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Forest Cover Mapping Based on Remote Sensing Data †

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Abstract: This paper presents a technique for mapping the vegetation cover of mountainous areas based on seasonal satellite data from Landsat-OLI 8, using information about vegetation growth conditions. This mapping is based on the creation of a layer of relatively homogeneous areas in terms of relief and climate. Training samples for the classification of images were formed within these areas. Satellite images were classified using the maximum likelihood method. The created map reflects the spatial distribution of 9 classes of forest vegetation and 10 classes of non-forest vegetation.

Keywords: vegetation cover; mapping; Landsat-OLI 8; digital elevation model; vegetation growth conditions

1. Introduction

Over the past three decades, there has been a significant increase in the number of space satellites. They provide us with unique information about the state of the earth's surface. Landsat satellite imagery is most widely used by scientists involved in vegetation cover mapping and monitoring.

One of the main sources of errors in the classification of images is the difference in the spectral brightness coefficients of identical objects in different parts of the satellite image [1], especially if the study is carried out in mountainous areas. This problem can be solved by processing the image in parts, using ground truth data in different parts of the image. Some researchers calculate additional features, such as spectral indices (for example, NDVI), different relief indicators (elevation above sea level, slope, aspect), etc.

To recognize the same classes of vegetation, processing information throughout the image is proposed. Training samples in different parts of the image should be formed, taking information about the diversity of vegetation growth conditions into account. Such information can be obtained by analyzing different thematic maps (landscape, vegetation, geobotanical, soil) together with the digital elevation model (DEM) and climatic data.

The aim of our research is to develop a technique for the mapping of vegetation cover, taking into account the seasonal dynamics of the spectral reflectance characteristics of vegetation in different types of vegetation growth conditions.

2. Materials and Methods

2.1. Objects and Data

The object of mapping is the vegetation cover of the Sayano-Shushensky biosphere reserve (51°46′–52°37′ N, 91°04′–92°26′ E, an area about 400,000 ha), which is located in the mountainous part of southern Siberia (Figure 1). Siberian pine, Siberian larch, Scots pine, fir, spruce, birch, and aspen form the forest cover at different altitudinal zones.

The following materials were used to analyze and map the reserve's vegetation: Landsat-OLI 8, obtained in different seasons (summer—June and early autumn—September) for 2016, DEM SRTM (90 m), forest inventory data for 2016, ground truth data, and thematic maps.

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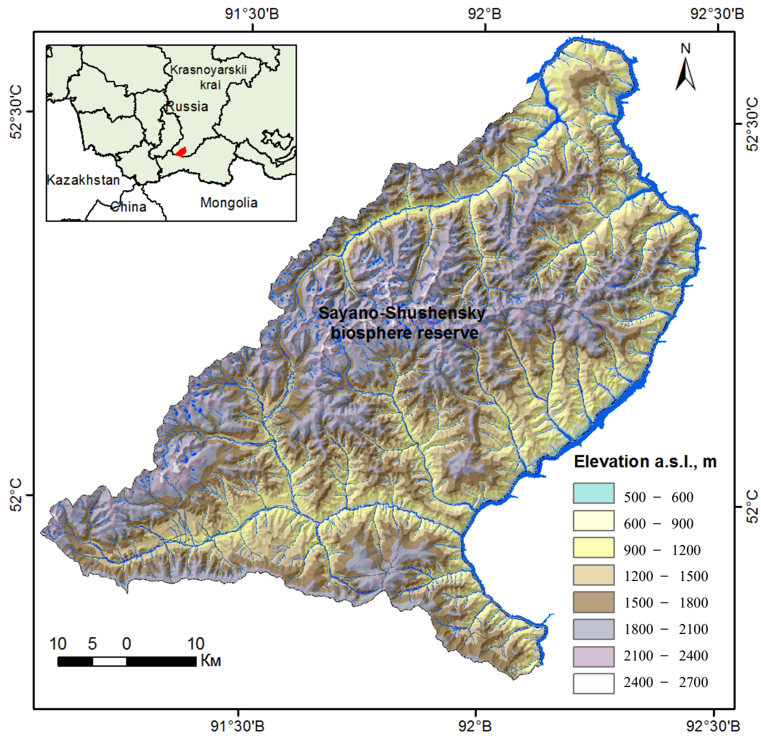

Figure 1. The study area location map.

