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Monitoring of reforestation on burnt areas in Mari El using Landsat time series

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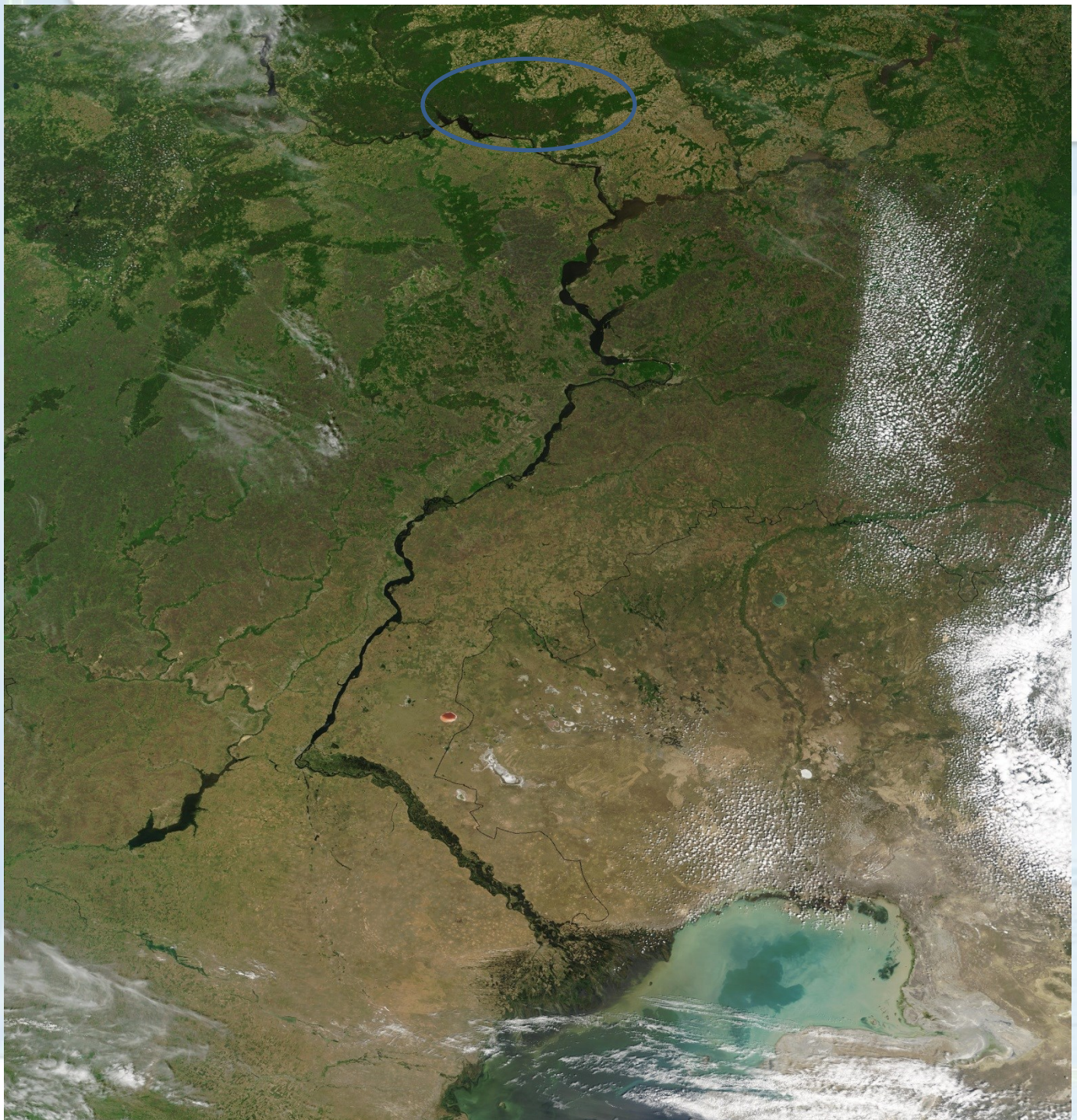

