

REGIONAL MONITORING OF FORESTS USING THE VEGA-LES SYSTEM: CASE STUDY FOR TUNGUSSKO-CHUNSKOYE FOREST MANAGEMENT UNIT AND TUNGUSKA RESERVE IN THE RUSSIAN KRASNOYARSK REGION

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Abstract. This paper demonstrates the capabilities of the Vega-Les (“Les” is the Russian word meaning “forest”) information system (IS) for forest monitoring. A brief assessment and characteristics of the Earth observation data and main available thematic products about Russian forests available in the system are given. An assessment of the capabilities of the Vega-Les IS for studying local scale forest changes was carried out. The Tungussko-Chunskoye forest management unit (FMU) and the Tunguska nature reserve in the Russian Krasnoyarsk Krai region were chosen as the test area. The analysis of forest cover changes over this area since the beginning of the 21st century, including the changes in the number and extent of wildfires, is presented. As a result, it is concluded that the Vega-Les IS is applicable for remote assessment and monitoring of various characteristics of Russian forests.

1 Introduction

Vega-Les information system (IS) [1] was developed by the Space Research Institute of the Russian Academy of Sciences (IKI) in 2019 based on the “IKI-Monitoring” center for collective use [2, 3] infrastructure. The main purpose of this system is to provide researchers with the capabilities for remote complex study of forest resources in Russia using Earth observation data. The system contains a huge amount of satellite data collected over a long period of time as well as the capabilities for its analysis and processing. Current volume and composition of the main remote sensing data available in the system are presented on the “IKI-Monitoring” center website (<http://ckp.geosmis.ru/default.aspx?page=6>). Various regularly updated cloud free composite images produced using a fully automated satellite data processing chain are available in the system as well.

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The system also includes a large number of various thematic maps of Russian forests mainly developed based on the moderate resolution data. These maps include annual land cover maps (23 classes), dominant tree species maps, growing stock volume (GSV) maps and others [4, 5, 6]. Additionally, the system contains information about forest fires and their effects. Data analysis capabilities implemented in the system include both basic geographic information system (GIS) instruments, as well as specialized information processing tools for studying the forest cover.

This paper presents the capabilities of the Vega-Les IS for the local scale analysis of the forest resources. These capabilities are demonstrated in a case study for the Tungusko-Chunskoye forest management unit (FMU) and the Tunguska reserve in the Russian Krasnoyarsk Krai region.

2 ANALYSIS OF FOREST COVER AND ITS CHANGES OVER THE TERRITORY OF TUNGUSSKO-CHUNSKOYE FMU AND TUNGUSSKA RESERVE

There are more than 10 million hectares of forested land on the territory of the Tungusko-Chunskoye FMU and the Tunguska reserve. The reserve is located in the center of the FMU. Its total area is 296.6 thousand hectares. The territory under consideration is characterized by a continental climate, with large variations of daily and seasonal air and soil temperatures, a small amount of atmospheric precipitation (predominantly in summer) and pronounced periods of summer drought [7]. The composition of forest stands is mainly represented by conifers - pine, larch, spruce, Siberian pine. The age of the stands is up to 200 years. There is practically no road network, the permanent population is concentrated in the administrative center and does not exceed several thousand people. Due to the vast and inaccessible territory, objective information about changes in forest cover throughout the Tungusko-Chunskoye FMU and the Tunguska reserve can only be obtained remotely. Main information about forest changes based on remote sensing data which can be obtained using Vega-Les IS is presented below.

2.1 Species composition of forest cover and its changes from 2006 to 2019

Estimates presented in this section are based on thematic products with information on different characteristics of forests obtained from MODIS data. These maps are regularly updated and are currently available from 2006 to 2019. A list of the maps available in the system and links to the methods for their development are given in more detail in the table 3 in work [8].

The analysis of these maps shows that larch is a dominant specie over the territory in question (total area ranges from 6.7 to 7.6 million hectares in different years). There are also pine (1.08 to 1.22 million hectares), birch (0.87 to 1.16 million hectares), Siberian pine (about 0.26 to 0.35 million hectares) and spruce (0.08 to 0.16 million hectares) forests; other dominant species are rare. To visualize annual changes in species' area let us take 2006 as the base year and calculate the changes relative to this base area. Fig. 1 shows base areas for 2006 and the annual changes in species' area.