2.2. Mapping Technique

The technique for mapping the vegetation cover included the following steps:

1. Analysis of vegetation growth condition diversity.

Topographic profiles were constructed based on DEM using thematic maps, forest inventory data, and literature information. Patterns of the association of vegetation classes with certain mesorelief elements were identified based on an analysis of profiles.

2. Classification of DEM features and creation of a raster layer map of vegetation growth conditions.

A classification of DEM features was carried out using a combination of approaches: the ISODATA unsupervised classification method (ERDAS Imagine software) and object-oriented segmentation method (eCognition software). Based on the analysis of the classes obtained because of the classification and segmentation of the DEM, geomorphological complexes (GMCs) of vegetation growth conditions were formed, corresponding to the highest units of vegetation growth condition classification. GMCs are areas that are relatively homogeneous in the ratio of mesorelief forms, the range of elevation and slope, and texture (degree of terrain roughness) [2].

3. Classification of satellite images.

Training samples for classifying multi-seasonal satellite images were formed in each GMC, according to the method developed by M.A. Korets et al. [3]. Forest inventory data and ultra-high-resolution images were used to create training samples. To assess the reparability of classes, an analysis of interclass transformed divergence was performed. Satellite images were classified using the maximum likelihood method, and the resulting classes were generalized using the fuzzy convolution method (ERDAS Imagine software).

4. Creation of a vegetation map for the test area.

The final vegetation classes were formed using all the available information on vegetation (forestry inventory data, literature information, geobotanical map). The composition of tree species in different types of vegetation growth conditions was analyzed.

3. Results

A joint classification of vegetation growth condition units and vegetation units was developed using DEM-based topographic profiles spanning the test area. Based on profiles, landscape and geobotanical maps, as well as forest inventory data, the diversity of vegetation in the reserve was analyzed. In addition, the list and number (19) of GMCs were defined.

To determine the boundaries of the GMCs, a classification and segmentation of DEM features was performed. Based on the unsupervised classification of DEM features (elevation above sea level and surface slope), 19 classes were identified according to the conjugate classification. To generalize the resulting classes, DEM segmentation (elevation) was conducted. As a result, segments that were relatively homogeneous in elevation and texture were identified. The final classes were interpreted as the GMCs of vegetation growth conditions. These areas are homogeneous in terms of the ratio of mesorelief forms, underlying rocks, the range of elevation above sea level, dissection surface degree (they are similar in climatic and ecological regimes), and the predominant type of vegetation: tundra, subalpine woodlands and sparse forests, mountain taiga forests, and sub-taiga forest–steppe complexes.

The diversity of the reserve's vegetation cover was assessed using the classification of the Landsat-8 (OLI) composite (June, September) for 2016. The composite consisted of 16 spectral channels (spatial resolution, 30 m).

An analysis of the spectral characteristics of forest classes showed that the same class had different spectral characteristics in different parts of the image. This is explained by the fact that the test area is very diverse. We observed an elevation difference from 500 to 2700 m, as well as macro- and mesoslopes of different steepness and aspects. Therefore, in order to create training samples for image classification, it is necessary to take into account the association of vegetation units with certain relief elements—that is, to certain units of vegetation growth conditions.

Training samples were created for classes of forest vegetation (Siberian pine, Siberian pine + larch, Siberian pine + fir, etc.) and non-forest lands (meadows, tundra, rocky placers, water, etc.) within the boundaries of each GMC based on forest inventory data and the 16-channel composite. Additionally, all training samples were checked against current information on vegetation from ultra-high-resolution images. Classification was then performed. As a result, the total number of classes for classification was 328, of which 285 classes were forest vegetation, represented in different GMCs, and 43 classes were non-forest lands.

