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Tree species classification with the use of Sentinel-2 data in the Middle Volga Region of Russia

Eldar Kurbanov, Oleg Vorobev, Sergey Menshikov

Volga State University of Technology
Jean Monnet Centre of Excellence
Center for sustainable forest management and remote sensing

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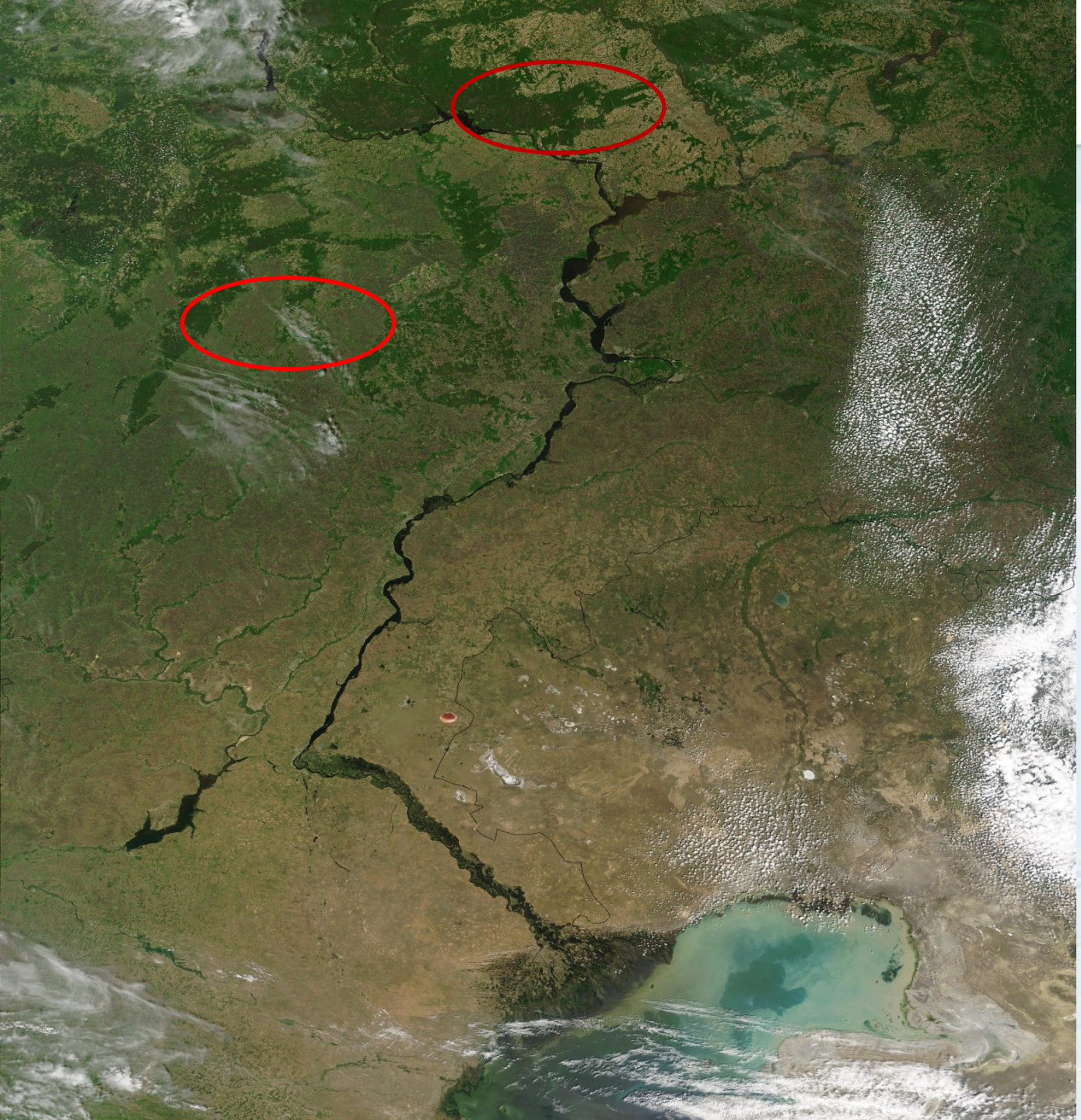

