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ASSESSMENT OF ECOLOGICAL AND ECONOMIC BALANCE OF THE TERRITORY OF THE KARAGANDA REGION

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Abstract. Currently, Kazakhstan is faced with the problem of a serious deterioration of the state of natural resources and the environment in all the most important environmental indicators. Almost a third of agricultural land is now degraded or is under serious threat, and more than 10 million hectares of potentially arable land in the past have been abandoned. This article discusses various methods and also carries out a comprehensive assessment of the environmental and economic balance of the Karaganda region. For the study on the state of the regional-scale object, the choice as the basis for analyzing the structure of the land seems to be the most adequate, since it is the land-use device that objectively reflects the current state of industrial, agricultural and recreational impact. A comprehensive assessment of the ecological and economic balance of the territory of the Karaganda region was carried out according to the ratio of the main land-use categories taking into account the intensity of anthropogenic load. The coefficient of natural protection of the territory is determined and the outlined trends in the ecological and economic state are analyzed.

Keywords: ecological and economic balance, Karaganda region, anthropogenic load, nature protection, geoinformation technologies, ecological cartography, ArcGIS 10.1

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INTRODUCTION

Soil is the most vital and precious natural resource that sustains life on Earth (Khadka *et al*. 2019). Monitoring and environmental assessment of a landscape structure development is commonly implemented on the basis of surface representation of the main land use forms. Several types of ecological stability coefficients are used to quantify this evaluation. Different approaches of evaluation are represented here. Some factors are based only on spatial assessment of land reserves; others include also a rating of individual landscape elements (Bažík *et al*. 2014).

The ecological and economic balance of the territory is a balanced ratio of various types of activities and interests of various population groups in the territory, taking into account the potential and real possibilities of nature, which ensures sustainable development of nature and society, reproduction of natural (renewable) resources and does not cause environmental changes and consequences (Pomazkova and Faleychik 2017). A cartographic assessment at the same time allows you to fully visualize the results obtained in the form of various cartographic works, work with which will further facilitate the perception and understanding of the current situation in a particular territory and will allow you to take the most correct decision (Karpik 2004). To maintain healthy ecosystems, natural-disturbance-based management aims to minimize differences between unmanaged and managed landscapes (Tittler *et al*. 2012). The problem of selecting the correct land for the cultivation of a certain agriculture product is a long-standing and mainly empirical issue. The increased need for food production and the shortage of resources stimulate a need for sophisticated methods of land evaluation to aid decision makers in their role to both preserve highly suitable lands and satisfy producers demand for increased profit (Hossein *et al*. 2015).

The purpose of this research work is to determine the main directions in territorial and economic zoning based on the ecological and economic balance and the ecological clustering of the regions of Karaganda region. During the study, one of the current tasks was the mapping of objects and the information obtained in the territory of the object of study.

MATERIAL AND METHODS

The tool for solving this problem was GIS (geographic information systems) (Kalogirou 2011). One of the most advanced mapping programs at the moment is the ArcGIS program, along with it the SAS. Planet program is used to obtain satellite images with reference to the coordinate system. These two electronic programs are quite advantageously used in tandem (ArcGIS 2011). Using the SAS.

Planet program, you can create a qualitative basis for the future map, using the ArcGis software modules, the map itself is created (Nikolaeva 2016).

As an indicator of a comprehensive assessment of the ecological state of landscapes, we used anthropogenic load indices (AL) (Kochurov and Ivanov 1999), which allow calculating and comparing the load levels in the territory with various forms of their manifestation taking into account the main forms of such loads expressed in dimensionless indicators (Panchenko and Dyukarev 2015).

The general assessment of ecological and economic balance can be carried out using the suggested coefficients (Table 1) (Kochurov *et al*. 2004).

