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The Influence of Climatic Changes on the Spatial Organization of Riverine Territories

Vadimov Vadim[1], Samoilenko Yevheniia[2]

[1]Department of Urban Planning and Architecture, Poltava Polytechnic National University "Yuriy Kondratyuk", Poltava, Ukraine

[2]Department of Architectural Design and Urban Planning, Prydniprovska State Academy of Civil Engineering and Architecture, Dnipro, Ukraine

Email address:

vmvadimov@ukr.net (Vadimov Vadim), jsamoilik@gmal.com (Samoilenko Yevheniia)

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Abstract: Climate change, due to many unknown factors, is one of the biggest challenges facing humanity today. The main ones among them are: at what speed the processes will take place, what level of climate change is expected at different territorial levels (macro, meso, micro), in different natural and climatic conditions. As well as which regions will be affected, how global climate change will be distributed and which ecosystems will be most vulnerable. The main purpose of this article is to consider possible options of climate stabilization in densely populated riverside areas. The study of the impact of climate change on the riversade areas of Dnipro, the main river of Ukraine, is relevant. The main methods with which the research was conducted were the analysis and logical construction of literature sources. Computer simulations were used to present analyzes related to the factors influencing the urban development of riverside areas. In conclusion it is proposed to develop and implementation of new strategies for adaptation, forecasting, and a new methodology of landscape-oriented spatial planning of riverside urbanized territories based on city-planning clusters.

Keywords: Climate Change, Globalization Processes, Recreation, Riverside Areas, Urban Space, Urban Planning Cluster

1. Introduction

The climate changes that have already occurred have presented humanity with the need to solve a number of extremely important and difficult tasks. These questions, related to the development and implementation of the strategy of their practical existence, affected the natural environment in the form of constant transformations of natural conditions, which affects the level of groundwater and river flow. Numerous studies around the world have been conducted to assess the impact of climate change on water resources. Conventional approaches involve creating scenarios for daily or monthly hy-dro climatic variables using climate model inputs and then applying them to water balance models to investigate implications at river catchment scales [15]. Climate change has transformed into one of the most acute problems of human development, threatening the global economy and international security. Recognition of this fact is highlighted in the Agenda adopted by the United Nations (UN) in 2015 for sustainable development and reduction of the negative impact of climate change for the period up to 2030. The United Nations Framework Convention on Climate Change (1992), the Kyoto Protocol to the Framework Convention (1997) and the Paris Agreement (2015) currently regulate the solution of tasks related to climate change at the global level. According to the Concept of implementation of state policy in the field of climate change for the period until 2030 adopted in Ukraine, the water resources sector is classified as one of the most vulnerable to climate change. In this regard, adaptation to the impact of climate change on the water area, water bodies, water resources, requires research and the formation of strategies, in particular, in the context of water security, and water resources management should be a key element of national adaptation strategies. The general expectation is that the climate will be wetter as a result of global warming. The consequences of climate change will include an increase in the total amount of precipitation in some regions, and in some regions, on the contrary, the appearance of drought and a sharp decrease in water resources. Forecasts of climatic, hydrological and river changes are based on various evidence and assumptions of researchers, including generalizations of climate models, historical and spatial analogies [5]. So the question arises as to how this will affect the cities located on the riverside territories.

2. Analysis Leading to the Determination of Factors Affecting the Urban Development of Riverside Areas

2.1. Redistribution of the Amount of Rainfall by Regions of Ukraine

Climate plays an important role in geological processes. Climate changes will lead to changes in the nature of geological processes and their intensity. Research in this field allows predicting the impact of surface geological processes and possible consequences. In order to prevent their destructive impact, it is necessary to regulate and control the river flow in order to fight floods. During the last decades (in comparison with the period 1961-1990), there was a redistribution of the amount of precipitation in the regions of Ukraine. In general, the amount of precipitation has not changed critically during the year, but there are changes in the intensity and nature of their precipitation. For example, when in a few hours half or a month's rate of precipitation could fall. An increase in temperature and a change in the moisture regime can lead to a further change in the water flow of rivers. This fact will accordingly affect the water supply of certain regions and coastal areas within cities.

