Creation of WPS Services: Case Study of Forest Dynamics Modeling

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Abstract. The article is devoted to the creation of WPS services for the geoportal using the case study of an online service for modeling the dynamics of forest resources. The resulting service works on the basis of a mathematical model of the dynamics of forest areas of a subregional level according to age classes in time and space. Verification of the selected mathematical model was carried out previously, for which the data of real observations and calculated values were compared. The service displays the simulation results on the geoportal in the form of a thematic map of the region. The map legend corresponds to the calculation results: dark shades indicate an increase in forest areas of the selected territory, light shades indicate their decrease over the calculation period. In conclusion, the directions of further development of the created online service for modeling the dynamics of forest resources are given.

Keywords: Forest Resource Dynamic, WPS Services, Forest Modelling, Geoportal.

1 Introduction

Modeling the forest resources dynamics helps to make forecasts of the development of the territory depending on the impact of natural and anthropogenic factors. The accuracy of the result is affected by the level of the model and the number of factors considered. Such forecasts provide information for analyzing the situation and making administrative decisions.

The paper describes a modeling system implemented in the form of an online geoportal service. This approach simplifies the use of the forecasting algorithm - to start the calculations users do not need to install the software system, the only need a regular browser.

2 Forest Dynamic Modelling

2.1 Mathematical model

Modeling in the work is based on the model of forest resources of the subregional level "Dynamics of stands". This model is based on the works of A.K. Cherkashin [3], taking into account the studies of [1-2, 4-6] and describes the dynamics of the distribution of forest areas by species and age classes in time and space.

The "Dynamics of stands" consists of a system of differential equations represented by formulas (1-3):

$$\frac{dS_N}{dt} = -a_{N0}S_N(t) + u_{non\,N}(t); \quad (1)$$

$$\frac{dS_0}{dt} = a_{N0}S_N(t) - a_{01}S_0(t) + u_{ncov\,0}(t) + u_{cut\,0}(t) - u_{non\,0}(t) \quad (2)$$

$$\frac{dS_i}{dt} = a_{i-1i}S_{i-1}(t) - a_{i\,i+1}S_i(t) - u_{non\,i}(t) - u_{ncov\,i}(t) - u_{cut\,i}(t) + a_{K1}S_K(t) \quad (3)$$

where a_{ij} are the coefficients of transition from one category of land or age group to the next;
S_N is the non-forest area;
S_0 is an area that is uncovered by forest;
Si is forest areas of different classes of age;
$u_{non\,i}$ is annual increase in non-forest area;
$u_{ncov\,i}$ is increase in the area uncovered by forest;
$u_{cut\,i}$ is the area of cutting.

The increase in non-forest area in the process of forest exploitation is as follows:

$$u_{non} = k_N\Delta N + \Delta S + \Delta R + \Delta G + \Delta Bl + \Delta Bv, \quad (4)$$

where k_N is the area of settlements per person, the remaining coefficients characterize the increase of forest population, ΔN, agricultural area, ΔS , recreational zones, ΔR, area of fields, ΔG, construction of linear objects, ΔBl, and maintenance of hydraulic structures, ΔBv.

The increase in the area uncovered by forest taken into account such factors:

$$u_{ncov} = S_g + S_{nas} + S_b \quad (5)$$

where S_g is an area of fires; S_{nas} is area of insect damage; S_b is an area of forest diseases.

2.2 Verification of the model

Verification of the adequacy of the model and coefficients of transition a_{ij} is done on the base of forestry input data of Baikal region for 1973. Input includes the distribution of forest areas by age categories, volumes of cuttings, fires and forest plantations on the territory of 53 forest districts. Computations for the model were conducted for an interval of 45 years. The final results of the simulation were compared with the

available data on forest areas for 2017, obtained from the official «Forest Plan of the Irkutsk Region».

It was taken into account that in 2008 the Ust-Ordynsky Buryat Autonomous Area with the area of 22,138 thousand km^2 was united with the Baikal region. Forest districts placed on its territory were not included in the final results for 2017. The total areas of different age categories for all forestry were calculated for comparison.

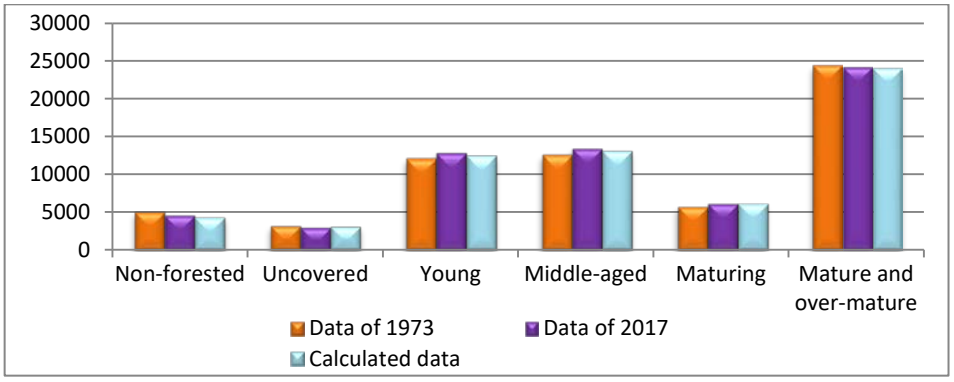

Fig. 1. Chart of comparison of calculated and real data.