Table 1. Coefficients of assessment of ecological and economic balance of the territory

The name of the coefficient	Formula	Used data	Characteristics of changes in values
Coefficient of absolute environmental stress	$\mathrm{Ca} = \frac{\mathrm{AL6}}{\mathrm{AL1}}$	Areas of territories with high anthropogenic load – AL6 areas of territories with minimal anthropogenic load (as a rule, protected areas) – AL1	**Ca** ↑ – rising tensions
Coefficient of relative environmental stress	$Cr = \frac{\mathrm{AL4} + \mathrm{AL5} + \mathrm{AL6}}{\mathrm{AL1} + \mathrm{AL2} + \mathrm{AL3}}$	Area of territories of different types of land use, typical for transformation processes in the region	**Cr→1** – the tension of the ecological and economic balance of the territory is balanced **Cr** ↑ – rising tensions
Coefficient of natural protection of the territory	$\mathrm{C}\,np = \frac{Sef}{Sta}$	Land area with medium and resource stabilizing functions (Rsf) = AL1 + 0.8 AL2 + 0.6 AL3 + 0.4 AL4 Sta-Area of the studied territory	**Cnp** ↑ – the growth of the natural protection of the territory **Cnp < 0.5** – critical level of protection of the territory

RESULTS AND DISCUSSION

Being the ninth largest country in the world, Kazakhstan is endowed with a large territory and vast natural resources such as oil, gas, uranium and copper (Orazgaliyev 2018). Karaganda region is the largest region of Kazakhstan by territory and industrial potential, rich in minerals and raw materials. Central Kazakhstan is one of the regions of the Republic experiencing strong anthropogenic pressure (Akpambetova 2016). High rates of development of mineral and raw materials, energy and agricultural resources led to the emergence of large urban and industrial agglomerations (Karaganda, Zhezkazgan, Balkhash) and many urban-type settlements (Aksuat, Konyrat, Satpayev, Kairauty, Zhezdy, Topar, etc.) (Bodeeva and Mukasheva 2017).

Almost a tenth of the total population of Kazakhstan lives in the region. The territory of the region is 42,798.2 hectares (15.7% of the total area of Kazakhstan), occupies 49th place in the list of the largest administrative units of the first level in the world and is distributed over nine rural areas (Fig. 1) and nine cities of regional importance (Kazakhstan 2018).

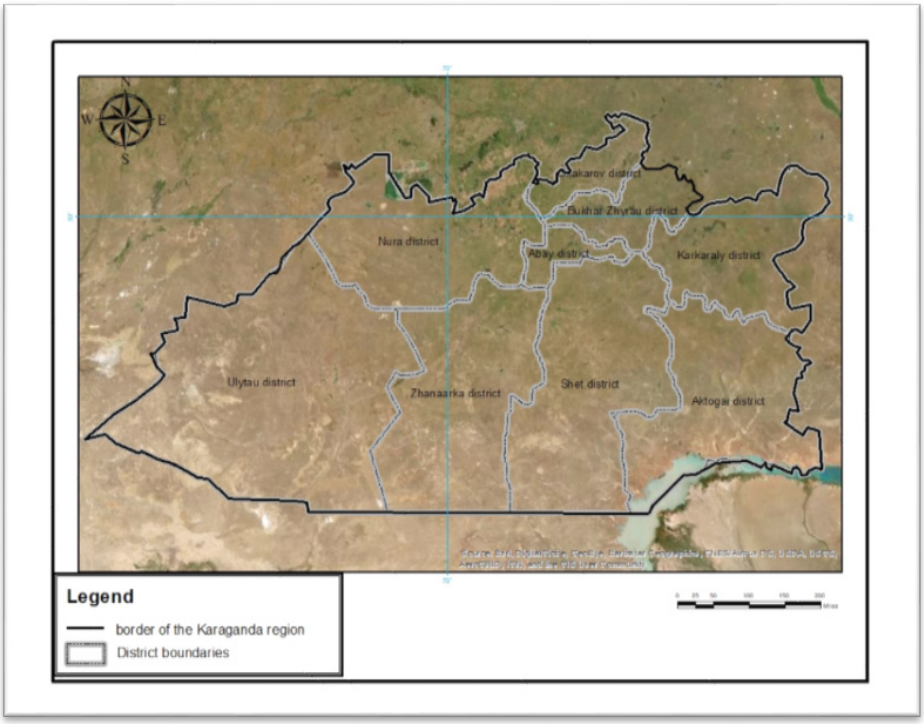

Fig. 1. Map of Karaganda region within the districts

The environmental and economic status indicator is obtained by determining the degree of AL on various groups of lands by introducing expert ballistic scores for them (Table 2).

