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THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF THE FORMATION OF SURFACE WATERS AND THEIR USE IN IRRIGATION IN THE OHANGARON REGION

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Abstract. The article analyzes the formation of surface waters in the Ohangaron region, their natural-geographical factors, and the theoretical and methodological foundations of their use in irrigation. The study evaluates, on the basis of a geographical approach, the formation of runoff, its seasonal distribution, its transformation under anthropogenic influence, and its functional role in irrigated agriculture in the mountainous, foothill, and plain parts of the Ohangaron River basin. On the basis of dissertation materials and geographical literature, the article substantiates the integration of territorial zoning, the basin approach, landscape-hydrological analysis, geoecological assessment, integral indicators, and GIS-cartographic methods. As a result, it is shown that the rational use of water resources in the Ohangaron region is closely connected not only with irrigation efficiency, but also with geoecological stability, soil salinization, erosion, mudflow risk, industrial-agro-irrigation pressure, and the restoration potential of landscapes. The article concludes with proposals for optimizing water use on the basis of basin management, monitoring, water-saving technologies, and geoecological zoning.

Keywords: Ohangaron basin, surface waters, irrigation, basin approach, geoecological zoning, landscape-hydrological analysis, water resources, anthropogenic load, GIS, monitoring, irrigated lands, water scarcity, erosion, mudflow risk, sustainable development.

Introduction.

The Ohangaron region is one of the important natural-geographical and economic regions of Uzbekistan. It forms a complex basin geosystem closely connected with the mountain ranges of the Western Tien Shan, foothill uplands, and the plains of the Chirchiq-Ohangaron Valley. In this area, surface waters are formed primarily in the mountainous part through snow and rainfall, seasonal snow cover, small streams, springs, and slope runoff. In the lower zones, these waters serve as a key natural resource ensuring the stability of irrigated agriculture, industry, municipal services, recreation, and ecological systems. Therefore, studying the patterns of surface-water formation in the Ohangaron region and developing the theoretical and methodological foundations of their use in irrigation is one of the urgent scientific issues.

The dissertation research carried out by Amanbaeva specifically examined the geoecological situation of the middle part of the Ohangaron River basin and ways of optimizing it. The study separately addressed the natural conditions of the area, the use of natural resources, anthropogenic factors, assessment of the geoecological situation, zoning, and optimization issues [1]. These scientific foundations make it possible to examine the formation of surface waters and their use in irrigation in the Ohangaron region through the unity of basin, landscape-hydrological, and geoecological approaches.

The theoretical problem of water-resource use in the region lies in the fact that surface waters must be assessed not only as a hydrological quantity, but also as a complex geoecological system connected with the functional state of landscapes, soil cover, vegetation, relief, geological structure, groundwater, population distribution, and economic pressure. In the basin of the Ohangaron River and its tributaries, the processes of water formation in mountainous areas are directly linked to irrigation demand on the plains. If forests, pastures, slopes, and mudflow channels are disturbed in the upper reaches, water scarcity, sediment-laden flows, pollution of canals and collectors, soil salinization, and a decline in irrigation efficiency intensify downstream.

The aim of the article is to analyze the formation of surface waters and the theoretical and methodological foundations of their use in irrigation in the Ohangaron region on the basis of geographical and geoecological approaches. To achieve this aim, the following tasks were set: first, to identify the natural factors of surface-water formation in the Ohangaron basin; second, to reveal the territorial differentiation of water use in irrigation; third, to substantiate the principles of water-resource zoning; fourth, to explain the content of landscape-hydrological, geoecological, cartographic, and integral assessment methods; and fifth, to develop ways to reduce the ecological consequences of water use.

The scientific significance of the topic is that, using the Ohangaron region as an example, the formation and irrigation use of surface waters are interpreted in relation to altitudinal zones within the basin, landscape typology, anthropogenic load, and levels of geoecological risk. Its practical significance is determined by the development of recommendations aimed at water-resource management, optimization of irrigation systems, territorial placement of water-saving technologies, reduction of land degradation, and improvement of basin monitoring systems.

