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ANALYSIS OF THE CURRENT STATE OF ECOLOGICAL AND GEOGRAPHICAL CHARACTERISTICS OF THE OMSK OBLAST

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Abstract. The development of any state depends on the steady growth of the country's economy, production, scientific and technical potential, socio-cultural development, and improvement of living conditions of the population. The foundation of the development of society and the state is based on natural resources. Therefore, it is becoming a crucial component of state policy to investigate the potential of natural resources in the country, evaluate their present condition, and anticipate future developments. The fundamental components of the formation of natural territorial complexes within the geographical environment include the degree of provision with heat and energy, and water resources. In most cases, it is the level of heat and moisture supply that determines the direction of economic use of territories. Their volume and variability over a year and a long-term period serve as the foundation for establishing the criteria for the geo-ecological condition of the landscape. In this work, based on the standard results of observations of the main meteorological characteristics in the Omsk Oblast, an analysis of the moisture and heat supply resources of the natural-territorial complex is performed as a basis for calculating the ecological and geographical characteristics. For meteorological stations, water balance and heat balance calculations are performed. Numerical values and equations for the relationship of balance characteristics are determined. The theoretical and practical aspects of determining the natural potential of natural reservoirs of the natural environment, such as air and water, as well as the ecological capacity of phytocenoses, are considered. The authors calculated the balance elements, moisture, and heat supply characteristics based on measured data from meteorological stations in the study area, which formed the basis for determining the natural capabilities of the components of the environment. The calculated values of the total ecological potential of surface waters of land and phytocenoses will provide the basis for standardizing the anthropogenic load on the considered natural territorial complexes of the Omsk Oblast.

Keywords: ecological and geographical characteristics, moisture resources, heat supply, natural potential, Omsk Oblast.

INTRODUCTION

The expansion of the industrial potential of society invariably leads to a rise in the degree of impact on the environment, potentially leading to a reduction in the ecological potential of landscapes. Subsequently, the determining factor in the natural and ecological potential of the landscape is the climate, which generates thermal comfort for the inhabitants (Antoniou *et al.*, 2024). The increased growth of urbanization of cities and the development of industrial capacities form a special microclimate of urban landscapes. In light of the above, it is necessary to study changes in climatic features and their relationship with ecological and geographical characteristics for the development of modern society.

Weather and climate, the geographical distribution of various meteorological and ecological characteristics, separately and in combination, affect human economic activities and underlie rational nature management (Ren *et al*., 2022). There is not a single sector of the economy that neglects the ecological and geographical characteristics of the territory. The problem of environmental regulation has been quite acute for a long time. Many studies have been conducted in order to assess and define environmental standards.

The climatic characteristics of the territory are determined by its geographical location, which influences the heat and moisture supply regime of the area.

The continental climate of the southern region of Western Siberia determines the direction of western air currents, which in turn weaken and give way to the leading position of air masses from the Arctic. In addition to Arctic air masses, dry warm air masses from the south also penetrate the territory. According to Hurrell (2015), the primary determinant of the thermal regime of the region is the radiative regime. The active surface is continuously exposed to various forms of radiation. It is distinguished by the radiation balance, which can exhibit positive or negative outcomes based on the season of the year and the distribution of thermal resources across the territory.

The study area is located south of the West Siberian Plain, which has a fairly flat relief. The surface height does not exceed 150 m. The flatness of the territory can be attributed to its location within the West Siberian Plate, which is comprised of pre-Paleozoic, Paleozoic, and Mesozoic secondary rocks in the form of calcareous rocks, dolomites, and argillites. Furthermore, a significant part of the basement is composed of igneous rocks, as well as layers of aqueoglacial deposits. The horizontal layers comprising the mass of sedimentary deposits form a flat-depression relief.

In the successful development of agricultural territories, soil characteristics are an important factor. The study of the state of natural soil resources is carried out in order to assess the suitability for various types of

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use and the need for engineering and meliorative measures to improve its condition.

According to soil types and physical and chemical properties, the territory of the Omsk region is divided into three main zones (Krasnitsky & Schmidt, 2016). The most developed area is the steppe zone, located in the southern part of the region. The zone is characterized by substantial thermal resources, but insufficient moisture. The land fund of the steppe zone is dominated by common and southern chernozems, often carbonate or solonetz.

The largest areas, more than 50% of the region's territory, are in the forest-steppe zone with a predominance of meadow-chernozem, chernozem-meadow and meadow soils, as well as solonetz complexes. This zone represents the transition from the steppe to the taiga zone (Brédoire *et al.*, 2020).