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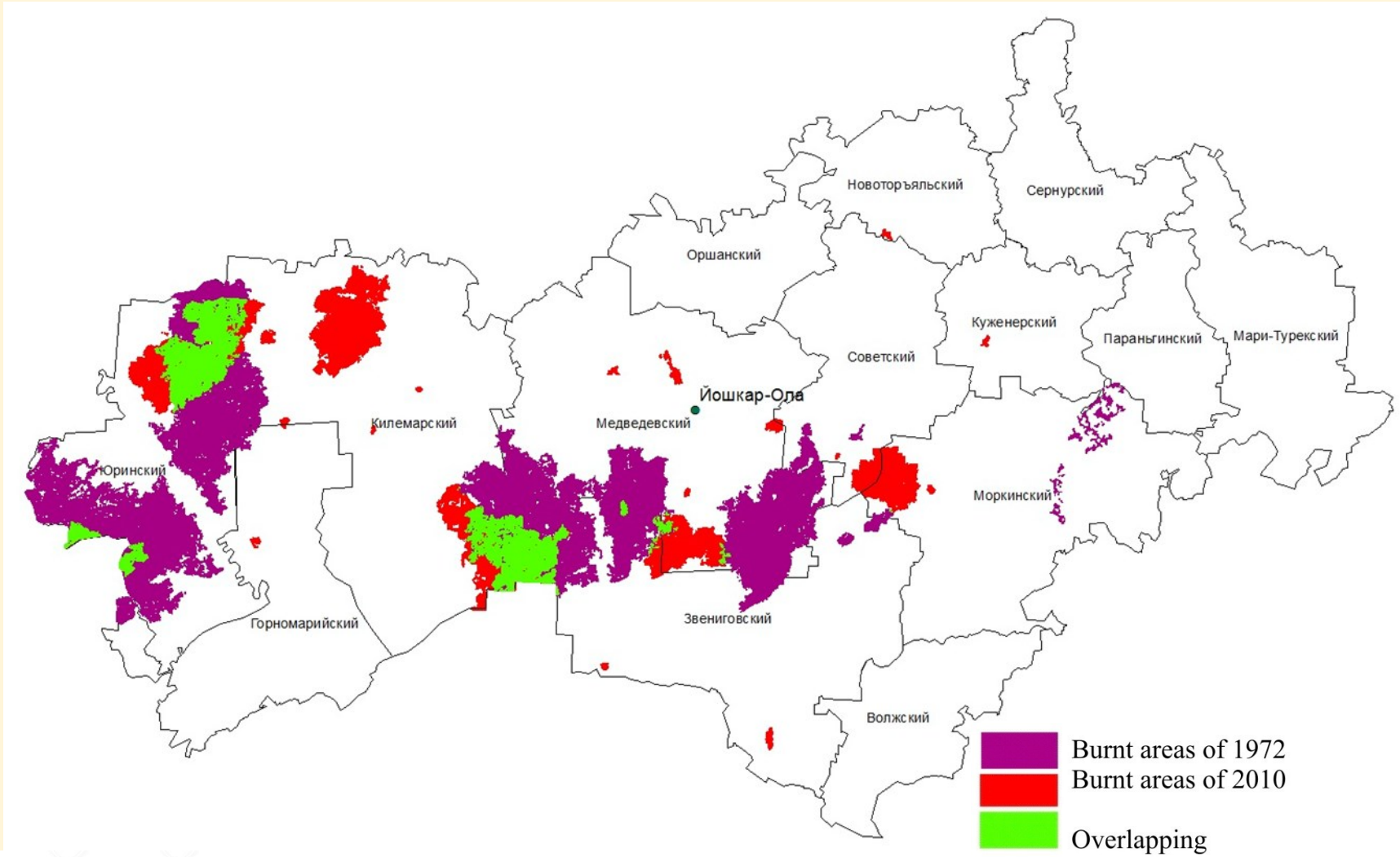
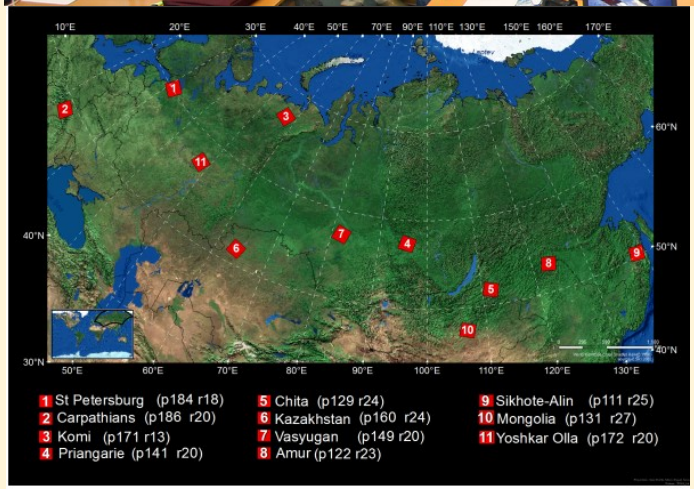
Forest fires are main disturbance factor for the natural ecosystems in Volga Region of Russian Federation. Monitoring the dynamics of forest cover regeneration in the post-fire period of ecosystem recovery is crucial to both estimation of forest stands and forest management (Loboda et al, 2017). This is also vital for conservation planning, soil erosion control, biodiversity assessment, and climate change studies. After the wild fires, full recovery of conifer stands in the Middle Volga region may take 50-70 years with extended effect on soil, wild life and carbon fluxes in these ecosystems.

Burnt areas of 1972 and 2010 in Mari El



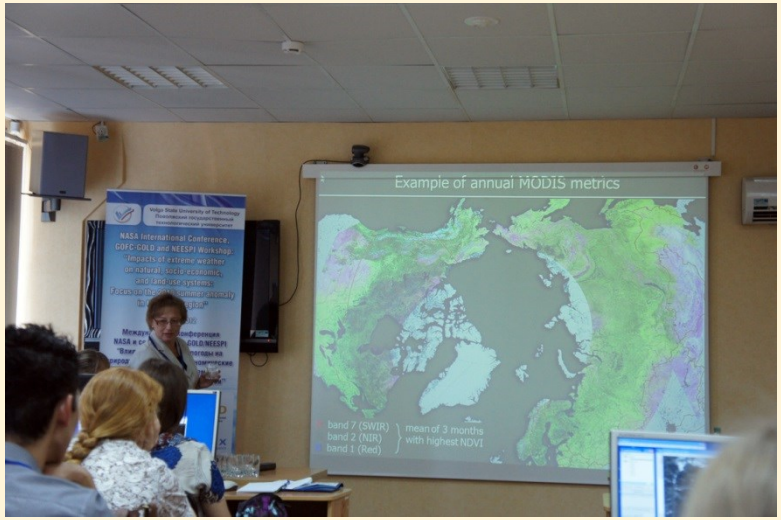
In 2012 in we organized international Conference with NASA.