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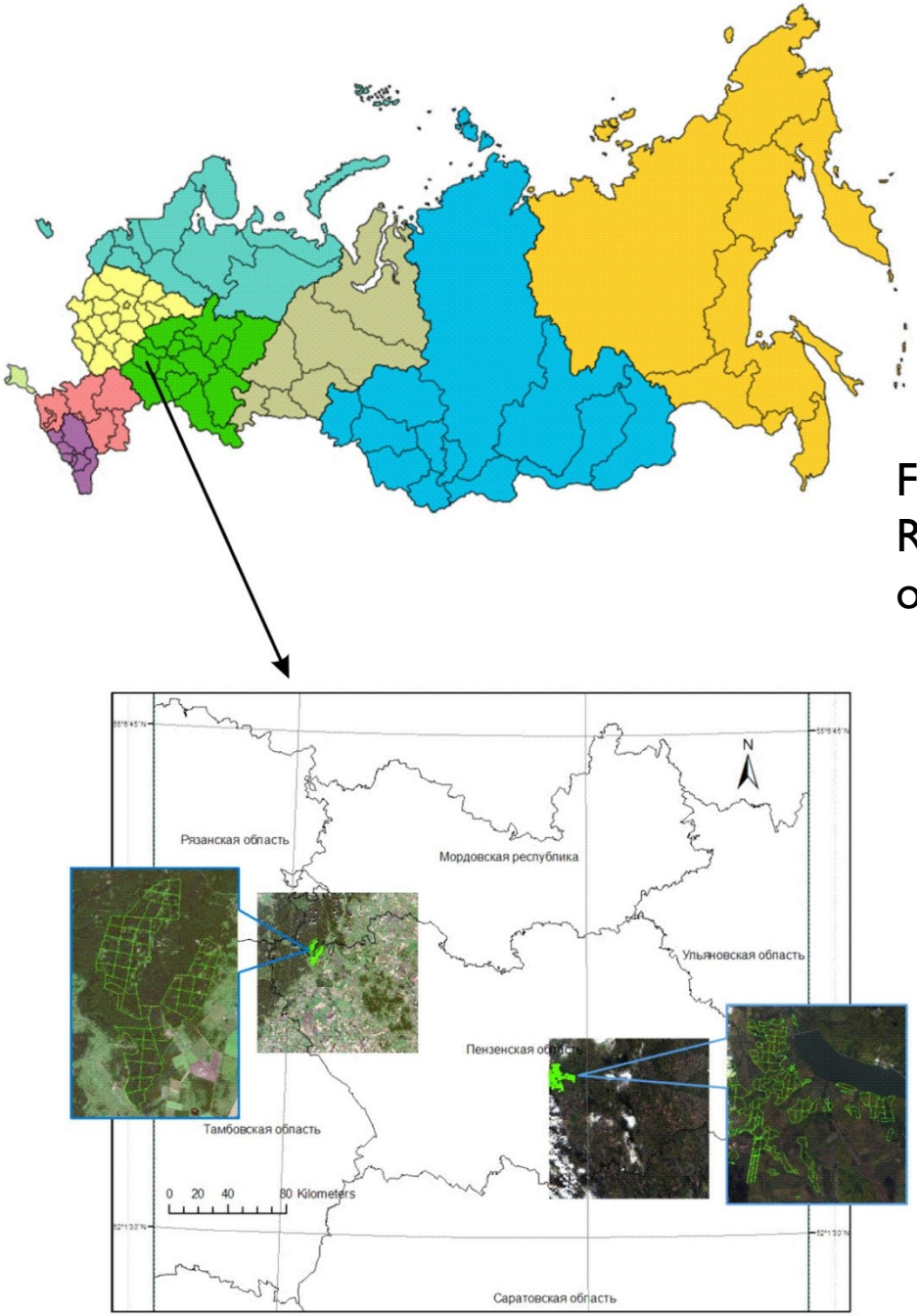
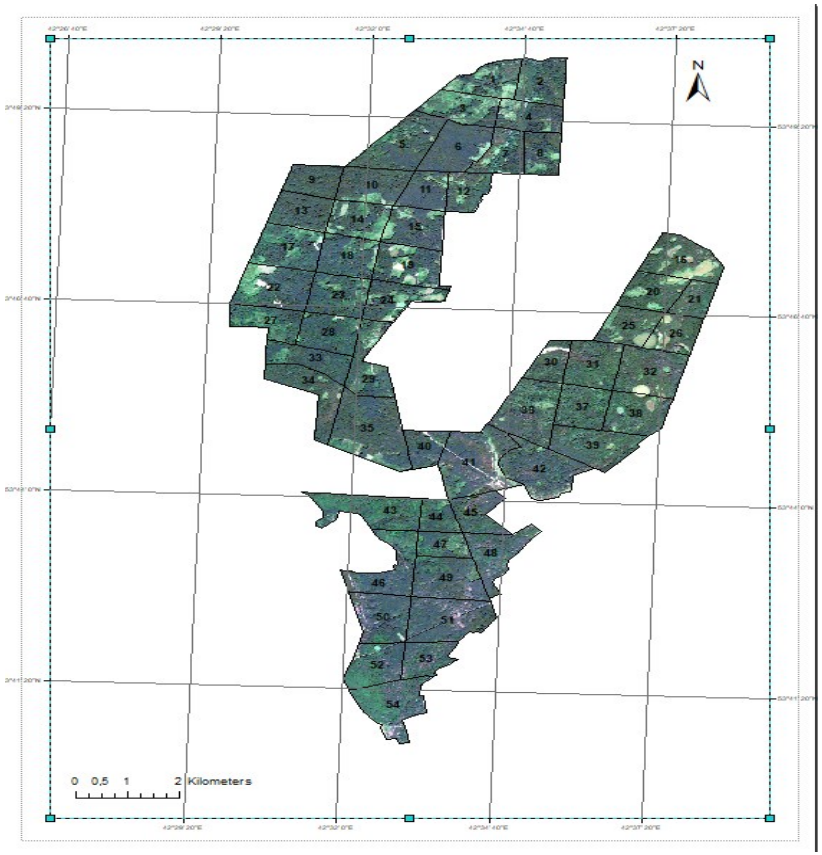


