International Cartographic Association
Association Cartographique Internationale

GIS-based approach for development of the "natural basis" for thematic mapping

Ryzhkova V.A. *, Korets M.A., Danilova I.V.
Sukachev Institute of Forest SB RAS, Krasnoyarsk, Russia, vera@ksc.krasn.ru, mik@ksc.krasn.ru, tiv80@ksc.krasn.ru
* Corresponding author

Abstract: A special approach for creating of natural basis for thematic mapping is described based on the developed semi-automated technique of spatial analysis of multisource data in GIS. Proposed approach using objective quantitative parameters of environmental factor and relief allows dividing natural continuum of vegetation cover into discrete parts.

Keywords: Central Siberia, potential vegetation growth conditions, digital elevation model (DEM); Geographical Information System (GIS); remote sensing data; forest cover map

1. Introduction

The modern thematic mapping branch is standing on automated GIS-based approaches, which is leading to higher accuracy and objectivity of mapping products. Building the data processing framework, we normally use combination of remote and ground truth data as well as conjunction of traditional and modern mapping methods.

The aim of our study is development of the natural basis for vegetation mapping, using the above principles. We are elaborating the semi-automated approach for mapping of forest cover. Forest cover is considered as a natural complex of vegetation and vegetation growth conditions, taking into account the statistical relationship between them.

The main theoretical background of our study is the principles of combined vegetation and growth conditions classification, which was developed by Kolesnikov (1956). According his work, forest ecosystems are classified on similarity of forest growth conditions, rather than on continuously changing species composition.

Classification of forest growth conditions is considered as a natural basis of automated (semi-automated) classification and mapping of vegetation cover by digital data and remote sensing methods.

A number of papers describe techniques for classifying habitats (habitat types) based on remote sensing information and other data types (Diaz Valera et al. 2008; Corbanea et al. 2015), the results of habitat mapping within a range of scales using digital elevation model (DEM) and low-to-high-resolution remote sensing data (RSD) and time series (Bock et al. 2005; Clerici et al. 2012). These papers, however, analyse mostly only one or two major factors, rather than combinations of multiple available. Vegetation cover mapping requires analysing ecological and geographical characteristics of the ecosystem of interest.

We developed a technique of classification and mapping of forest growth conditions (FGC) based on climatic, orographic (DEM-based), soil, and hydrological factors (Ryzhkova & Danilova 2012). This technique was implemented on the example of the test area in Southern Part of Near-Yenisei Siberia (Ryzhkova et. al., 2016). Further research allowed testing and improving the technique in other test areas. In this work, we aim to present this approach on the example of the mountain test area in Sayano-Shushenskiy Biosphere Reserve.

2. Materials and Methods

2.1 Study Area

Sayano-Shushenskiy Biosphere Reserve is a part of Altai-Sayan highland. It is situated in the mountains of Middle Siberia, in the sought of Krasnoyarsk Region (91°45'50"E, 52°11'23"N). This territory characterized by high diversity of geomorphological, geological, soil, and climatic conditions, as well as vegetation cover.

According to vegetation growth conditions hierarchical zoning (Smagin, 1980), a boundary of different regions and districts of vegetation growth conditions passes along the Sayan Range.

Alpine tundra, subalpine dark coniferous forests, subalpine sparse forests and mountain taiga forests are represented in the northern macroslope of the Sayan Range. The southern macroslope differs in the composition of tree species: larch woodlands dominate in the highlands, in the middle mountains - larch with Siberian pine, Scots pine with birch and aspen and fragments of steppes in the near-Yenisei valley.

2.2 Methods

To automate vegetation cover classification and mapping, it is necessary to choose objective quantitative classification criteria. We did the classification based on the principles and approach of a Russian forest scientist Kolesnikov. According to these principles, the entire diversity of vegetation communities is classified based on growth condition similarity, and not based on continuously changing species composition characteristics. According

Proceedings of the International Cartographic Association, 2, 2019.
29th International Cartographic Conference (ICC 2019), 15–20 July 2019, Tokyo, Japan. This contribution underwent single-blind peer review based on submitted abstracts. https://doi.org/10.5194/ica-proc-2-109-2019 |

to this approach, forest ecosystem diversity is formed by forest development or regeneration stages present in a given area.

