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Thematic interpretation of high-resolution satellite images of vegetation based on field research data

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The article presents the results of studies on decoding vegetation using high and ultra-high resolution satellite images and ground-based observation data using direct decryption signs. Space images from the WorldView-2 apparatus with a spatial resolution of 0.5–1.0 m were selected for the dates of late spring, summer, early autumn during the period of a stable state of the deciduous vegetation cover. The work describes the communities of pine, spruce, mixed forests, as well as overgrown with trees areas of meadows in the territory of the Orichevsky district of the Kirov region. An explanation of the necessity of using images in a certain period of the year is given. Images taken in early spring (late april – early may) and in mid-autumn (late september – early october) are the most acceptable for interpretation in order to map forest tree communities.

In the work, we used such deciphering signs as tone, color, structure, texture, background. The image of forest stands has a pronounced photographic drawing, which allows them to be distinguished in photographs from areas not covered with forest. When decoding, first of all, a grainy pattern is visible. Differences in the shapes and sizes of tree crowns, as well as in the outlines of their shadows in high- and ultra-high resolution images, make it possible to determine the composition of plantations. An important feature of the image of woody vegetation in a satellite image is its tonality. Mostly spruce, fir and pine forests in panchromatic black-and-white images are characterized by a darker tone than deciduous ones. The data of interpretation of space images can be used as the basis for creating a map of vegetation of the studied area.

Keywords: interpretation, space images, direct interpretation signs, vegetation.

УДК 528.72:004.93

Дешифрирование растительности по космическим снимкам высокого разрешения с использованием данных полевых исследований

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В статье приведены результаты исследований по дешифрированию растительности по космическим снимкам высокого и сверхвысокого разрешения и данных наземных наблюдений с использованием прямых дешифровочных признаков. Космические снимки с аппарата WorldView-2 с пространственным разрешением 0,5–1,0 м были выбраны на даты конца весны, лета, начала осени в период олиственности деревьев. В работе описаны сообщества сосновых, еловых, смешанных лесов, а также зарастающие деревьями участки лугов территории Оричевского района Кировской области. Обоснована необходимость использования снимков в определённый период года. Наиболее приемлемыми для дешифрирования с целью картирования лесных древесных сообществ являются снимки, сделанные ранней весной (конец апреля – начало мая) и в середине осени (конец сентября – начало октября).

В работе использовали такие дешифровочные признаки, как тон, цвет, структура, текстура, фон. Изображение древостоев имеет ярко выраженный фоторисунок, позволяющий выделять их на снимках от непокрытых лесом площадей. При дешифрировании прежде всего виден зернистый рисунок. Различия в формах и размерах крон деревьев, а также в очертаниях их теней на снимках высокого и сверхвысокого разрешения позволяют определять состав насаждений. Важным признаком изображения древесной растительности на космоснимке является его тональность. Обычно леса из ели, пихты и сосны на панхроматических чёрно-белых снимках характеризуются более тёмным тоном, чем лиственные леса. Данные дешифрирования космоснимков могут быть положены в основу создания карты растительности изучаемой территории.

Ключевые слова: дешифрирование, космические снимки, прямые дешифровочные признаки, растительность.

Earth remote sensing (ERS) methods are based on obtaining information about the earth's surface by registering electromagnetic radiation coming from it, reflected or its own, in various parts of the spectral range. Analysis of the spectral characteristics of objects, structural and textural features of images allows you to obtain information for their subsequent decoding and interpretation [1]. The inherent properties of terrestrial ecosystems are their hierarchical structuredness and heterogeneity. These properties are clearly manifested in satellite images of various spatial resolutions: from small-scale (Modis) and medium-scale (Landsat, Aster, Spot) to large-scale (Quick Bird).

The leading role in the formation of the image of a satellite image is played by the vegetation cover, which forms a mixture of spectral responses of different brightness on digital images, which, within the framework of automatic processing of remote sensing data, does not allow solving the problem by standard methods of delimiting the analyzed area by classes of homogeneous fields represented by pixels with the same spectra. The study of the vegetation cover requires up-to-date and objective information that can be obtained by processing space imagery data [2]. Vegetation is the most informative element of the ecosystem and is best displayed on multispectral satellite images, reflecting various characteristics of the state of the territory.

