Geoinformation modeling of socio-ecological safety of rural areas on the example of settlements of the Belgorod region

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Abstract. In the course of the study, geoinformation resources were created for the rural areas of the Belgorod region. The created GIS consists of a system of hierarchically subordinate sections of rural territories of the Belgorod region - agrolandscapes of Strigunovsky (Borisovsky district), as well as Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements. The results of ecological and geochemical studies were used as databases and thematic cartographic tools reflecting the natural resource potential, socio-economic and ecological-hygienic situation. The study of the spatial and temporal characteristics of the degree of anthropogenic pressure in rural areas of the Belgorod region on the example of Strigunovsky (Borisovsky district), Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements, as well as adjacent agricultural landscapes using Earth remote sensing materials, made it possible to differentiate studied territories. 4 zones are identified - high anthropogenic load (residential and outbuildings of a rural settlement), medium anthropogenic load (agricultural land and other anthropogenic objects), natural frame (territories occupied by green vegetation), water bodies.

1 Introduction

Studies of the state of environmental safety of rural areas of the Belgorod region on the example of agrolandscapes of Strigunovsky (Borisovsky district), as well as Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements require prompt processing and analysis of ecogeodata. With an integrated socio-ecological approach, they usually rely on the generalizing characteristics of the environment, as a result of which, the volumes of even minimally sufficient initial information, of course, must be large. Otherwise, the validity of actions and decisions cannot be achieved. In addition, the data obtained should be easily accessible and systematized [1]. These conditions make it necessary to use modern geoinformation technologies and Earth remote sensing data in assessing the socio-ecological state of rural areas [2].

A.M. Berlyant, I.K. Lurie, V.S. Tikunov, A.V. Koshkarev and other leading cartographers [2]. Thus, the geoecological atlas of the Republic of Mordovia, created under the leadership

of A.A. Yamashkin, has become a vivid example of a regional GIS that allows generalizing and quickly analyzing environmental information, which contributes to the optimization of environmental management at the regional level [3].

In 2018–2019 by a team of Voronezh researchers led by Professor S.A. Kurolapa created an electronic medical and environmental atlas of the city of Voronezh. This resource includes sections:

- state of the environment (environmental background: parameters of anthropogenic impact and pollution of the atmosphere, soil, snow cover; state of springs;
- background radiation; phytotoxic effects; state of biota);
- the state of health of the population (according to the main socially significant classes of diseases, separately for the adult and child population, according to the service areas of the city's polyclinics);
- assessment of the environmental risk for public health (risks associated with microclimatic conditions, industrial and transport impact and technogenic pollution of the urban environment) [4].

The electronic medical and environmental atlas of the city of Voronezh provides a comprehensive view of the environmental safety factors of the territory of the urban district of an industrial city [5].

In order to effectively ensure the environmental safety of the population of rural areas and make decisions in accordance with an adequate management formula, a system of operational environmental monitoring is needed, which makes it possible to respond in a timely manner to changing conditions. The functioning of this system is carried out on the basis of geoinformation technologies. It is expedient to analyze the dynamics of many natural and anthropogenic factors in rural areas according to the Earth remote sensing data [1, 2, 6, 7].

In the course of the research, geoinformation resources were created for rural areas of the Belgorod region - agro landscapes of Strigunovsky (Borisovsky district), as well as Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements, providing a comprehensive analysis of the socio-ecological comfort of the population.

2 Materials and Methods

The developed geoinformation resources provide:

• accurate spatial reference, generalization and systematization of the obtained data, selection, analysis of representativeness and adaptation of all incoming information with its subsequent storage (single address space);
• clarity and reliability of information for making decisions on an adequate management formula;
• possibility of dynamic modeling of processes and phenomena;
• the possibility of automated solution of problems related to the analysis of the characteristics of rural areas;
• Possibility of prompt analysis of the situation in emergency cases.

The developed geoinformation resources are considered as a kind of extension of the database technology for coordinate-referenced information with the possibility of organizing a query to the database along with the means of generating a "graphical" report, as well as analyzing spatial relationships between objects.

