Digital Approach to Forest Cover Mapping: a Case Study of Forest-Tundra in the near-Yenisei Siberia

V A Ryzhkova*, I V Danilova, M A Korets
Sukachev Institute of Forest Siberian Branch, Russian Academy of Science, Akademgorodok 50/28, Krasnoyarsk, Russia,

E-mail:*vera@ksc.krasn.ru

Abstract. An algorithm of semi-automated classification and mapping of vegetation cover was developed based on the digital data (satellite images, digital elevation model, and climate data base) and ground truth data. The obtained maps cover a range of vegetation growth conditions, diversity of the vegetation types, and bog complexes in the forest-tundra zone of the Middle Siberia.

1. Introduction
Remote sensing data (RSD) have been widely used for vegetation mapping in combination with the analysis of topographic and climatic factors, which affect the vegetation spatial patterns. Mapping is an effective method for monitoring vegetation cover changes. It is especially important for large remote areas of Siberia. The objective of this study is to develop an approach to vegetation cover mapping based on RSD, digital elevation model (DEM), forest inventory data, and ground truth data using a GIS-technology.

2. Materials and Methods
The test area (68°20' - 69°30' N, 87°30' - 91°00' E) is partly located in the forest-tundra and northern taiga subzones. The area contains various vegetation types, which, in their combination, form tundra, forest-tundra, taiga forest, and bog complexes. Forests occupy not more than 15-20% of the area.

The GIS Data Base was used to automate mapping of the vegetation types and vegetation growth conditions. The GIS basic information layers, such as the topographic map, raster-vector relief model, satellite imagery, general geographic and thematic maps, as well as, the database of the ground observations were used and their spatial analysis was carried out. The satellite images and DEM were analyzed in a stepwise way, with the GIS technologies and standard procedures of ERDAS IMAGINE 2013 and ESRI ArcGIS 10 [1]. Pixel-based classification algorithms (unsupervised clustering – ISODATA and supervised Maximum Likelihood Classification (MAXLIKE)) were used to perform the automatized classification of the DEM-composite (elevation above sea level, slope) and satellite images. A summer (July) cloud-free Landsat 8-OLI scene (2013) obtained as close as possible to the period of the field studies was used.

3. Results and Conclusions
We developed an algorithm of the semi-automated creation of vegetation cover maps of the test area in the north of the near-Yenisei Siberia. It includes four main steps.
1) The inventory and preliminary classification of the vegetation cover taking into account the regularities of its natural and anthropogenic dynamics in a range of vegetation growth conditions (VGC). We used DEM (http://www2.jpl.nasa.gov/srtm/russia.htm) to build topological profiles crossing the area of study and analyzed these profiles using the thematic maps, literature information, and ground observation data to build a combined classification of the growth conditions and vegetation. This classification was taken as the basis for developing the vegetation cover map legend.

2) The semi-automated classification and mapping of potential VGC on the basis of the conjugate analysis of dissimilar data (DEM, climatic, orographic and soil data) using GIS technologies [2]. Using the topological profiles and landscape map [3], we analyzed the geomorphological conditions of the area of interest and identified the sites relatively similar in the relief characteristics, i.e., in the mesorelief form, range of elevations above the sea level, and dissection of the surface to determine the number of classes for the unsupervised classification. Then, the areas similar in the morphometric (intervals of the altitude above the sea level and surface slopes) climatic and soil parameters were selected using ISODATA and interpreted as the geomorphological complexes (GMC) of VGC. More detailed units (VGC types) were identified for each GMC based on a certain ranges of slope (flat surfaces (0-1°), soft slopes (1-2° or 1-3°), moderate slopes (3-5°), steep slopes (5-8°), very steep slopes (8-15°), benches and rocks (>15°)), which had relatively similar soil conditions and hydrological regimes. Thus, the map of potential VGC consists of two raster layers, which show the hierarchical levels in the classification of the growth conditions - GMC of VGC and VGC types. We identified 7 GMC of VGC and 21 types of VGC for the test area based on the slope angle and elevation above the sea level. The map of the potential VGC types is a «natural» basis of vegetation cover mapping.

3) The automated recognition of the Landsat-8-OLI images by the MAXLIKE method to identify the land cover classes based on the spectral characteristics. To classify the multiband image, training samples for the major land cover classes were obtained with the help of an photogrammetry interpretation based on the field observations, literature data, and thematic maps. We obtained a total of 43 land cover classes from classifying RSD and they were interpreted by the ground truth data as follows: 17 classes of forests and woodlands, 10 classes of forest-bog complexes, 8 classes of tundra, 4 classes of bogs, 1 class of tundra-forest complexes, and 3 classes of stone runs.

4) The development of the map of vegetation cover based on the Decision Tree Classification with the help of the Knowledge Engineering Module [1]. The inputs of the expert classification included a layer of satellite imagery recognition and raster layers of the potential VGC map. The initial land cover classes were distributed using a layer of the VGC types with the help of the expert Decision Tree Classification. As a result, 16 vegetation types and their complexes were obtained and described in the map legend. The accuracy of the vegetation cover map obtained was estimated through Kappa analysis [4]. The overall the Kappa coefficient is 0.79.

Within this approach, the quantitative characteristics of the environmental factors were used to identify the land cover units, which were relatively homogeneous from the point of view of the climatic, orographic, edaphic, and vegetation parameters. These sites are considered to be relatively similar taking into account VGC. The combined use of the automated methods and expert interpretations of the classes obtained allowed us to map the vegetation cover characteristics (VGC types, forest types, forest-tundra, and forest-bog complexes) directly unrecognizable in the space images, but very important for thematic mapping.

Acknowledgments
The Russian Foundation of Basic Research (Grant 18-05-00781) funded this work.

References
[1] ERDAS Field Guide 1999 (Atlanta, Georgia USA: ERDAS Inc)
[2] Ryzhkova V, Danilova I and Korets M 2016 Contemporary Problems of Ecology, 9 (6) 692-701
[3] The USSR Landscape Map (1:2 500 000) ed I Gudilin (Moscow, Minist. Geol. USSR)
[4] Monserud R and Leemans R 1992 Ecological modeling 62 275-293