Soil ecological zoning in the middle Volga region using GIS technologies

D V Antropov¹, A I Chursin², D N Konokotin¹, S M Salov¹, D V Samoylenko¹

¹ State University of Land Use Planning, 15, Kazakov st., Moscow, 105064, Russia
² Penza State University of Architecture and Construction, 28, German Titov st., Penza, 440028, Moscow

E-mail: antropovzem@gmail.com

Abstract. The article examines the issue of soil ecological zoning of territories. GIS technologies used for the soil-ecological zoning are described. A new type of soil-ecological zoning of the Middle Volga region by means of GIS technologies is presented. It is in compliance with the current state of the soil cover, erosion processes and the agricultural land structure in the region.

1. Introduction

The concept of zoning is multifaceted and depends on the purposes of zoning, which has formed many types of zoning in public life, in the system of civil, land, and other relations (Fig. 1).

Nevertheless, we can conclude that most authors define it as division of the territory into different parts (different in a number of features), forming their geographical differences. In the explanatory dictionary by Ushakov, zoning is defined as the administrative-territorial division of the country into regions. At the same time, in political science, zoning is defined as a process of territorial distribution of various economic activities by government authorities within their powers. In ecology, zoning is a set of measures aimed to identify territorial differentiation and integration of the geographical shell or its area, as well as natural and socio-economic processes of interaction between society and nature. However, the meaning of the term zoning is ambiguous [1–7].

One of the important issues is the need to develop and establish methodological approaches to the soil-ecological zoning of lands on the landscape-ecological basis, as well as to use land typification methods for the rational use in modern agricultural landscapes [1]. In these conditions, the methods of cartographic modeling and graphical presentation of zoning results are required.
2. Methods
Soil-ecological zoning requires various methods. It is obvious that the zoning methods differ from the restrictive zoning urban planning ones. Thematic maps containing the zoning results and other characteristics are of great importance. GIS technologies can be an optimal tool. However, GIS tasks go far beyond cartographic ones, making them the basis for integrating geography and other sciences (geology, economics, etc.) in complex systemic studies of territories [1].

Figure 1. Specified classification of zoning types according to D.V. Antropov [5]

Figure 2. Geoinformation technologies for zoning territories (the general scheme) [1]
However, it is necessary to combine various types of subject spatially distributed data about territorial resources and combine them with cartographic data on the basis of modern information technologies, including technologies for creating, maintaining and managing databases [8, 9].

The descriptive information is linked to spatial data by means of GIS. GIS functions include collection, system processing, modeling and analysis of spatial data, display and use of these data for making management decisions. GIS is a toolkit for solving problems in a territorial context. When compiling digital maps in the GIS environment, the emphasis is on the structure of spatial relationships between the objects. Moreover, this database should be stored on the relational principles, i.e. based on a relational database model, which is a collection of interconnected tables that model a domain (Fig. 3).

![Diagram](https://via.placeholder.com/150)

**Figure 3.** The procedure for creating a spatial data structure in relational tables

As for the directly applied solution, Russian monitoring software tools "Panorama" GIS, ArcInfo (ArcView) and MapInfo are widely used. In the current study, the MapInfo GIS was used.

### 3. Results

The middle Volga region has an advantageous economic, geographical and transport position. Occupying the southern part of the Volga Federal District, it includes the Republic of Tatarstan, Samara, Saratov, Ulyanovsk and Penza regions. The landscapes are composed of the Volga Upland, which is elongated in the meridian direction, which is the largest upland in the East European Plain. Pastures and hayfields are characterized by a high degree of cultivation in broad-leaved forest and forest-steppe zones. Agricultural lands are subject to negative processes, such as water and wind erosion, waterlogging, alkalinization, salinity, etc. Arable land is more susceptible to the negative processes. It occupies 44% of the area of the Middle Volga region and experiences the strongest
anthropogenic pressures. The territory has a wide variety of soils, including leached, typical, ordinary, southern, chestnut, light chestnut, light gray and gray forest chernozems and dark gray forest soil.

On the basis of previous studies (Chursin, Antropov), a new schematic map of typification of the Middle Volga region was compiled using the GIS technologies. It is in compliance with the current state of the soil cover, erosion processes and the structure of agricultural land. Five soil-ecological regions were indicated: northwestern (1), northeastern (2), central (3), western (4), southern (5).

![Figure 4. The new schematic map of typification of the Middle Volga region using the GIS technologies](image)

4. Conclusion

Legal rules on soil ecological zoning should be consolidated. Any type of zoning requires a graphical presentation of its results. One of the key directions in the development of information support systems for government bodies is geoinformation technologies and geoinformation systems, since geographic information is an integrating basis for a wide range of problems in ecology, land management, forecasting and monitoring.

The GIS technologies allow the visualization of information about the elements of zoning on electronic maps (or materials printed from the GIS systems) and provide access to electronic maps,
make it possible to graphically present the object with a transition to the database. If the GIS is considered as a technology, it is a means, a system for collecting, storing, displaying, using spatial data in order to solve forecasting, planning, and management problems. Hence, the GIS technologies used for zoning territories are a tool, an administrative system of the cartographic (and sometimes semantic) database, and a research method, which allows the solution of tasks in the land and territories management system.

A high level of specification of the soil-ecological zoning makes it possible to improve the validity, clarify the targeting and improve the adaptability of forage production technologies, as well as to improve the sustainability, optimize and protect agricultural landscapes, and improve the efficiency of rational nature management. The soil-ecological zoning map for the Middle Volga region will allow for determining the ways of solving the following important tasks: to choose ecologically and economically expedient areas for land management, to choose crop and livestock production areas in accordance with the soil-ecological conditions of the territory; to identify areas where the hydraulic load should be limited; to identify areas more prone to erosion and to choose methods to eliminate it; to determine economic policies in each region.

References
[1] Antropov D V, Varlamov A A, Komarov S I 2019 Theory and methods of zoning territories for land management purposes: monograph (Moscow: RADUGA) 228 p
[2] Borodina O B 2019 Modern trends in land zoning in the Russian Federation Moscow economic journal 13
[3] Varlamov A A 1990 On-farm land organization on a landscape basis (theory, methods, practice) (Moscow: MIIZ) 46 p
[4] Totonova E E 2016 Analysis of methods of zoning and zoning of northern territories (on the example of Canada) Arctic XXI century. Humanitarian sciences 1 28–36
[5] Chursin A I, Antropov D V, Bibaeva R A, Semenova Yu K 2020 Typification of the territory of the middle Volga region on the basis of soil-ecological zoning Land management, cadastre and monitoring of lands 9(188) 24-28
[6] Buldakova E, Zaikanov V, Minakova T 2019 Geo-environmental Zoning for Urban Planning and Design. DOI: 10.1007/978-3-319-91833-4_14.
[7] Komarov S, Zhdanova R, Galchenko S, Varlamov A, Antropov D 2019 Zoning as a tool of land management IOP Conference Series: earth and environmental science 451 012060
[8] Volkov S, Cherkashina E, Shapovalov D 2019 Digital land management: new approaches and technologies IOP Conference Series: earth and environmental science 350 012074
[9] John Kingsley, Afu Sunday, Isong Isong, Aki Ene, Kebonye Ndiye, Ayito Esther, Agyeman Prince, Eyong M, Penížek V 2021 Mapping soil properties with soil-environmental covariates using geostatistics and multivariate statistics International Journal of Environmental Science and Technology. DOI: 10.1007/s13762-020-03089-x.