The smallest agricultural production areas are occupied in the taiga-forest zone. This territory is characterized by excessive moisture and low ground levels, which contribute to the spread of waterlogged grounds. The soil types in this zone are represented by podzolic, bog soils, and meadow types with an insignificant humus layer.

A key characteristic necessary for the normal growth and development of crops, as well as for crop yield, is heat supply. The supply of heat resources, as well as the timing of the transition to positive and negative temperatures, determine the duration of the growing season.

According to the agroclimatic resources of the Omsk region (Cherkashenina, 1971), the average duration of the frost-free period increases from north to south within the range of 100 to 125 days, amounting to about 115 days in the central part. The total number of days with positive temperatures varies within the range of 185 days in the north, 189 days in the central part, and 195 days in the south of the region.

The study of natural processes and the determination of moisture and heat supply resources enables us to determine ecological and geographical characteristics and their territorial distribution, thereby enabling us to evaluate the impact of anthropogenic activity on natural and territorial complexes.

MATERIALS AND METHODS

The methodological basis of modern studies of the dynamics of the climatic background is a combination of a systems approach to the analysis of field studies of meteorological parameters and quantitative methods - measurements, calculations, and mathematical analysis (Abu Arra, Alashan & Şişman, 2024). This method combines analytical and synthetic research techniques. In the conditions of modern agricultural production, methods of remote sensing of spatiotemporal variability of climatic factors and crop growth conditions have demonstrated their effectiveness (Gwate & Munyaradzi, 2024).

One of the methods used is to assess the state of changes in the meteorological components of the environment. These include weather observations, measurements of temperature, humidity, precipitation, radiation background parameters, determination of the man-made load on environmental parameters, etc.

In order to standardize the anthropogenic load and the permissible usage of natural resources, it is imperative to quantitatively determine the ecological and geographical characteristics and carry out their comprehensive assessment within the context of three components of the environment: atmospheric air, surface water, and phytocenoses formed on the daylight surface.

In the research conducted by T. A. Akimova and V. V. Khaskin (2012), a quantitative assessment of the natural capabilities of natural-territorial systems to perceive anthropogenic load without altering their natural characteristics was evaluated. From a scientific standpoint, such an assessment enables us to determine the natural potential of the territory on a geographical scale. From a practical standpoint, it will enable us to establish and refine a system of standards for the maximum permissible impacts on natural-territorial complexes. This paper examines the definitions of "ecological potential" as the volume or mass of the natural environment, and "technogenic environmental capacity" as an ecological and geographical characteristic of a territory that is quantitatively equivalent to the maximum anthropogenic load that natural-territorial complexes can withstand or accommodate (Wang, Xu & Liu, 2022). Technogenic environmental capacity allows us to determine the degree of compliance between the technogenic load and the natural capabilities of the territory, while establishing the limit of its equilibrium.

The environmental assets of any territory consist of the capacities of three components of the surrounding natural environment: the phytomass of the territory under study, as well as natural volumes of water and air. The analytical dependence for determining the natural ecological potential is the following equation (Akimova & Khaskin, 2012):

$$E_i = W_i \cdot C_i \cdot f_i \quad (1)$$

where E_i – environmental assets of the natural "reservoir" being studied, t/year;

W_i – volume or area (Si), (respectively km^3 or km^2);

c_i – content of ecologically limiting component, t/km^3 or t/km^2;

f_i – parameter that denotes the rate at which the capacity of the "reservoir" is renewed (1/year).

All parameters included in the calculation dependence possess a physical meaning, which must be taken into account in order to ascertain the ecological components of the analyzed "reservoirs". Considering the ecologically significant components, we can conclude that for the air reservoir, it is oxygen and carbon dioxide, for the water reservoir, it is water, and for the earth's surface, it is its average annual phytomass.

In order to determine the rate of multiple renewal of the studied volume, it is necessary to have data on the wind speed for the air "reservoir", the volumes of local and transit runoff for the water "reservoir", phytomass and annual production of dry basis for the earth's

surface, respectively.

There is no doubt that when determining all the considered parameters, we can conclude the territorial and temporal variability of the numerical parameters of natural-territorial complexes. Hence, it is advisable to determine these characteristics by considering the specific values, which have been numerically determined for a land area equal to 1 km^2, namely t / km^2 per year.