Materials and Methods

The methodological basis of the study consists of the basin approach, landscape-hydrological analysis, geoecological zoning, the theory of natural-anthropogenic systems, the geosystem approach, and the concept of sustainable development. The basin approach makes it possible to consider the Ohangaron River and its tributaries as a single natural-economic system. Within this approach, the area of water formation, flow direction, water-use area, return waters, collector-drainage flows, and ecological consequences are evaluated as a single integrated process [2].

Landscape-hydrological analysis reveals the interrelationship among relief, geological structure, soils, vegetation cover, climate, and the hydrographic network. In his doctrine of geosystems, Sochava explained the interconnection of natural components as the principal condition for comprehensive geographical analysis [3]. From this perspective, runoff in the Ohangaron region is not only the result of precipitation and snowmelt, but is also determined by the internal structure of landscapes, slope exposure, the permeability of rocks, vegetation density, and anthropogenic changes.

The methodology of geoecological zoning involves the differentiated assessment of the territory according to ecological situation, water supply, irrigation load, soil-meliorative condition, erosion and mudflow risk, and the influence of industry and settlements. Rafiqov and Abdulkosimov note the importance of a territorial approach and the integrated analysis of natural conditions and economic activity in studying geoecological problems under the conditions of Uzbekistan [4;

5]. This approach makes it possible to identify the different ecological consequences of water use in the mountainous, foothill, and plain parts of the Ohangaron basin.

The study used methods of theoretical analysis, historical-geographical approach, comparison, cartographic generalization, indicator-based assessment, scoring criteria, expert evaluation, zoning, and systems analysis. The scientific views presented in the dissertation regarding the natural conditions of the area, forms of natural-resource use, assessment of the geoecological situation, and zoning were taken as the main source [1]. In addition, literature on landscape studies, hydrology, land reclamation, geoecology, and the natural geography of Uzbekistan was analyzed [6; 7; 8].

Table 1.

Main methodological directions for analyzing surface waters in the Ohangaron region

No.	Methodological direction	Object of analysis	Main indicators	Practical outcome
1	Basin approach	River and tributary basins	Flow direction, catchment area, return waters	Basin-based management of water use
2	Landscape-hydrological analysis	Mountain, foothill, and plain landscapes	Relief, precipitation, vegetation, infiltration, slope runoff	Identification of water-formation zones
3	Geoecological assessment	Natural-anthropogenic systems	Pollution, salinization, erosion, mudflow risk	Determination of the level of ecological risk
4	Irrigation analysis	Irrigated lands and canals	Water discharge, filtration, collector-drainage flow	Improving water-use efficiency
5	GIS-cartographic method	Territorial database	Remote sensing, maps, indices	Zoning and monitoring maps

Results.

The formation of surface waters in the Ohangaron region is determined primarily by the vertical zonation of the territory. In the upper mountainous zone, snow and rain waters, springs, small streams, mudflow channels, and slope runoff serve as the main hydrological sources. In the foothill uplands, runoff has a seasonal character: it increases during spring precipitation and snowmelt and decreases sharply in summer. In the plain part, water resources enter the economic cycle mainly through river flow, canals, reservoirs, collector-drainage systems, and return irrigation waters.

In the dissertation source, the natural components, economic activity, and geoecological situation of the middle part of the Ohangaron River basin are analyzed as an interrelated system [1]. Based on this scientific conclusion, it can be stated that the formation and use of surface waters are connected not only with the volume of hydrological resources, but also with the ecological stability of landscapes located in the upper, middle, and lower parts of the basin. For example, degradation of forests and pastures in the upper reaches increases the risk of mudflows, turbidity, and erosion; industry and settlements in the middle reaches generate water-quality problems; and irrigation use in the lower reaches increases the risk of soil salinization and secondary pollution through return waters.

Surface waters in the Ohangaron region are of strategic importance for irrigation. If the water supply for irrigated lands is unstable, agricultural production, food security, employment, and territorial socio-economic development are directly affected. At the same time, excessive and improper use of water worsens the meliorative condition of lands, increases filtration losses in canals, produces mineralized waters through collector-drainage flows, and intensifies secondary anthropogenic changes in landscapes.

From the perspective of zoning, surface waters and irrigation use in the Ohangaron region can be analyzed through the following functional zones: 1) the mountainous zone of water formation; 2) the foothill-upland zone regulating runoff; 3) the intensively used irrigated plain zone; 4) the zone of strong anthropogenic pressure under industrial and urban influence; and 5) the lower-flow zone where return waters and meliorative problems accumulate. Such zoning requires organizing water-resource use not on the basis of simple administrative boundaries, but according to natural and economic functions within the basin.