Table 2. Point classification of land areas of the Karaganda region according to the degree of anthropogenic transformation (AL)

No.	Indicator / Region	Land area (thousand ha)	Types and categories of land					
			Specially protected natural areas (PAs), reserve lands	Lands of water fund, forest fund	Hayfields, perennial plantations	Agricultural land (arable land, fallow land, pastures)	Residential area	Lands of industry, transport, communications, defense and other non-agricultural purposes
			Degree of anthropogenic load					
			Very low	Low	Average	High	Very high	Higher
			Number					
			AL_1, ha	AL_2, ha	AL_3, ha	AL_4, ha	AL_5, ha	AL_6, ha
1.	Abay	672.5	140.3	3.2	332.5	98.9	79.2	18.4
2.	Aktogai	5,199.7	2,929.1	74.9	1,658.8	120.2	345.2	18.5
3.	Bukhar-Zhyrau	1,440.3	189.6	13.7	566.6	277.6	372.2	16.9
4.	Zhanaarka	6,234.8	1,792	21.5	1,588	70.1	313.4	11.8
5.	Karkaraly	3,547.2	1,282.3	25.2	1,504.2	161.3	541.9	32.3
6.	Nura	4,632.6	2,139.8	0.3	1,703	367.2	412.6	9.7
7.	Osakarov	1,126.1	97.1	21.1	382.1	469.7	145.1	11
8.	Ulytau	1,2293	6,408.2	57.9	2493.7	96.7	282.9	15.3
9.	Shet	6,569.5	1,722	8.4	2,152.3	187.3	619.9	14.5

On the basis of the point classification of lands of Karaganda region according to the degree of anthropogenic transformation, the coefficients characterizing the ecological and economic condition of the study area were calculated (Table 3) and maps of the distribution of values of these indicators are constructed using geographic information system ArcGIS (Fig. 2–5). As a result of the joint processing of all available data in the geographic information system ArcGIS 10.1 (ESRI 2011), a map was constructed with land diagrams for the types of agricultural land use in the Karaganda region (Fig. 2).

The analysis of cartographic material showed that the basis of the land reserves is agricultural land, which occupies 97.2% of the area of the districts. The distribution of agricultural land within individual farms of administrative districts depends on the features of the relief. Pastures prevail in the territories of Aktogai (98%), Zhanaarka (96%), Karkaraly (91.9%), Ulytau (96.3%) and Shet (94.7%). The second place in terms of area is occupied by arable land in the plain part of the Osakarov district and occupy 53.95% of the entire territory. Other lands with small areas include development land, under roads, underwater, deposits, perennial plantings and other lands.