Fig. 2. Penza region on the map of Russian Federation. Two forest districts on the Sentinel-2 images.

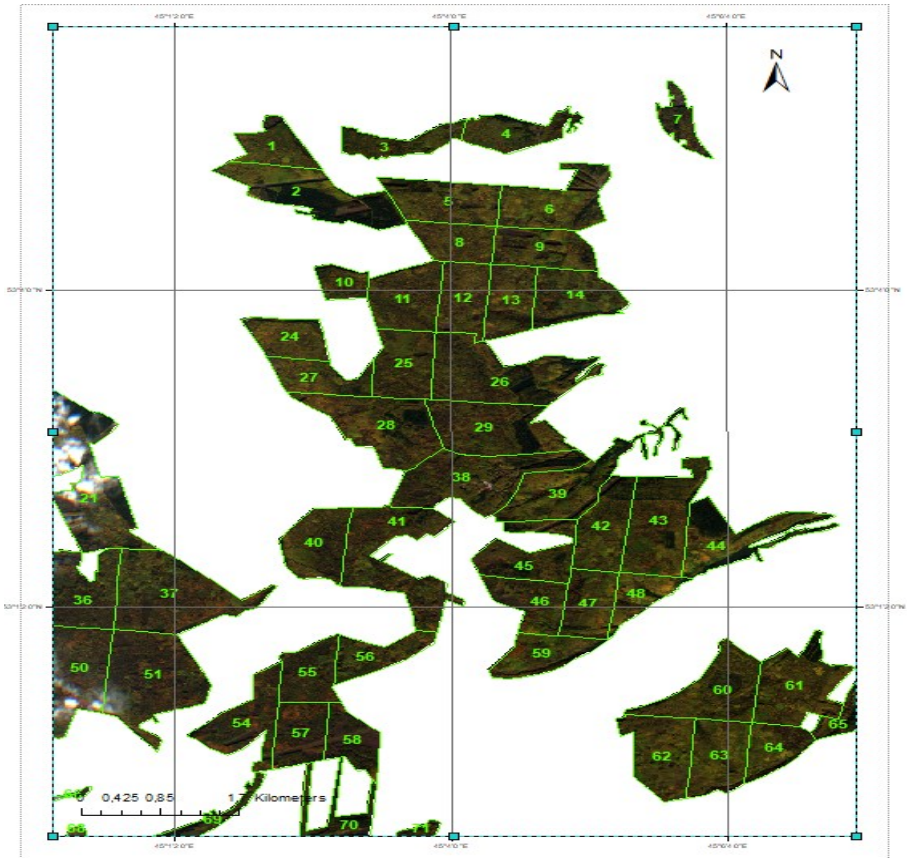
The study objects were forest stands on the territory of the Jursovo and Leninsky forest districts of the Penza region (Figure 1.), which are part of the forest-steppe region of the European part of the Russian Federation