Impacts of extreme weather on natural, socio-economic, and land-use systems: Focus on the 2010 summer anomaly in the Volga region
June 17 – 22, 2012
Volga State University of Technology, Yoshkar-Ola, Mari El, Russian Federation



GOFC-GOLD
Global Observation of Forest and Land Cover Dynamics

NASA



Conference participants on the field trip and in classes.

The NASA science meeting had a specific focus on evaluating the available satellite-based information, its availability and utility in operational monitoring and scientific studies and identifying the potential and shortcomings of existing data products as well as focusing on future needs for satellite information.

Meeting participants concluded that the scientific community has built a solid basis in summarizing the biophysical conditions that led to the development of extreme drought of 2010 and observing the direct impact of drought on forested and agricultural systems.

Objective of the research

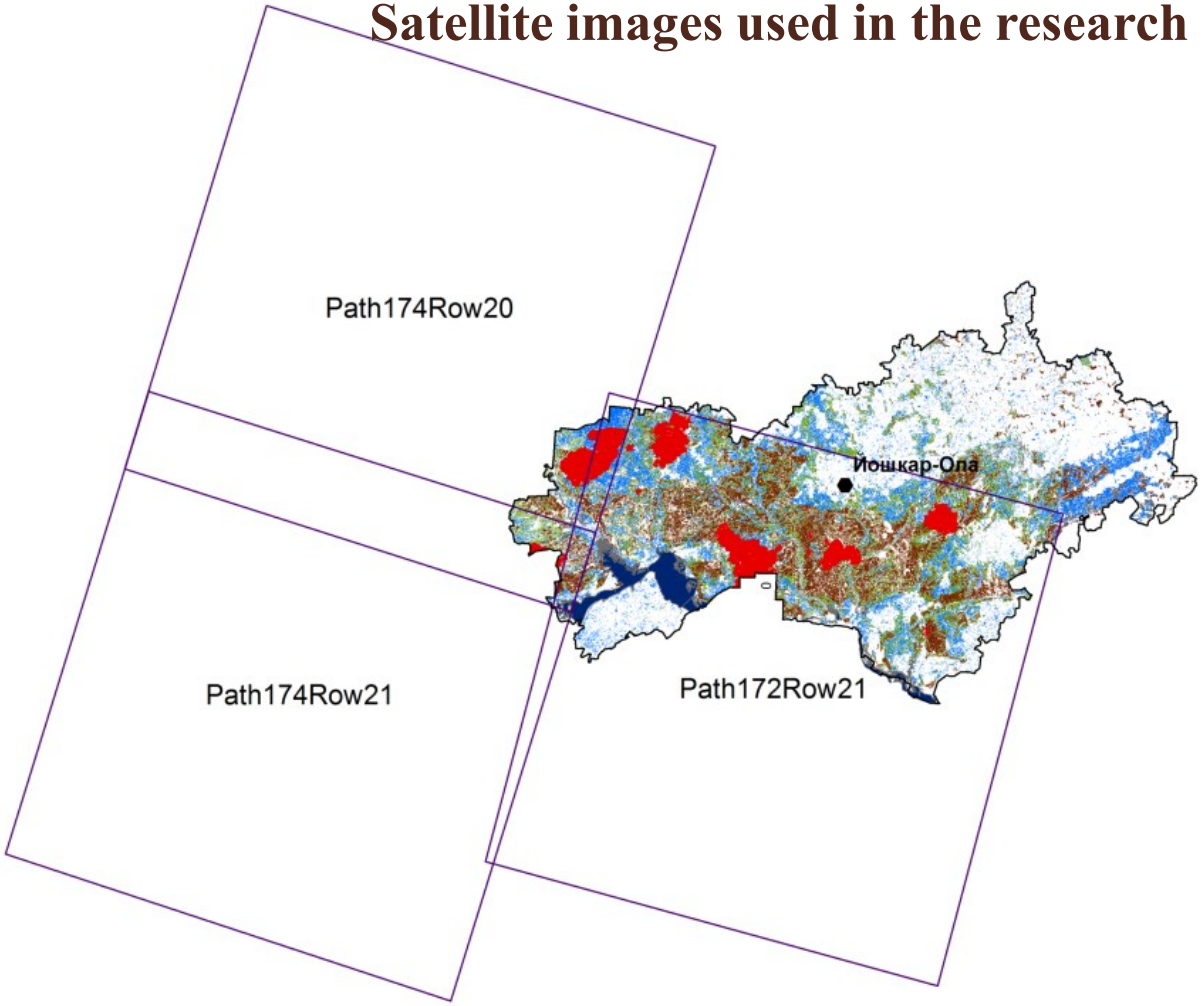
In this study we present a regionally adaptable approach to mapping forest recovery on the burned areas of 2010 in Republic Mari El using Landsat data. The case of Republic Mari El is quite illustrative for the Volga Region of Russian Federation where wild fires of 2010 seriously destroyed about 10% of the forest lands

In order to support of image classification and compare the forest recovery, three field campaigns were carried out in 2011-2016 between 11 June and 22 August in the burnt areas of Mari El.