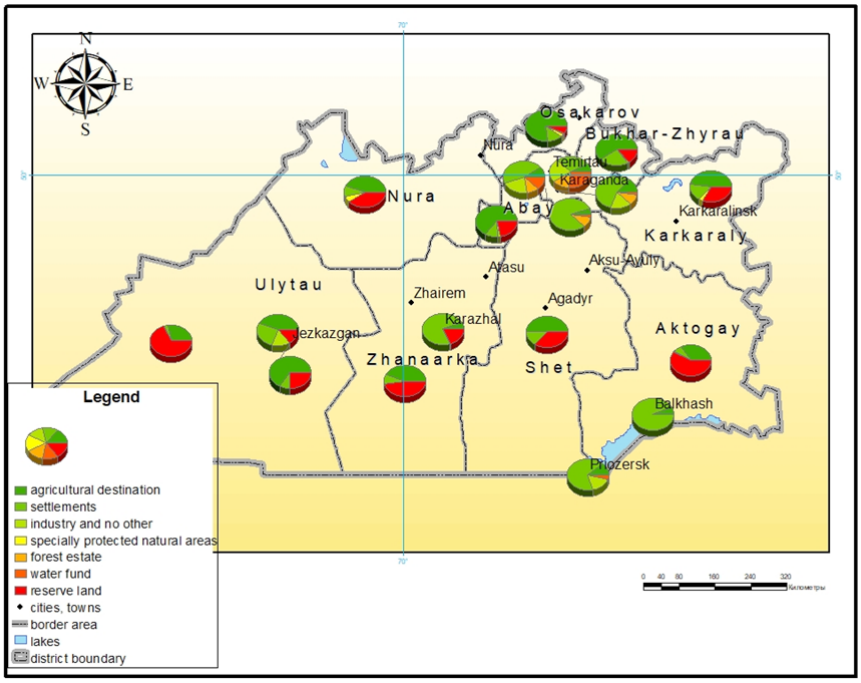

Fig. 2. Map of land composition by type of use of the Karaganda region within the districts

Given the structure of land use, as well as the availability of land of different categories, it is possible to calculate the level of anthropogenic transformation of the territory. The level of anthropogenic load of the studied areas was determined by the method of Kochurov (2013). To determine the degree of anthropogenic load of land, expert point estimates are introduced. Each type of land receives a corresponding score (Khlebnikova and Miroshnikova 2016). The joint analysis of the results of the processing of satellite images, cadastral information and data of the land reserves (Land… 2018) for 2018 of Karaganda region allowed to conduct an area assessment of land classified according to different degrees of anthropogenic transformation.

The category of land with the lowest anthropogenic load includes especially protected and unused for economic purposes land, and the category of the maximum anthropogenic load is industrial, construction, transport, and disturbed land (Karpova 2016).

We estimated the intensity using a ball-based assessment of the lands, calculated the coefficients characterizing the ecological and economic condition of the territory, namely the coefficients of absolute environmental stress (*Ca*) and relative environmental stress (*Cr*), the area of lands with environmental and resource-stabilizing functions (*Rsf*) concerning territory security (*Cnp*) (Kochurov 1999a, b) (Table 3).

Table 3. Indicators of the main coefficients of the ecological and economic condition of the territory of the Karaganda region

Indicator / District	*Ca*	*Cr*	*Rsf*	*Cnp*	*Rsf* % of S_{total}
Abay	0.13115	0.41282	381.92	0.56791	56.79108
Aktogai	0.00632	0.10378	4032.38	0.7755	77.55024
Bukhar-Zhyrau	0.08914	0.86596	651.56	0.45238	45.2378
Zhanaarka	0.00658	0.11621	2790.04	0.44749	44.74947
Karkaraly	0.02519	0.26159	2269.5	0.6398	63.98004
Nura	0.00453	0.20543	3308.72	0.71423	71.42253
Osakarov	0.11329	1.25085	531.12	0.47165	47.16455
Ulytau	0.00239	0.04407	7989.42	0.64991	64.99109
Shet	0.00842	0.21163	3095.02	0.47113	47.11267

In the ArcGIS 10.1 program, the corresponding maps were constructed, and there was made the classification of areas according to these indicators. The analysis of this coefficient is necessary in order to balance the strong anthropogenic impacts with the potential to restore the landscape. The lower the *Ca*, the better the state of the environment (Bodrova 2013) (Fig. 3).