Objective of the research

The purpose of this research was to assess the suitability of using Sentinel-2 satellite images for mapping tree species composition and forest inventory strata on the example of forest stands in Penza region (two forest districts).



Yursovskoye forest district



Leninskoye forest district

In order to support of image classification and compare the forest species, two field campaigns were carried out in 2016-2017 between 10 June and 30 August in in the forest districts of Penza region. Test sites with an area of at least 10x10m for the validation of thematic mapping were selected along transects to represent the full range of the main land cover classes and species typically occurring in these ecosystems.

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birch trees (B*etula pendula*)

Mixed with Quercus robur

Scotch pine (*Pinus sylvestris*)

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Table. 1. Sample plots

Tree species	Number of forest polygons	Average size of polygon, pixels	Total pixels
Pine	16	720,4	11526,4
Birch	18	1111,8	20012,4
Oak	12	496,5	5958
Aspen	14	294,1	4117,4
Lime	16	621,2	9939,2
Alder	6	487,8	2926,8
Young plantations	14	1167,1	16339,4
Total	96	**699,9**	**70819,6**

The area of the test site on the ground was at least 0,5 ha, which allows its identification on a satellite image of Sentinel-2. Estimation of forest stands was carried out using the forest inventory methods of ground-based measurements. For each test site the trees composition (not less than 7 units of the main species), the average height and diameter of the stand, and the age of the dominant species were determined. For two field seasons, 298 test sites were established, most of which (70%) were used to create a training sample. The remaining 30% were included in the database for the of the accuracy assessment of thematic mapping

Table 2. Sentinel 2A data sets used in the research

Tile	Date	Cloud %	Pixel size (m)	Sensor
T38UND	2017.10.10	0	10 (band 2,3,4,8)	MSI
T37UGV	2017.09.21	10	10 (band 2,3,4,8)	MSI
T38ULE	2017.08.19	10	10 (band 2,3,4,8)	MSI
T38UMD	2017.09.15	5	10 (band 2,3,4,8)	MSI

In the research we used Sentinel-2A (Table 1) satellite images acquired in early September of 2017 for the area of investigated forest districts. The images went through radiometric and atmospheric correction, are Level 1C (Top-of-atmosphere reflectance). Satellite images of Sentinel-2A, visually correlated with existing raster data (Landsat-8, Resource-P, Canopus-B), and showed good agreement of both spatial and spectral characteristics.

Table. 3. The J-M separability of the estimated forest ROI (classes) represented by the main tree species of the Yursovo forest district

Pair of ROI (classes)	J-M
Birch – Pine mature	1,73
Birch– Pine middle aged	1,96
Birch– Aspen	1,07
Birch – Oak	1,99
Birch – Alder	1,18
Birch – Young stands	1,93
Birch– Swamp area	1,71
Birch– Open space	2,00

The ROI spectral separability of the forest cover classes studied in the summer and autumn images of the Sentinel-2 satellite is estimated using the Jeffries-Matusita algorithm (distance function) for each of the four Sentinel-2 spectral bands. These algorithms for quantitative expressions of the ROI separability are based on the covariance and weighted distance between the mean values of the classes. The values of the J-M criterion, indicating the degree of statistical separability of the ROI pair, range from 0 to 2.0. The zero value of the J-M criterion shows no difference, and a value higher than 1.41 indicates a good separation of the studied classes (Trigg, Flasse, 2001).