Table 2.

Theoretical model for zoning the use of water resources in the Ohangaron

region

No.	Region/zone	Water-formation characteristics	Irrigation significance	Geoecological risk	Management direction
1	Upper mountainous basin	Snow-rain, spring, stream, and mudflow runoff	Important mainly as a water source rather than for direct irrigation	Erosion, mudflows, forest and pasture degradation	Protection of forests and pastures, mudflow monitoring
2	Foothill-upland zone	Seasonal runoff, infiltration, and slope runoff	Potential for local irrigation and water collection	Surface washout, gully formation, soil erosion	Micro-reservoirs and agrotechnical measures
3	Irrigated plain	River, canal, and reservoir flow	Main irrigation zone	Salinization, filtration, return waters	Water-saving technologies and improvement of drainage
4	Urban-industrial influence zone	Mixture of natural flow and technogenic wastewater	Affects the quality of irrigation water	Chemical pollution and wastewater	Water-quality monitoring and treatment facilities
5	Lower-flow and collector zone	Return waters and drainage flow	Limited irrigation use	Mineralization and secondary salinization	Management of the collector-drainage system

The analysis shows that the efficiency of irrigation water use in the Ohangaron region is determined by three main indicators: the natural formation potential of water resources, the technical condition of water-delivery infrastructure, and the ecological consequences of water use. While the first indicator depends on natural-geographical conditions, the second and third indicators are directly determined by human activity, quality of management, technological approach, and the monitoring system.

When assessing the use of water resources in the Ohangaron basin, it is appropriate to apply a system of integral indicators. In this case, the level of water supply, the share of irrigated lands, losses in canal networks, the salinization condition of lands, erosion risk, population and industrial pressure, water quality, and criteria of ecological stability are assessed together. Integral assessment makes it possible to determine the complex state of water resources, which is associated not only with quantitative indicators, but also with qualitative and territorial problems.

Discussion

Geographical zoning principles play an important role in the theoretical assessment of surface-water formation and irrigation use in the Ohangaron region. The first principle of zoning is the principle of basin integrity. According to this principle, a river basin is regarded as an interconnected space of natural and anthropogenic processes from the upper to the lower reaches. Administrative boundaries cannot fully express the movement of water flow, soil erosion, mudflows, pollution, or return waters. Therefore, water-resource management should be carried out on the basis of basin boundaries and internal landscape-hydrological differences.

The second principle is the unity of natural and anthropogenic factors. In the Ohangaron region, water resources are formed under the influence of climate, relief, geological structure, and vegetation cover, while their actual condition changes under the influence of irrigation, industry, settlements, transport, mining, pasture use, and agricultural technologies. Therefore, in theoretical and methodological analysis, natural runoff and the economic water cycle must be studied within a single system.

The third principle is functional differentiation. Each territorial zone performs a specific function in the water-resource system: the mountainous zone forms water, the foothill zone regulates flow, the plain zone uses water intensively, and the lower zone receives return waters and meliorative consequences. Therefore, water-use regimes should also be differentiated by zones. A single irrigation norm, a single meliorative approach, or a single monitoring criterion cannot be effective for all zones.

The fourth principle is the principle of ecological limitation and sustainability. If water use in irrigation systems is aimed only at increasing productivity, then in the long term soil salinization, rising groundwater levels, mineralization of drainage flows, leaching of agrochemicals, and landscape degradation may intensify. Therefore, in each irrigation area, the water-supply norm should be determined by taking into account the ecological capacity of the landscape, the meliorative condition of the soil, and the potential for natural restoration.

The fifth principle is the principle of monitoring and adaptive management. Water resources in the Ohangaron region are a constantly changing system due to climate change, seasonal unevenness of precipitation, population and industrial pressure, and increasing water demand in agriculture. Therefore, water management should be based not on static plans, but on continuous monitoring, GIS, remote sensing, hydrological stations, soil-moisture sensors, water-quality analysis, and forecasting models.