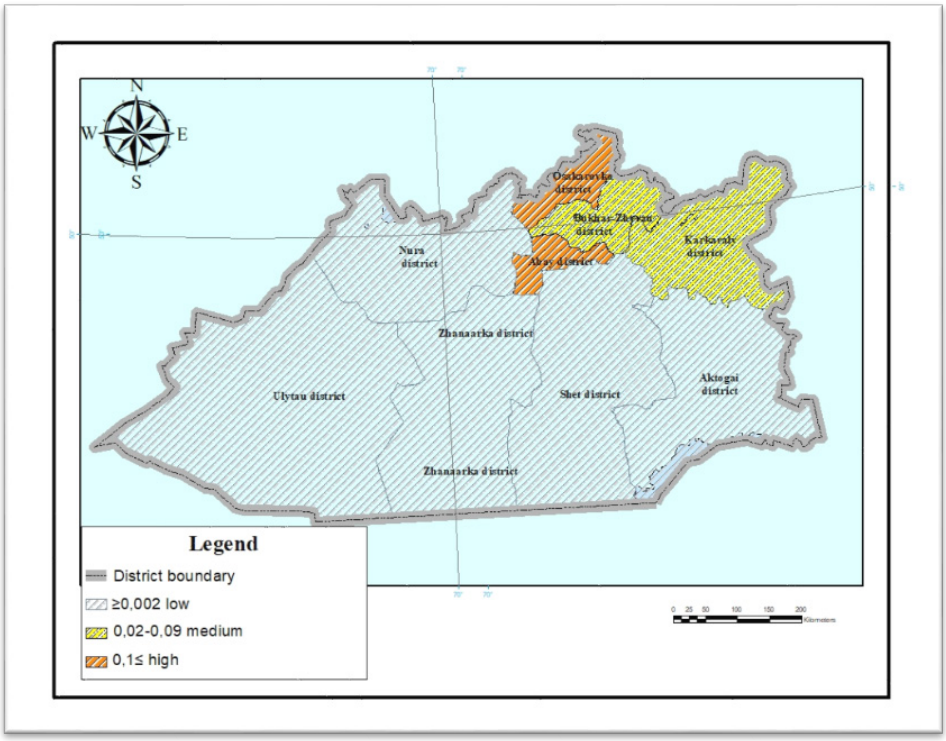

Fig. 3. Map of the distribution of absolute anthropogenic tensions (*Ca*)

It is considered that at $Ca > 0.5$, the ecological condition of lands of the territory is characterized as intense, i.e. the territory is overloaded with economic activity. High values of the coefficient indicate problems in the natural environment, therefore, to maintain its recovery potential, measures are required to reduce the load and expand the network of protected natural areas to the required ratios (Khovansky *et al*. 2006). The absolute intensity factor *Ca* for the regions of Karaganda region: from 0.002 to 0.131. The lower the *Ca*, the better the state of the environment. Analysis of the spatial distribution of *Ca* showed the areas with the most intense situation (Table 3, Fig. 3).

According to this indicator, the most unfavorable situation develops in Abai and Osakarovsk districts. These are the areas most developed in both industrial and agricultural terms. For them, it is necessary to provide for measures to reduce the load, reduce the area of disturbed lands, and rehabilitate them. The lowest indicators of Ca are in 5 districts – Ulytau, Nura, Aktogay, Zhanarka and Shet. These are predominantly areas of large territory and relatively low population. In general, on the edge, the value of the indicator is 0.043, which suggests that in the region the balance of natural and anthropogenic systems is not disturbed, and the regenerative potential of natural ecosystems is preserved. However, the results of the calculation of the coefficient of absolute tension

