Storage and analysis of natural resources information in various territories

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Abstract. The article is devoted to the creation of a system of cartographic models of natural resources for a specific territory. The reasons for the inefficient use of natural resource information in modern Russia are described. The place of natural resource mapping in the formation of a natural resource information space is characterized. The task of systematic consideration of natural resources when creating cartographic support for solving the problems of natural resource management and environmental management planning has been set. It is proposed to develop a program for processing images in the GeoTIFF format, intended for the analysis of natural resources. The structure of the program for the planning and management of environmental management is presented. The main functional types of CMRD are outlined: inventory, estimated, forecasted, recommended. The features of their use at various stages of environmental management are identified.

1. Introduction
Mapping of natural resources occupies an important place in the formation of natural resource information space since it provides an informed basis and a methodological basis for solving problems in the field of nature management using spatial-temporal analysis and visualization of its results [1]. However, in modern natural-resource mapping, only methodological issues of visualization of mineral resources and forest resources have been worked out in detail [2]. Universal recommendations for mapping other types of natural resources (air, water) are still missing, as a result of which a significant part of modern research and development devoted to this topic is adapted to solve a specific nature-user problem [3, 4]. The lack of universal recommendations makes them extremely difficult to use in cartographic projects carried out in other territories or other software.

Assessment of natural resources includes taking into account many factors (economic, social, technical, ecological and geographical) that determine spatial differences and the importance of natural resources for human life and activity [5, 6].

The information support system should be formed and developed within the framework of the integrated territorial cadastre of natural resources – ITCNR, which is state code of data on natural resources.
resources and natural objects in the territorial context, necessary for making managerial decisions in the field of socio-economic development of territories, taxation and environmental management [7].

The basic principles of the formation of this system are to ensure the requirements of integrated environmental management, the full reliability of the quantitative and qualitative accounting of natural resources, their distribution among users and territories, and the assessment of the actual state of natural resource potential.

Data from an inventory of natural resources, which is the identification and periodic accounting of the quantity, quality, dynamics of reserves and changes in the operation of various types of natural resources, are used to compile a cadastre.

2. Functional types of cartographic models of natural resources

Modern thematic cartography is constantly developing all new types of maps in order to most fully satisfy the scientific and practical needs of users. Maps of various functional types have been created: inventory, evaluation, indication, forecast and recommendation. Let considering in more detail.

Inventory maps detail the presence, location and condition of objects and phenomena. Examples include maps for the placement of minerals, medicinal plants, the working population, pastures and arable land.

Score maps are created on the basis of inventory. These are maps of an applied nature containing a targeted assessment of an object in a given relation (or from a certain point of view). For example, there are maps for assessing the natural conditions of the territory for road construction, civil engineering, agricultural development, development of oil and gas fields, analysis of environmental conditions of the population, environmental protection measures. It all depends on the application and the set of source data.

Indication maps are designed to predict and identify unknown phenomena based on the study of other, well-known. The compilation of indicative maps is based on the notion of the close relationship of indicators and indicated phenomena. Thus, vegetation indicator maps are utilized to detect tectonic faults, since special groundwater circulation conditions arise over their zones, and this immediately affects the species composition of the vegetation.

Predictive maps reflect unknown, currently unavailable or inaccessible to the direct study of phenomena and processes. Such maps may reflect:

- Forecasts over time (the synoptic situation for tomorrow, the state of the environment in five years).
- Forecasts in space (assessment of the oil and gas potential of the territory, the structure of the bowels of the moon).

3. Methods of raster graphics

One of the most important steps in building a graphic database is the geometric transformation of data on the spatial location of objects from one coordinate system to another in a common cartographic projection. Such transformations are necessary for comparing and analyzing objects whose graphical information is stored in the GIS database in different cartographic projections. The corresponding mathematical apparatus is widely represented in standard GIS software.

The raster model is particularly well suited to represent real-world phenomena that have a continuous distribution, such as the temperature of the Earth’s surface.

The raster method is based on dividing the surface into many elements of equal size (cells, pixels). A raster is a rectangular table consisting of many rows and columns formed by pixels having a specific color. In a normal display, the elementary particles of the raster are not visible, but with a significant increase they are easy to detect.

