Assessing the ecological and economic state of agricultural land in the border areas of the Altai Krai

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Abstract. The article discusses the method of integrated assessment of ecological and economic state of agricultural land territory of the Mikhailovsky District of the Altai Krai. The joint analysis of the results of remote probing data processing, cadastral information and statistical reporting allowed us to carry out an areal assessment of lands classified according to different degrees of anthropogenic transformation. The characteristics of the areas exposed to anthropogenic influences were identified, which allowed us to isolate land with a special regime of use and adjust the ecological and economic state towards a balanced and sustainable development.

1. Introduction
Currently, the concept of sustainable development has found wide application in the economic, social and environmental spheres of public activity. One of the main objectives of the program for sustainable development is the optimization of the spatial organization of rural areas based on the rational use of existing resource potential. For the successful implementation of this task in the framework of the concept of sustainable development, new approaches to the study of natural-anthropogenic systems are needed. One of such approaches is the concept of ecological and economic balance of the territory, which includes the following conditions: the organization of territories on a landscape-ecological basis; preservation and maintenance of natural and slightly modified landscapes that perform important environmental and resource-forming functions; rational use of the natural potential of the territory; development of innovation processes [1]. The study and analysis of the prerequisites that exist in a particular territory for the implementation of each of the conditions of the concept of ecological and economic balance will identify the main problems, as well as positive and negative development factors for taking measures for its sustainable development.

2. Materials and Methods
The object of research was the border area of the Mikhailovsky District, located in the south-west of the Altai Krai. The territory borders on Kazakhstan, Kliuchevsky, Uglovsky and Volchikhinsky District of the Altai Krai.

To solve the problem of assessing the ecological and economic condition of agricultural territories, in order to ensure their sustainable development, the following methods were used: analysis of the land use structure based on the land cadastre classification units and remote sensing data; definitions of integrated environmental and economic assessment; geo-information technologies for creating thematic cartographic material based on the results of the research.
The study used, remote sensing data obtained by Aster and Landsat multi-zone satellite systems, cadastral information and statistical reporting forms No. 22-2 of the Mikhailovsky District [2, 3].

3. Results
An analysis of the joint processing of all available data shows that the total area of the Mikhailovsky District within the administrative boundaries is 311,712.59 ha. The basis of the land fund is agricultural land (54.4%). Arable land prevails in the northern part of the district and occupies 35% of the entire territory. Hayfields and pastures are spread throughout the Mikhailovsky District and account for 22%. The second largest land area of 43.1% is occupied by forest land. Forests are widespread in the southern part of the Mikhailovsky District and occupy 38% of the territory’s area. Other lands with small areas include development land, under roads, under water, deposits, perennial plantings and other lands.

Given the structure of land use, as well as the availability of land of various categories, it is possible to calculate the level of anthropogenic transformation of a territory [4], [5]. The level of anthropogenic load of the study area was determined by the method of B. I. Kochurova [6]. According to the proposed method, in the case of extensive development of the territory, the analysis of the structure of land use is carried out within administrative boundaries. To determine the degree of anthropogenic load of land, expert point estimates are introduced. Each type of land receives a corresponding score. The area valuation of lands classified by varying degrees of anthropogenic transformation is shown in Figure 1 and Table 1.

![Image](image_url)

**Legend:** 1) Very low (conservation and unused land); 2) low (hayfields, forests used sparingly); 3) average (perennial plantations, recreational land); 4) high (arable land, areas of intensive logging, pastures and hayfields, used irrationally); 5) very high (irrigated and drained lands); 6) higher (land of industry, transport, settlements, infrastructure, disturbed land). Village councils: I – Ashchegulsky; II – Poluyamsky; III – Nazarovsky; IV – Nikolayevsky; V – Rakitovsky; VI – Malinovozersky; VII – Bastansky; VIII – Mikhailovsky.