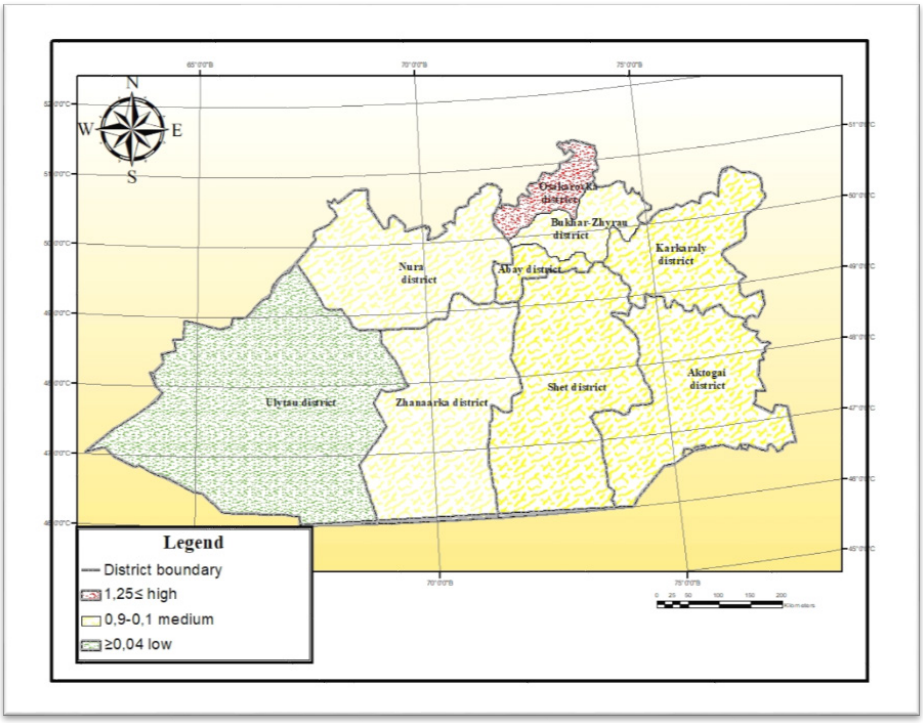

Fig. 4. The distribution of the coefficient of relative anthropogenic intensity (*Cr*)

have errors associated primarily with the features of departmental accounting of lands of different categories. Thus, the high values of tension in these areas are partly due to the lack of PA territories on their territory that is included in the state land cadaster, since nature-sanctuaries are most often created on forest or water fund lands. In addition, some districts do not provide updated information on disturbed lands to the territorial land registry. In the Karaganda region, the share of the territory of the protected areas is no more than 10%.

According to the indicator of relative tension, referring to the ecological and economic state of the territory as a whole, it is more informative since it covers the entire area under consideration (Fig. 4).

Low values indicate low environmental stress, high values indicate high. If the value of the coefficient is close to 1, then we can say that the territory is balanced by the potential of sustainability of nature and the degree of anthropogenic load on it (Kochurov 2015).

If the value of *Cr* rises, then environmental tensions in the territory increase. The highest coefficient of relative tension of the territory is 1.25 points in Osakarovsky district, which indicates the insufficiency of the environmental fund of its territory. Osakarovskiy district is still almost the entire volume of gaseous and liquid pollutants enter without purification into the environment.

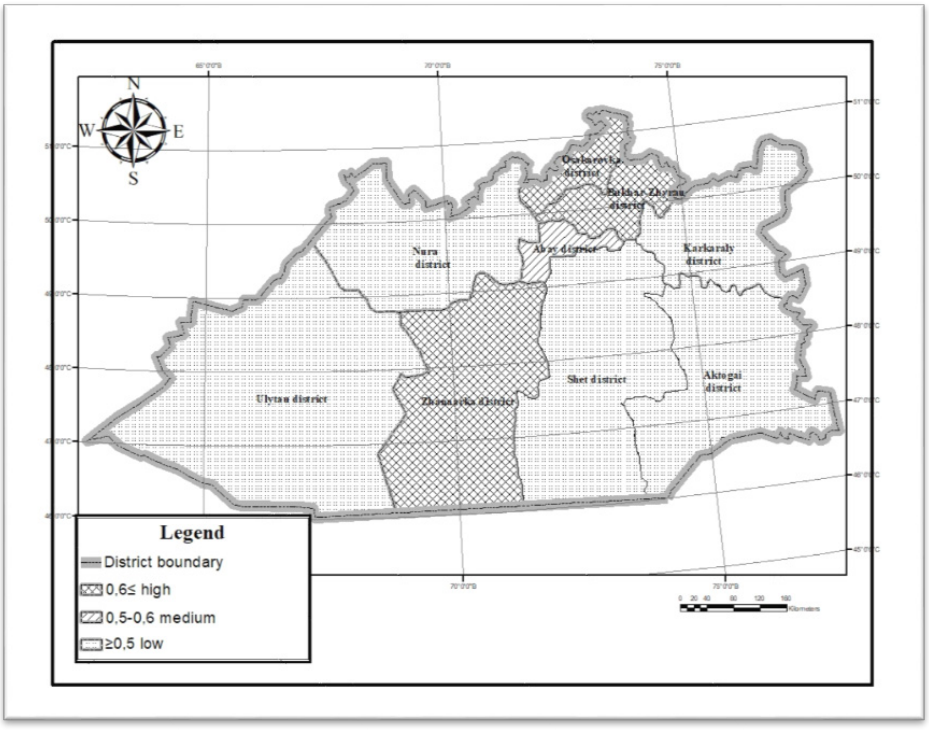

Fig. 5. Map of distribution of natural protection ratio (*Cnp*)

