Methodology of planning of landscape and ecological sustainability of natural components in the virtual model (on the example of Volgograd)

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Abstract. Urban planning is a critical issue in urban planning around the world. Real monitoring of landscape and environmental processes, urban planning and sustainable development designers associate with the construction of virtual models. The aim of the study is to develop methodological approaches to planning in the field of landscape and environmental sustainability taking into account the landscape features of the city of Volgograd and the formation of a topographic basis of a virtual model aimed at resolving environmental, social and figurative problems of the city. The construction of the landscape object of the Green ring in the suburban area of Volgograd and the environmental impact of the water surfaces of the Volga river on the sustainable development of the comfortable spaces of the city were analyzed. The modeling for the integration of a system of natural components of the landscape based on the climate aspect and the specifics of the topography in the virtual model of landscape ecological sustainable development the water-green landscapeology. The results of the study reveal the scientific and methodological provisions of urban planning and establish practical goals and implementation of virtual models aimed at preserving the true image of the city

1 Introduction

The urgency of the problem lies in the expansion of approaches to the planning of sustainable development of the system of natural components (landscaping and water resources) in the context of landscape and environmental aspects, on the basis of the results ("environmental quality index"), the design of a virtual model of the landscape is proposed. The aim of the study is to develop a methodological framework for the organization of the system of water-green landscape spaces in the process of urban planning and building a topographic basis of the virtual model. Landscape and ecological study of natural spatial and structural features of the landscape also covers the identification of urban loads (products targeted human activities, the results of man-made intervention and economic development of inter-urban areas) to determine the quality of the city environment.

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The theoretical basis of the article is scientific publications on the issues of sustainable spatial and urban design of landscape components in the following areas:

- study of the features of sustainable multifunctional development of territories in Russia, the definition of the function of sustainable development of territories, proposed methods for solving urgent problems and a comprehensive approach to the transformation of the urban environment [1,2,3,4];
- consideration of the theoretical aspects of landscape planning in the city [5];
- modern ecological situation of water areas, which are devoted to special studies, among them deserves attention work aimed at establishing sustainable development of the Volga river and the Volga basin [6].

The sustainable development of the city landscape in the context of regional subjects is studied in the following works:

- study of the urban possibilities of using the natural terrain of the landscape of the city in improving the comfort of building of the Volgograd [7,8,9,10,11];
- study of the aesthetic potential of water surfaces and the Volga river in the context of environmental sustainability [12,13,14];
- development of models of natural and man-made landscapes on the basis of urban development and urban planning [15,16,17].

Many scientific works are devoted to the study of the creation of virtual spaces of the city. For example, scientific publications analyzing the ways of representation of structurally complex everyday urban space in a virtual network, in which the author believes that the city is presented in the Internet to a greater extent meaningfully, and its topographic model differs greatly from the real [18]. Studies aimed at revealing the characteristics of virtual cities show that models become similar to real ones, combining things from the real world and providing virtual convenience [19,20,21]. Also important are the articles on solving social problems: physical and mental perception of the city by a person, in which through the analysis of scientific theories and cultural practices an attempt is made to identify the structural elements of the urban image. The author believes that the establishment of links between the real and the virtual in the phenomenology of the city allows to describe more broadly the nature of the formation of the image of the city [22].

However, there is no single theoretical approach to the formation of landscape and environmental conditions for sustainable development of the system of natural components of the landscape (landscaping and water resources) in urban planning. The problem of sustainable development has its own aspects for each of them, as well as the landscape serves as a starting point for the formation of a virtual environment at all levels of urban planning. For the purpose of studying and research of formation of landscape and ecological conditions of sustainable development of system of natural components of a landscape of the city in aspect of development of virtual model of the city this work is undertaken. The research covers the methodological basis of the organization of the system of water-green landscape spaces in the process of urban planning and building a topographic basis of the virtual model.

2 Natural and climatic conditions of the Volgograd region

2.1 Climatic characteristic

Volgograd region is located in the South-East of the European part of Russia on the banks of the lower Volga and The middle don. The region is located in the Southeast of The Russian plain, far from the oceans and seas. Therefore, the climate is continental, with cold, snowy winters and long, hot, dry summers. Spring is short, autumn is warm and clear. On abundance of solar heat the area doesn't concede to the southern coast of the Crimea. Plain relief

promotes penetration into the region of different air masses: in winter invades the cold, dry, continental air of the Siberian anticyclone, increasing the severity of winter (average temperatures are the same as in Petrozavodsk, Moscow, -10° , -11°); in summer there is an influx of air masses from the Atlantic ocean. Having passed over the heated surface of The Russian plain, they dry up, heat up and almost do not temper the heat.