Table. 4. Forest cover thematic classes

1	Pine (*Pinus Sylvestris*), middle-aged (41-60 years), medium and high-density. The pine covers more than 65% of the stand area. Bonitet I-II.	
2	Pine (*Pinus Sylvestris)*, under mature (61-80 years), mature (81-120) and over mature (120 and over), medium- and high-density. The pine covers more than 75% of the stand area. Bonitet I-II.	

Based on the results of the field surveys, 10 land cover classes were distinguished to estimate the tree species in forest stands.

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Forest cover thematic classes

3	Birch *(Betula Pendula*), under mature (40-60 years) and mature (61-80), medium and high-density. Bonitet I-III. Birch covers 70% of the stand area.	
4	Aspen (*Populus Tremula*), undermature (31-40 years old) and mature (41-60), medium and high-density. Bonitet II-III. Aspen covers 70% of the stand area	

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Forest cover thematic classes

5	Lime (*Tilia Cordata*), under mature (40-60 years) and mature (61-80), medium and high-density. Bonitet I-II. Lime covers 65% of the stand area.	
6	Oak (*Quercus robur*), middle-aged (40-60 years), under mature (60-80) and mature (81-120), medium and high-density. Bonitet 1-II. Oak covers 65-75% of the stand area.	

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Forest cover thematic classes

7	Young stands of conifers and broadleaved species of natural and artificial origin (5-40 years)	
8	Alder (*Alnus incana),* mature (60-80) and overmature (80 and over), medium and high-density. Bonitet 1-II. Alder covers 75% of total stand area.	

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Land cover thematic classes

9	Bare land. Not covered with vegetation.	
10	Marsh area (boggy)	

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Results

A Supervised Classification (Maximum likelihood) was used to perform classification of each resulting Sentinel-2 scenes of 2017.

