Experience in analysing the landscape morphological structure based on innovative methodological approaches

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Abstract. The current tendencies in studying landscape geosystems direct to increase information support of processes using innovative spatial information processing methods. The paper represents the developed complex analysis of theoretical, cartographical, and geo-informative studies, including automated decoding techniques of remote sensing data. Problems of approval of methodology and interpretation of results are considered. They were received with multi-channel segmenting of pixel images from satellite vehicles for a long-term period (1989-2018). Spectral channels of visible, near-infrared, and short-wave infrared diapasons were used. Parameters were identified to select territorial units on the geosystem level – the landscape province. Steppe and forest-steppe areas of the Orenburg region were chosen to conduct the study. The results were compared with existing landscape zoning. Anthropogenic factors defining the dynamics of the morphological structure of landscape geosystem were identified: subsurface and land use, abandonment of agricultural landscapes, self-restoration of inter-component and inside-landscape interconnections on steppe strips, urbanization processes. The developed algorithm promotes a maximal possible objectiveness of the conducted study at the expense of using automated mathematic methods and realization of repeated verifications of the results. The universality of the methodology promotes extrapolating its principles in areas of various natural zones.

1. Introduction
A composition and configuration of the landscape structure (fragmentation, transformation, biodiversity), the change in the land use structure (abandonment/intensification of landscape use) demand its assessment in "numeric expression." The development of modern methodology of automated processing of spatial data is required to promote metrical landscape study to estimate the current conditions and receive a notion to make decisions directed to the areas' stable development [1]. Specifics of landscape study in the steppe regions consist in identifying the role of environmental and anthropogenic factors, their spatial configuration, and intensity of economic land use in agricultural landscapes [2]. Two principal methods of spatial data collecting are field studies, and topographic and thematic maps use. Despite their significance, both methods have limits: a high labor intensity, inaccessibility, and cost [3]. The most rapid and effective way of reflection of the existing situation within a geosystem and possible variants of its development is informative geographic systems (GIS) [4]. The strategy's geophysical data promotes to realize management of information bases, visualization, and analysis of information, using a set of spatial variables and functional (mathematic) relation between them [5]. Ecological monitoring, nature conservation, territorial zoning, and
ecosystem-oriented management of natural resources are the urgent questions, information for the solution of which can be taken from remote sensing data (RSD) [6]. RSD is a non-contact recording of the electromagnetic specter of the Earth's surface using satellite vehicles to measure, detect and classify ground objects and landscape components. They promote receiving efficient spatial information required to increase the topicality of landscape studies. RSD from the Landsat series satellite is suitable for monitoring the Earth's surface changes on the regional level [7]. Modern thematic maps created based on synthesized and persistent satellite data, to the most degree, reflect the outer world of geosystems' state [8]. Imagery conditioned by reflecting properties of a landscape promotes estimating the size, shape, and connectivity of different ecosystems in the vast territory [9]. Several models and algorithms for automated modeling of the landscape structure changes can be either complicated for evaluating transformations of land use or resource-expensive to use them in limited computing function [10]. Complex geo-informational models promote recognizing peculiarities of geosystems' landscape structure and genesis to identify system-forming flows of substance and energy [11]. To simplify the landscape structure study, we developed a complex geo-information analysis algorithm, including traditional geographical studies and innovative methodologies of analysis and decoding of remote sensing data.

2. Material and Methods
An algorithm of complex geoinformation analysis was developed to identify structural and dynamics properties of geosystems. It included innovative methods of automated decoding of remote sensing data (RSD) and calculating numerical characteristics based on RSD, reflecting special landscape differentiation features (figure 1). Existing theoretical, cartographic, and digital data on the study's territory are collected in the first stage. Using it, based on Excel and ArcGIS, a geoinformation database was formed. The cartographical and statistical analysis of informational massif with the making vector models reflects basic notions on the landscape structure for the study's beginning. Collecting, preliminary processing, and automated decoding of RSD have happened in the second stage. The most urgent was the use of satellite images from spacecraft of the Landsat series. They promoted to receive efficient multi-spectral data that was the principal factor in the objectification of results. For grassy grasslands of the steppe zone of Russia, the analysis should be conducted based on synthesized data: using channels of visible specter – red, blue, green channels (RGB) and near-infrared (NIR) and short-wave infrared (SWIR) diapasons. Such a set of channels was conditioned by the vegetation cover differentiation's spectral properties as the principal physiognomic component of landscapes on satellite data. The most contrast ratio of absorption and reflection of solar radiation by photosynthetic pigments happened in a zone of red and near-infrared diapasons. It was reflected in calculations of vegetation indexes. The use of visible diapason was conditioned by a necessity for expert verification in the field and laboratory stages of the study.

