A conceptual model for geodata processing for sustainable forest management

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Abstract. In scientific work, the process of sustainable forest management is considered as a guiding industry principle for the interaction of man and the ecosystem. The purpose of sustainable forest management is the formation of a forest ecosystem with various resources and functions. Effective forest management is not possible without the corresponding information support. The goal of the scientific work is to develop a conceptual model of geodata processing for sustainable forest management. The objective function of the model is investigated - reforestation modeling, the result of which is the preparation of a spatial solution for sustainable forest management (managerial decision model). An algorithm for performing interconnected functional subsystems is presented: «Processing GEODATA», «Mapping», «Prediction», «Analytics», «Economic calculation», «Modeling of reforestation activities». The contextual chart “Processing GEODATA” has been developed, which describes a macromodel of the process of processing geospatial data in order to build a cartographic basis of the system under study. A general view of the geodata processing function is presented, the result of which is a three-dimensional spatial information model. The final result of the work can be used to solve the problems of forestry management at different levels of management.

1. Introduction

Formation of forest management requirements is one of the main tasks of forestry. Sustainable forest management refers to targeted, long-term, economically beneficial relationships between humans and forest ecosystems. This relationship may be accompanied by technology.

The concept of sustainable forest management, which is based only on maximizing income, without taking into account the maintenance of medium-forming and non-market benefits of forests, can lead to irreversible changes in landscapes and species composition of flora and fauna, to a general depletion of the natural environment, a decrease in biological diversity and, as a result, a sharp decrease in the biological stability of the forest [1].

Sustainable forest management is quite often seen not as a kind of independent management activity, but as a guiding industry principle. Both approaches can be considered correct, since sustainable management is based on achieving strategic goals in the framework of the country's sustainable development and fulfilling its international obligations on forests [2].

The purpose of sustainable forest management is forming of the forest ecosystem possessing different resources and functions. At the same time, the satisfaction of the vital needs of the present generation of people should be achieved without depriving such an opportunity of future generations.

Forest management in Russia is carried out on the basis of scientific knowledge, experience, a comprehensive assessment of possible impacts on forest ecosystems, enshrined in the relevant
legislative and regulatory legal acts, manuals, recommendations, reference books. Sustainable forest management takes into account environmental and socio-economic criteria. The criteria are a set of basic provisions for forestry, the following of which ensures the conservation and sustainable development of forests [3].

Today it is difficult to imagine sustainable forest management without forest management materials and forest environmental monitoring data. The main objective of forest management is to obtain reliable and comprehensive information about the forest fund, to develop a system of measures aimed at ensuring the rational management of the forestry and the use of the forest fund, and the efficient reproduction, conservation and protection of forests. The data obtained by forest management are one of the most important sources of generating information resources on the state of the environment and the anthropogenic impact on it, including through the transboundary transfer of pollutant flows. These data help to use more rationally natural resources, to reveal condition of potentially dangerous objects of the national economy [4, 5].

Effective management of heterogeneous spatial data is impossible without appropriate information support. The rapid development of computer technology, information and communication technologies and GIS, ensuring the use of spatially distributed heterogeneous information, has led to the need to radically change the system of forest management and forest management [6].

In the scientific work, the task is to develop a tool for managing geospatial information in the forestry industry to ensure the development of an optimal solution for the tasks of forestry management at different management levels, characterizing the country as a whole or a large natural and economic region.

2. Methods and Materials

The work used methods of system analysis, algorithmization and data processing. At the heart of conceptual representation of any system under study is set of interacting and interrelated elements (processes and resources), the functioning of which is aimed at obtaining a specific result.

The objective function of the system under study is the modeling of reforestation activity $F(\text{mod})$, the result of which is the preparation of a spatial solution for sustainable forest management (managerial decision model — Mod).

The tasks solved by the model: obtaining forest inventory, statistical and operational information; processing of incoming information; forest register maintenance; analysis of the information received; calculation of economic indicators; preparation of information to support decision-making on forest management.

The system is based on sequential processing of the results of each process. Let's introduce the following notation:

- Converted resources — $d$;
- Management resources — $F(\text{Rman})$;
- Security resources — $F(\text{Rmec})$;
- Treatment process — $F(d), F(\text{map}), F(p), F(\alpha), F(e), F(\text{mod})$;
- Processed resources — $D, \text{Map}, P, A, E, \text{Mod}$.

In figure 1 the chart «Treatment process» — a generalized contextual macromodel of the studied system.
The studied management system is based on consecutive accomplishment of the interconnected functional subsystems: Processing GEODATA, Mapping, Prediction, Analytics, Economic calculation, Modeling of reforestation activities. Depending on the target settings, the processes can perform the functions of processing, analysis, prediction, monitoring and supporting the selection of the optimal solution.

Let’s consider the listed functions as their realization in technological process. The sequence of processes and their final results is presented in table 1.