As the forest recovery on the burnt areas began in spring 2011, we were able to perform comparison of the vegetation parameters among different test sites. At some test sites, field studies were conducted in very difficult conditions, caused by the occurrence of dead wood, which also led to additional time costs for these works. We randomly divided all sample plots into selected training (136) and validation (accuracy assessment) sets (120).

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.

Satellite images used in the research



The mask of burned areas after wild fires of 2010 in the Republic Mari El was extracted from our previous study (Vorobev et al. 2014). To assess the post-pyrogenic succession, we used Landsat-8 OLI scenes (WRS path/row 172(174)/21(20) (USGS GLOVIS). The images acquired in June 2010, 2011, 2014, 2016, were completely covering the sites of the 2010 forest fires in the Republic Mari El.

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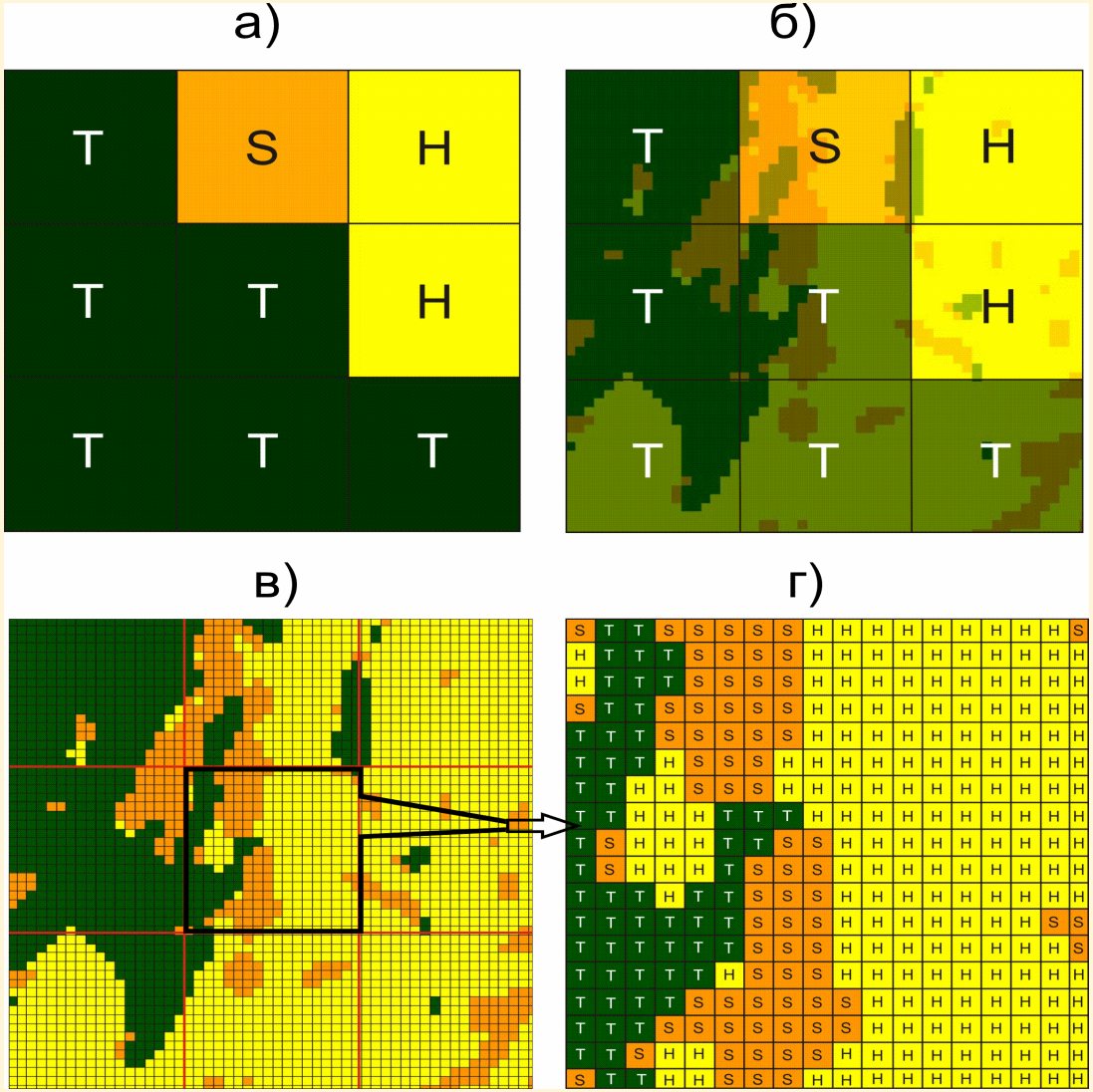
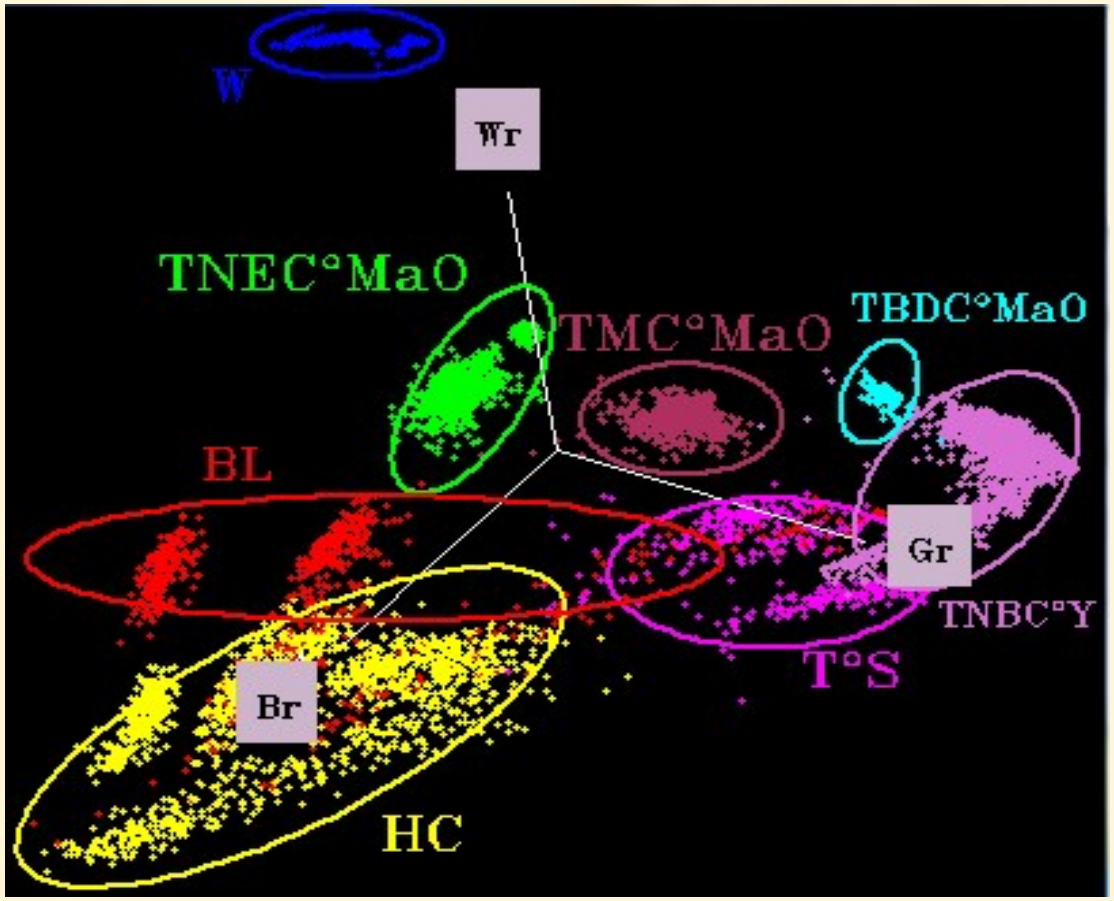
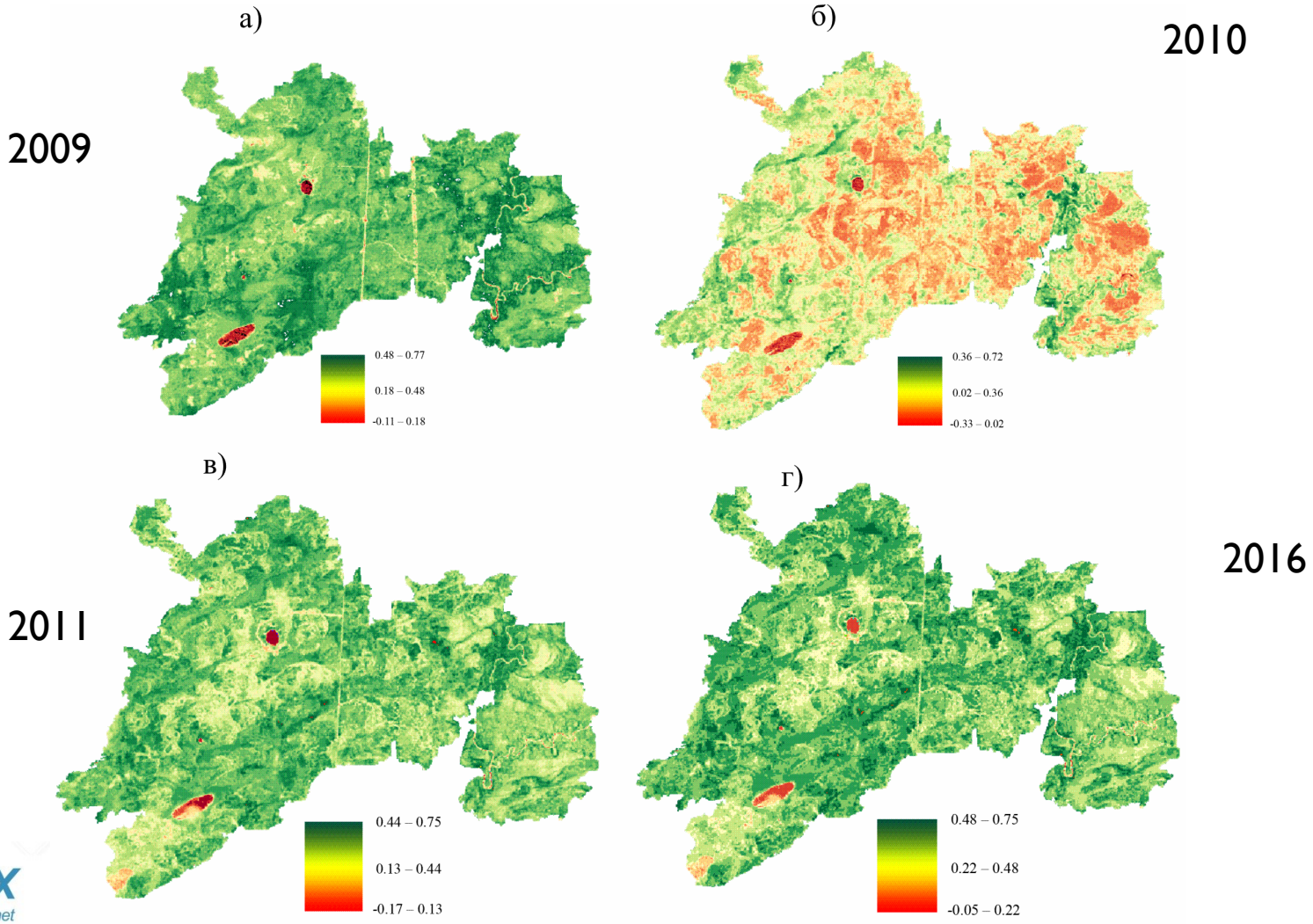
Spectral Mixture Analysis (SMA) is a technique for estimating the proportion of each pixel that is covered by a series of known cover types - in other words, it seeks to determine the likely composition of each image pixel. Pixels that contain more than one cover type are called mixed pixels. “Pure” pixels contain only one feature or class. For example, a mixed pixel might contain vegetation, bare ground, and soil crust.