In the following regions, tensions range from 0.86–0.1: Bukhar-Zhyrau, Abai, Karkaraly, Shet, Nura, Zhanarka and Aktogai. 85% of the total rural population of this region lives in these areas, there are main cities (Karaganda, Temirtau, Balkash), and industrial facilities, roads. With the smallest coefficient, only the Ulytau district distinguished itself.

The higher the value of *Cnp* (Fig. 5) coefficient, the better the situation, *Cnp* < 0.5 is the critical level of protection of the territory (Kochurov *et al*. 2004).

According to the coefficient, the prosperous situation is in Aktogai, Nurinsk, Ulytau and Karkaraly regions. The situation in Abay district is less favorable. The critical areas of protection include the following areas: Zhanaarka, Bukhar-Zhyrau, Shet and Osakarov. To identify the territories of regions for which, first, it is necessary to develop recommendations for improving the balance of EEB, using geoinformation tools and analysis, the regions were clustered according to the level of tension in the ecological and economic state of lands (Fig. 6).

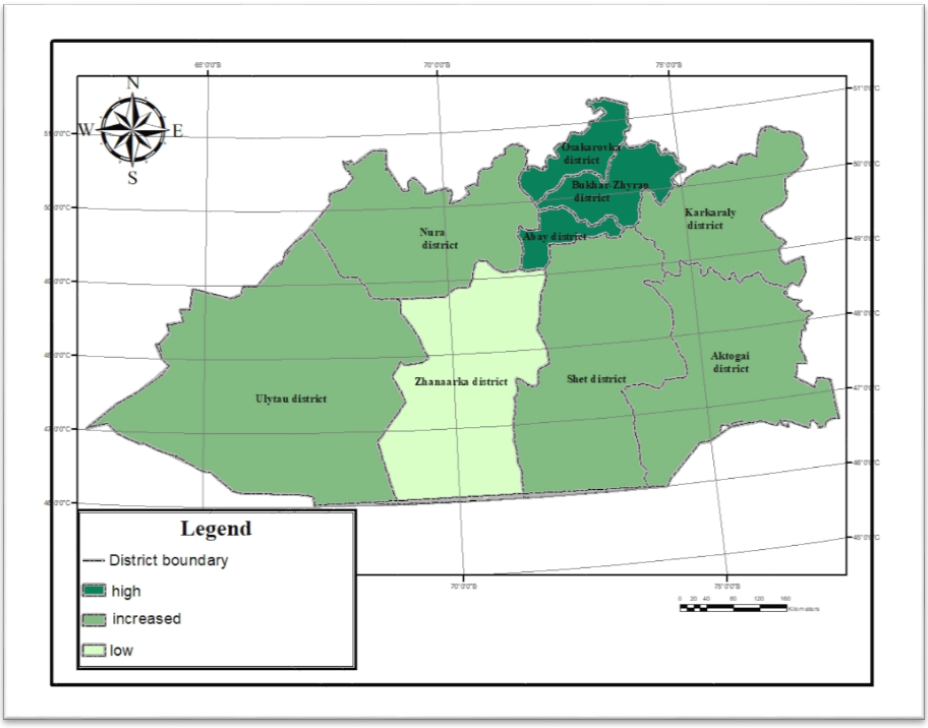

Fig. 6. Clustering areas of the Karaganda region on the tensions of the environmental situation

Two clusters of regions with an unfavorable assessment of the ecological and economic state and one cluster with low values of tensions were identified. The areas with the highest absolute and relative environmental tensions of the lands: Osakarov, Abay, Bukhar-Zhyrau, Shet were referred to as the cluster of

areas with high anthropogenic tensions of the ecological and economic condition of lands. The cluster of areas with an increased anthropogenic intensity of the ecological and economic state of the land is formed by areas where relative intensity indicators are low ($0.01 \leq Cr \leq 0.1$), but the absolute intensity indicator is higher than 0.5: Aktogai, Karkaraly, Nurinsky and Ulytau.