Table 1. Description of the process «GEODATA Processing».

| Stage | Process name                        | Results process                      |
|-------|-------------------------------------|-------------------------------------|
| 1     | Processing GEODATA — F(d)           | GEODATA — (D)                       |
| 2     | Mapping — F(map)                    | Maps — (Map)                        |
| 3     | Prediction — F(p)                   | Predict value — (P)                |
| 4     | Analytics — F(a)                    | Analysis result — (A)              |
| 5     | Economic calculation — F(e)         | Result of Economic calculation — (E) |
| 6     | Modeling of reforestation activities — F(mod) | The model of managerial decisions — (Mod) |

Thus, the finite function $F(\text{mod})$ has the following form:

$$F(\text{mod}) = \text{Mod}$$  \hspace{1cm} (1)

where, $F(\text{mod}) = F(d, \text{map}, p, a, e) \rightarrow F(D, \text{Map}, P, A, E) = \text{Mod}$.

The structure and functions of the macromodel are presented in figure 2. The scheme reflects the interconnection of the system’s processes, from processing the initial geodata to issuing the final solution to the system user. At each stage, the system has the ability to adjust and return to the previous stage [7].
Stage 1 - “Processing GEODATA” is considered in detail in the work. The final result of the geodata processing algorithm is the prepared cartographic data — $D$, the basis for the transition to stage 2 — the “Mapping” $F(map)$ process and subsequent processes. Necessary resources for ensuring performance of process of "GEODATA Processing" are presented in table 2. Resources are subdivided into input and output and also resources of management and providing.

**Table 2. Description of the process «GEODATA Processing».

| Resource                          | Input $(d)$                  | Output $(D)$     | Mechanism $(R_{mec})$ | Management $(R_{man})$ |
|-----------------------------------|------------------------------|------------------|------------------------|------------------------|
| Remote sensing data.             | Geometric data.             | GIS web services | Regulations.            |
| Satellite image.                 | Topological data.           | Database         | Standards.             |
| Digital image.                   | Identification data.        | Automated        | Instructions.          |
| Laser scanning.                  | Semantic data.              | workplace        | Mathematical model.    |
| Photo and video shooting.        |                              | Staff             |                        |
| Geodetic measurements and etc.   |                              |                  |                        |

Figure 3 shows the context chart “Processing GEODATA”, which describes a macromodel of the process of processing geospatial data, with the aim of constructing a cartographic basis of the studied system — Map.
Figure 3. Context chart of the process «GEODATA Processing».

In the process of processing geodata, the output includes: geometric \( (D_g) \), semantic \( (D_s) \), topological \( (D_t) \) and identification \( (D_i) \) data about the object of study — \( D \), regardless of the form of their presentation (spatial and non-spatial — \( (C_p; C_{up}) \)).

\[
D = F(d, Rmec, Rman)
\]

(2)

where \( D = (D_g, D_t, D_s, D_i) \).

Thus, the \( F(d) \) function carries out processing and display of the considered data to the great number of \( D \), in the result of what function can be presented in the form:

\[
F(d) : C = (C_p; C_{up}) \rightarrow D,
\]

(3)

The data is processed, during which the coordinates and, if necessary, the heights of the representative points are calculated and equalized. As a result, the data is subject to conversion and displayed in a single spatial information field. In this case, initial information is used in the form of coordinates and heights of control points in a given coordinate system and cartographic projection.

Thus, the geometric information \( (I_g) \) is obtained. Topological data from a schematic image of the territory is converted into a digital tabular form for describing contours and objects - topological information \( (I_t) \). Topological information, together with geometric information, forms spatial information \( (I_p) \) that fully reflects the spatial properties of objects. The processing of semantic data
consists in the systematization, classification and coding of the characteristics of the non-spatial properties of objects. As a result of this processing, attribute information \( (I_a) \) is obtained.

An ordered collection of geometric, topological, identification and semantic data about the territory and its spatial objects forms a three-dimensional spatial information model of data — Mod.

\[
F(d): D \rightarrow \text{Mod},
\]

where, \( \text{Mod} = \{I_p, I_a, I_g, I_t\} \).

The three-dimensional spatial information model is a complete result and can be further processed to solve forest management problems at different management levels.

3. Conclusions

As part of this study, a conceptual macro model of geodata processing was developed and presented to support decision-making on sustainable forest management. The resulting conceptual macromodel has the ability to use the described approach to solve forest management problems, since it basically has a clear ordered sequence of behavior, the necessary set of system elements, the structure of subsystems and data processing functions, the mathematical prediction apparatus, the economic calculation of management decision-making efficiency indicators and the model of managerial decisions.

The proposed macromodel does not describe the state of the elements inside the object of study, the contents of the “black box” are not detailed in the work, the full model for describing the system and the elements included in the system are subject to further research and development of the topic. Further development of scientific research is aimed at adding new geodata processing techniques to the model and improving the quality of existing ones.

The developed conceptual model of geodata processing can be implemented in a number of information systems, web services and GIS to support management decisions for sustainable forest management.

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