A pure pixel would contain only one feature, such as vegetation. Mixed pixels can cause problems in traditional image classifications because the pixel belongs to more than one class but can be assigned to only a single class. One way to address the problem of mixed pixels is to use SMA, (sometimes called subpixel analysis), and hyperspectral imagery.



Remote sensing indices. For the study we selected four indices of NDVI (Normalized Difference Vegetation Index), EVI (Enhanced Vegetation Index), dNBR (Normalized Burn Ratio), and LAI (Leaf Area Index).



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Land cover thematic classes

1	Hight density reforestation (HDR)	Mixed tree-shrubs vegetation with projective cover 85% and more	
2	Middle density reforestation (MDR)	Mixed tree-shrubs vegetation with projective cover from 40 to 80%	

Based on the results of the field surveys, 8 land cover classes were distinguished to estimate the post-fire succession on the burnt areas.

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Land cover thematic classes

3	Low density reforestation (LDR)	Mixed tree-shrubs vegetation with projective cover below 40%, with a partial sodding and wet and open area	
4	Forest (F)	Areas of the remaining stand of deciduous and coniferous trees.	

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Land cover thematic classes

5	Deadwood (D)	Sites of dead wood of various tree species left after the fire in 2010, partially or completely sodden.	
6	Sodding (S)	Overgrown by perennial herbs	