Since natural and climatic characteristics make it possible to determine the volume or mass of natural reservoirs under consideration, the calculations are based on the determination of the numerical values of the parameters of moisture and heat supply resources.

In order to determine these parameters, meteorological characteristics obtained from meteorological stations located within the Omsk Oblast were studied and analyzed. Figure 1 shows a map diagram of atmospheric moisture across the Omsk Oblast.

It is undeniable that the air environment is regarded as less vulnerable and prone to man-made burdens, in contrast to other components of the natural environment. This is due to the mixing of air masses in the ground layers of the atmosphere, which results in a faster renewal of ecologically significant components. The higher the wind speed in any territory under consideration and the larger its area, the greater, of course, the ecological potential of the air basin increases (Kazimirovsky, 1994). To ascertain the specific natural potential of the air reservoir, actual data on average wind speed, derived from standard meteorological measurements, were used. Therefore, standard observations at meteorological stations make it possible to territorially assess the natural potential of the air.

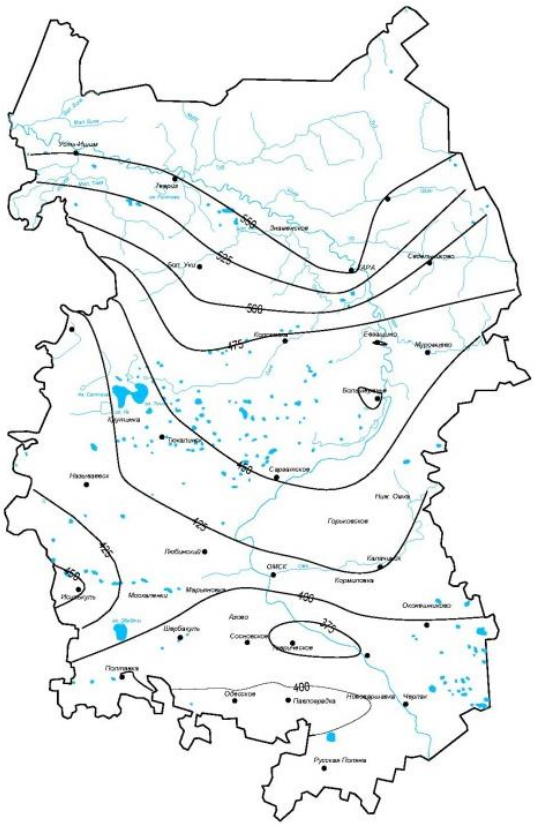

Fig. 1. Total moisture X in an average year in mm, in the Omsk Oblast.

The quantitative assessment of the natural potential of the aquatic environment was based on the evaluation and comparison of the characteristics of the humidification and heat supply resources. The determination of local and transit runoff of surface waters was based on the implementation of the process of conversion (transformation) of the heat and moisture resources of a section of the earth's surface, taking into consideration the availability of these resources, as well as the characteristics of the geological substrate.

Water balance and heat balance calculations were conducted based on meteorological station data, and their outcomes enabled us to determine the temporal and spatial distribution of moisture resources and evaporation resources, resulting in quantitative values of surface water runoff (Yang & Yang, 2011). Considering the obtained data, we can conclude that the obtained values of water resource potentials per unit area repeat the variability of surface runoff of the catchment basin within a time interval and depending on the territorial distribution. The distribution of surface runoff in an average year within the study area is shown in Figure 2. In order to assess the specific natural potential of phytocenoses, it was necessary to determine the value of annual plant matter production (Tusupbekov, Ryapolova & Nadtochiy, 2021). It is undeniable that the distribution of phytomass across the territory and the annual production of phytocenoses are influenced, among other factors, by climatic factors, principally heat and energy resources, and moisture resources.