According to forecasts, during the 21st century, the majority of administrative regions of Ukraine will see a decrease in surface water flow, which is associated with warming and a decrease in precipitation [12]. According to the estimates of Ukrainian scientists, in the period 2030-2040 there will be less water in the Dnipro River by 29%, and by 37% in the Dniester River. This will lead to reduced productivity and problems in the operation of nuclear power plants, which supply more than 50% of electricity and require constant cooling. Settlements located on riverine territories will need immediate measures to reduce the negative consequences of climate change.

2.2. Raising the Level of the Black and Azov Seas

The results of the research conducted by the Ecodia organization together with scientists show the possible risks of sea level rise. Namely, how the sea level rise will affect the coastal areas of the southern regions of Ukraine [4]. As a result of climate change, in the year 2100, according to the calculations, we should expect flooding of the territory with an area of almost 650 thousand hectares. A rise in the level of the Black Sea means the threat of flooding important infrastructure facilities, industry, entire residential districts, as well as major changes in the ecosystems of coastal regions.

The formation of the flood zone is caused by three main factors: global sea level rise due to warming, movements of the Earth's crust, and seasonal forcing and storms. This zone is modeled on the basis of the maximum justified indicator of global sea level rise – (+ 82 cm) by 2100. What is predicted according to the scenario of maximum projected greenhouse gas emissions? To reflect these features, a zone of possible flooding is modeled (Figure 1).

Source: voda_blyzko_report_full-c.pdf

Figure 1. *Formation of the flooding zone when the sea level rises by 0.82 - 0.91 m.*

As a result of sea level rise, the groundwater level is expected to rise. The change of which will affect the transformations of hydrological flows of coastal areas, affecting the nature of runoff and evaporation. As sea levels rise, levees along the coast and riparian areas that currently protect low-lying areas from flooding will be subjected to additional stress and will be partially destroyed. This will lead to additional flooding and damage both in cities and beyond. This threat is most relevant for Odesa and

Kherson regions, where dams protect the most pastures, fields, and settlements. However, other dams built on the Dnipro may also be destroyed, which puts the territories of the Dnipro and Zaporizhia regions at risk of flooding (Figure 2). The diagram simulates zones of possible inundation of territories, in case of raising the water level to the first and second floodplain terraces.