An automated algorithm of multi-channel segmentation of RSD was used to analyze the regional differentiation of landscape geosystems. Such a stage promoted the identification of large polygonal objects within the study region; the items were divided according to parameters of spectral brightness, texture, and continuity. Territorial units identified by such a method can correspond to geosystems of the different hierarchical levels. In approbation of the way in the Orenburg region, it was ascertained that formed limitation on the maximal size of a polygon varied at the level of 5 million pixels (an area of one pixel is 900 m²) that corresponded to a level of landscape regions. Therefore, the segmentation of satellite images promoted the realization of small-scale geo-informational modeling of the polygon's borders corresponding to the physical-geographical areas, taking into account the actual degree of anthropogenic load.
3. Results and Discussion
According to the results of conducted segmentation, there was an increase of polygons' amount at 20% and a decrease of indicators of their area and extent of their borders for 1989 to 2018 (figure 2, table 1). Thus, a degree of differentiation of the environmental-anthropogenic geosystems has increased; the length, the diffusiveness, and complexity of anthropogenic ecotones have risen for 30 years. We cannot exclude a sharp increase of shapes of a natural formation at the expense of the

Figure 1. A block diagram of the algorithm of the complex analysis of landscape geosystem dynamics.
emergence of large plots of protected territories, construction of a stable network of steppe fallows, intensification or exploration of oil deposits, the emergence of abandoned settlements, rapid widening of the areas of marginal development. We detected a degree of segment borders' coincidence with the natural zoning of A.A. Chibilev and the administrative-territorial division of the Orenburg region [12]. Dynamics tendencies of spatial transformation of plots during the time were revealed. The medium length of borders between segments was considerably increased (the growth was more than 80 %) under reduction of the total extent. The largest components coincided with the east part of the region. The decline of the maximal area was less than 3% of the 1989's values.

![Figure 2. Comparison of the results of automated segmenting of the Orenburg region with landscape zoning (on A A Chibilev).](image)

In 1989, segments comparable with borders of administrative-territorial division in the Orenburg region were often noticed. A high degree of anthropogenic load on the steppe landscapes and features of agricultural land use, in the frame of the USSR's administrative command economy, decreased influence of landscape geosystems on parameters of spectral brightness of the surface detected by spacecraft.

| Year | N   | S min, km² | S mid, km² | S max, km² | L mid, km | L sum, km |
|------|-----|------------|------------|------------|-----------|-----------|
| 1989 | 39  | 313        | 3190       | 7956       | 23.8      | 5440      |
| 2018 | 47  | 278        | 2647       | 7723       | 43.4      | 4601      |

Segmentation of 2018 was close to natural zoning. The river systems of Ural, Sakmara, and Samara were represented as the leading of natural borders. An interesting trend was an increase of environmental-anthropogenic differentiation for 30 years in the west part of the oblast, especially within Obshchý Syrt and the Ural-Tobol watersheds. In connection with a change in the economic
structure laid inside the region, the growth of oil and gas production and reduction of agriculture extensity led to more fragmentation and complexity of the landscape structure at the expense of the number of oil wells on the background of a decrease in productivity of deposits and self-restoration steppe ecosystems within abandoned agricultural landscapes.

4. Conclusion
According to the results of the conducted study, we revealed anthropogenic factors identifying dynamics of landscape geosystems' morphological structure. The dynamics of anthropogenically disturbed lands were conditioned by transformations of the economic situation directed to the most profitable kinds of subsurface and land use. An increase of high fragmented fallows is a factor affecting the degree of complexity and diversity of the landscape structure. Degradation of forest belts provides the growth of the mosaic system of woody-shrubs plantations. Depopulation in the rural area and, consequently, economic load led to the activation of the landscape structure's self-restoration. Urbanization and urban polarization of financial processes led to the transformation of the fragmentation degree in urban and marginal development zones. The reduction of anthropogenic load activated self-restoration processes of broken inter-component and inside-landscape interactions that increased the level of mosaic structure of geosystems.

The developed algorithm provides the study's maximal possible objectiveness for the account of the use of automated mathematical methods and realization of repeated verifications of the results. The universality of the way promotes extrapolating its principles to areas of other steppe regions in Russia and different suburban zones.

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