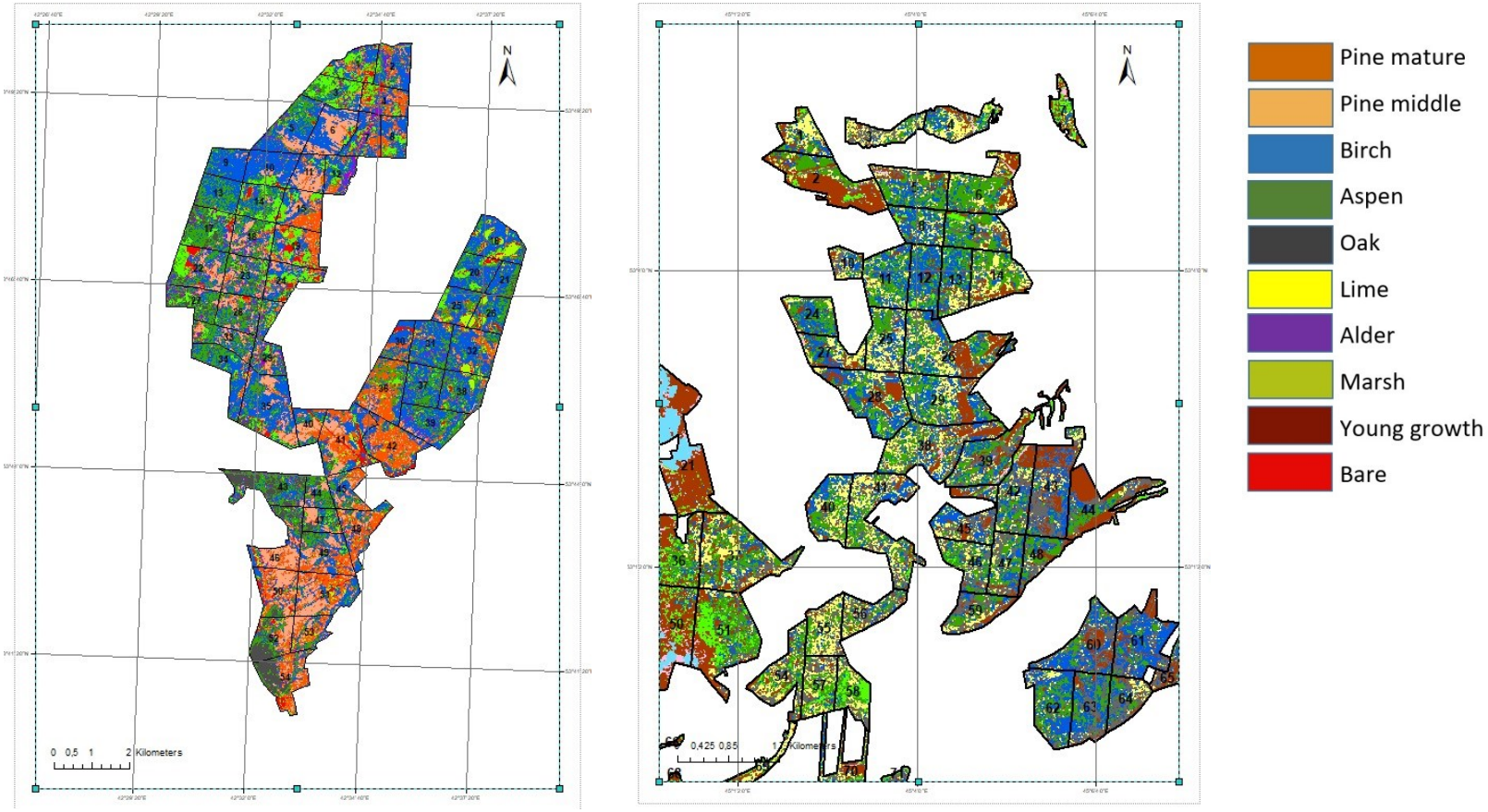

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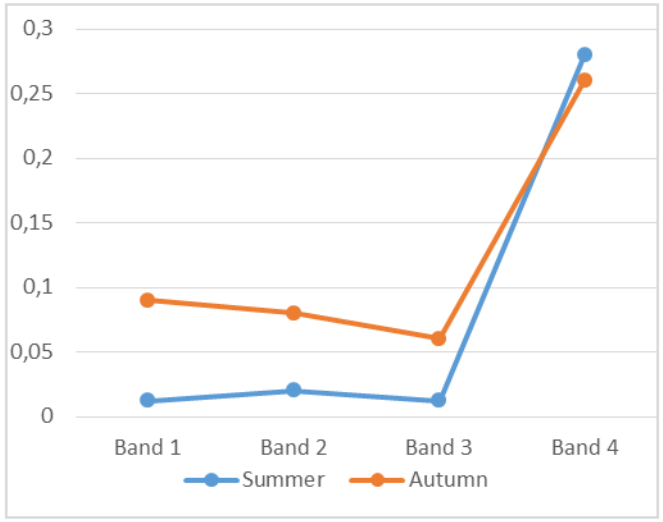
Table 5. Confusion matrix and statistical measures for the MLC species classification for the sites of Yursovskoye forest district