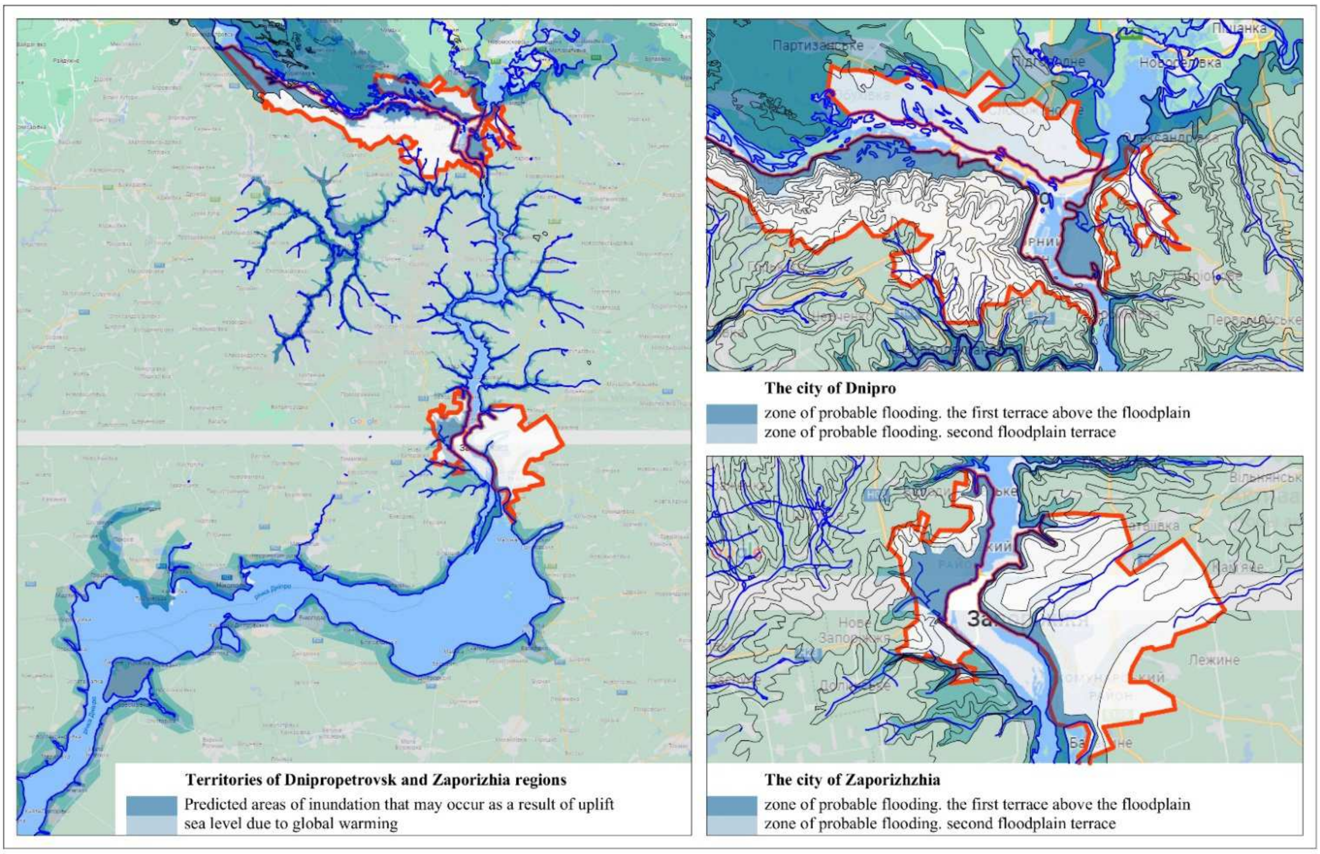

Figure 2. *Formation of the zone of flooding of the territories between the Dnieper and Zaporizhzhia.*

3. Directions of Water Policy in the Conditions of Climate Change

3.1. Projected Climate Change in Europe

When predicting possible consequences of climate change and their reflection on rivers, there are two most important issues that should be recorded. How sensitive is river flow to climate change, and do river channels change annually in response to changes in flow. According to research, even small changes in average climatic conditions can cause large changes in the morphology of rivers [7]. The illustration reflects the importance of the Dnipro river basin and a comparison of the level of urbanization of the Dnipro basin in Europe (Figure 3).

Climatic fluctuations in periods from decades to centuries, as is known, caused significant morphological changes in rivers in Europe and beyond (Figure 4).

Climate change could cause changes in river systems, according to Canadian River Systems Research. Global warming may contribute to more active hydrological processes. Gradually, changes in the regime of precipitation and runoff will affect the morphology and dynamics of river systems. Potential changes will include an increase in precipitation, the proportion of it falling as rain, a decrease in glacier mass, melting of permafrost, and a change in dominant flood-generating processes. Response times to river processes and morphology will vary from years to centuries. According to research, in the case of artificial regulation of the flow, the river undergoes almost instantaneous changes in the flow regime [4].

3.2. Urban Planning Cluster for Urbanized Riverside Areas

Climate change is not the only cause of changes occurring in river ecosystems. Human activity has already changed land use in the riverine territories within the city limits and beyond, affecting the water regimes of most of Ukraine.