The territory of the Volgograd region receives a lot of heat and has a long growing season, its duration is from 145-160 days in the North to 165-175 days in the South. Rainfall receives is not enough - in the Volga during the year receives only 270 - 300 mm of rain in the North-West – 400 - 500 mm. the Lack of moisture in the southern regions and the Volga, to some extent is compensated by artificial irrigation. The distribution of precipitation is influenced by the terrain, usually falls on the hills more. The territory of the region is very extensive, so the climate is not the same, there are noticeable changes - from the Northwest to the Southeast. In this direction, continental, decreasing rainfall, increasing evaporation and dryness.

2.2 Characteristics of green areas

Volgograd region is located in the South-East of Russia, it includes all the main natural areas of the arid zone-Chernozem steppe, dry steppe and semi-desert, the area where drought and droughts, dust storms and water erosion are observed. In the direction from North-West to South-East and the steppe with its black soil is quickly replaced by the southern black soil and the dry steppe, where common dark-chestnut and chestnut soils. The extreme Southeast of the region belongs to semi-desert with its typical light chestnut soils. Along with the General aridity of the climate in some years there are severe droughts: early spring-summer, late-summer or autumn, as well as stable (long-term). Insufficient humidity, salinity, and sometimes salinity, adverse physical properties of soils – all this creates great difficulties in the selection of tree species and their cultivation. For steppe and semi-desert landscapes of the Volgograd region of particular value is woody vegetation. The main role — a multifunctional impact on the environment: protection of agricultural land from droughts, dry winds and wind erosion; water conservation and water management in the basins of small and large rivers; recreational and aesthetic functions, etc.in the region currently there are about 400 thousand hectares of natural forests and 250 thousand hectares of artificial forest plantations for various purposes. Natural forest is confined mainly to low relief elements — the floodplains of the Volga river, Medveditsa, Khoper, don and beams. Only in the North-Western regions - in the subzone of the black earth steppe-they rise to the watersheds. Such their distribution is connected with natural and historical conditions. The average forest cover is about 3.8%. They are distributed unevenly: forest cover in the North-West is 5.8%, in the Volga and southern — only 1.8%. All areas of forests are classified as the first group, which produces only felling and reforestation; 200,5 thousand hectares are green areas, serving as a resting place for workers. The main forest — forming species are: oak — 52,9%, pine — 10,7, poplar-8,2, elm -6,1, ash-4,8, willow-3,9, alder-2,4, aspen-2,4, birch -1,4, maple-1,0, acacia white-0,8%. In the undergrowth there are thorns, birch bark, juniper Cossack, hawthorn, buckthorn, elderberry, Tatar maple and some other naturally growing shrubs.

The region created more than 200 thousand hectares of protective forest plantations, taking into account purpose can be divided into the following categories: state of the forest belt, forest shelter belts, plantations in ravines, roadside, on the banks of reservoirs, on the Sands of the collective and state farms, on the Sands of the state forest [27].

Many factors are responsible for drying up the most valuable forests. Felling during the war period, as a result of which there was a thinning of the forest stand and the introduction of steppe grassy vegetation, led to a significant disorder of the forest stand. Large recreational loads, excessive grazing, soil compaction, mechanical damage to trees, lowering the

groundwater level due to water intake for irrigation and other factors in the complex were the cause of extinction of many valuable forests.

In order to preserve the unique oak forests exposed to high recreational loads, it is necessary to transfer them to the Park area with the appropriate method of management and carry out improvement activities that will improve forest conditions.

2.3 Characteristics of water bodies

More than 240 water bodies are located on the territory of Volgograd region: there are about 190 rivers of various sizes, relating to the basins of the Azov and Caspian seas, the Caspian and Sarpino basins. Most of the territory of the region is drained by the Don with its tributaries: the Khoper, Bear, Ilovlya, Cirom, don Queen, Myshkova, Aksai, Aksay Serverskin with only 165 rivers. The Volga basin occupies a narrow strip along the Volga valley and includes 30 watercourses. The total length of the rivers flowing through the territory of the Volgograd region is 7981 km, 9 of them have a length of more than 200 km, their total length within the region is 1947 km. the rivers are Fed by precipitation (80-90% of the total volume) and groundwater.

Volga, don with large tributaries are used as water transport highways. Large hydroelectric power stations have been built on them, reservoirs have been created, which make it possible to use water to generate hydropower and irrigate fields. Volga and don are connected by a navigable channel, thanks to which a deep-water route between the Baltic, White, Caspian and Azov seas is laid [28].

Volga with tributaries, its sleeves, including Akhtuba river, the territory of the Volga-Akhtuba floodplain and the Caspian sea together constitute a single Volga-Caspian ecosystem, which corresponds in space to the Volga-Caspian basin (figure 1).