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Land cover thematic classes

7	Open areas	Sand areas and artificial areas (highway and forest roads)	
8	Water	Lakes, bogs	

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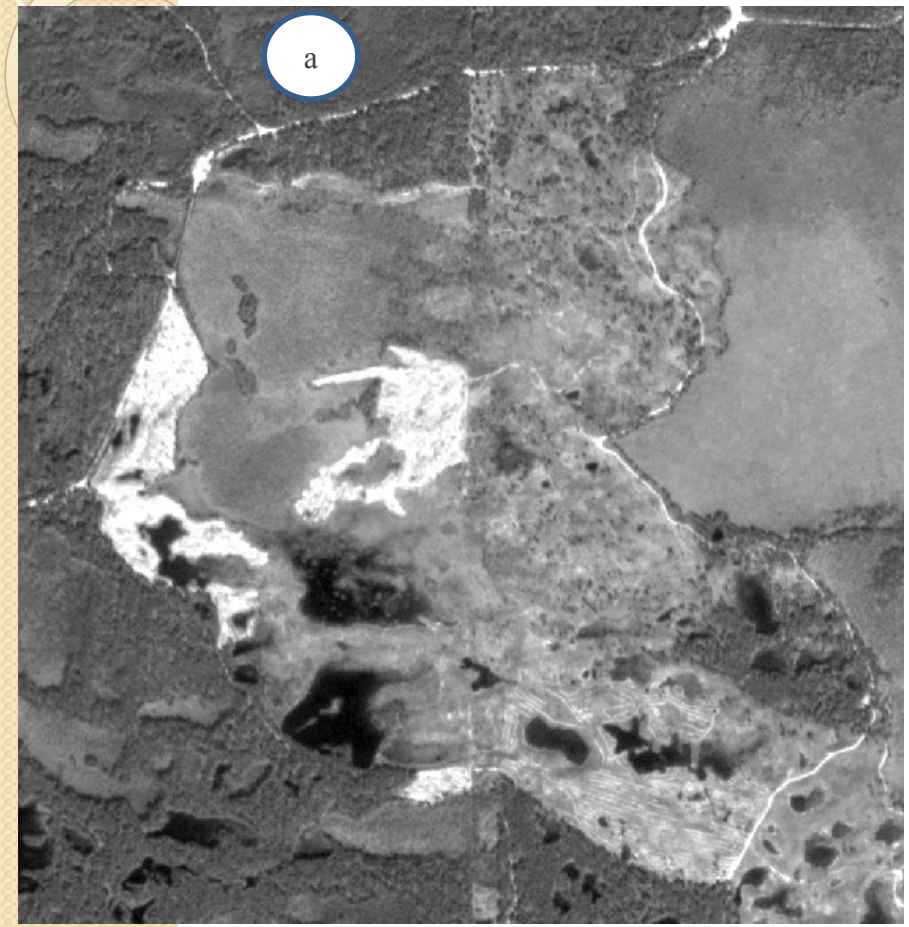
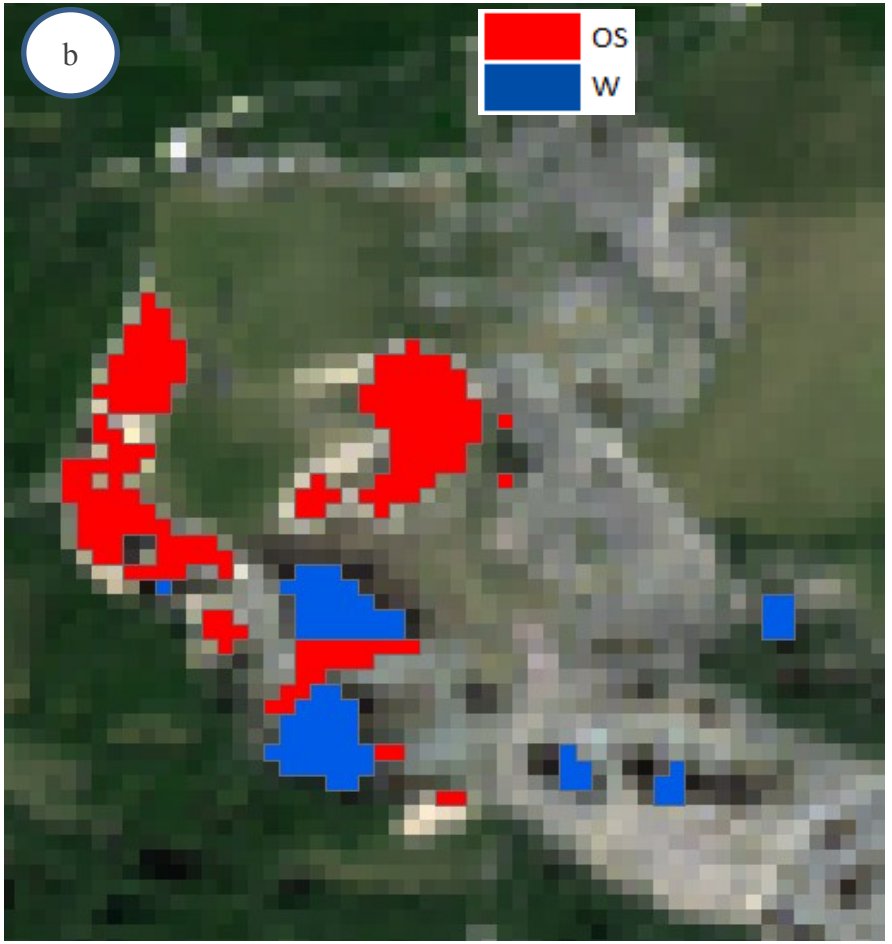
The land cover classes were recognized on the base of combination the Landsat (b) (multispectral) and Kanopus-V (a) (panchromatic, 6.5m) images on the post fire burnt areas.