The direct consequences of human activity are more immediate and radical than any climatic influence, which can either intensify or mitigate the impact of climate change. For Portugal, Spain, Ukraine and Bulgaria, where currently from 10% to 39% of electricity is provided by hydropower, a decrease in hydropower potential by 20–50% is predicted. In general, for Europe, where the share of hydropower in electricity production is 20%), by the 2070s a decrease in the potential of hydropower by 7-12% is predicted [11].

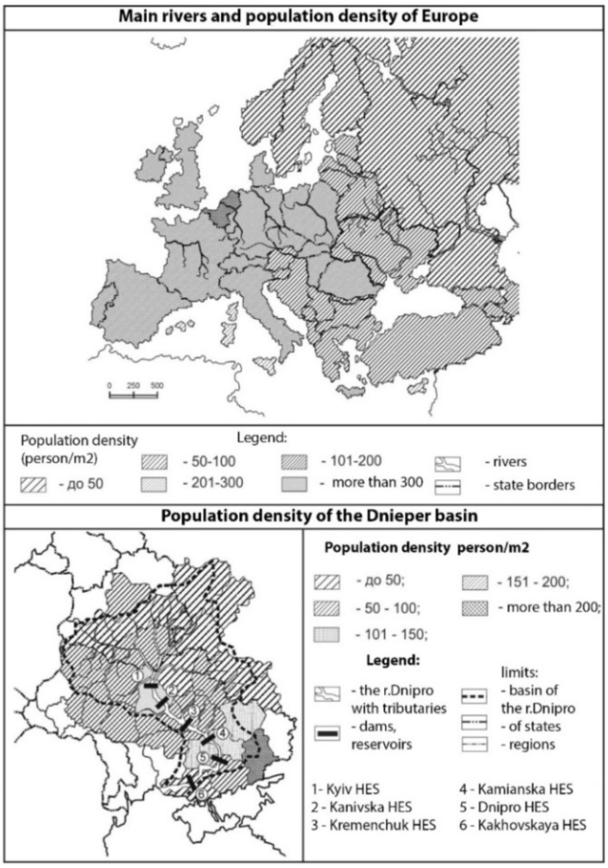

Figure 3. *Comparison of the level of urbanization of the Dnieper basin in Europe.*