This is not always convenient, since the pixel size captured during the creation of the raster may be too large and many details will be lost. However, the raster shape is well suited for modeling spatial
continuity, especially if the corresponding attribute has a high degree of spatial variability. Such situations often arise when processing satellite images.

It is necessary to have a large number of measurement points that should be evenly spaced in the study area in order to more accurately simulate spatial continuity by the averaging method. Methods for interpolating the surface of raster maps can be used with insufficient data. In this case, the coordinates of the raster \((x, y)\) are considered as arguments of the function of two variables, and the quantitative characteristic of a given pixel \(z\) as the value of the function. Therefore, the problem of approximation arises and its special cases – interpolation and extrapolation of surface data of raster maps.

Approximation is the process of obtaining an estimate of attribute values at points located close to measurement points. It is used:

- When transforming bitmap images.
- Transformation of terrain models.
- Modeling a continuous surface using a set of individual points.

An approximation in which the accuracy requirements at the nodes of the initial grid provide for the coincidence of the corresponding values of the initial and approximating functions is called interpolation.

The following surface interpolation methods are available: global, local, exact, and approximate.

In global methods, the same function is applied to all measurement points. As a rule, polynomials of the first, second, and third degree are used as interpolation functions.

In local methods, interpolation is applied sequentially for small groups of points in the original dataset. The optimal and widespread local interpolation method is kriging. This method is easily modifiable and can be utilized to interpolate any type of data. It combines a whole family of linear regression algorithms: simple, standard, universal, block kriging and co-kriging.

In exact interpolation methods, the resulting function takes the same values at the measurement points that were before the interpolation. These methods include the Thyssen polygon method and the spline method.

The Thyssen polygon method, due to its local nature, does not change the global characteristics of the data set. This method is a non-smooth interpolation method, since jumps of a function occur at the boundaries of polygons. Thyssen polygons are used for interpolation with a small number of reference points, and it is assumed that the value at each measurement point is absolutely accurate.

The spline method, or spline interpolation, is based on the use of lumpy polynomial functions called spline functions for interpolation in the vicinity of a given node. For the two-dimensional case (on the plane), the spline function is mathematically equivalent to a flexible ruler and is a cubic polynomial (polynomial of the third degree) - a continuous function that has continuous first and second derivatives. For the three-dimensional case, when an interpolated surface is taken instead of a line, bicubic splines are used - polygons of the third degree of two space coordinates. In spline interpolation, the interpolated line (two-dimensional case) or surface (three-dimensional case) at the measurement points coincides with the previously obtained values.

The advantages of spline interpolation include the high processing speed of the computational algorithm. Since a spline is a piecewise polynomial function, then interpolation simultaneously processes data on a small number of measurement points belonging to the fragment under consideration. The interpolated surface describes spatial variability of various scales and at the same time is smooth. The latter circumstance makes it possible to directly analyze the geometry and topology of the surface using analytical procedures.

However, the smoothness of the interpolated surface makes it impossible to correctly display sharp changes in the original surface, which is one of the drawbacks of the splines method. Other disadvantages of this method include the high dependence of the accuracy of surface modeling on the location of measurement points (or observations), the presence of points on the structural lines of the
original surface – watersheds and talwegs, if it is a topographic surface – is especially critical; the dependence of the result of interpolation on the nature of the selection of fragments; lack of methods for direct estimates of errors associated with spline interpolation.

Another option for spline approximation is a generalization of the moving average method. Each value of the approximating function (spline) is made up of nearby initial values with coefficients in the form of some polynomials. And since not all polynomials used are subject to simultaneous coordination, but only nearby, then splines of this kind are called local, or B-splines.

The recognized advantages of the main splines and B-splines are high accuracy, sufficient smoothness and technological sophistication. However, these advantages are fully manifested only on a uniform grid and with low gradient gradients. Therefore, to replenish the data and ensure their comparability, it is desirable to preserve the advantages of splines, but to get rid of the disadvantages noted above.

After calculating the values of the intermediate points of the raster map, it is necessary to distribute the map data beyond its limits for the purpose of forecasting. Extrapolation is, in fact, the forecasting process itself using a formula or algorithm obtained from approximation. With the seeming simplicity of substituting values into the already found function, it is necessary to make sure that the domain of the obtained function on the predicted interval fits into the allowable values of the real physical quantity, which is approximated.