**Figure 1.** The classification of the territory of the Mikhailovsky District according to the degree of anthropogenic transformation.
distributions of these indicators were constructed (Figure 2). The condition of the studied territory were calculated (Table 2) using the following formulas:

\[ K_a = \frac{An6}{An1}, \quad K_o = \frac{An4 + An5 + An6}{An1 + An2 + An3}, \]  

where \( An1, \ldots, An6 \) proxies the numerical value of the degree of anthropogenic transformation corresponding to the point score.

The grouping of lands according to the degree of anthropogenic load allows us to estimate the anthropogenic transformation of the territory in comparable terms [7, 8]. They are the absolute \( K_a \) and relative \( K_o \) coefficients of the ecological and economic situation of the territory, calculated using the following formulas:

\[ K_a = \frac{An6}{An1}, \quad K_o = \frac{An4 + An5 + An6}{An1 + An2 + An3}, \]  

where \( An1, \ldots, An6 \) proxies the numerical value of the degree of anthropogenic transformation corresponding to the point score.

The lower \( K_a \) shows a better state of the environment. In general, the ecological and economic balance of the territory is characterized by the coefficient \( K_o \). When \( K_o \) is equal to or close to 1.0, the tension of the ecological and economic balance of the territory is balanced in terms of the degree of anthropogenic load and the potential for sustainability of nature.

Each anthropogenic impact, or their combination, has its own limit of sustainability of natural and natural-anthropogenic landscapes. The more diverse the landscape, the more stable it is. This is expressed, first of all, by a large number and uniform distribution of natural biogeocenoses, the total area of which is the ecological fund of the territory. The larger this fund, the higher the natural security of the territory and, accordingly, the stability of the landscape. Thus, the total land area with environmental and resource-stabilizing functions can be calculated using the following formula:

\[ P_e = An1 + 0.8An2 + 0.6An3 + 0.4An4. \]  

If we correlate the area of land \( P_e \) to the total area of the study area (\( P_o \)), then we obtain the coefficient of natural protection of the territory:

\[ K_e = \frac{P_e}{P_o}. \]  

Values of \( K_e \) are less than 0.5; therefore, it is characterized by a critical level of protection of the territory.

On the basis of the point classification of the lands of the Mikhailovsky District according to the degree of anthropogenic transformation, coefficients characterizing the ecological and economic condition of the studied territory were calculated (Table 2), and the relevant cartograms of the distributions of these indicators were constructed (Figure 2).

**Table 1.** Point classification of lands according to the degree of anthropogenic transformation within the administrative boundaries of the village councils of the Mikhailovsky District.

| Village Council | Degree of anthropogenic transformation |
|-----------------|----------------------------------------|
|                 | Very low | Low | Average | High | Very high | Higher |
| Ashchegulsky    | An1, ha  | An2, ha | An3, ha | An4, ha | An5, ha | An6, ha |
| Poluyamsky      | 1,477.77 | 1,165.78 | 19.03 | 13,110.88 | 0 | 248.61 |
| Nazarovskoy     | 2,915.67 | 1,054.89 | 12.30 | 9,194.79 | 297.78 | 272.70 |
| Nikolayevskoy  | 4,866.68 | 14,183.27 | 138.53 | 24,636.14 | 1,056.40 | 1,374.45 |
| Rakitovskoy     | 4,988.33 | 1,567.73 | 87.86 | 31,030.30 | 701.52 | 687.22 |
| Malinovozersky  | 1,776.80 | 15.43 | 0 | 567.66 | 0 | 563.54 |
| Bastansky       | 4,570.56 | 26,031.68 | 2.44 | 17,797.02 | 602.66 | 594.21 |
| Mikhailovsky    | 3,843.10 | 88,548.12 | 142.81 | 23,671.65 | 889.42 | 3719.10 |

The grouping of lands according to the degree of anthropogenic load allows us to estimate the anthropogenic transformation of the territory in comparable terms [7, 8]. They are the absolute \( K_a \) and relative \( K_o \) coefficients of the ecological and economic situation of the territory, calculated using the following formulas:
Figure 2. The distribution of the values of the coefficients of the relative anthropogenic intensity (a) and natural security (b).