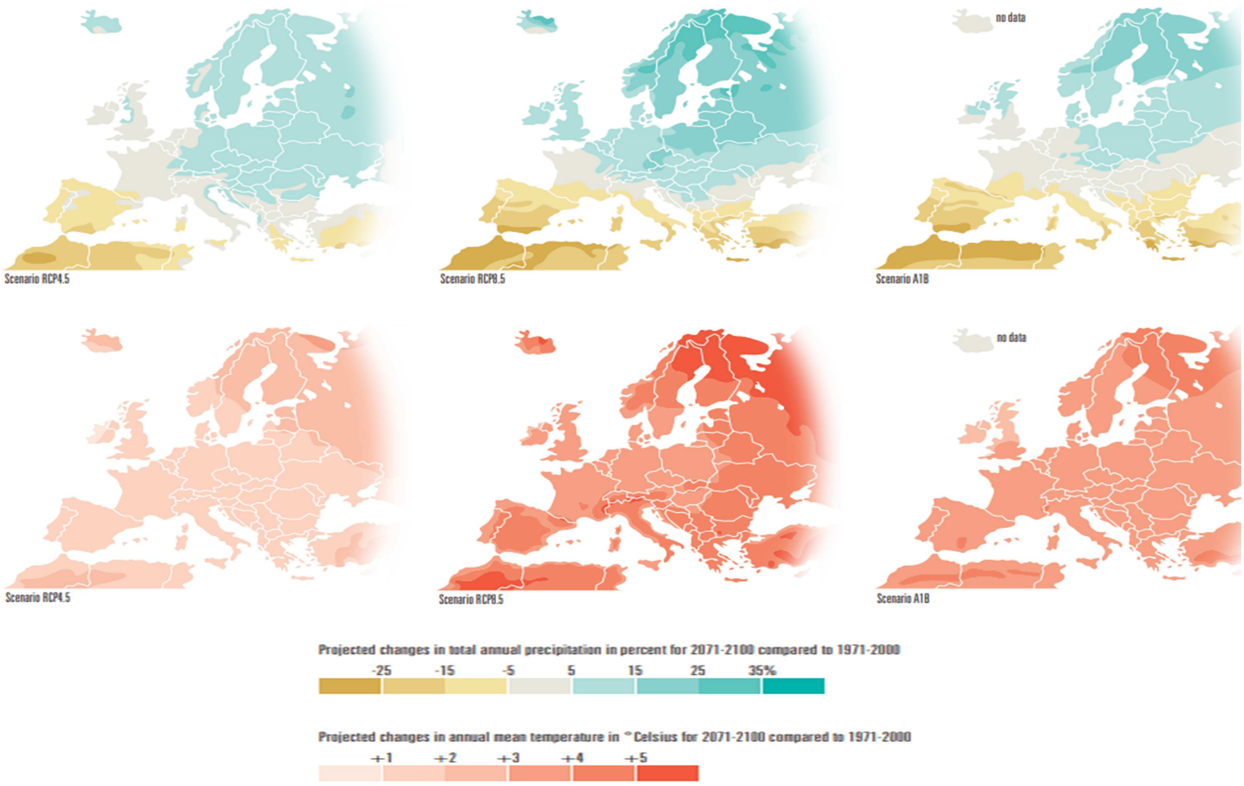

Figure 4. *Projected climate change in Europe. Estimates for 2071–2100 compared to 1971–2000 based on the EURO-CORDEX ensemble under RCP4.5, RCP8.5 and the A1B emission scenario. Source: Jacob et al., 2014, with revisions.*

Rivers are sensitive to natural climate changes, as well as anthropogenic influences, such as changes in river flow, regulation of river systems, intensity of land use, urbanization. Future global climate change may lead to changes in precipitation, which will affect the hydrology and morphology of river systems. Changes in their structure, the rate of coastal erosion of floodplain areas, and the rate of channel migration are also possible. According to research on adaptation to climate change, rising water temperatures and changes in the nature of extreme events, including more intense floods and droughts, are expected to negatively affect water quality, increase pollution and cause warming with possible negative consequences for ecosystems, system reliability water supply and operating costs for them [3]. Thus, it is hypothesized that future increases in precipitation will be amplified by the hydrologic system, leading to increased flood runoff, which may lead to significant changes in the river. Changes in river systems will accordingly affect urban areas within contact zones.

Channel transformations pose a significant risk to urban structures in river valleys, including dams, bridges, intakes, floodplain structures, and riparian areas. Existing flow regulation schemes can counteract the effects of climate change on large rivers, but small rivers remain at risk. It is necessary to assess under what circumstances these direct actions will be leveled or intensified under the consequences of climate change [8]. Large water areas, in particular such as the Dnipro with a system of artificial reservoirs, have a significant stabilizing potential, influence on microclimatic conditions and climate in general. The comprehensive influence of large water areas on riverine territories reaches up to 4 km. The magnitude of the effects will vary regionally and between small and large river basins. In larger watersheds, land-use change is rarely widespread enough to affect the entire basin. The main impact on rivers is expected due to a change in the amount, intensity and type of precipitation, which will lead to a change in the regime of river flow and affect flow processes [3]. Thus, small basins will be affected by micro-level changes, while larger basins will be affected by macro-level cyclonic phenomena. The nature of changes caused by climate change depends to some extent on the size of the watershed. The size of which also affects the large-scale effects of climate change at the macro level compared to local local land use. According to research, the magnitude and direction of changes can be predicted with some knowledge of changes in flow. For example, an increased flow causes channel expansion, migration of its structure [2].

