Environmental and economic model for sustainable development of a region (the case of Samara Oblast)

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Abstract Biodiversity in natural ecosystems, with the increasing anthropogenic transformation of the environment, is becoming an increasingly important direction of research every decade. We propose to consider the number of game animals as one of the indicators of biodiversity. Since they are the most steadily observed objects in specially protected and anthropogenically transformed territories. Biodiversity conservation ensures sustainable development. In this regard, using the example of Samara Oblast, we considered the principles of biodiversity conservation in environmental and economic systems, including anthropogenically modified and specially protected natural areas, in order to ensure sustainable development at the regional level. We selected some ecological and economic spatially distributed characteristics of the environmental-economic system and compiled equations of multiple linear regression of the dependence of the number of game animals on the factors that have the greatest influence. These are the following factors: the volume of industrial production, investments in fixed assets, the value of fixed assets of industry, payments for natural resources, fines for violation of legislation in the use of natural resources, species diversity of animals, generalized assessment of atmospheric air pollution, percentage of forest cover. We offer some management actions of influencing ecological and economic systems that ensure sustainable development. The authors determined that at the regional level it is necessary to revise and increase the normative fees for natural resources, as well as to increase the size of fines for violation of environmental legislation. We have carried out clustering of municipal districts by economic indicators affecting the number of biological resources, and we propose the necessary priority management actions based on the obtained models.

1. Introduction
Conservation of the biodiversity of our planet is becoming more and more important every decade [1]. Anthropogenic transformation of the territory continues, associated with industrial and agricultural impacts [2]. Conservation of biodiversity, natural habitat for flora and fauna, natural ecosystems is increasingly important in the developing world [3]. The transition to the path of sustainable development is the only correct way to ensure the preservation of the natural environment and humanity, as a constituent part of it [4, 5]. The most complete and qualitative preservation of natural ecosystems and biodiversity is possible in protected areas (PA), separated from industrial and agricultural use [6].
We should consider the transition of civilization to the path of sustainable development systematically, comprehensively and interconnected: anthropogenic load (economy), ecosystems (ecology), that is, to consider ecological - economic systems (EES).

The preservation of protected areas and biodiversity in these territories is the most important task and indicator of the degree of self-sufficiency of steadily developing EES. By sustainable development, we mean such a development of EES, which preserves the ability to self-regulation and self-preservation by maintaining biodiversity at the "reference" level. We propose to consider the “reference” level of biodiversity such a state of nature in which it is in a state of ecological equilibrium, keeping the EES in a qualitatively specified state [7].

As an indicator of sustainable development, we analyzed number of species of game animals (GA) in Samara Oblast. We consider the GA numbers in the Zhigulevsky State Reserve (Zhigulevsky SR) to be the "reference" level. Since in protected areas, the maximum safety and the most optimal conditions for life and reproduction of the selected species for analysis are ensured. We chose the following species as GA indicators (marten, fox, wild boar, elk) due to the fact that they are consistently observed throughout the region and in protected areas; there are long-term observations that are recorded in detail in the materials of statistical reporting and allow us to analyze the dynamics of biodiversity. To preserve biodiversity and ensure sustainable development of the region, combining anthropogenic territories and structures of protected areas, it is important to develop mechanisms for economic stimulation of rational nature management [8]. Until now, no such mechanisms have been developed to ensure the conservation of biodiversity in anthropogenic ecosystems at the “reference” level.

The aim of this study is to develop an environmental and economic model (economic mechanisms) for ensuring sustainable development of a region on the example of Samara Oblast.

2. Materials and Methods
The general normative process of this scientific research is built from hypothesis to analysis and interpretation of facts, modeling, design, confirmation or refutation of the results obtained.

To achieve this goal, we used an interdisciplinary approach to the analysis of EES and the following methods: system analysis, structural-functional analysis, economic analysis, economic and mathematical modeling, mathematical statistics, correlation and regression analysis.

3. Results and Discussion
Previously, we analyzed the legal support for the sustainability of ecosystems and came to the conclusion that economic methods are closely related to the administrative and legal ones, since they provide a more favorable "climate" for environmental preservation [9]. Consequently, to ensure sustainable development of EES, it is ineffective to use strict administrative coercion [10].