To use satellite images as a source of information about the vegetation growing in the study area, it is necessary to use the features of specific objects, by which they can be identified on aerospace images [3]. The predominant plant species or their groups and groups of plantation composition are deciphered mainly by color, microstructure and confinement to certain types of forest growing conditions. Completeness and age groups are determined (using high-resolution images) based on the microstructure of the plantation canopy and their statistical characteristics [4]. The use of narrow spectral intervals makes it possible to decipher individual trees. According to satellite images with a resolution of 10 m and better, after determining the prevailing and constituent species, the type of forest or a group of forest types and the class of bonitet, the group or age class of the prevailing species is deciphered. In high-resolution satellite images (1–2 m), the height of the plantation can be determined by measuring the length of the shadows of the trees (especially when shooting in the morning and evening hours). According to the measured diameters of crown projections (areas of crown projections), the average diameter of trees in stands at a height of 1.3 m, as well as the height and closeness of the plantation canopy, can be determined [4]. Satellite images allow the use of morphological signs when interpreting the composition of plantings, growing conditions, measuring and determining the taxation characteristics of plantations with greater accuracy [4–6].

The aim of the work was to develop approaches to the selection and interpretation of high-resolution satellite images for drawing up a detailed map of vegetation.

Research objects and methods

Field studies within the framework of this work were carried out in the period 2004 to 2017 in the territory of the Orichevsky district of the Kirov region. Communities of pine, spruce, mixed forests, as well as overgrown areas of meadows were described. Geobotanical descriptions of plant communities were carried out in layers. For interpretation, the indicators of the tree layer are important, therefore, the main attention was paid to the following characteristics: height, age and state of the main forest-forming species. The work shows an example of deciphering two areas, which represent several communities.

For the recognition of plant objects on the images, direct (general, basic) decoding features were used. Direct deciphering signs are the properties of an object that are directly displayed on images, inherent in the objects themselves. The properties of direct signs [4, 7–10] include geometric (shape, configuration, size, volume, pattern of objects) or structural (linear and volumetric), general (photogrammetric) – phototone, color, relative position. According to other data [4, 11], three groups of features belong to direct deciphering features: geometric (shape, shadow, size); luminance (phototone, color, spectral image); structural (texture, structure, pattern).

Deciphering of various tree species is carried out on spectrozonal images, which do not convey the actual colors of nature, but strongly emphasize the difference in the color of objects with a color contrast [12–18]. An additional feature of the image of woody vegetation in the satellite image is its tonality. Most of the forests of spruce, fir and pine in panchromatic black and white images are characterized by a darker tone than deciduous or larch trees.

Deciphering vegetation can be divided into contour and taxation. Contour interpretation consists in the selection of various categories of areas and taxation areas among the arrays which are subsequently characterized by means of field measurements. When deciphering stands, it is necessary to consider carefully not only the central parts of the image, but also the marginal ones, where differences in the structure of the crowns are better visible [16].

The work used ultra-high resolution space images from the WorldView-2 spacecraft with a spatial resolution of 0.5–1.0 m. The images were obtained on the following dates: June 2, 2007; May 8, 2011; September 12, 2014; September 10, 2018.

Satellite images were selected for dates (late spring – summer – early autumn), providing analysis of the time series during the period of a steady state of the deciduous vegetation cover. This time interval is interesting for research with a fairly smooth change in spectral characteristics.

Results and discussion

The image of forest stands has a pronounced photographic drawing, which allows them to be distinguished in photographs from areas not covered with forest. When deciphering, first of all, a grainy pattern is visible, created by the alternation of rounded specks – projections of tree crowns and gaps between them of different outlines, partially or fully occupied by dark shadows cast by trees. In stereoscopic viewing of images, the height of the stands is perceived quite clearly [12]. The density of the forest, the size and structure of tree crowns in the area have a major influence on the size and shape of the “grains” of the forest images in the image. These differences in the shapes and sizes of tree crowns, as well as in the outlines of their shadows in high- and ultra-high-resolution images, make it possible to determine the composition of plantations (Fig. 1, see color inset).

Monochrome images of pine forests have a general gray tone. Light gray rounded crown projections are almost the same in size, usually located in area. The surface of the canopy of a pine forest during stereoscopic viewing is visible without the “dips” typical of spruce and fir forests. In color images, pine forests are characterized by a dark green color (Fig. 2, see color insert).