Table 2. Indicators of the main coefficients of the ecological and economic condition of the territory of the Village councils of the Mikhailovsky District.

| Village councils     | $P_a$  | $K_a$ | $K_o$  | $P_e$, га | $K_e$ |
|----------------------|--------|-------|--------|-----------|-------|
| Ashchegulsky         | 16,022.07 | 0.17  | 5.02   | 7,666.16  | 0.48  |
| Poluyamsky           | 23,184.15 | 0.26  | 6.77   | 10,300.168| 0.44  |
| Nazarovsky           | 13,748.13 | 0.09  | 2.45   | 7,444.88  | 0.54  |
| Nikolayevsky         | 46,255.47 | 0.28  | 1.41   | 26,150.87 | 0.56  |
| Rakitovsky           | 39,062.96 | 0.14  | 4.88   | 18,707.35 | 0.48  |
| Malinovozersky       | 2,846.42  | 0.32  | 0.66   | 1,939.20  | 0.68  |
| Bastansky            | 49,779.19 | 0.13  | 0.62   | 32,696.80 | 0.66  |
| Mikhailovsky         | 120,814.20 | 0.97  | 0.31   | 84,235.94 | 0.70  |

4. Discussion

An analysis of the results shows that the territories of village administrations located in the south and west of the Mikhailovsky District have a prosperous ecological and economic condition, since their lands contain a sufficient proportion of tree-shrub vegetation.

The high degree of development of the territory in the form of arable land and pasture with insufficient land with environmental and resource-stabilizing functions in the form of forests, land in the redistribution fund, etc., determined the coefficient of relative tension greater than 1.0 in most village councils. The prosperous situation is developing in the Mikhailovsky, Bastansky, and Malinovozersky village councils, as there is a sufficient amount of forests and unused lands on the territory for their stabilization. The unfavorable situation develops in the Ashchegulsky, Poluyamsky, and Rakitovsky village councils, the coefficient of natural security is critical. Here there is an intensive use of land; therefore, measures are required for environmental stabilization. In the Nazarovsky and Nikolayevsky village councils, the coefficient of natural security is slightly above the norm. However, a high value of the coefficient of relative tension indicates an imbalance in the degree of
anthropogenic load and the sustainability of nature. This situation has arisen due to the fact that in these areas, a significant proportion of arable land in the composition of land.

In general, the ecological and economic balance of the territory of the whole Mikhailovsky District is characterized by the following indicators: $K_a = 0.30$; $K_o = 0.94$; $P_e = 189141.37$ ha; $K_e = 0.61$.

According to the results obtained, a favorable situation remains in the territory of the district in terms of the ratio of the highest and very low anthropogenic load, thanks to a significant share of the forest cover. In general, the situation on the anthropogenic load in the general territory of the district can be considered satisfactory.

5. Conclusion

The study of the natural conditions and resources of the area allows one to conduct a successful economic activity. The modern economic system has developed in such a way that most of the land area of the district has the category of agricultural land. Extensive farm management has led to a number of environmental problems associated with the presence of high anthropogenic pressures, which in turn identified a number of negative phenomena in the territory: a pasture digression, a soil erosion, a decrease in humus in the soil, waterlogging, salinization, etc. The study of the ecological and economic condition of the Mikhailovsky District was carried out within the boundaries of village administrations. As a result of the analysis, the characteristics of areas of land exposed to anthropogenic influences were identified. This allowed us to allocate land with a special mode of use and adjust the ecological and economic state in the direction of balanced and sustainable development. Also, on the territory of the Mikhailovsky District, it is necessary to revise the nature of land use, moving to intensive management, introducing innovative technologies and projects, to eliminate and solve the growing problems of the environment.

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