Forest type as a main unit of this classification represents a series of sequentially replaced communities developing within a certain type of forest growth conditions (FGC) (more generally - vegetation growth conditions (VGC)). FGC type presents a key element of the forest type concept. It is identified based on climate, geological, geomorphological, and soil parameters of a given area.

The correspondence between forest vegetation units and hierarchical FGC found with this classification is shown in Table 1.

Forest units	FGC units
Stand type (age stage)	Elementary ecotope
Forest type (forest regeneration series, a part of long-term natural succession)	***Forest growth conditions type***, i.e. sites similar in slope, aspect, soils and hydrological regime
Group of forest types	***Group of FGC types*** - sites similar in mesorelief elements (watersheds, slopes, river valleys, depressions, etc.) and moisture regime
Geomorphological complex of forest types	***Geomorphological complex of FGC*** - sites similar in mesorelief forms, elevation, aspects, slope, and terrain roughness

Table 1. Forest units and their relatively correspondent forest growth conditions units

This approach opens new possibilities for automated mapping vegetation cover using GIS.

To carry out automatized classification of a DEM-composite (elevation a.s.l., slope, and curvature), we used standard methodologies, such as ISODATA (Richards & Xiuping 1999) as well as ERDAS IMAGINE 9.2 (1999) and ESRI ArcMap 9.3 products.

Segmentation of DEM was carried out with help of Trimble e-Cognition.

3. Results and Discussion

We developed a technique of semi-automated creation of potential vegetation growth conditions map, which includes the following main steps.

1) Regionalization and preliminary classification of vegetation growth conditions using hierarchical zoning approach (Smagin, 1980).

2) An automated classification of potential vegetation growth conditions (VGC) based on the analysis of DEM, climatic, orographic, soil, and hydrological factors.

3) Development of a map of potential VGC as a basis of vegetation cover mapping.

Using DEM (SRTM) six topological transects that crossed the test area were built (http://www2.jpl.nasa.gov/srtm/russia.htm). These transects were then analysed using thematic maps contained in the GIS database, literature information, and ground truth data and characteristics of orographic structure of the test area were done. We identified distribution of vegetation types across the basic elements of macro- and mesorelief, on light (west and south) and shadow (north and east) aspects, the association of vegetation complexes with elevation and mezorelief forms.

According to vegetation growth conditions hierarchical zoning, two districts are allocated in this territory, differing by macroclimate (Nazimova, 1968). The border of these districts passes along the Sayan Range. Using DEM the territory was divided into two parts along the center line of a mountain range (Fig. 1), which are relatively homogeneous by macroaspects and type of macroclimate

Then this macrorelief slope was divided to 4 classes of mesorelief aspects: two light aspects (west and south) and two shadow aspects (north and east). The distribution of basic tree species across macro- and mesoslops of light and shadow aspects (in percentage of the total area) was calculated for each class based on forest inventory data. Larch (*Larix sibirica*) prevails on light slopes; Siberian pine (*Pinus sibirica*) dominates on shadow slopes (Table 2). This indicates a significant role of slope aspect in the characteristics of vegetation growth conditions. Using the aspects, we indirectly consider influence of climate.

Macrolight aspect (southern macroslope)		Macroshadow aspect (northern macroslope)	
Mesolight aspect	Mesoshadow aspect	Mesolight aspect	Mesoshadow aspect
L 51	L 39	SibP 41	SibP 44
SibP 24	SibP 20	L 5	L 6
ScP 5	ScP 3		

Table 2. Distribution of basic tree species across macro- and mesoslops of different aspects (in percentage of the total area). L –Larch, SibP – Siberian pine, ScP – Scots pine.

Using the DEM-based features (elevation, slope and aspect) and topological transects, we assigned six classes of altitude-belt complexes (ABC). Then for each ABC we assessed the relationship of vegetation and relief elements, relevance of various vegetation types to specific elevation intervals and forms of mesorelief.

The analyzed diversity helped us to assign the initial number of classes for unsupervised classification method (Isodata, ERDAS IMAGIN software).