Based on the created training samples, classification (MAXLIKE method) and subsequent generalization (fuzzy convolution method) of the image were performed. The set of classes of forest cover, obtained in different forest growth conditions, were combined into 9 classes: (1). SP (Siberian pine without an admixture of other species), (2). SP + F(S) (Siberian pine with an admixture of fir/spruce), (3). SP + L (Siberian pine with an admixture of larch), (4). L + SP (larch with an admixture of Siberian pine), (5). L + S(F) (larch with an admixture of spruce/fir), (60. L (larch), (7). L + P (SP, S) (larch with an admixture of Scots pine/Siberian pine/spruce), (8). P + L (Scots pine with an admixture of larch), and (9). S + F(L, SP) (spruce with an admixture of fir/larch/Siberian pine). Figure 2 illustrates the result of satellite image classification.

The quality of classification was assessed using the values of Kappa coefficients. A comparison was made between the classified image and forest inventory data. The Kappa coefficient for forest classes was 0.74.

Thus, a forest cover map was created for the Sayano-Shushensky biosphere reserve at a scale of 1: 200,000.

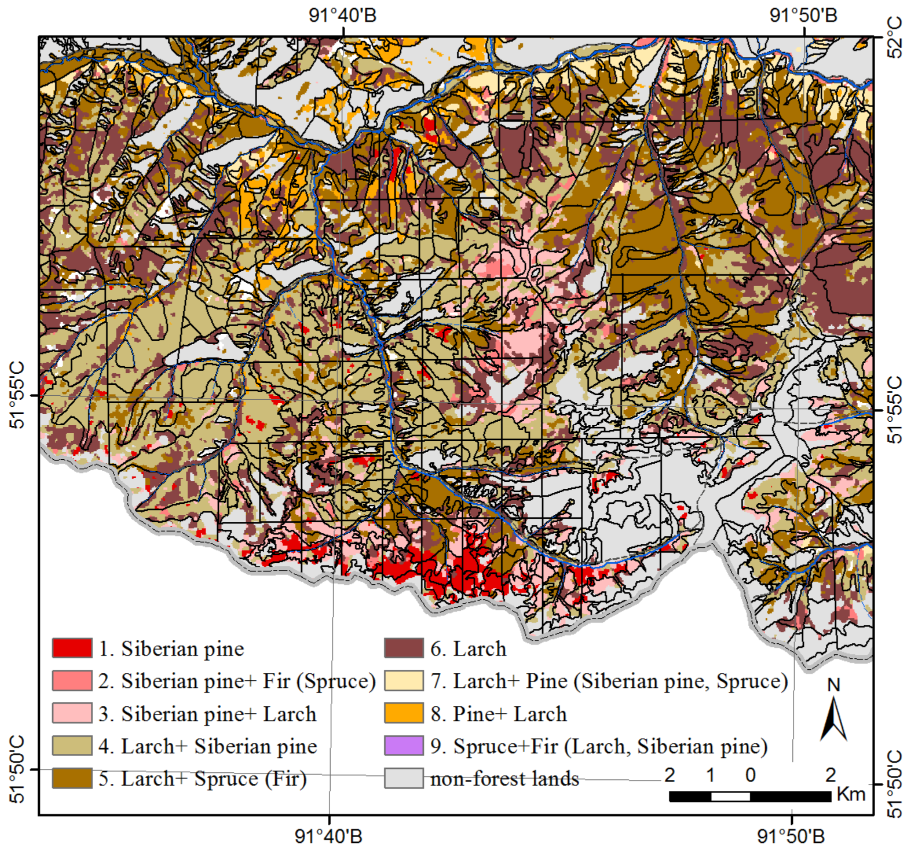

Figure 2. A fragment of the forest cover map of the Sayano-Shushensky biosphere reserve.

4. Conclusions

The combination of various classification methods—pixel classification (ISODATA, ERDAS IMAGINE 2014 software) and an object-oriented approach (Multisolve Segmentation, Trimble eCognition Developer 64 software)—allowed for the most informative use of direct and indirect features of the DEM and satellite images.

Quantitative characteristics of environmental factors can be used to identify areas that are relatively homogeneous by climatic, orographic, edaphic, and biotic parameters. The integrated use of spectral characteristics of vegetation cover in combination with information about the vegetation growth conditions obtained from an analysis of relief, climate, and soils makes it possible to more effectively classify a widely diverse vegetation cover. The results obtained and the developed technique can be useful for mapping inaccessible mountainous areas.

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