To ensure the “reference” level of biodiversity in anthropogenic territories, we have developed the structure of an economic mechanism that ensures sustainable development of the region, which includes:

- eco-monitoring - the study of the state of EES according to the available data and results:
  - data on anthropogenic load on the ecosystem;
  - cadastral data on biodiversity in protected areas;
  - cadastral data on biodiversity in EES.
- eco-audit - analysis and selection of factors influencing the biodiversity of EES:
  - selection of significant factors of anthropogenic load;
  - determination of the reference number of biodiversity:
  - biodiversity analysis at EES.
- ecomarketing - identifying financing that ensures sustainable development:
  - determination of biodiversity in EES, missing to the reference;
  - calculation of financial investments providing the reference number in EES.
- environmental management - modeling of management actions on EES.
- specific influence of factors on the number of hunting - game animals;
- development of management actions for EES.

As indicator species of GA, in this paper we use the following ones: marten, fox, wild boar and elk. We conducted a study in all districts of Samara Oblast and Zhigulevsky SR to identify the dynamics of the abundance of indicator species of biodiversity and established a “reference” level of biodiversity in these territories.

We selected some ecological and economic characteristics, on the basis of which, using the expert information database REGION (REGION) [11, 12, 13, 14], we carried out a correlation-regression analysis and compiled multiple linear regression equations for the indicator species of GA [15, 16, 17]. Only statistically significant factors that have direct and indirect impacts (figure) on biodiversity conservation were included in the resulting equations. Figure presents the specific influence of factors on the number of game animals, revealed on the basis of the analysis and calculations.

![Figure](image)

**Figure.** Specific influence of factors on the number of game animals

(X1 is population density; X2 is the volume of industrial production; X3 is the volume of agricultural production; X4 is investments in fixed assets; X5 is the number of farms; X6 is the value of fixed assets of industry; X7 is the value of fixed assets in agriculture; X8 is generalized characteristic of industrial load; X9 - generalized characteristic of agricultural load; X10 - total anthropogenic load; X11 - generalized recreational load; X12 - generalized characteristic of transport load; X13 - payment for natural resources (rubles); X14 - fines for violation of legislation when using natural resources resources (rubles); X15 - species diversity of animals according to the Shannon-Weaver index; X16 - generalized assessment of atmospheric air pollution; X17 - percentage of forest cover; X18 - other unaccounted for factors)

On the basis of the obtained equations, we have considered the management actions (economic mechanisms) for the preservation of species diversity at the “reference” level [4].
We propose the following management actions to achieve the "benchmark" level of biodiversity in EES:

- the first management action (MA1) is the application of progressive methods of management by increasing investments in fixed assets.
  
  MA1 aims to improve the quality of use of investments in fixed assets. An increase in the investments in production and construction in progress will lead to an improvement in the state of fixed assets of the industry, affecting the atmospheric air, products produced and entering the ecological subsystem, causing a change in the level of biodiversity and, as a consequence, a change (increase) in the number of GA.

- the second management action (MA2) is the introduction of advanced technologies into production by increasing investments in fixed assets of the industry.
  
  Some investments in fixed assets are required in order to reduce the anthropogenic load on the ecological subsystem. These investments will improve the technologies used, and reduce the load on the ecosystem from the release of a large number of ecologically low-quality products. The use of high-quality technologies, the transition from extensive to intensive farming methods, also increases the stability of the economic subsystem, provides high quality products and services, leading to the stabilization of the state of the ecosystem as a whole (and the state of biodiversity - in particular). Consequently, the use of MA2 will lead to an increase in the abundance of indicator species of biodiversity.

- the third management action (MA 3) is an increase in financial investments in restoration and environmental protection measures, an increase in payments for natural resources withdrawn from the ecological subsystem.
  
  An increase in the number of GA can be achieved as a result of the implementation of MA 3. But to achieve the "reference" level, it is necessary not only to reduce the anthropogenic load, but also to introduce intensive farming methods, effective economic methods of influencing the ecosystem.
  
  In this case, the funds received when paying for natural resources will be spent on increasing the level of biodiversity. It affects both the development of the economic subsystem and the ecological subsystem, making it possible to achieve the “reference” level of GA abundance in anthropogenically deformed territories. Along with this, the use of MA3 can reduce the intensity of the use of natural resources.