An unsupervised classification was done using a preliminary number of classes obtained from an analysis of topological transects. We established the boundaries of these classes base on a two-layer (elevation and slope) image classification by Isodata. We identified nineteen land cover classes relatively similar in morphometric relief parameters (in certain ranges of elevation and prevailing slope) corresponded to certain landscape types and their combinations. As an output, we got the map for 19 initial classes, which were grouped according to multi-level hierarchy of potential forest growth conditions.

To develop the units of GMK level a segmentation of DEM was carried out with help of Trimble e-Cognition. Using object-oriented segmentation method (Multiresolution), we divided a raster elevation layer into relatively homogeneous by elevation and texture (degree of terrain roughness) units. According Table 1, these subdivisions correspond to the level of geomorphological complexes (GMK) of VGC.

Input parameters of segmentation method were the following: accuracy coefficient and texture effect were selected experimentally and amounted to 250 and 0.2, respectively, taking into account the spatial resolution of DEM 90 m.

Then the layers of segmentation and initial classes were crossed and the segments relatively homogeneous of primary classes (relatively similar in morphometric relief parameters, ranges of elevation) were combined as classes of GMK VGC (Fig.1).

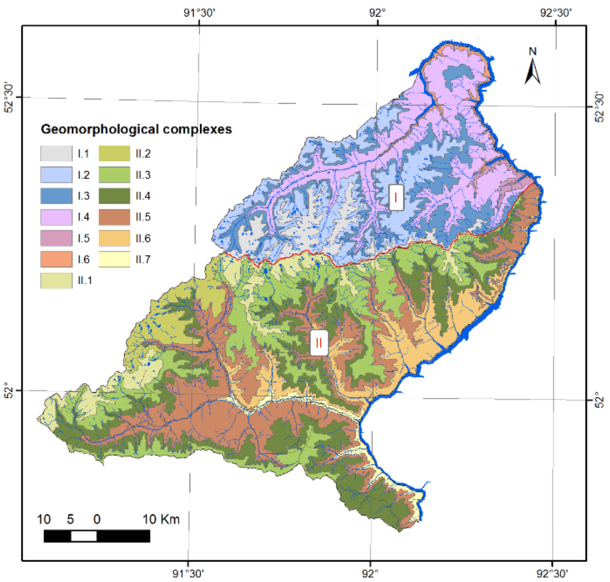

Figure 1. Map of potential vegetation growth conditions of Sayano-Shushenskiy Biosphere Reserve. Level of regionalization: I, II – fragments of districts, I.1-I.6, II.1 - II. 7 – areas within districts. Level of classification: I.1-I.6, II.1 - II. 7 – GMK of VGC.

Each class is characterized by certain parameters of the environmental and relief factors (qualitatively or quantitatively), which is reflected in the specifics of the vegetation cover formed under these conditions.

Table 3 shows the distribution and ratio of the main tree species within GMK II.4, depending on the different mesoaspects (in percentage of the area of GMK).

Macrolight aspect (southen macroslope)				
	Mesolight aspect		Mesoshadow aspect	
	South	West	North	East
1.	1,8	3,0	5,8	3,1
2.	7,1	7,3	13,4	8.1
3.	2,3	3,0	4,5	4,5
4.	0,6	0,7	1,2	1,8

Table 2. Allocation of basic tree species combinations within GMK II.4, depending on the different mesoaspects (in percentage of the area of GMK). 1-4 combinations of basic tree species: 1- Siberian pine+larch, 2 - larch+Siberian pine, 3 – larch+birch, 4 – larch+Scots pine

Finer units, i.e. types of FGC, will be identified for each GMC based on elevation above sea level and slope angle: flattened surfaces (0-3°), gentle slope (up to 10°), moderate slope (10-20°), steep slope (20-30°), very steep slope (> 30°), benches and rocks (>45°). These sites were relatively similar in soil conditions and hydrological regimes.

The final map will be reflected the spatial distribution of relatively homogenous areas that are similar in topographic position and soil-hydrological conditions that determine the characteristics of the vegetation cover for a given territory. Thereby this map could be used as a “natural basis” for other thematic maps.