The created GIS consists of a system of hierarchically subordinated sections of rural territories of the Belgorod region - agrolandscapes of Strigunovsky (Borisovsky district), as well as Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements. As databases and thematic mapping tools reflecting the natural

resource potential, the socio-economic and environmental and hygienic situation, the results of environmental and geochemical studies conducted by the team of authors at the Voronezh State University, as well as the FBUZ "Center for Hygiene and Epidemiology in the Voronezh Region".

Various approaches are used to analyze spatial data summarized in a GIS. In some cases, it is sufficient to use visual analysis - making management decisions based on the created GIS maps. In situations that require a deeper analysis, making unambiguously correct decisions based on a GIS map is impossible, since the use of visual analysis alone does not allow obtaining complete information without additional mathematical, statistical and geoinformation data processing.

Based on the data obtained in the environment of the GIS "Ecological safety of rural areas of the Belgorod region", it is supposed to calculate the carcinogenic and non-carcinogenic risks of the population living in the cities under study according to the methodology of the Center for Hygiene named after. Erisman, described in the regulatory document "Guidelines for assessing the risk to public health when exposed to chemicals that pollute the environment" (R. 2.1.10.1920-04).

The research scheme includes the following stages - hazard identification; assessment of the dose-response relationship; exposure assessment (calculation of average concentrations of carcinogens, determination of probable average daily doses of carcinogens entering the body by inhalation) [2, 8, 9].

The ScanEx RDC GeoMixer portal was used as a source of Earth remote sensing data for assessing the environmental safety of rural areas of the Belgorod Region on the example of the agrolandscapes of Strigunovsky (Borisovsky district), as well as Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements. This portal is a web-based geoinformation platform for a wide range of tasks that allows you to work with geodata. The multi-channel space images received on the portal, taken from the Landsat-8 and Sentinel-2 satellites for the period from 2015 to 2021, are summarized in the archive. Satellite images of the archive containing the most up-to-date information for 2021 are presented in Table 1.

Table 1. Satellite images of 2021 used to assess the ecological state of rural areas of the Belgorod region Actual space images used to assess the environmental safety of the urban environment.

Date of shooting, time	**Satellite**	**Image code**	**Visible cities**
16.08.2021, 8.24	Landsat-8	LC817702 52021228 LGN00	agricultural landscapes of Strigunovsky, Obukhovsky and Dolgopolyansky rural settlements
5.02.2021, 8.24	Landsat-8	LC817702 52021036 LGN00	
20.01.2021, 8.24	Landsat-8	LC817702 52021020 LGN00	

To assess the dynamics of the state of environmental safety of rural areas of the Belgorod region on the example of agrolandscapes of Strigunovsky (Borisovsky district), as well as Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements over a twenty-year period, the created archive was supplemented with archival multi-channel space images from the Landsat- 7 taken in 2001 (Table 2).

Table 2. Archival space images of 2021 used to assess the ecological state of rural areas of the Belgorod region.

Date of shooting	Satellite	Image code	Visible cities
10.08.2001	Landsat-7	LE717602 42001222 KIS00	agricultural landscapes of Strigunovsky, Obukhovsky and Dolgopolyansky rural settlements
16.08.2001	Landsat-7	LE717702 52001197 EDC00	

To solve individual problems related to the storage, analysis and visualization of Earth remote sensing data, the ArcGIS software package was used.

Spatio-temporal analysis of the degree of anthropogenic impact on various rural areas of the Belgorod region, as well as adjacent agricultural landscapes, was carried out by determining the NDVI index within cities and suburban areas [2]. Based on the NDVI values, it seems possible to identify both natural and anthropogenic objects on a satellite image, followed by an analysis of the degree of anthropogenic pressure on the territory [2, 10].

Multispectral space images collected in the archive made it possible to carry out spatial thematic interpretation of rural areas of the Belgorod region - Strigunovsky (Borisovsky district), as well as Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements using different options for color synthesis.