Their structure is characterized as coarse-grained, the texture is arcuate-scalloped. The shape of the crown projections is oval; there is no sharp border and tone intensity of the crown projections and darkened areas between them. The shadows are elliptical in shape. In young trees with small crowns, due to the high degree of closeness, their projections merge with each other.

Images of spruce forests (Fig. 1, 2, see color insert) on the satellite image are characterized by a dark tone with light gray, with gray rounded “grains” of crowns and almost round gaps between them. Spruce is shown in blue-green color in spectrozonal aerial photographs.

Changes in the diameter of crowns in one massif within a wide range (by a factor of 4–5) and a significant difference in heights of trees within a plantation of one type, which is significantly higher than in stands of other species, are noted.

An important feature is elongated cone-shaped and needle-shaped shadows (Fig. 3, 4, see color insert). Falling shadows cast by trees are clearly visible. They convey the shape of objects in a form close to the usual. By measuring the length of the shadow, you can quickly and accurately determine the height of an object.

Aspen forests in the satellite image dated May 8 (Fig. 4, see color insert) have a light gray tone, lighter than all other considered stands. The lighter tone of the aspen allows it to be distinguished from other stands. In the photographs, the shadows of aspens are shaped like those of pines; when viewed stereoscopically, the crowns seem to be torn off the ground. Aspens have a curtain or group arrangement of crowns. Aspen grows together with coniferous and deciduous trees, but it also forms pure aspen forests.

In color images, deciduous forests (aspen) are characterized by a light green color. Their structure is characterized as coarse-grained, homogeneous, dense, the texture is spotty-granular, the grains are smeared (Fig. 4, see color insert). On the pictures they are arranged in the form of a closed canopy with dark gaps. The projections of tree crowns are light, indistinct. The shape of the crowns is rather round, the crowns are arranged in groups, overlapping with each other.

The image of solid thickets of shrubs is characterized by a fine-grained photo-pattern structure, a gray or dark gray tone, small falling shadows and a usually rounded shape of the contours. The thickets of shrubs differ from young shoots in a more even tone, due to the homogeneity of the composition. For reliable recognition and differentiation of shrubs and undergrowth, it is necessary to take into account the peculiarities of the growth and placement of certain species in the specific conditions of the survey area. As a rule, shrubs are confined to the floodplains of rivers, the bottoms of ravines, the edges of steppe oak forests, etc., while the shoots are found in overgrown clearings in forest areas.

The analysis of the images taken at different times of the year, at different phenophases, has a different color and structural pattern. So, in the photo dated May 8 (Fig. 4, see the color insert), areas with a green and gray phototone are clearly distinguished, which reflect, respectively, coniferous and mostly deciduous trees that have not yet blossomed at this time. The pictures taken in September (Fig. 2, 3, see color insert) clearly show areas of different shades of green. Arrays of conifers are denoted in dark green, and lighter shades of green to yellow are inherent in communities that are dominated by birches, in which an autumn change in foliage color occurs. Sometimes one can see separate pink and purple spots (Fig. 3, see the color insert) of the beginning of the color change of aspen leaves. In the photographs taken after mid-May and until mid-September, woody plants are practically not deciphered by color. They can hardly be distinguished solely by the microtexture of the pattern.

The analysis of satellite images of other forest areas of the Kirov region shows that in different years the images taken at the same time (spring or autumn) have different information content, since phenophases rarely coincide in different years [8].

Thus, for interpretation, the images obtained in different seasons of the year were selected and analyzed taking into account data from field studies. Based on the images, the boundaries of plant communities were established and their contours were outlined.

Figure 5 shows a fragment of a schematic map based on decryption data. The constructed map reflects the diversity of the vegetation cover of the territory and can serve as an initial geobotanical basis for studying the dynamics of vegetation.

Conclusion

For greater reliability, interpretation of plant communities should be carried out using data from field studies conducted over several years in the same territory.

The most suitable images for interpretation in order to map forest tree communities are images taken in early spring, when the snow has mostly melted, but the foliage on the trees has not yet blossomed (late April – early May) and in mid-autumn, when the leaves acquire characteristic tree species shades of color (late September – early October). Satellite images taken in summer are not very informative for the purpose of mapping forest plant communities.

