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Research Article

Digital Mapping of East Fennoscandian Vegetation Based on Remote Sensing Data

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Abstract. Digital mapping of boreal zone vegetation based on remote sensing data is of the utmost significance for monitoring the natural and anthropogenic dynamics of North Russian forest ecosystems. Revealing the actual state and qualitative changes of the forest cover at the regional and local levels can help achieve a wide range of sustainable development targets. Interpretation of alternative Landsat multispectral images has enabled spatial models to be developed for a number of East Fennoscandian regions. Over the last 30 years, four zones with active logging operations and substantial reduction in mature conifer forest areas have been revealed along with a substantial increase in clear cutting and the area occupied by deciduous stands. During this period, the natural landscapes of the Onezhskoe Pomorye National Park and Kostomukshsky Strict Nature Reserve managed to avoid large scale catastrophic events. So, most appear stable at the moment.

Keywords: multispectral space images, supervised classification, Landsat program, vegetation spatial dynamics, forests, remote sensing data, interpretation

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1. Introduction

The plant cover is the most dynamic component of ecosystems of any rank. At present, an overwhelming majority of Russian regions have no up-to-date digital vegetation maps of the general topographic level (1: 150,000-200,000 scale) and larger, which would exhibit trends in the natural dynamics and anthropogenic transformation of the plant cover. The solution to this problem is seen in a step-by-step acquisition of this kind of cartographic information for specific large areas of a particular region based on interpretation of multispectral satellite image of medium spatial resolution.

Currently, a large number of various techniques and methods for remote sensing (RS) data interpretation have been developed, based on the unsupervised and supervised classification approaches [1, 2, 3]. The aim of this study was to assess changes in the spatial structure of the main types of vegetation communities in Eastern Fennoscandia through analysis of alternative multispectral satellite images of medium spatial resolution (Landsat 5 and Landsat 8).

2. Methods and Equipment

To achieve this goal, open sources [4, 5] of remote sensing data were analyzed and multispectral LandSat-5 and LandSat-8 satellite images were selected. The main advantage of these satellite images is a reasonable spatial resolution - 30 m/pixel, as well as a set of spectral bands sufficient to perform various tasks with scientific and applied data [3]. The requirements when selecting the images applied to seasonality (growing season: June - September), minimum cloud cover (ranging from 0% to 10%) and maximum possible time span in space imagery:

- Landsat-5 ETM - 1985, 1987;

- Landsat-8 OLI– 2018.2

Standard processing of remote sensing data, including atmospheric and radiometric correction, was carried out using the open-source software Quantum GIS [6]. Multispectral RGB-composite image of LandSat-8 remote sensing data was created from a combination of 7-5-3 channels: 7 - shortwave infrared 2 (SWIR2); 5 - near infrared (NIR); 3 - green. Methods for thematic processing of remote sensing data are described in detail in numerous publications devoted to remote sensing of the Earth from space [3, 7, 8, 9]. In the case where the classification is based on the characteristics of objects belonging to a certain known class on the ground, it is defined as supervised classification or classification with training. In this work, the classifier was developed on the basis of an original methodology using digital cartographic-attributive databases of the Kostomukshsky Nature Reserve, Kostomukshsky and Muezersky forestry units, as well as landscape profile data.

The classification procedures, as well as the calculation of estimated accuracy and reliability were performed using specialized modules ENVI 5. The following methods of controlled classification were used: minimum distance, Mahalanobis distance, and maximum likelihood.

3. Results and Discussion

The spatial dynamics in Eastern Fennoscandia was analyzed using the example of several interpretation zones: zone 1 – "Karelian White Sea area", located within the Karelian