Fig. 1. Volga river (panorama of the city and the Volga-Akhtuba floodplain)

2.4 Materials

The creation of an artificial human environment-the urban environment-has contributed to the emergence of urban landscapes that are expanding, capturing large suburban areas. In the aspect of urban planning landscape-a natural resource that significantly affects the process of urbanisation. Sustainable development of the city and its territories involves the protection of the environment and the rational use of natural resources [1], the creation of favorable sanitary and comfortable living conditions of urban residents. Protection of the urban environment in the aspect of sustainable development of cities in the process of urban development is carried out taking into account the organization of the urban environment [1]: inclusion in the planning structure of the city of natural landscapes – water bodies, forest parks, establishing a balance between urban and natural areas of the city, increasing the area of green spaces for public use at the expense of urban forests and forest parks, the creation of recreational areas on the banks of water bodies and watercourses, On the other hand, there

is a need to maintain the quality of the natural environment, to comply with scientifically based standards of impact on it.

One of the aspects of urban planning approach to the landscape is the study of its state in the urban environment. The urban environment of life is a combination of artificially created elements and living conditions, cultural environment and elements of nature. The assessment of the state of the environment of the city life includes the assessment of a variety of environments and factors: air basin, water bodies, geological environment and violation of the territory, soils, flora, in particular the assessment of the quality of green areas, environmental criteria – degradation of gardening, performing a protective function, the rational ratio of green and built-up areas [5].The main task in the development of recreational areas is to create "good" biogeocenosis - landscapes that in conditions of progressive urbanization would have increased resistance to the effects of human activities on them [3]. When assessing the landscape and recreational territory of the city at different stages of urban planning, it is possible to establish the achievement of its functional sanitary and aesthetic functions. In the study of the process of influence and interaction of urban systems, and landscape-recreational territories, there arises the problem of evaluation of quality of landscape-recreational territories on the many factors that influence the status of this territory (figure 2).

Fig. 2. Structure of landscape and recreational environment.

Landscape and recreational area, where a certain environment can be formed, may have a diverse combination of natural ecosystems. The assessment indicators can be climatic factors, vegetation and water bodies, relief and a combination of ecosystems. The following can be accepted as the main indicators of the condition of the greened territories in the conditions of the city environment in relation to objects of flora (table1).

Table 1. Criteria of the status of flora for environmental evaluation of the building site and the surrounding area [23]

Status indicators	Characteristic	
	Norm	The threshold critical impact
1	2	3
Biodiversity (decrease of diversity index Simpson's, %)	less than 10	10–20
Forest cover, % zonal	more than 80	60–80
Damage to forest stands by anthropogenic emissions emissions, % of covered area	less than 5	10–30
Damage of needles by anthropogenic emissions, % of biomass	less than 5	10–20
Forest stands disease , in % of trees	less than 10	10–30
Changing the areas of rare species and species	absents	weakening, thinning

listed in the Red book		
The density of recreational pressure, in % of the norm	less than 10	10–20
Species composition, % decrease in the area of the main forest species in 20 years	less than 5	5–10
The clutter of the forest, in % mortality over 20 years	less than 10	10–30
Alienation of vegetation, in % of area: wind erosion of soils water erosion of soils exposure of indigenous breeds	less than 5 less than 10 less than 5	5–10 10–25 5–10
Degree of drying of the forest	absent or negligible; fallback does not exceed the norm	slight; drop no more than 1.5 times higher than normal
General background of plantings	dark green	green
The characteristics of the crown	trees without signs of damage	trees with less openwork crown, burn the crown more than 10%, a loss of more than 10% needle or leaf, the yellowing of the crown to 5%.
Area of specially protected areas, % of area	more than 5	3–5
The spatial criterion of the degradation of the vegetation cover, ha	less than 1	1-100 (depending on the nature and type of impact)
Temporary criterion for degradation of vegetation cover, years: woody vegetation grassy vegetation	less than 3 less than 2	3–5 2–3

Table 2. Resource criteria for assessing the state of surface waters [23]

Status indicators	Parameters status of surface waters	
	Norm	The threshold critical impact
Change in river flow, % of original	no more than 15	50-70
Volume of possible one-time selection, m³/s	not less than 5	less than 1

Volgograd has a unique landscape and planning structure, the system of which consists of natural and climatic conditions, forest protection forests of natural and artificial nature, forming a kind of "green ring" around the city and water bodies of various categories (watercourses, lakes, eriks, ponds, reservoir). Over the past decades, there has been a tendency to reduce the green areas of different categories, which leads to a decrease in the loss of environmental and protective functions of green spaces and vegetation cover.