Cubic spline extrapolation is a fast and stable way to extrapolate functions and is an alternative to polynomial extrapolation. Cubic spline extrapolation is based on the principle of dividing a given extrapolated interval, borrowed from spline interpolation, into small segments, on each of which the function is defined by a polynomial of the third degree.

The main advantages of cubic spline extrapolation are its stability and low complexity, which allow obtaining the cubic polynomial coefficients with high accuracy. In the process of extrapolation is the nearest point at which the spline coefficients have already been calculated, and a polynomial is constructed that gives the value of the desired function at the current point.

However, the spline extrapolation method also has a serious drawback: the error value will increase with the distance of the extrapolated point from the given initial interval in the case of linearity of the initial function.

When implementing approximation algorithms, it is proposed to combine the methods of cubic and quadratic (linear) extrapolation at the boundaries of the extrapolated interval, which will help reduce the error if there is no information about the nature of the behavior of the function from one side of the point under study.

Thus, the most effective method for approximating the surface data of raster maps is the spline method.

4. Proposed software
Consider a program that analyzes the reserves of natural resources. Figure 1 shows the use-case diagram of the program.

Next, consider the functionality of the program.

The program downloads a geo-referenced raster image in the GeoTIFF format, compares points storing data on the reserves of natural resources that are collected by the teams and are the input data for the program with the geographic coordinates of the image; calculates the total area of the area highlighted in the image, as well as the area of each class and the amount of reserves in this area. The program has the ability to edit and add points, classes and stocks stored in the database.

When entering the program, the main menu of the program opens, where in the «Classes» group user can view and add a new class.

The «Calculate» button in the «Area» group allows calculating the total area of the selected rectangular area in the image, as well as the area of all classes in this area and their percentage of the total area.
Moving the mouse cursor over the image with the left mouse button pressed allows select a rectangular area.

In the «Stock» group the total amount of stock in the selected area for all points located in this area is displayed.

When user right-click on an image, the geographical coordinates of the selected point are displayed in the program status bar, as well as the color code of the point.

The view of the main application window is shown in figure 2.
When user click the «Download points» button of the «Tools» tab, all points are read from the database, the geographical coordinates of which are located in the geographical area of the image, and these points are displayed on the image.

The dialog boxes for adding a new point and stock can be seen in figure 3.

![Figure 3. Dialogs for adding a new point and stock.](image)

GeoTIFF format is an open metadata format that allows user to include geo-referencing information in TIFF files. The format may include a type of cartographic projection, a system of geographical coordinates, a geoid model, date, and any other information necessary for accurate spatial orientation of the satellite image.

The GeoTIFF format is fully compatible with the TIFF 6.0 format, so software without GeoTIFF support will be able to open images in this format.

5. Conclusion
In the course of the work done, the problem of analysis and storage of information on natural resources in various territories was considered. The main methods of raster graphics and functional types of cartographic models of natural resources are also considered.

A program for processing images in the GeoTIFF format, which is intended for the analysis of natural resources, is considered. The program allows downloading a raster image in the GeoTIFF format with a geographic reference, compares points storing data on natural resources with the image by geographic coordinates. It can also be utilized to calculate the total area of the area highlighted in the image, as well as the area of each class and the amount of reserves in this area. The program has the ability to edit and add points, classes and stocks.

References
[1] Nikolaeva O N 2013 On improving information support for mapping natural resources In: Interexpo GEO-Siberia-2013 2(2) 107-12
[2] Plastinin L A and Nikolaeva O N 2013 Application of cartographic models of natural resources for system planning and management of rational nature management *Proceedings of higher educational institutions Geodesy and aerial photography* **4**(1) 113-6

[3] Deren L, Jie S and Jianya G 2009 *Geospatial technology for Earth observation* (Springer)

[4] Nikolaeva O N 2003 The System of natural resources Map-Models for the environment sustainability *In: Int. research and practice conf. “Science, technology and higher education”* pp. 98-102

[5] Painho M, Santos M Y and Pundt H 2010 *Geospatial thinking* (Springer-Verlag, Berlin Heidelberg)

[6] Wilson A C, Rowell D J, Seim G Wm and Debicki R L 2008 Procedural guidelines for provincially significant mineral potential mineral resource assessments *Geological Survey, Open File Report 6141* 91

[7] Nikolaeva O N 2009 *Guidelines for conducting the state forest inventory* (Moscow: Federal agency for forestry)