When deciphering the objects of ecological risk that have the greatest anthropogenic load on rural areas, buildings, agricultural landscapes and other anthropogenic objects were identified [2, 10]. Their deciphering features are very diverse, but some indirect features make it possible to identify this group (Figure 1).

For example, increased brightness in the visible range of the spectrum indicates disturbed soils, on which, as a rule, anthropogenic objects are located [2, 10].

NDVI analysis of areas where anthropogenic objects are located shows zero or negative values due to a decrease in brightness in the near infrared range.

Interpretation and spatial assessment of the anthropogenic load and zones of the natural framework of rural areas of the Belgorod region - agrolandscapes of Strigunovsky (Borisovsky district), as well as Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements - was carried out using the NDVI analysis method. This method is based on a comparison of the contrast of two characteristics - the absorption of chlorophyll by the pigment in the red channel and the high reflectivity of plant materials in the infrared channel [2, 10].

3 Results

The study of the spatial and temporal characteristics of the degree of anthropogenic load in rural areas of the Belgorod region on the example of Strigunovsky (Borisovsky district), Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements, as well as adjacent agrolandscapes using Earth remote sensing materials, made it possible to differentiate the studied territories . 4 zones have been identified - high anthropogenic load (residential and utility buildings of a rural settlement), medium anthropogenic load (agricultural land and other anthropogenic objects), natural frame (territories occupied by green vegetation), water bodies.

The dynamics of the anthropogenic load over a twenty-year period in the rural areas of the Belgorod region, using the example of Strigunovsky (Borisovsky district), Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district) rural settlements,

as well as the agricultural landscapes adjacent to them, shows a slight increase in territories related to the average anthropogenic load. This fact can be explained by the active development of the agricultural sector, which has a positive economic effect, but requires monitoring environmental studies.

Fig. 1. Interpretation of anthropogenic objects on the territory of the Strigunovsky rural settlement of the Borisovsky district of the Belgorod region and adjacent agricultural landscapes.

4 Discussion

Protective green zones, according to the urban planning code of the Russian Federation [1, 2], should be located on the windward side of the settlement. In a settlement, it is necessary to provide, as a rule, a continuous system of green areas and other open spaces. The general principle of organizing a green zone is the maximum preservation of natural green spaces, as well as the introduction of gas-dust-resistant rocks [2].

Analysis of the wind rose of the Belgorod region in the summer period shows the predominance of northwestern, northeastern and western points.

According to remote sensing data of the territory of the Strigunovsky rural settlement of the Borisovsky district of the Belgorod region, as well as suburban landscapes, most of the natural frame zone is located on the north side of the residential zone, which is the leeward side. These territories do not provide a positive impact on the degree of self-purification of the atmosphere. Only a small part of the natural frame, located on the southwestern (windward) side of the settlement, optimizes the microclimatic conditions of the territory.

A similar situation is developing on the territory of the Obukhovsky rural settlement, which belongs to the Starooskolsky urban district. The Obukhovskaya Dacha natural boundary, located in the northern part of the settlement, does not provide the necessary ecological effect. A positive impact on the microclimatic conditions of the Obukhov rural settlement is exerted by the tract "Kazyonny forest".

The most optimal location of the natural frame zones was revealed based on remote sensing data on the territory of the Dolgopolyansky rural settlement of the Starooskolsky district of the Belgorod region - around, as well as inside the residential areas.

5 Conclusions

In the environment of the GIS "Ecological safety of rural areas of the Belgorod region" a set of environmental, socio-economic, and climatic data of rural areas of the Belgorod region is generalized on the example of agrolandscapes of Strigunovsky (Borisovsky district), as well as Obukhovsky (Starooskolsky urban district) and Dolgopolyansky (Starooskolsky district).

Along with the addition of the data described above, the detailed collection of which is expected at the next stage of the research, will allow us to determine the integral indicator of social and environmental safety for each studied settlement according to the methodology we have developed.

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