In the conditions of climate change, the directions of water policy should be implemented at the international, national, regional and local levels. According to research by the Institute of Water Problems and Reclamation of the National Academy of Sciences [1]. In order to reduce the negative impact of climatic transformations on the water security of the state in the future, it is necessary to introduce mitigating and adaptation measures: determining the vulnerability of water resources, territories and economic sectors to climate change, forming a national strategy and adaptation plan to climate change. The national strategy should be coordinated with the relevant development strategies of economic sectors and regional development strategies. Measures to combat land degradation and desertification, scientific and monitoring studies on the impact of climate change on water resources, and determination of acceptable levels of water risks are also important.

The ecological aspect of water resources management implies the need to take into account the requirements of the ecosystem to comply with the conditions of natural, extended reproduc-tion of the local flow [6]. Integrated water resources management (IWRM) should be an effective tool for solving strategic tasks of water policy and solving urgent water-ecological problems in the conditions of current and expected climate transformations. In this context, it is necessary to note methodological developments regarding the adaptation of water resources management to climate changes in Ukraine. They were prepared by the UN Economic Commission for Europe and the network of basin organizations:

1) Guidelines on water resources and adaptation to climate change (2009);
2) Guidelines for integrated management of water resources in transboundary basins of rivers, lakes and aquifers (2012);
3) Guideline to the Water Framework Directive (WFD) 2000/60/EU No. 24 "River Basin Management in Climate Change";
4) Water resources management, water security and adaptation to climate change, in the Publication of the Technical Committee of the GWP, No. 14, 2009.

The state of water resources and water supply for the population and economic sectors of Ukraine remains one of the main and urgent threats to the country's national security. This acuteness is due to the fact that Ukraine is one of the countries in Europe least equipped with its own water resources in terms of the specific amount of local runoff in a low-water year, calculated per inhabitant, only 0.6 thousand m^3, and taking into account transit runoff - 1.2 thousand m^3.

Based on this, in accordance with Article 7 of the Law of Ukraine "On the Basics of National Security of Ukraine", dated May 26, 2015 No. 287/2015, among the main directions of state policy is the need to raise the issue of climate stabilization in riverine territories. Implementation of the basin principle of water resource potential management in practice is considered as a necessary condition for the stabilization of the ecological situation. The basin principle of management in the field of water use and protection creates conditions for their rational consumption, provides for the creation of basin water management departments, which will perform functions of planning, coordination and control within catchment basins. The basin approach is also proposed when solving issues of spatial organization of urbanized zones [13]. The Dnipro river basin has a high level of urbanization and population density (Figure 5) comparable to other river basins in Europe.

Engineering and technical measures for adaptation of cities to flooding are the modernization and expansion of the urban storm sewer system to receive large volumes of water during torrential rainfall and the control of sewer cleaning and maintenance [9]. Cities and urban agglomerations are located here: Kyivska, Dniprovska, Kremenchukska, Nikopolska, Kakhovska. Energy- and water-intensive territorial-production complexes and agrarian-processing enterprises are located in the river basin territories. Post-socialist cities in Europe, in Ukraine in particular, were focused on the consumption of resources, ecologically dangerous production with the formation of a residential environment without landscape-oriented design. In order to solve the optimization of the spatial organization of riverside urbanized zones, it is necessary to use modern methodologies, such as fractal urbanism [14]. The methodology of fractal urbanism involves the formation of territorial-spatial, urban-planning clusters. The term "cluster" is most widely used in the field of economics, when forming production based on innovative approaches [10].

In the field of urban planning, the term "cluster" means an innovative urban planning entity with a poly-functional content and with an unstable form-forming morphology, which is able to respond to changes in the clarifying environment. Uncertainty and risks of development of negative consequences of climate change, various projections of climate models require adequate spatial solutions. The urban cluster for urbanized riverine areas will have system-forming elements at three interconnected levels: macro, meso, and micro. The flexible system-forming basis of the urban cluster allows it to adapt to climatic changes in the riverside areas. The diagrams show urban development clusters of riverside territories and the influence of river systems on the planning organization of urban development objects at different territorial levels. At the macro-territorial level, the basin approach will make it possible to determine the stable morphology of the ratio of landscape zones to urbanized ones, at the meso-territorial level, the ratio of natural axes (watercourses of rivers and their tributaries) to urbanized axes, at the micro-territorial level, the ratio of green spaces (natural framework) to built-up areas (Figure 6).