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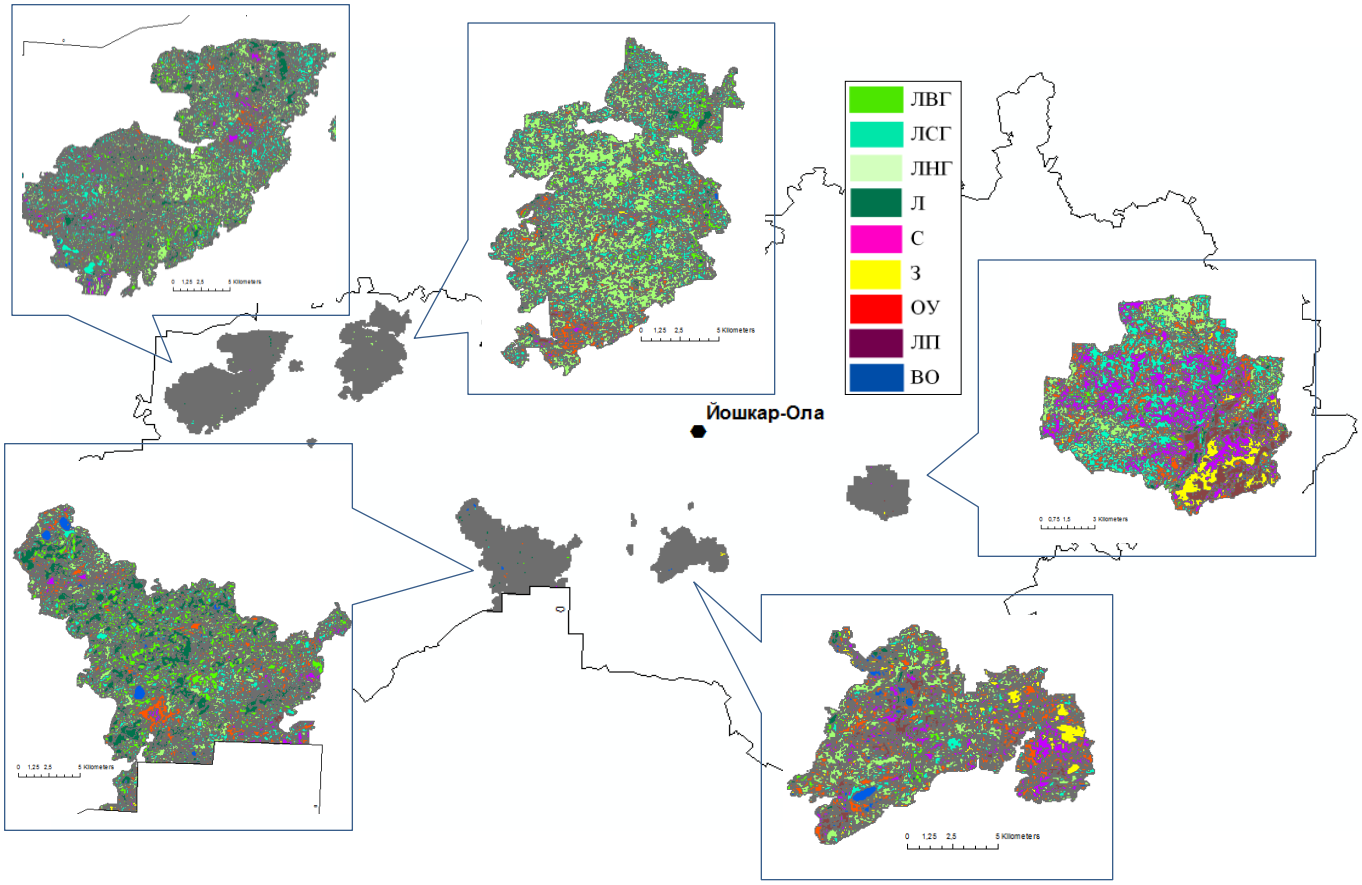
The spectral mixture analysis (SMA) was applied in this study for estimation and identification of spectrally separable 8 land cover classes.
A Supervised Classification (Maximum likelihood) was used to perform classification of each resulting Landsat scenes of 2016 in the form of burnt areas, since this approach specifically developed for thematic land cover extraction over larger area. The overall supervised classification accuracy was 81.2%, kappa statistics = 0.76.



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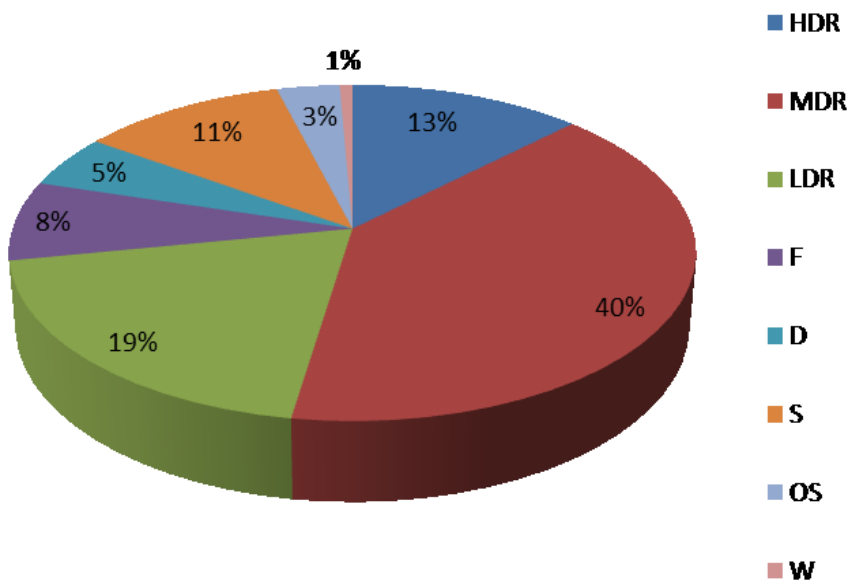
Results

Table. Distribution of land cover classes on the burnt areas of Republic Mari El in 2016

Land cover classes	Area, ha
High density reforestation	16884
Middle density reforestation	53397
Low density reforestation	26117
Forest	10273
Deadwood	6843
Sodding	14950
Open space	4552
Water	923
Total	133938

Figure. Classification of land cover on the burnt areas



Classes of high, middle and low density reforestation cover the 72 % of the total study area (Tab. and Fig.). 8% of the total area of the burned areas is covered by forest that has survived after the fires of 2010. Classes of Sodding (Grass), Open space and Water cover 15.0% of the investigated areas.

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Conclusions:

Based on an initial visual comparison of Landsat composite images and the 8 land cover classes, there was good overall correspondence of forest regeneration on the burnt areas and image spatial patterns. The study demonstrated that from 2010 to 2016 the 72% of the total burnt area in Republic Mari El was naturally reforested.

The use of the index values LAI, NDVI, dNBR and EVI in the assessment of post-pyrogenic processes significantly increases the possibility of monitoring on large burnt areas. Research results can be applied for the long term succession monitoring and management plan development for the reforestation activities on the lands disturbed by fire.

The structure of the post-fire reforestation of the study area depends to a large extent on the state of the soil and the degree of disturbance of the stands after the fire. The analyses and field survey indicated that the dominant species on the burnt areas are deciduous with a predominance of birch (*Betula)* and willow (*Salix*) species, even on medium podzolic sandy soils.

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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.