We attributed the Zhanaarka district to a cluster of areas with low anthropogenic tension of the ecological economic state of lands – areas with minimal values of absolute ($Ca \leq 0.006$) and relative tensions ($Co \leq 0.1$). The spatial distribution of the tension of the ecological and economic balance shows an imbalance in the structure of land use, mainly in the central regions of the Karaganda region. These are areas of the most transport developed, with a high proportion of disturbed from industrial (Bukhar-Zhyrau) and agricultural production of land (Shetsky, Osakarovsky, Nurinsky, Zhanaarkinsky), some of them have high rates of tension due to the significant areas of disturbed land mining enterprises (Abai). Analysis of cartographic materials shows that the differences in the ecological and economic balance are to a certain extent zonal in nature, due to the landscape structure and the level of social development, the industry specialization of the economy. A significant role in the spatial differentiation of the ecological and economic balance is played by agro-climatic resources affecting the availability of water resources, the distribution of soil and plant cover, and agricultural specialization. This is confirmed by a paired analysis of the coefficients of the ecological and economic balance and indices of the natural resource potential.

Correlation relations (r) of the coefficients of the environmental and economic state of tension and indices of the level of the region's natural-resource potential (Minnikov and Kurolap 2013). Due to regional differences in the combinations of analyzed indicators, there is no strong spatial correspondence between the three coefficients, although the general pattern is obvious: with an increase in the absolute, and especially relative intensity of the ecological and economic condition of the territory, its natural security decreases (a reliable linear correlation of Co and Kez reaches an average strength: $r = –0.5248$).

CONCLUSIONS

Thus, the assessment of the ecological and economic balance of the territory indicates that in the Karaganda region the balance of anthropogenic impacts is disturbed in relation to the restoration potential of natural ecosystems, but it can still be restored with the help of man, i.e. land management. To increase the sustainability of ecological and economic balance and increase the security of the territory in risk zones (unfavorable ecological and economic balance), it is advisable to expand and create new medium-stabilizing, protected areas while limiting agricultural and industrial development as well as:

- to increase the number and territory of protected areas,
- to transfer arable land from grain production to perennial grasses for grazing,
- to provide subsidies to help the farmers when sowing perennial grasses,
- reduction of mechanical tillage,
- comprehensive planning of environmental measures for the restoration of disturbed land by mining enterprises,
- prevention of the negative impact of industry, pollution, land debris,
- reclamation of disturbed land, the involvement of restored land into agricultural use,
- environmental education, awareness and promotion of environmental knowledge among the population of the region,
- environment pollution problems have to be made transparent in the monitoring approach and communicated to stakeholders in a understandable way,
- rehabilitation of areas devastated by mining activities.

Modern mining activities have great impact on the natural environment but also on the social and economic environment. The Kazakh Government are aware of these impacts and regulates the mining activities on different levels. A missing link between the legal regulation and the on-site activities are technical guidelines which translate and concretize the legal expressions into practicable actions of the responsible managers and allow the supervising authorities active control of the mining activities.

With regard to the rehabilitation, the Guideline on the Rehabilitation of mining in Kazakhstan explains international standards and gives practical recommendations and examples of different fields of the rehabilitation work in mining activities. Any rehabilitation in any kind of mining has to deal with the impact on water, the influence of water on the mine during its active phase and post-mining phase and the impact on the soil.

Land use should include a set of land reclamation activities aimed at improving the quality of soil cover. It is necessary to develop methods for each district in order to improve not only the quality of the soil cover but also the quality of life for the population of the region as a whole. Careful studies are needed of the spatial patterns of the structure of environmental management and the types of land use that have arisen on its basis and, in our opinion, within the territory of the districts. This will allow us to assess the degree of anthropogenic transformation in the territory of each district and facilitate the development of a new balanced territorial structure of environmental management to achieve an optimal regional ecological and economic balance.

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