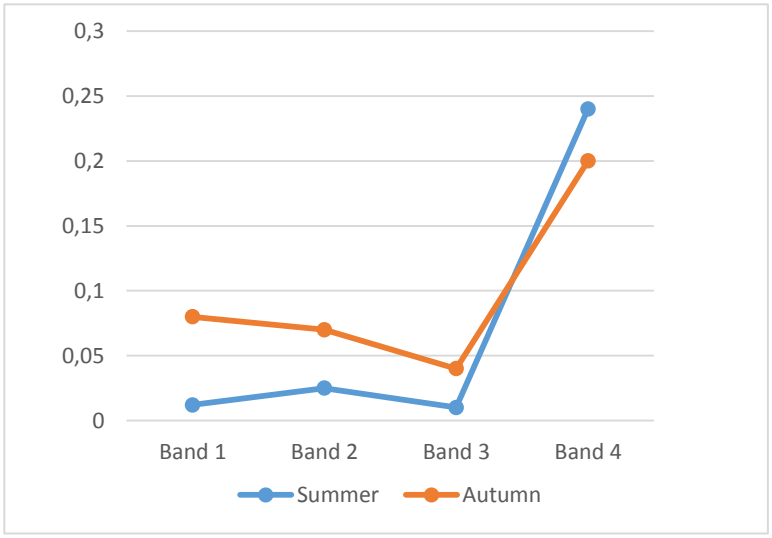
Classes	Young	Pine 1	Pine2	Oak	Marsh	Birch	Aspen	Alder	Open	Total	UA%
Young	462	0	23	0	0	0	22	54	161	722	64,0
Pine 1	0	629	44	0	121	0	0	0	0	794	79,2
Pine2	0	87	770	0	11	112	0	23	0	1 003	76,8
Oak	0	0	0	435	0	16	98	0	0	549	79,2
Swamp	0	2	0	0	521	0	0	0	51	574	90,8
Birch	65	5	82	21	16	860	89	83	0	1 221	70,4
Aspen	0	0	3	21	0	5	530	22	0	581	91,2
Alder	0	0	0	0	0	11	43	428	2	484	88,4
Open	2	0	0	0	2	0	0	0	614	618	99,4
Total	529	723	922	477	671	1004	782	610	828	6546	
PA%	87,3	87,0	83,5	91,2	77,6	85,7	67,8	70,2	74,2		

The overall supervised classification accuracy was 81%, kappa statistics = 0.76. The decrease in accuracy was observed for young forest and birch stands.

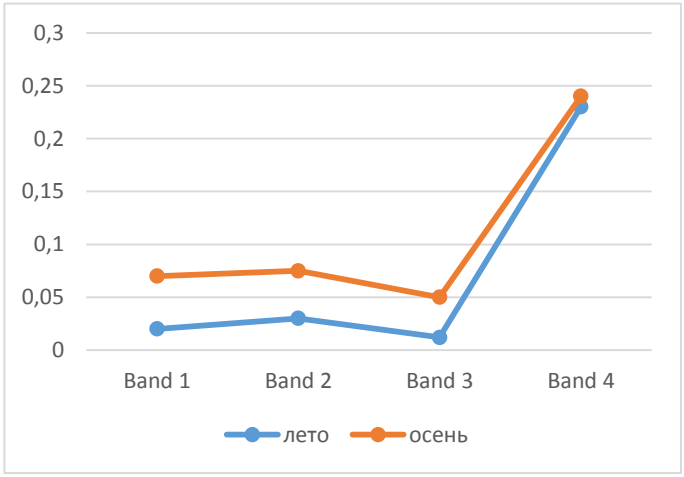
Spectral signatures of the forest cover



Aspen stands



Birch stands



Lime stands

The use of the autumn Sentinel-2 data allows delineating the forest species with more accuracy, which in some cases are difficult to do on the summer images due to similarity in spectral characteristics of deciduous species (alder, lime, birch and aspen).

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Conclusions:

The results of this research show that the Sentinel-2A MSI imagery could further strongly support activities for forest inventory and mapping. For forest classifications, images acquired earlier (end of spring) and later (beginning of autumn) lead to higher classification accuracies.

In the case of the tree species classifications, however, it was difficult to identify and classify mixed forests stands at 10 m spatial resolution. Therefore in our study we used combined series of Canopus-V images of high resolution, which also contributes to delineation of textual attributes of the forest cover.

The classification algorithms have to be chosen according to the forest cover characteristics. We have chosen ML algorithm for the flat area where the forest cover features were with clearly spectral behaviour. The resulted forest cover maps have a high level of detail as they are produced from Sentinel-2 images at 10 m resolution.

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The four spectral bands, the training sets and classification algorithm represent key factors for the forest stand (tree species) map production. The ROI created on multi-temporal images provide various spectral signatures of the forest cover features in different seasons (summer –autumn) of the same year. Using multiple spectral bands from Sentinel-2 images acquired in two seasons, improves the accuracy of the classification as the spectral separability between tree species increases.

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The Jean Monnet center of Excellence "European Expertise and Technology for Environmental Protection and Sustainable Forestry" at Volga State University of Technology has been funded with support from the EU ERASMUS+ program.