The data of interpretation of satellite images can be used as the basis for creating a map of vegetation of the studied area.

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References

1. Kozoderov V.V., Dmitriev E.V. Remote sensing of forest cover: an innovative approach // Lesnoy vestnik. 2012. No. 1. P. 19–33 (in Russian).

2. Levadny Yu.V., Telesh V.A. Technique for decoding terrain objects on radar images // Informaciya i kosmos. 2017. No. 1. P. 160–161 (in Russian).

3. Golovina L.A., Dubovik D.S. Topographic interpretation of images: study guide. allowance. Novosibirsk: SGGA, 2011. 60 p. (in Russian).

4. Labutina I.A. Deciphering aerospace images: Textbook. manual for university students. Moskva: Aspect Press, 2004. P. 60–79 (in Russian).

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Fig. 1. Fragment of the image from the WorldView-2 spacecraft dated May 18, 2014. Resolution 1 m

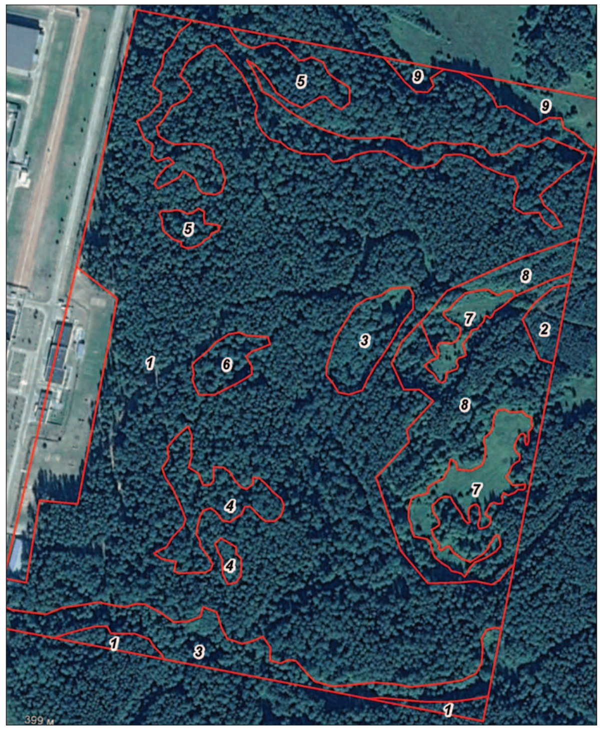

Fig. 2. Fragment of the image from the WorldView-2 spacecraft dated September 2, 2017. Resolution 1 m

Note for Figures 1 and 2: 1 – spruce-pine forest and pine forest, 2 – small pine forest, 3 – willow forest, 4 – deciduous forest (aspen, birch, willow), 5 – deciduous forest (birch, aspen, willow), 6 – deciduous forest (birch, aspen), 7 – arable land overgrown with small pine forests, 8 – former arable land, overgrown with small pine forests, willow forests, etc., 9 – overgrown meadow