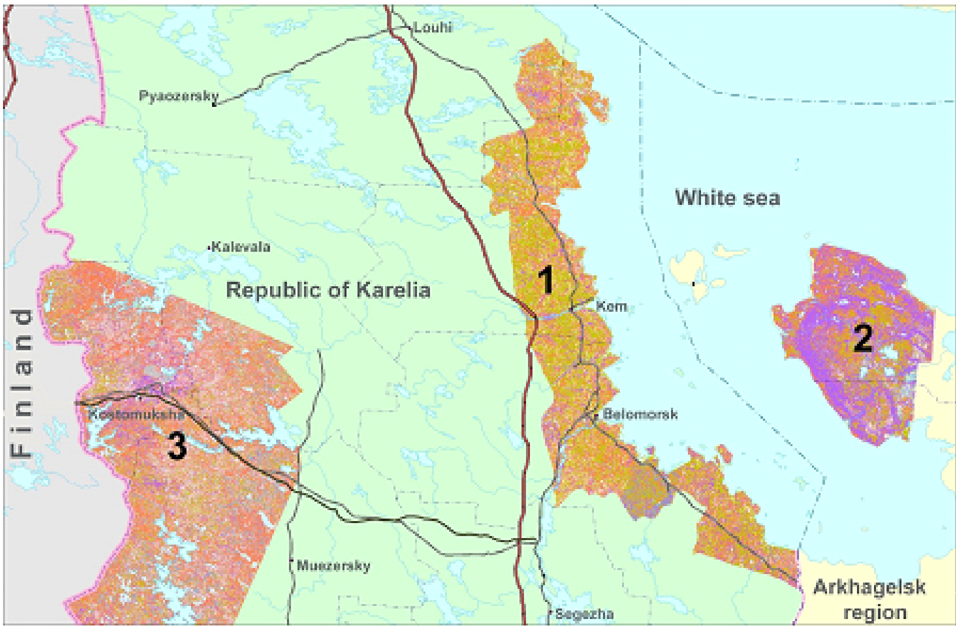

Figure 1: Digital mapping regions. 1, 2, 3 – zones of interpretation.

Table 1: Surface areas (ha) of digital layers for land categories in zone 1.

Categories	1985		2018		Δ 2018-1985
	ha	%	ha	%	
Forests	341239	45.4	349657	45.3	8418
Mires	402311	53.5	411500	53.3	9189
Water bodies	7753	1.0	10736	1.4	2983
Total(*)	751303	100.0	771893	100.0	20590

geomorphological region #5 with a predominance of strongly and moderately paludified flatland landscape types [10]; zone 2 – ”Onega Peninsula”, representing moraine landscapes of the northern part of the Russian Plain, and zone 3 - ”Kostomuksha”, which is situated in the central part of the West Karelian Upland (geomorphological region #4) and characterized by tectonic-denudation and morainic-ridge types of landscapes. The study area covered 2.5 million hectares in total (Fig. 1).

The total areas of the digital layers of zone 1 classification by land categories are given in Table 1.

(*)Note - the difference between the total area of the classification for 1985 and 2018 is due to the presence of clouds in the 1985 satellite images.

Speaking of the analysis by land categories, interpretation of the results of space image classification at different time instants is considered to be the most reliable. Without active human interference (industrial-scale timber harvesting), the structural

Table 2: Areas (ha) of digital layers for ecosystem types in zone 2.

Group of layers	1987	2018	Δ 1987-2018	%
Deciduous forests	30123	34663	4540	15.1
Pine forests	94185	90875	-3310	-3.5
Spruce forests	156723	128791	-27933	-17.8
Mires	66238	56096	-10143	-15.3
Recent cuttings	1418	5089	3671	258.9
Regenerated cuttings	22579	48686	26108	115.6
Water bodies	15349	15168	-182	-1.2
Other land	6327	9828	3501	55.3
Total	392942	389196	-3747	-1.0

characteristics of the studied landscapes remain stable. A slight increase in the area of mires in the study area was detected. This requires further research, since this finding may be due to the ongoing process of mire formation, accompanied by opening of sparse pine forest canopy (pine bogs) in the ecotone zone and within large wetlands, as well as to errors in the classification of these communities. An increase in water surfaces was noted, which is most likely associated with the launching of a hydroelectric power station on the Kem River and the associated flooding of a certain area.

The results of the statistical analysis of the spatial structure of the Onega Peninsula ecosystems (zone 2) in 1987 and 2018 by groups of layers are given in Table 2.

The data in Table 2 indicate that over the past 30 years, at least 28 thousand hectares of mature and overmature natural spruce stands have been harvested on the Onega Peninsula i.e., about 900 hectares were clear-cut annually.

It follows from the data in Table 2 that more than 26 000 hectares moved into the regenerated cuttings category, which included secondary spruce-deciduous forest stands. The establishment of the Onezhskoe Pomorye National Park in 2013 undoubtedly played a positive role in preserving the diversity of natural ecosystems of the peninsula, considering that recent clear-cuts are present throughout the central part of the peninsula, coming close to the park's inland boundaries.