The most significant variations in the absolute area are observed for larch. Its area decreased by almost 1 million hectares in 2017-2018. Mostly this area changed into the "recent burns" class present in the dominant tree species maps in the system, and to a lesser extent into the class with a prevalence of birch. For the remaining significant classes for this territory (pine, birch, Siberian pine) the variations in the absolute area are small, but in relative numbers they are noticeable. For other classes, including spruce, variations are not

representative since the base area is too small. That being said, it can be noted that the total area of the birch-dominated forests increased by 23 percent by the end of 2019 compared to 2006. The main changes also took place in 2017-2018. The area of the classes dominated by pine and Siberian pine is slowly decreasing throughout the observation period. By 2019 their area has decreased by 12 percent for pine and by 26 percent for Siberian pine compared to the base area in 2006. Generally we associate these changes with forest fires and post-fire damage to the forest. The scale and impact of wildfires in this area is considered in the next section.

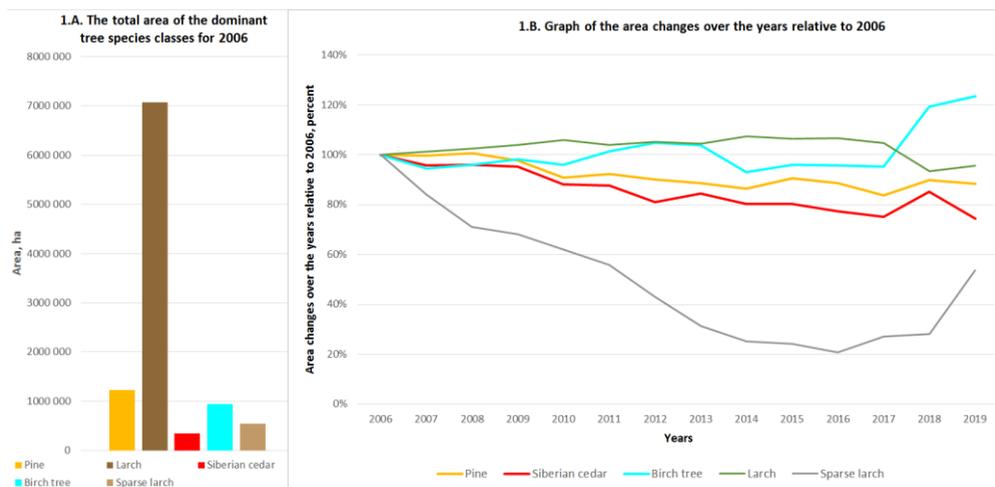


Fig. 1. Distribution of the area of dominant tree species. Fig. 1.A. The total area of the dominant tree species classes for 2006. Fig. 1.B. Graph of the area changes over the years relative to 2006.

2.2 Analysis of forest fire and post-fire damage areas

Estimates given in this section are based on the active fire detection using MODIS sensor (AQUA and TERRA satellites), as well as the improved burned area identification based on Landsat and Sentinel-2 data (ETM+, OLI and MSI sensors). The system uses a technique developed at IKI which allows combining individual “hot spots” into fires, tracking their dynamics and assessing the area. This technique is described in sufficient detail in [9, 10, 11]. The main active fire detection data was obtained for the period from 2001 to 2020 from MODIS collection 6 [12], with subsequent integration and correction according to the technique referenced above. To improve the estimates of the post-fire damage to the forest based on Landsat and Sentinel-2 data the method described in [13] was used. All 2020 fires over the FMU territory were analyzed by an expert in an interactive mode to improve the estimates of the post-fire forest damage based on Landsat and Sentinel-2 data using the abovementioned approach.

Forest fires in the area under consideration are widespread which makes extinguishing and localizing them difficult due to the inaccessibility and lack of infrastructure. The points of origin of forest fires are fairly evenly distributed over the territory in question. Fig. 2 shows maps of forest fires from 2015 to 2020 (for 2020 - until September 28) based on the indicated information from active fire detection. Fig. 3 shows the change in the number and total area of forest fires over the territory of the Tungusko-Chunskoye FMU and the Tunguska nature reserve.