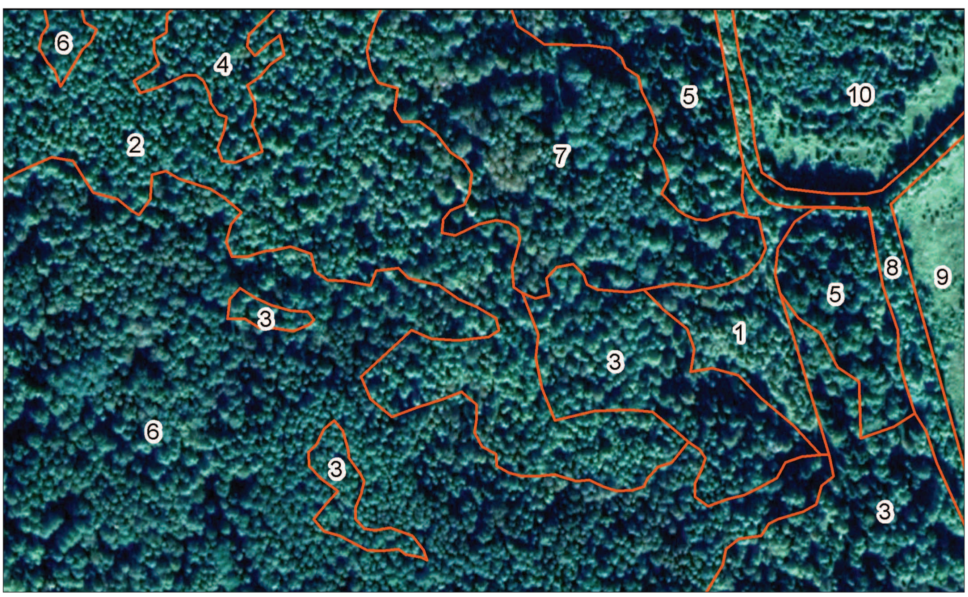

Fig. 3. Fragment of the image from the WorldView-2 spacecraft dated September 10, 2018. Resolution 0.5 m

Note to Figures: 1 – young pine forest, 2 – spruce-pine forest with old-growth aspens, 3 – old-growth spruce forest (cone-shaped and needle-shaped shadows), 4 – aspen-spruce forest, 5 – aspen-spruce old-growth forest (cone-shaped and needle-shaped shadows), 6 – aspen forest with rare spruce and single pines, 7 – aspen forest with rare old spruce, 8 – willow forest, 9 – arable land, 10 – arable land overgrown with pine forest

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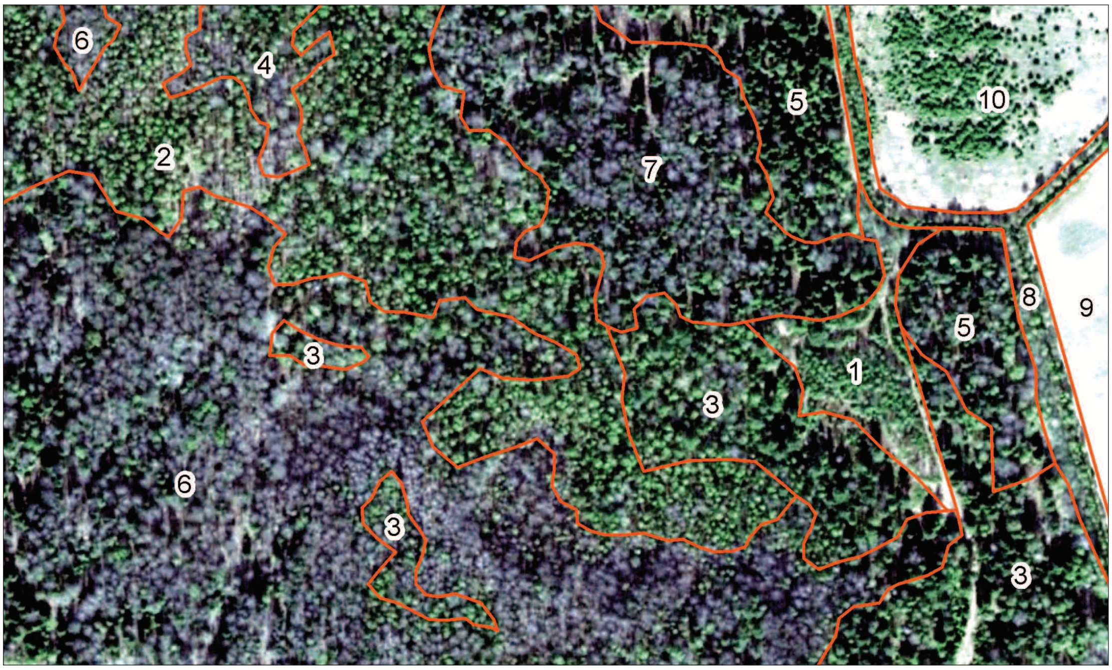

Fig. 4. Fragment of the image from the WorldView-2 spacecraft dated May 8, 2011. Resolution 1 m

Note to Figures 4, 5: 1 – young pine forest, 2 – spruce-pine forest with old-growth aspens, 3 – old-growth spruce forest (cone-shaped and needle-shaped shadows), 4 – aspen-spruce forest, 5 – aspen-spruce old-growth forest (cone-shaped and needle-shaped shadows), 6 – aspen forest with rare spruce and single pines, 7 – aspen forest with rare old spruce, 8 – willow forest, 9 – arable land, 10 – arable land overgrown with pine forest