Table 3 shows the final results of boreal landscape interpretation using the LandSat-8 image (2018) within the boundaries of 8 forestry districts, which entirely fall into the classification zone 3. These are: Ladvozerskoe and Kostomukshskoe (Kostomukshsky forestry unit), as well as Kimasozerskoe, Konets-Ostrovskoe, Emelyanovskoe, Rebolskoe, Tulosskoe, Kimovaarskoe (Muezersky forestry unit).

For those categories where a correct comparison with the forest fund survey data is possible, we also indicate the relative difference from indicators in the state forest

Table 3: Areas (ha) of digital layers for ecosystem types in zone 3.

Group of layers	Results of interpretation	SFR data on 01.01.2018	%
Deciduous forests	10372	6334	63.7
Pine forests	301566	326551	-7.7
Spruce forests	103500	113555	-8.9
Mires	170394	170693	-0.2
Recent cuttings	25536	16903	51.1
Regenerated cuttings	21228	–	–
Water bodies	90777	84385	7.6
Roads	14334	2932	–
Open cast mines	5136	–	–
Artificial reforestation	8533	50734	–
Meadows	7114	45	–
Human settlements	3762	–	–
Open spaces	4662	173	–
Total area	745684	732465	1.8
Forested area	423970	446782	-5.1
Coniferous stands	405065	490841	-17.5

register (SFR) as of 01.01.2018. Analyzing the data in Table 3, we can conclude that the results of the interpretation reflect quite reliably the main trends in the anthropogenic transformation of the forest cover in the study area.

One thing to be specifically highlighted is that the satellite image classification reveals a significant contribution of deciduous species to the formation of secondary forests after clear-cutting of coniferous stands, as well as a significant increase in the area of recent cuttings with a simultaneous reduction in the area of mature and overmature pine and spruce stands.

4. Conclusions

Interpretation of Landsat multispectral images of average resolution using various classification methods makes it possible to build a reliable spatial model of the dynamics of vegetation communities. Models of this kind can be visualized on regional digital vector maps of scale 1: 150,000-200,000.

On such maps, forests can be represented by species composition, by enlarged groups of forest types, as well as by the degree of anthropogenic transformation. Cuttings can be classified into recent (0-5 years old), regenerated (6-10 years old), and forested (over 10 years old, young stands). Mires can be classified into types. Areas with active anthropogenic transformation and natural catastrophic dynamics can be identified, as well as forest landscapes that are in a state so called gap dynamics or are not actively exploited at present.

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References

[1] Shovengerdt RA. Remote sensing. Models and methods of images processing. Moscow: Tekhnosfera; 2010.

[2] Bartalev SA, Egorov VA, Jarko V. O. et al. Satellite mapping of the vegetation cover of Russia. Moscow: IKI RAS. 2016.

[3] Kurbanov EA, Vorob'ev O.N. Remote sensing in forestry. Joshkar-Ola: Povolzhskij Gosudarstvennyj Tekhnologicheskij Universitet. 2020.

[4] United States Geological Survey (Official website of the USA Geological Survey). Available from: 2019.07.07. URL: http://earthexplorer.usgs.gov/

[5] Basic products bank NTs OMZ (Basic products bank. Scientific Centre of Earth Monitoring. AO Rossijskie kosmicheskie sistemy) Available from: 2019.08.10. URL: https://bbp.ntsomz.ru

[6] Free and Open Source Geographic Information System (Quantum GIS). Available from: 2020.02.06. URL: http://www.qgis.org

[7] Evdokimov S.I., Mikhalat S.G. Determination of physical meaning of combination of channels of LandSat images for monitoring the state of terrestrial and aquatic ecosystems//Series "Natural and mathematical sciences" V. 7. 2015, P. 21-32.

[8] Modern technologies of remote sensing data processing // Yeremeev V.V.(edt). Moscow. FIZMATLIT. 2015.

[9] Shihov AN, Gerasimov AP, Ponomarchuk AI et al. Thematic interpretation of space images of middle and high space resolution. Russia: Perm State National Research University. 2020.

[10] Gromtsev A.N. Fundamentals of the landscape ecology of boreal forests of European Russia. Petrozavodsk: KarRC RAS. 2008.