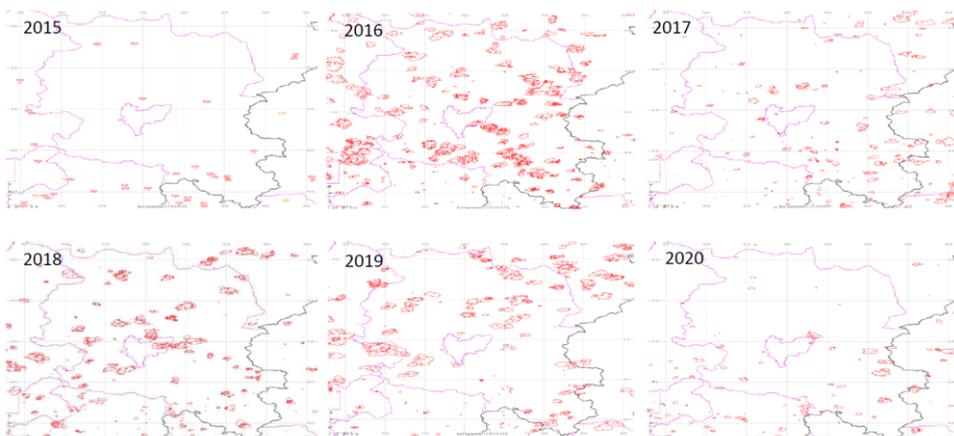


Fig. 2. The data from 2015 to 2020 (for 2020 - until September 28) on fires that occurred on the territory of the Tungusko-Chunskoye FMU and the Tunguska reserve.

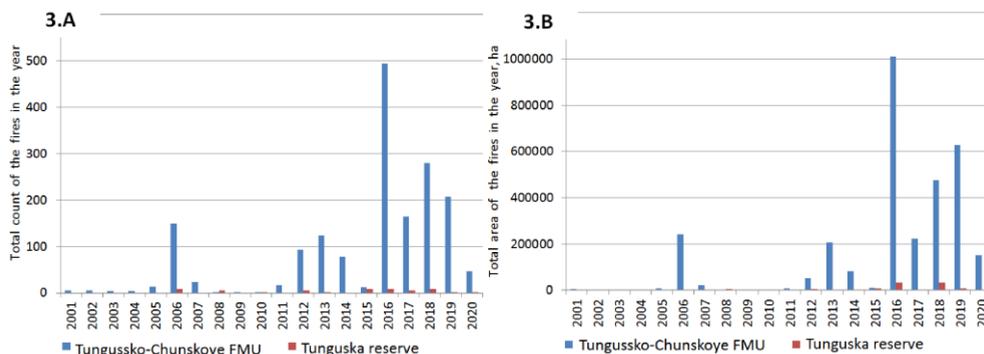


Fig. 3. Changes in the number and total area of forest fires in the Tungusko-Chunskoye FMU and the Tunguska fire reserve. 3.A. The total number of fires per year. 3.B. Total area covered by fires during the year.

A clear increase in the number of fires and the area covered by fires occurred in 2016-2019, with fires affecting the territory of the reserve as well. Improved estimates for 2020 based on high resolution data yielded results comparable to active fire detection data. In 2020 (at the time of September 28) 150 thousand hectares were burned according to active fire detection data, and a similar figure was obtained based on high spatial resolution data (the discrepancy was less than 1 thousand hectares). Thus the technique for assessing the area based on active fire detection gave very accurate estimates for the territory under consideration for 2020, which indicates its high reliability.

3 Conclusions

As a result of the analysis of data from 2001 to 2020, the following conclusions can be made about the forest cover changes in the Tungusko-Chunskoye FMU and the Tunguska reserve:

1. Fires in the area have become more intense with a visible trend towards an increase in their total number and area covered by fire. The years from 2016 to 2019 were the most intense in terms of forest fires. At the same time the current year 2020 doesn't demonstrate a high fire intensity - by the end of September the fire has covered only 150 thousand

hectares which is less than in the last four years (although more than the average at the beginning of the century).

2. The territory in question is dominated by larch. Its area in the FMU and the nature reserve is fairly constant (variations in the range from 6.7 to 7.6 million hectares). At the same time during 2017-2018 there was a sharp decrease in the area of larch. The area of other classes of dominant conifers (pine, Siberian pine) is insignificant in relation to larch. However, by the end of 2019 their total area has decreased by 20 percent compared to the maximum values for the observation period (2006-2019). Conversely the area of the class with a prevalence of birch has grown by similar amount. We attribute these changes in the species composition to fire damage to the forest.

Presented estimates are preliminary and may require some ground-based verification allowing to take into account the specifics of the area in question. At the same time, it should be noted that all the analysis capabilities and data available in the Vega-Les IS have been verified in various regions and have shown their efficiency [6]. In the future it is possible to conduct a separate study to clarify and confirm the data presented. However, the territory under consideration is characterized by extreme inaccessibility. Relevant and reliable information on it can be feasibly obtained only using remote sensing data.

Thus, based on the analysis of the territory of the Tungusko-Chunskoye FMU and the Tunguska reserve, it can be concluded that the Vega-Les IS is applicable for remote study and monitoring of various characteristics of Russian forests at the regional and local levels.

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