Methodologically, research on the use of surface waters for irrigation in the Ohangaron region may be conducted in four stages. In the first stage, the natural-geographical foundations of the basin are studied: relief, climate, hydrographic network, soils, and landscape typology are analyzed. In the second stage, the water-resource use system is identified: canals, reservoirs, irrigated areas, water users, return waters, and drainage networks are evaluated. In the third stage, the geoecological situation is determined: salinization, erosion, pollution, mudflow risk, water scarcity, and anthropogenic load are mapped. In the fourth stage, optimization measures are developed: water saving, reclamation, monitoring, zoned management, and a system of ecological limitations are proposed.

The content of the dissertation also frames the assessment of the geoecological situation, the consequences of natural-resource use, zoning, and optimization pathways in the middle part of the Ohangaron River basin as a scientific problem [1]. When this approach is applied to surface waters and irrigation, water resources are interpreted not as a passive factor of territorial development, but as the main component connecting landscape and economic systems. It is precisely through water flow that changes in the upper basin reach the lower basin; through irrigation, plain landscapes are anthropogenically reorganized; and through drainage and return waters, ecological problems appear in secondary forms.

The most important theoretical issue in the use of water for irrigation in the

Ohangaron region is the balance between the quantitative sufficiency of water and its ecological acceptability. When large amounts of water are supplied, crop yield may increase in the short term, but soil salinization and drainage load intensify. When less water is supplied, productivity decreases; however, in some cases, opportunities for water saving and soil-moisture management increase. Thus, in irrigation management, the principle of 'optimal water - sustainable productivity - ecological safety' should prevail instead of the principle 'more water - higher efficiency'.

GIS-based modeling of hydrological and irrigation processes in the region has great scientific and practical significance. With the help of GIS technologies, layers such as catchment areas, slope gradients, erosion risk, irrigated lands, canal networks, saline areas, settlements, and industrial facilities can be analyzed together. This transforms zoning from a subjective description into a precise spatial-analytical model [9].

Table 3. Criteria and assessment directions for irrigation water use in the Ohangaron region

No.	Criterion	Assessment content	Risk indicator	Recommended solution
1	Water supply	Seasonal stability of river and canal flow	Scarcity during the vegetation period	Reservoirs and water-saving technologies
2	Water quality	Mineralization, pollutants, turbidity	Decline in suitability for irrigation	Treatment, monitoring, and control of sources
3	Soil-meliorative condition	Salinization, groundwater level, drainage	Decline in productivity	Improvement of drainage and optimization of leaching norms
4	Landscape stability	Erosion, mudflows, pasture and forest degradation	Sediment-laden flow and basin disturbance	Reclamation and phytomelioration in the upper basin
5	Management	Water	Losses and	GIS, water meters,

	efficiency	accounting, monitoring, digitalization	inefficient distribution	and adaptive management

Conclusion

The formation and use of surface waters in irrigation in the Ohangaron region represent a complex natural-anthropogenic process that must be studied not only from a hydrological or meliorative point of view, but through the unity of basin, landscape-hydrological, and geoecological approaches. In the region, water resources are formed in mountainous zones and serve economic activity, especially the needs of irrigated agriculture, in the foothill and plain parts. Therefore, the relationship between natural processes in the upper basin and irrigation use in the lower basin is the central issue of scientific management.

The study shows that, in order to organize the effective use of surface waters in the Ohangaron region, it is necessary to rely on the principles of basin integrity, the unity of natural and anthropogenic factors, functional differentiation, ecological limitation, monitoring, and adaptive management. These principles require managing water resources not according to administrative boundaries, but according to landscape-hydrological and geoecological regions.

The theoretical and methodological model of water use in irrigation should include indicators of water quantity, water quality, soil-meliorative condition, anthropogenic load, landscape stability, and management efficiency. In particular, the introduction of water-saving technologies, improvement of collector-drainage systems, reduction of erosion and mudflow risks in the upper basin, control of industrial and municipal wastewater, and GIS-based monitoring are important practical tasks.

In general, the issue of surface-water formation and irrigation use in the Ohangaron region is directly connected with territorial ecological security, agricultural sustainability, population well-being, and landscape protection. Therefore, scientific research in this field should contribute to water-resource conservation, strengthening of basin management, and optimization on the basis of geoecological zoning.

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