a city garden “Rozsadnyk”, created by the NGO “Plato”. There are designated areas for growing organic vegetables; composting facilities for recycling of organic waste and waterproof paths made of wood chips (Fig. 2);

a

b

c

d

Fig. 2. Examples of eco-oriented solutions of medium-term and cost:
a – city garden “Rossadnyk”, a space for urban gardening (project of NGO “PLATO”
in the park “Zalizna Voda” in Lviv); b – Rain park “Enghaveparken” in Denmark (Copenhagen);
c – road made of wooden cobblestones in Pittsburgh city (USA);
d – green terrace of theAndrey Sheptytskyi Center at Ukrainian Catholic University in Lviv

2) arrangement of existing parks and streets, creation of new green spaces in the form of pocket parks, rain parks, etc. A pocket park is a space that is both a green zone and a public space of up to 1000 m^2 in an area characterized by dense construction. Rain parks are deep parts of parks and squares, which in normal times serve as public spaces, and during the period of intense rainfall, they serve as reservoirs for accumulation of rainwater. Examples: Nebesna Sotnia Square in Kyiv city, mini-park next to the shopping mall "Pivdenny" on Shchyretska street in Lviv or rain park "Endhavenparken" in Copenhagen (Denmark);

3) placement of permeable surfaces in parks, playgrounds, parking lots, bicycle paths. Permeable surface is a type of pavement that helps rainwater or melted snow quickly and efficiently penetrate the soil. Permeable surfaces are an alternative to traditional asphalt, concrete, tile or rubber surface. An example is a road made of wooden cobblestones in the city of Pittsburgh (USA) (Fig. 2);

4) green roofs on public or residential buildings. Green roofs are roofs partially or completely planted with plants, and they are divided into extensive and intensive. Extensive green roofs are roofs with a thin vegetation cover consisting of low grass, mosses, and lichens. Intensive green roofs are plant systems with tall plants and even trees. Green roofs can be used to grow food, providing residents with fresh vegetables and greens. The cost of green roofs varies and depends on the complexity of the work, type of roof, selected vegetation, and the expertise for implementation. Examples: a green roof on a building of Polytechnic University in Singapore city; green terrace of the Andrey Sheptytskyi Center at Stryiska Street, 29A, in Lviv.

Eco-oriented solutions that require a significant amount of physical, material and time resources, however, compensate all costs by providing a wide range of ecosystem services:

1) placement forest strips (planted trees) along roads, reservoirs, agricultural lands, fruit gardens. Forest strips provide a number of ecosystem services, in particular they clean the air, serve as ecological corridors and homes for various representatives of fauna, protect crops and pollinating insects (Fig. 3);

a b

Fig. 3. Examples of eco-oriented solutions that require a significant amount of physical, materialand time resources:
a – urban eco-corridor along the "Plante" embankment (Paris, France);
b – landscape reserve "Torfovyshche Bilogorshcha"

2) support and preservation of urban wetlands. Wetlands are areas with constant or seasonally high humidity. In cities and villages with a significant amount of precipitation, wetlands accumulate and purify rainwater or river water, affect changes in the microclimate in the surrounding areas, and serve as a habitat for representatives of flora and fauna. Therefore, instead of draining wetlands, they should be protected and used as an eco-oriented solution. A good example of conservation of wetlands is granting of nature protection status to the landscape reserve "Torfovyshche Bilogorshcha", which is located in the city of Lviv (Fig. 3);

3) urban eco-corridors are areas that connect the key green areas in the city into a single and integral space to create safe conditions for the movement and life of fauna representatives in the urban and urbanized environment. Urban ecological corridors perform the most important ecological function of green and blue infrastructure. This is an ideal system in which eco-

oriented solutions unite and create a green background of a city, an ecological network. Ecological corridors are a natural place in the city that cleans the atmospheric air, mitigates the anthropogenic consequences of the "urban heat island" effect, and creates a comfortable environment for residents. In addition to the ecological potential, eco-corridors have a touristic potential that enhances the aesthetic attractiveness of a city. Staying in urban eco-corridors improves physical and mental health of citizens. Creation of urban eco-corridors requires a significant amount of costs and involvement of specialists from various fields, but ecosystem services that the city will receive are very valuable. The availability of eco-corridors in a city is indication of well-being and significant development of a city in terms of environmental protection (Fig. 3).

3. Results and Discussion

Appling a thorough analysis of scientific publications on issues of the formation of green-blue infrastructure, we have made proposals for the implementation of eco-oriented solutions for the city of Kamianka-Buzka. The city is located in Lviv district of Lviv region, 41 km from the regional center; the area of the city is 8.63 km^2. According to its natural features, the city is located within the boundaries of Male Polissia, a plain terrain with separate hills.