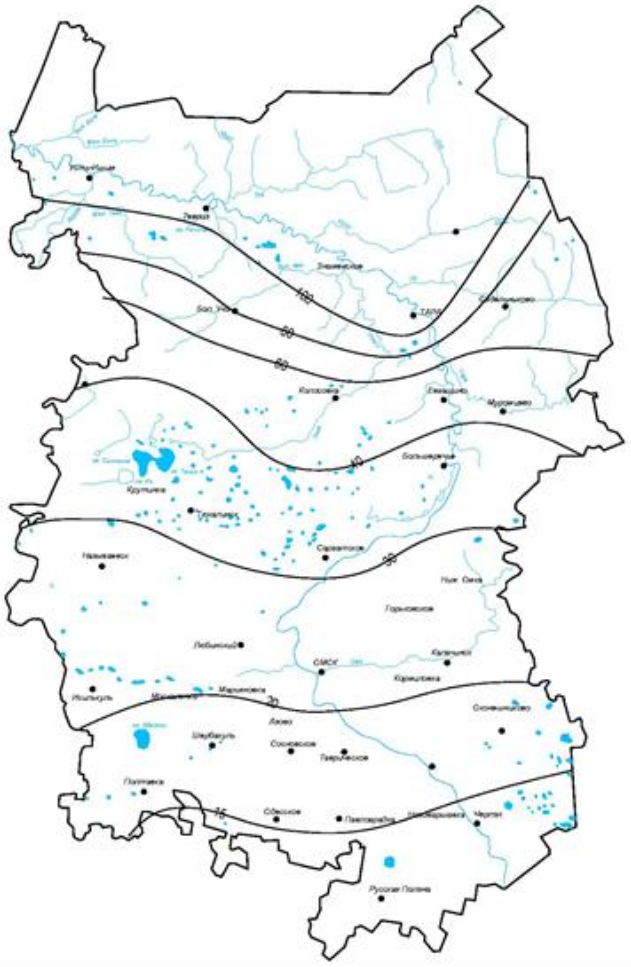

Fig. 2. Territorial distribution of surface runoff *Y* in an average year, in mm.

Numerous studies, including those conducted by A.A. Grigoriev and M.I. Budyko in the domain of spatial and temporal variability of climatic characteristics, provided the foundation for determining the correlation between the values of annual production of phytocenoses and water and heat supply. It is evident that in order to determine the annual production, it is necessary to determine the humidity factor Kn, the maximum possible total evaporation Zm, the water equivalent Zk, as well as other balance characteristics.

RESULTS

Due to the sparse network of monitoring points in the northern regions of Western Siberia, the distribution of heat and energy resources has not been sufficiently studied. The humidity resources were estimated using standard meteorological observations. The calculation method for the joint solution of water and heat balance equations allowed it to substantiate natural and climatic changes in the study. The initial data used in this study reflect the characteristics of the formation of humidification and heat supply resources at the zonal and local levels (Ryapolova, Tusupbekov & Nadtochiy, 2024).

As a result of mathematical processing, calculated dependencies of the primary heat and water balance characteristics were obtained, and the correlation between heat and energy resources and humidification resources was established.

The correlation dependence of atmospheric precipitation and total evaporation is shown in Figure 3.

The primary components of the water balance of the Omsk Oblast were obtained through calculations based on the available meteorological stations over a prolonged period. The distribution of the water balance elements is depicted in Figure 4. From the obtained results, one can conclude the spatial change in moisture and heat supply resources depending on the geographical latitude.

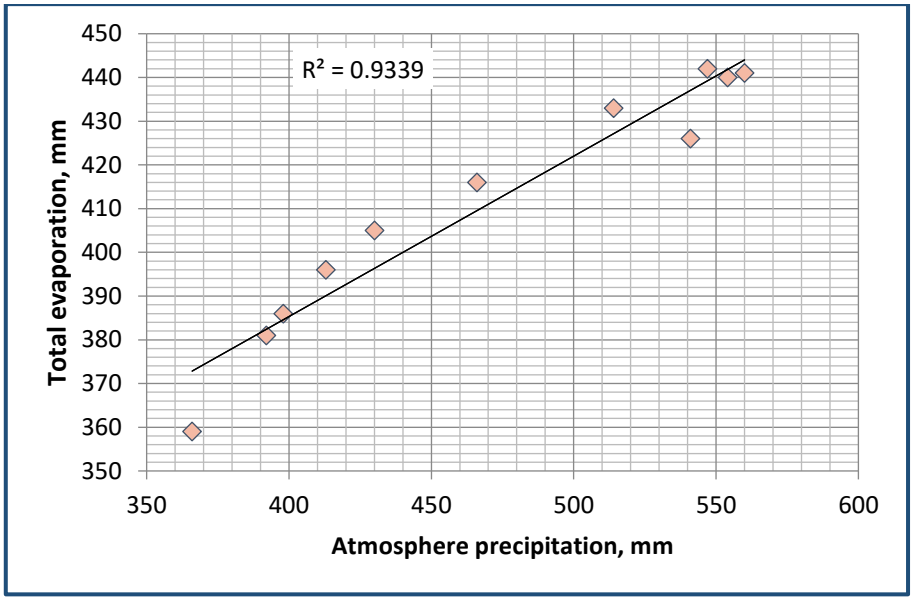

Fig. 3. Graph of the correlation between moisture and heat resources (compiled by the authors).