The need to assess the quality of the environment, landscape and recreational areas in the conditions of the planned economic activities should be incorporated at all stages of city planning with the aim of preserving the natural potential of the territory and forming a healthy urban environment and comfortable living environment.

2.5 Statistical and mathematical procedures used to analyze and summarize data

In the course of the assessment it is necessary to analyze the state of the components of the natural environment, information about which is necessary for decision-making, to study in detail all types of impacts. To identify indicators and evaluation criteria for each natural component, to determine the magnitude and significance of the impact, to determine the quality of the environment at the stages of the existing and projected state of the landscape and recreational environment.

There is a step by step procedure of prediction of impacts, assessment of significance and development of measures to reduce impacts [23].

- Step 1. determine possible impacts;
- Step 2 Study of existing natural conditions;
- Step 3-become familiar with the standards, rules and regulations;
- Step 4 Prediction (magnitude) of impacts;
- Step 5 assessment (relevance) of impacts;
- Step 6 measures to reduce impacts.

An example of a step-by-step evaluation procedure is given in table 3.

Table 3. Step-by-step procedure for the assessment of impacts, assessment of significance and development of measures to reduce impacts

Steps of the evaluation	Flora	Visual impact
Identification of possible impacts	The seizure of land, ingress f toxicants in ecosystems, noise and ther disturbing, alien species	New buildings, structures and processes (for example. smoke plumes) dominating the visual field, new buildings and structures atypical for the area, capable of changing its visual character, destruction and change of the characteristic visual characteristics of the area (e.g. forests, parks, mountains, historical buildings)
Description existing condition	Lists of species in the affected area; biodiversity, rare species, description of habitats, ecosystems and succession	Identification of impact areas and valuable visual resources in this area (e.g. parks, monuments, historic urban landscapes). Population survey
Introduction to existing requirements	Existence of especially protected natural territories, special measures for protection of animals/ plants	Requirements for the architecture and protection of existing landscapes (usually local level)
Prediction of impact magnitude	Qualitative methods (analysis of habitats and impacts of the project) Quantitative models of ecosystems. Impact analysis in analog projects	Descriptive approach with photos of the existing views on which the project view is superimposed. Semi-quantitative determination of species value with and without the project Computer simulation of" visibility " of the project from different points
Assessment of significance of impacts	Rare species, the role of species in ecosystems. The uniqueness of ecosystems. Vulnerability/ resilience	Correlation with the existing requirements, surveys of the population and "users" of the area (for example, tourists)
Identification and inclusion of mitigation measures in the draft	Prevention of impacts. Correction effects	Painting, materials, architectural features of buildings "Embedding" into existing buildings and structures, the use of materials of destroyed historical buildings "Green belts" and other barriers around the buildings Transfer of part of the buildings under the ground

The study of the process of influence and interaction of urban systems and landscape and recreational area raises the problem of assessing the quality of landscape and recreational area for a variety of factors that have an impact on the state of the territory [27].

The results of the analysis are presented in the form of a matrix ("natural components - effects"), which allows to identify indicators and criteria of the ecological state of the components of the natural environment of the landscape and recreational area [28]. Using the qualimetric method of quality assessment it is possible to use the concept of "environment quality index" (better quality index meets the greater value of the index). The quality level is determined by the ratio of the value of the main indicator of the quality of the estimated natural component to the value of the main normative indicator.

3 Results

The assessment of the quality of landscape and recreational environment is carried out on the example of urban green areas – urban forests, the main purpose of which – the implementation of environmental, water protection and protective functions. Identified relevant quality indicators assessment of the current state of green areas: the area of green space, forest cover, degree of drying of the forest, the density of recreational pressure. In addition to qualitative indicators, the visual impact of the surrounding space is based on a comparison of visual impressions. Therefore, it is important to realistically imagine, to see the current state of the green areas of the city, and to try to be present in the projected environment, in an environment that has not yet been created, but with specified quality parameters. Modern possibilities in the field of interactive modeling allow to build virtual models of projected areas (Fig. 3).

Fig. 3. Projected model of the existing state of landscape and recreational area – "green ring»

The landscape-ecological principles of design and methodical sequence of formation of virtual spaces of a natural landscape of the city are offered.

Experimental design was supported by the developed virtual model of the natural landscape of Volgograd. The results of the study reveal the scientific and methodological provisions of urban planning (sequence of assessment and urban planning landscape and environmental measures for the sustainable development of the system of water-green landscapes, methodological approaches to the formation of a virtual model) and establish practical goals and questions of implementation of virtual models aimed at preserving the true image of the city (urban planning, security, navigation systems, information and search tasks, tourist attraction, etc.).

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