According to V. B. Sochava (1979), “the plant community, as a component of the geosystem, is not strictly determined within its limits and often develops almost autonomously.” The map of potential forest growth conditions is not a “fixed” basis, which is then saturated with the characteristics of the vegetation cover. Interpretation and refinement of the obtained classes is carried out as a result of subsequent analysis applied for the climatic data bases, soils, and vegetation from satellite images.

As an example, we can use such map of potential vegetation growth conditions as one of the input for the Decision Tree Classification method (Erdas Imagine) to produce the actual vegetation map, while the other input was the result of the satellite image interpretation.

3.1 Conclusions

Systematization of complex ecological systems (biogeosystems) is very complicated problem. Quantitative characteristics of environmental factors must be used to identify the sites relatively homogeneous by climatic, orographic, edaphic, and biotic parameters.

The proposed approach using objective quantitative parameters of environmental factor and relief for the generalization (or segmentation) allows dividing natural continuum of vegetation cover into discrete parts in accordance with applicable principles. Thus, combining various classification methods - pixel-based classification (e.g. Isodata in ERDAS software) and object-oriented approach (Multiresolution Segmentation in Trimble eCognition) we can provide the most informative use of direct, indirect and remotely detected features of the DEM and vegetation cover.

Proceedings of the International Cartographic Association, 2, 2019.
29th International Cartographic Conference (ICC 2019), 15–20 July 2019, Tokyo, Japan. This contribution underwent single-blind peer review based on submitted abstracts. https://doi.org/10.5194/ica-proc-2-109-2019 |

3.2 Acknowledgements

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

4. References

Corbanea, Ch.; Lang, S.; Pipkins, K.; Alleaumea, S.; Deshayes, M.; Milláne, V.; Strasser, T.; Vanden Borref, J.; Toonf, S.; Michael, F. Remote sensing for mapping natural habitats and their conservation status– New opportunities and challenges. International Journal of Applied Earth Observation and Geoinformation, 2015, 37, 7–16.

Diaz Valera, R.; Ramil Rego, P.; Calvo Iglesias, S.; Munoz Sobrino, C. Automatic habitat classification methods based on satellite images: A practical assessment in the NW Iberia coastal mountains. Environ. Monit. and Assess, 2008, 144, 229-250, DOI 10.1007/s10661-007-9981-y.

Bock, M.; Xofis, P.; Mitchley, J.; Rossner, G.; Wissen, M. Object-oriented methods for habitat mapping at multiple scales – Case studies from Northern Germany and Wye Downs, UK. Journal for Nature Conservation, 2005, 13, 75-89.

Clerici, N.; Weissteiner, C.; Gerard, F. Exploring the Use of MODIS NDVI-Based Phenology Indicators for Classifying Forest General Habitat Categories. Remote Sens. 2012, 4, 1781-1803, DOI: 10.3390/rs4061781.

ERDAS Field Guide. 1999. Fifth edition. Atlanta, Georgia. USA: ERDAS Inc.

Kolesnikov, B. Siberian pine forests of the Russian Far East, Nauka Publisher, Moscow-Leningrad, 1956.

Nazimova D.I. Regionalization of forest growth conditions of West Sayan. Lesovedenie, 1968, 1, 3-17.

Richards, J.A. & Xiuping, J. 2005. Remote Sensing Digital Image Analysis: An Introduction. Birkhäuser.

Ryzhkova V., Danilova I. GIS-based classification and mapping of forest site condition and vegetation // BOSQUE. 2012. 33(3). pp. 293-297.

Ryzhkova V.A. Danilova I.V. and Korets M.A. Classification and Geoinformation Modeling of Forest Regeneration Dynamics (Based on the Example of the Southern Part of Near-Yenisei Siberia) Contemporary Problems of Ecology, 2016, Vol. 9, No. 6, pp. 753–762.,

Smagin V.N. Principles and scheme of forest regionalization of mountain territories of South Siberia. In: Forest types of the mountains of South Siberia. Nauka Publisher, Siberian Branch, Novosibirsk, 1980. P. 5-25.

Sochava, V. Vegetation cover on thematic maps, Nauka Publisher, Siberian Branch, Novosibirsk, 1979.

SRTM-3-DEM (Shuttle Radar Topography Mission, Digital Elevation Model). 2010. California Institute of Technology.URL: http://www2.jpl.nasa.gov/srtm/russia.htm.