- the fourth management action (MA4) is an increase in the size of fines for the violation of environmental legislation.
  
  MA4 is useful to compensate for damage caused by the activities of the economic subsystem. An increase in fines in case of violation of the law will increase investments in the production of products and services for restoration and environmental protection, and will also lead to an improvement in the state of the ecological subsystem, leading to the rapid restoration of resources, maintaining self-organization processes in it.

  We carried out a cluster analysis to be sure of management schemes and obtained groups of territories, formed according to the degree of similarity of economic and environmental factors. Table shows the grouping of municipal districts by economic indicators affecting the number of biological resources.

  Cluster analysis made it possible to come to the conclusion about the mosaic nature of the distribution of municipal districts, the heterogeneity of elements within the EES and, as a consequence, the impossibility of applying a single scheme for managing and regulating the number of GAs. According to the results of the expert assessment, we revealed that the classification of Samara Oblast districts for the development of management actions is the most optimal according to the group of economic indicators.
Table. Grouping of municipal districts by economic indicators affecting the number of biological resources

| Cluster no. | Districts combined into homogeneous clusters |
|-------------|---------------------------------------------|
| Cluster No. 1 | Sergievsky; Neftegorsky; Privolzhsky; Kinel-Cherkassky; Stavropolsky; Krasnoyarsky; Volzhsky; Koshkinsky; Kinelsky; Bezenchuksky |
| Cluster No. 2 | Syzransky; Krasnoarmeisky; Chelno-Vershinsky; Klyavlnsky; Shentalsky; Isaklinsky; Bolshe-Glushitsky |
| Cluster No. 3 | Pohvistnevy; Shigonsky; Pestravsky; Borsky; Bolshe – Chernigovsky; Bogatovsky; Khvorostnyansky; Alekseevsky |

We propose the following levels of management for modeling management actions:
1. Regional (Samara Oblast) is the level of strategic management of the territory.
2. Municipal districts (based on clustering of the studied region) - this is the tactical level of management. The ability to implement common management principles, exchange experience, form a scenario for the development of territories.
3. Local (agglomeration, settlement, agricultural enterprises) is the level of operational management.

3.1. Regional level
The calculation of the financial investments required to achieve the "reference" level of the number of game animals in Samara Oblast is possible in several ways: assessment of the replacement cost of the number of GA; assessment of civil claims (the amount of claims brought against organizations and individuals in compensation for damage caused to the state hunting fund) and assessment of the maximum fees (maximum fees for using GA under permits (licenses) for hunting).

It is necessary to apply management action MA 3 to achieve the reference abundance of the indicator species in Samara Oblast. This provides for compensation for the amount of damage caused by the economic subsystem through an increase in financial investments in restoration and environmental protection measures, an increase in payments for natural resources withdrawn from the ecological subsystem in the amount determined by the replacement cost assessment method.

3.2. Municipal district level
We have identified administrative-territorial associations, consisting of three clusters (see table).
  • the first cluster districts: to increase the number of the indicator species, financial investments in restoration and environmental protection measures are rational, as well as an increase in payments for natural resources withdrawn from the ecological subsystem by the method of replacement cost and payments for civil claims;
  • the second and third cluster districts: to increase the number of the indicator species, financial investments in restoration and environmental protection measures are rational, as well as an increase in payments for natural resources withdrawn from the ecological subsystem by the method of replacement cost.

4. Conclusions
The developed environmental and economic models prove that sustainable development of EES at the regional and district levels is possible with additional financial investments, the size of which corresponds to the requirement to achieve a "reference" level of indicator species of biological resources. To ensure sustainable development and preservation of biodiversity at the regional level, using the example of Samara Oblast, it is necessary to consider complex measures of an economic, legal and financial nature, to introduce management actions that allow achieving the “reference” level of GA. So, for example, it is required to revise and increase the normative fees for natural resources, to increase the size of fines for violation of environmental legislation, to introduce advanced
management technologies. At the regional level, we conducted a clustering of municipal districts by economic indicators that affect the number of biological resources. We also propose the necessary priority management actions based on the obtained models.

Funding
This work was carried out within the framework of the Program of Fundamental Research of the State Academies of Sciences in 2013-2020 (projects nos. AAAA-A17-117112040040-3 and AAAA-A17-117112040039-7).

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