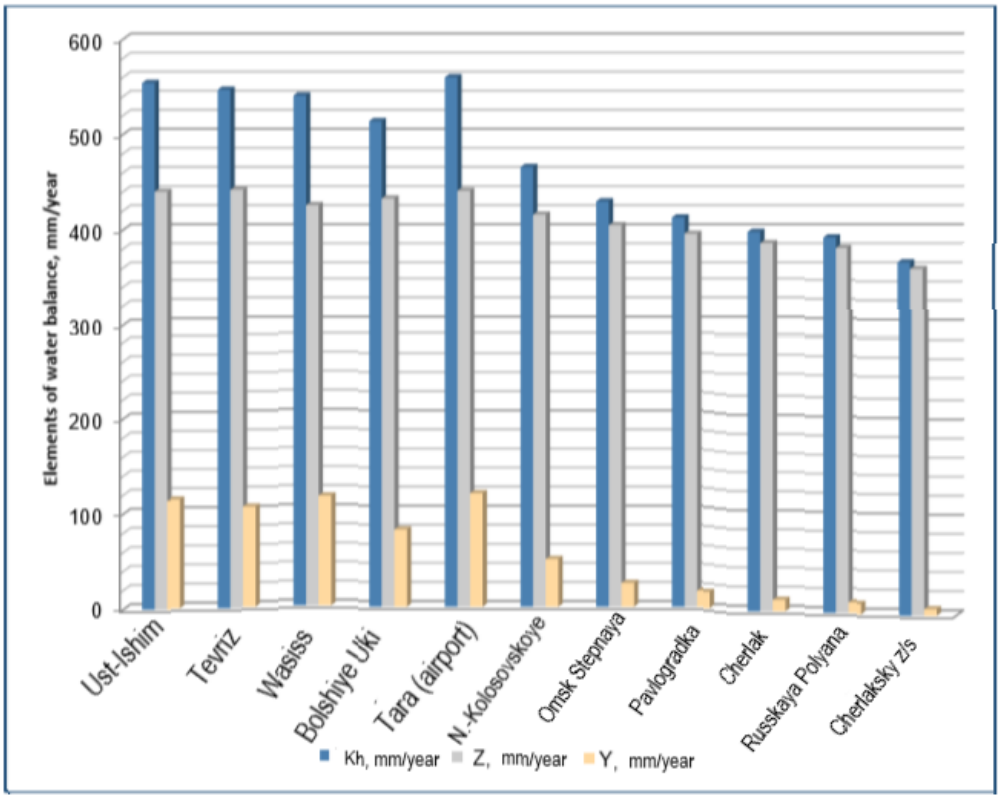

Fig. 4. The distribution diagram of water balance elements in the studied territory (compiled by the authors)

Therefore, based on the conducted research, the primary parameters of the ecological and geographical characteristics of the south of Western Siberia were identified. For the territory under consideration, the values of the specific ecological potentials of surface waters and the values of phytocenoses were obtained for a unit area. It is evident that with an increase in humidification resources, the share of local runoff generated within the territory increases, thereby augmenting the natural potential of the water "reservoir." This distribution has a latitudinal correlation. The ecological potential of natural waters varies within the range of 10,000 t / km^2 per year, reaching the highest values in the north of the Omsk Oblast. A similar situation occurs with the territorial distribution of the specific potential of phytocenoses, confirming the relationship between humidification and heat resources and the distribution of ecological and geographical characteristics. The calculation results are presented in Table 1 in the form of characteristics of water balance calculations, as well as ecological and geographical values of the specific natural potentials of the territory.

Table 1.

Calculated characteristics of water balance calculations and specific values of ecological and geographical parameters

Weather station	Kh, mm	Zk, mm	Zm, mm	Kn= Kh/Zm	Z, mm	Y, mm	e_2, t/km^2 per year	e_3, t/km^2 per year
Ust-Ishim	554	1199	684	0,81	456	98	98000	716
Tevriz	547	1204	688	0,8	458	89	89000	717
Wasiss	541	1172	664	0,81	445	95	95000	716
Bolshiye Uki	514	1204	688	0,75	422	92	92000	716
Tara (airport)	444	1203	687	0,65	385	59	59000	693
N.-Kolosovskoye	466	1221	699	0,666	416	50	50000	700
Omsk (Stepnaya)	430	1276	742	0,58	395	34	34000	671
Pavlogradka	413	1308	762	0,542	396	17	17000	648
Cherlak	398	1318	769	0,517	386	12	12000	632
Russkaya Polyana	392	1328	776	0,505	381	11	11000	623
Cherlaksky z/c	366	1319	769	0,476	359	7	7000	601