Kamianka-Buzka stretches linearly along the valley of River Western Bug. The local landscape is characterized with numerous rivers and swamps. The green infrastructure of Kamianka-Buzka city is formed by nature conservation areas (natural parks) and all green areas (gardens, squares, street planting, etc.).

Within the boundaries of the Kamianka-Buzka territorial community, the following objects are under protection there: 1) "Park of the 19th century" is located on the area of 3.67 hectares, and has a status of garden and park art of local importance; 2) "Chornyi Park" is located on the area of 1.74 hectares and has a status of garden and park art; 3) "Park named after Taras Shevchenko" with a status of garden and park art of local importance (Kamianka-Buzka territorial community).

The blue infrastructure of Kamianka-Buzka city is formed by the Western Bug and its tributary Kamianka. According to the data of the Water and Soil Monitoring Laboratory on the Western Bug and San River, an excess of ammonium ion, nitrite ion, biochemical oxygen demand and phosphates is regularly observed in the Western Bug. The coastal protection strip along the Western Bug in the city limits is not under protection and is polluted with household waste. After conducting field study in the city of Kamianka-Buzka, we can come to the conclusion that the city is not sufficiently green and eco-oriented, therefore, it requires implementation of a number of eco-oriented solutions.

We propose to implement a number of eco-oriented solutions (optimization measures) that would help improve the living conditions of citizens. We have divided the list of eco-oriented solutions for the city of Kamianka-Buzka into three categories according to affordability for implementation (simple, medium-term, and long-term measures of high cost).

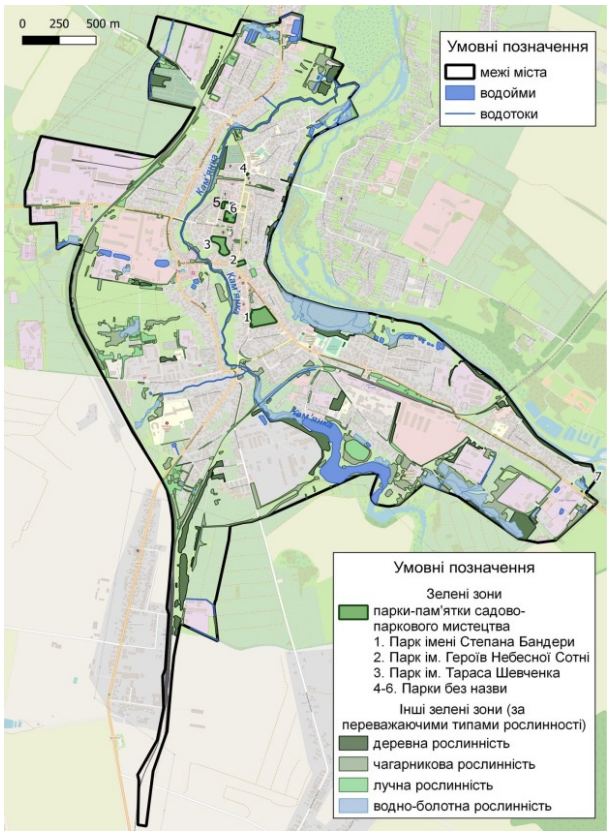

Fig. 4. Map of green area in Kamianka Buzka city

Among the number of simple eco-oriented solutions we suggest:

1) increase the density and number of trees in city parks;

2) greening the central part of the city by planting plants in pots and barrels, arranging flower beds in walking areas;

3) establish communication between the city council and Kamiankavodokanal company regarding the strategy of effective use and high-quality maintenance of parks;

4) organize cleaning activities via ecological clubs.

Category of medium-term eco-oriented solutions includes:

1) plant forest strips on the most congested streets, which will help solve the problem of air pollution;

2) create a buffer zone in “Chornyi Park” (named after Stepan Bandera), which will become a natural barrier between the park and the road with heavy traffic;

3) replace the surface in the parks and repair the fountain.

Eco-oriented solutions of long-term duration and high cost include:

1) clean the coastal-protection strip from waste;

2) carry out works on revitalization of the Western Bug;

3) set up the embankment;

4) modernize sewage facilities and reconstruct water supply and drainage systems.

a

b

c

Fig. 5. a – c – City parks in Kamianka Buzka that require modernation and rennovation

4. Conclusions

The conducted study has identified the potential of green-blue infrastructure in the creation of an eco-oriented city; a list of basic eco-oriented solutions, divided into three categories according to the affordability for implementation by communities, was analyzed; successful examples of international and national experience in the formation of green-blue infrastructure were given. Using the list of eco-oriented solutions, a number of proposals were made for eco-oriented solutions in Kamianka-Buzka city. For the post-war period, there will be a need to make proposals for the formation of green-blue infrastructure and introduction of eco-oriented solutions in urban development. Strengthening role of green-blue infrastructure is a point of growth that will help Ukrainian cities to become more sustainable, progressive, comfortable and developed in the future.

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