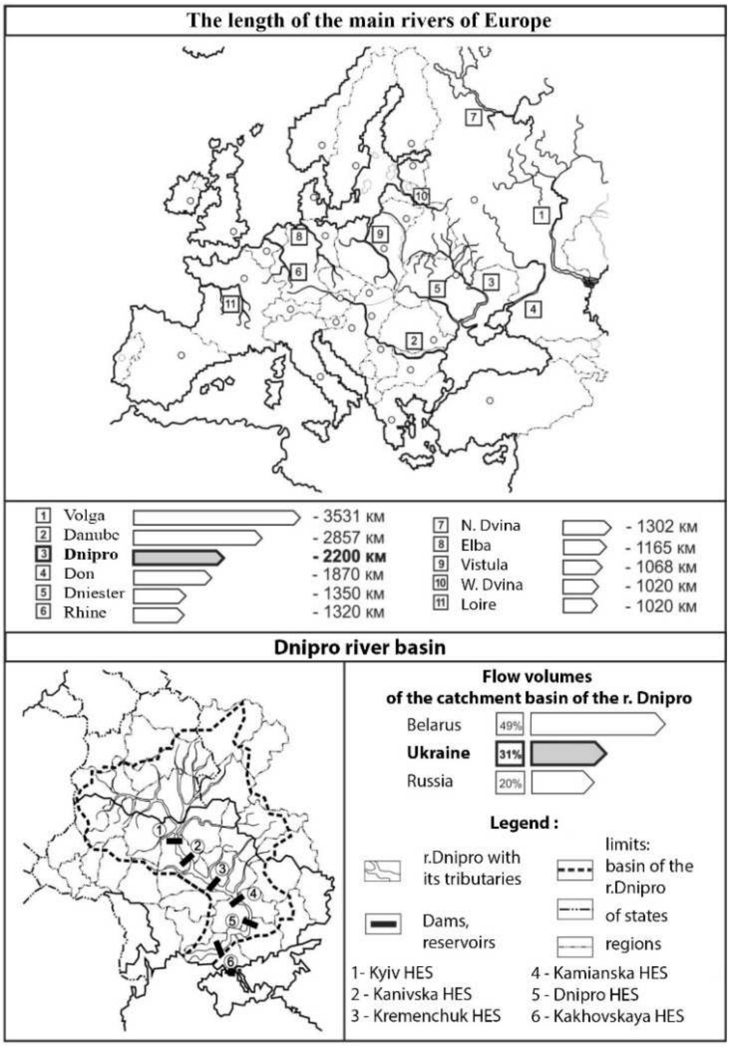

Figure 5. *The importance of the Dnieper river basin.*

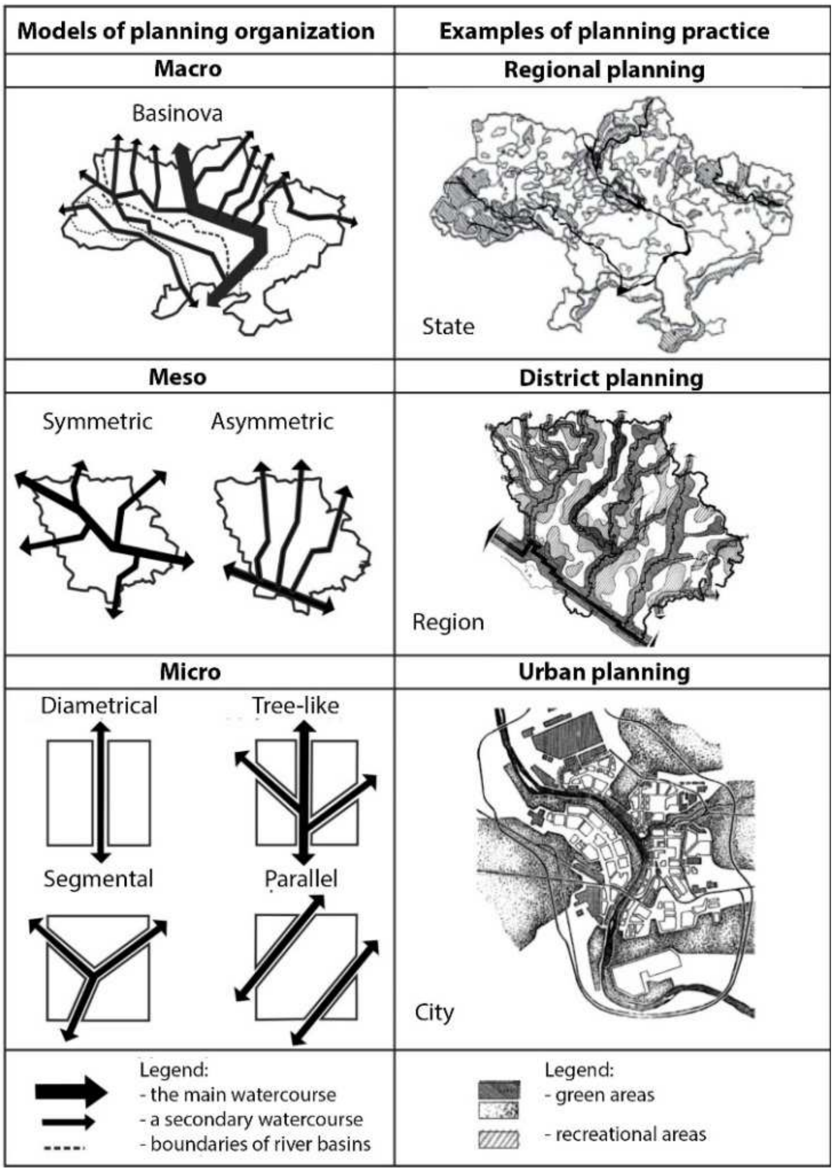

Figure 6. *Formation of the zone of flooding of the territories between the Dnieper and Zaporizhzhia.*

4. Conclusion

This article presents evidence of the most significant effects of climate change, which are expected to shape the future spatial organization and functioning of urban systems in riparian areas. According to observations and climate projections, freshwater resources are vulnerable and have the potential to be significantly affected by climate change, posing a potential threat to the population of urbanized, riverside areas.

However, the ability to quantify future changes in hydrological variables and their impact on systems and sectors is limited by uncertainty at all stages of the assessment process. Uncertainty arises from different scenarios of socio-economic development, different projections of climate models, assessment of the scale of climate impacts depending on the local or regional level. Management strategies that adapt to climate change still need an adequate monitoring network to obtain adequate information.

Methods for monitoring the impacts of climate change on freshwater resources must be improved. In particular, there is a need to obtain local-scale datasets and develop simple climate-related computer models for watersheds that will enable water managers to assess impacts and analyze the performance and sustainability of their systems, taking into account the range of uncertainty associated with projections future climate.

In particular, it is possible to record the vectors of strategic planning in riverside areas.

1) The ecological direction of the protection of riverside territories can be implemented on the basis of the principles of: preservation, restoration and development of the natural potential of river basins and the ability of the water body to self-purify; formation of a barrier-free ecological environment;

2) The urban direction of protection of riverside areas from climatic changes can be implemented on the basis of the principles of sustainable development. Formation of city-planning clusters at three interconnected levels (macro, meso, micro) based on the system-forming elements of the river network together with the transportation and communication framework and multiplicative functional zones.

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