KX – atmospheric precipitation layer for the calculated time interval, mm;
Zk – water equivalent of climate heat and energy resources, mm;
Zm – maximum possible evaporation, mm;
Kн – moisture factor;
Z – total evaporation, mm;
Y – total (surface and underground) runoff layer, mm;
e_2 – specific ecological potential of surface waters t/km^2 per year;
e_3 – specific ecological potential of phytocenoses t/km^2 per year;

Upon examination of the calculations conducted, it is evident that the composition of the incoming and outgoing components of the heat and water balances within the Omsk Oblast will be contingent upon the geographical latitude of the region (Gwate & Munyaradzi, 2024). Climate changes in natural-territorial complexes lead to the formation of latitudinal typifications of the parameters of ecological and geographic characteristics.

DISCUSSION

Based on the results of calculations performed to assess the ecological and geographical parameters of natural territorial complexes, it was possible to obtain the values of the main elements of heat and moisture within the Omsk Oblast.

Taking into account the latitudinal zonality of the distribution of moisture circulation elements, it is possible to characterize the territory with sufficient confidence in terms of moisture supply conditions. In turn, the quantitative distribution of moisture reserves determines the possibility of using the territories for agricultural development. An increase in humidity to the north as heat resources decrease contributes to the accumulation of moisture in soils over a long-term period, which can ultimately lead to their over-moistening.

Thus, based on the studies performed by the authors, the main parameters of the ecological and geographical characteristics of the south of Western Siberia were determined. The values of specific ecological potentials of surface waters and the values of phytocenoses for the territory under consideration were obtained for a unit area. It becomes obvious that with an increase in moisture resources, the share of local runoff formed in the territory increases, which increases the natural potential of the water "reservoir". This distribution has a latitudinal pattern. The ecological potential of natural waters varies within the range of 10,000 t/km^2 per year, reaching the highest values (98,000 t/km^2) in the north of the Omsk region.

In this regard, the results of the assessment of ecological and geographical parameters obtained in this study will form the basis for determining the methods of hydro land reclaiming of natural territorial complexes. It is noteworthy that the collaborative analysis of heat and moisture conditions enabled us to identify the relevant characteristics for the economic development of the territory, such as the distinct ecological capacity of surface waters and the distinct ecological potential of phytocenoses. The novelty of this study is the establishment of these values for the studied territory. The values of these parameters determine the ecological resistance to anthropogenic loads, limiting the maximum load on natural complexes.

CONCLUSION

The outcomes of the study and the calculated values obtained for ecological and geographical parameters enable us to conclude the spatial and temporal distribution of calculated incoming and outgoing elements of the thermal and water balances of the territory and their significance in assessing the impact of human activities on natural systems.

The studies of heat and energy and water balance elements of the Omsk Oblast carried out by the authors allowed testing the methodology for assessing the ecological and geographical characteristics of natural territorial complexes and determining their resistance to maximum permissible impacts. The calculations were based on standard measurement data from hydrometeorological stations located in the Omsk Oblast.

Based on the analysis of the incoming and outgoing elements of the natural environment, quantitative values of the integrated assessment of the ecological potential of the air and water "reservoir", as well as phytocenoses of the earth's surface, were obtained.

The obtained data enables the analysis of the spatio-temporal variability of ecological and geographical characteristics at the current stage of development, as well as to predict their further development, taking into account climate change.

The results of the studies performed serve as the basis for further scientific developments to determine the parameters of natural and man-made landscapes, their natural potential in the context of the growth of economic activity in the Omsk Oblast. The necessity for this is derived from the analysis and forecasting of economic activity, taking into account the rational environmental management.

AUTHORS CONTRIBUTION

Conceptualization, N.L.R., V.S. N., Z.A.T.; data curation, N.L.R., V.S. N., Z.A.T.; formal analysis, N.L.R., V.S. N., Z.A.T., investigation: N.L.R., V.S. N., Z.A.T., methodology: N.L.R., V.S. N., Z.A.T.

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CONFLICT OF INTERESTS

The authors report no conflicts of interest.

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