As can be seen from Table 1, the dynamics of areas change of different categories according to real and calculated data is the same. Non-forest areas and covered with mature and over-mature forest plantations have slightly decreased; uncovered, the area of young, middle-aged and maturing are increased. The difference between statistical and forecast data is due to the lack of accurate information on fires and the volume of all cutting over a period of 45 years. Some areas of Baikal region are difficult to access or inaccessible, hence, a regular forest pathological examination is difficult there.

Table 1. Comparison of real and calculated data.

Area type	Actual data, years		Simulation	Error, %
	1973-1985	2017		
Non-forested	5108,223	4670,194	4401,66	5,75
Uncovered	3273,893	3032,455	3166,37	4,42
Young	12161,067	12847,546	12044,61	6,25
Middle-aged	12648,814	13411,571	13137,08	2,05
Maturing	5783,593	6170,173	6215,15	0,73
Mature and over-mature	24444,429	24128,406	23089,60	4,3

In the last column of Table 1 is the calculated relative error of the forecasting. The formula of the error is as follows:

$$E = \frac{|S_{calc} - S_{true}|}{S_{true}} * 100\%, \quad (6)$$

where S_{calc} is simulation data, S_{true} is actual data.

The relative error should not exceed 10% for the model to be considered valid. In "Dynamics of stands" the average error was 3.43%, therefore this model can be used for predictive simulation and assessment of the trends of the general dynamics of forest resources under influence of various management decisions.

2.3 WPS Service

The web service was created for use on the portal of IDSTU SB RAS. The service is written in JavaScript, the open library Leaflet is used to display the map. The table with the initial data is uploaded by the user to the geoportal, the service receives the data through a JSON request. To form a scenario, it is necessary to specify the length of the calculation period in years, the volumes of felling, fires and economic impact. Next, the calculation algorithm begins using a mathematical model, which at the end gives the predicted value of the forest areas of each age class for all forestries.

To build a visual map based on the calculation results, for each section of the territory its dynamics is calculated - the difference between the forest area in the last and first years of the modeling period. Then, the difference obtained is divided by the total forestry area to obtain relative values. According to these values, all forest areas are divided into four categories, each of which has its own color value. The service transfers the received information in the GeoJSON format to the geoportal, where the result map is displayed using the Leaflet.

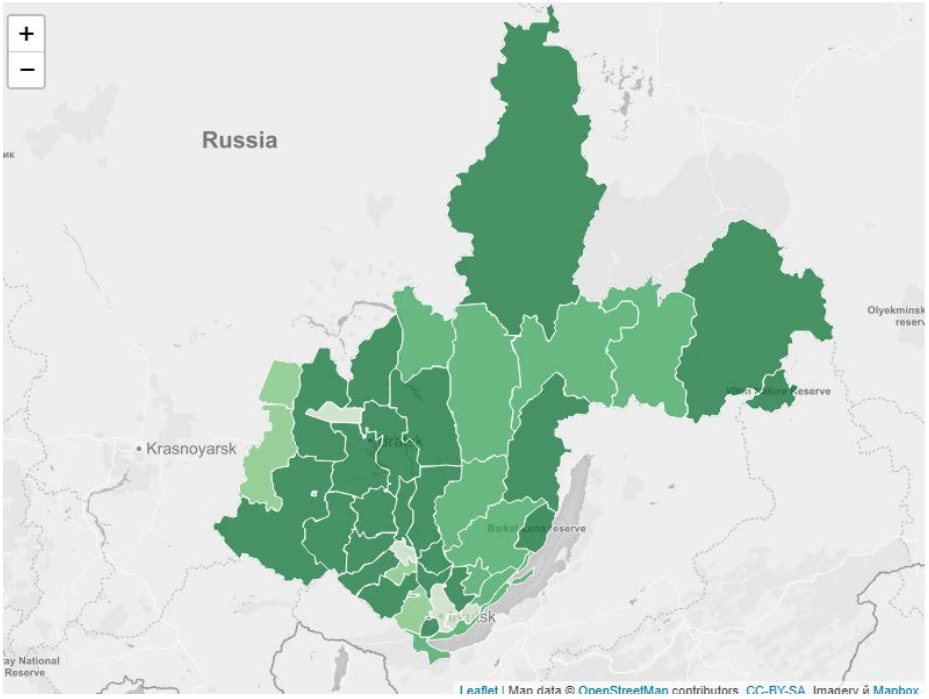

Fig. 2. Map with calculation results for Irkutsk region.

3 Conclusions

The created online service helps to model the dynamics of forest resources, taking into account the impact of natural and anthropogenic factors. Users interact with service through the geoportal, setting the initial calculation parameters, which form the scenarios of forest resources changes. The calculation results are presented to the user in the form of tables and maps. Tables represent total values for each year from a given period for each land category and tree age class. It is intended for deeper analysis of the simulation results. The map shows the result of calculations in a visual form for a quick assessment of the scenario of the forest resources dynamics.

The verification of used model "Dynamics of stands" was made before start of the simulations. The calculated data for a period of 45 years based on available data on the forests of Irkutsk region for 1973 were compared with the actual data for 2017. As a result, the accuracy of the model is 3.43% with an allowable relative error of 10%, therefore, "Dynamics of stands" can be used to assess the consequences of management decisions for the territories of the rank of forestry and the region.

In the future, it is planned to develop the service - supplementing it with lower-level models that consider the forest dynamics of small areas and therefore allow you to build more accurate forecasts. It is also promising to combine calculations with other services that can provide additional information for analysis - these are services

that make available information about the weather, the road network, and the anthropogenic load on the territory.

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