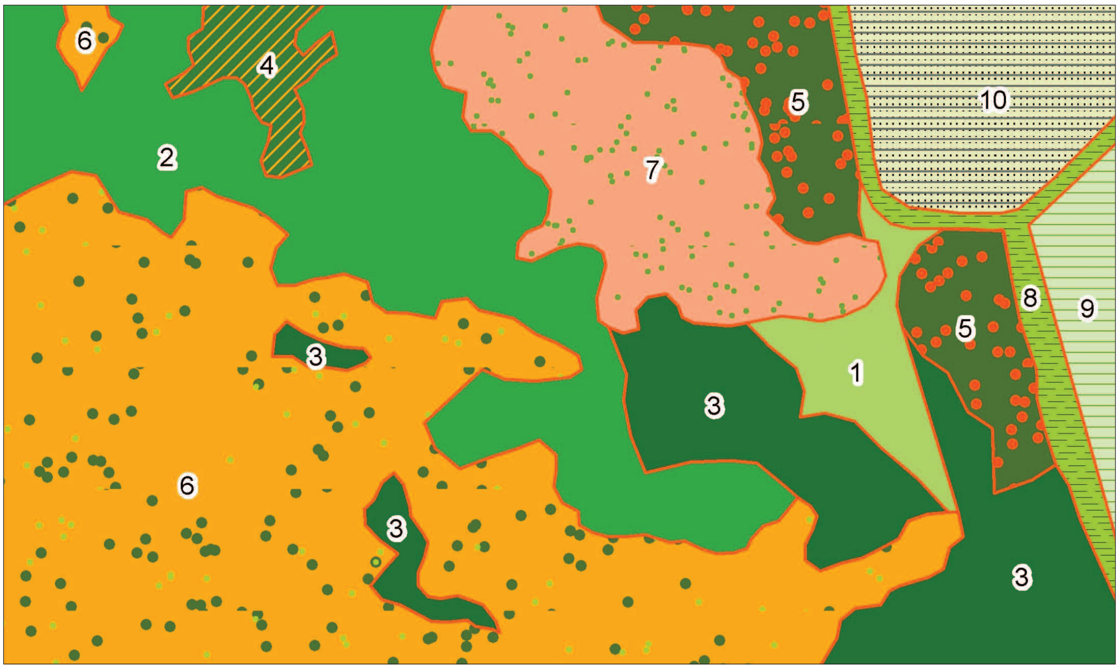

Fig. 5. Schematic map of vegetation of one of the sites in the Orichevsky district of the Kirov region

5. Korelskiy D.S. Evaluation of soil and plant communities experiencing technogenic stress using cosmomonitoring // Zapiski Gornogo instituta. 2013. V. 203. P. 170–173 (in Russian).

6. Greenberg J.A., Dobrowski S.Z., Vanderbilt V.C. Limitations on maximum tree density using hyperspatial remote sensing and environmental gradient analysis // Remote Sensing of Environment. 2009. V. 113. No. 1. P. 94–101. doi: 10.1016/j.rse.2008.08.014

7. Marchukov V.S. Automated methods for assessing the dynamics of the spatial distribution of vegetation cover and soils based on remote monitoring data // Issledovanie Zemli iz kosmosa. 2010. No. 2. P. 63–74 (in Russian).

8. Adamovich T.A., Domnina E.A., Timonov A.S., Rutman V.V., Ashikhmina T.Ya. Methodological methods for identifying plant communities based on data from remote sensing of the Earth and field research // Theoretical and Applied Ecology. 2019. No. 2. P. 39–43 (in Russian). doi: 10.25750/1995-4301-2019-2-039-043

9. Leimgruber P., Christen C.A., Laborderie A. The impact of Landsat Satellite monitoring on conservation biology environmental monitoring and assessment // Remote Sensing of Environment. 2005. V. 106. P. 81–101. doi: 10.1007/s10661-005-0763-0

10. Hojas-Gasc n L., Belward A., Eva H., Ceccherini G., Hagolle O., Garcia J., Ceruttid P. Potential improvement for forest cover and forest degradation mapping with the forthcoming Sentinel-2 program // Int. Archives of the Photogram., Rem. Sens & Spatial Inf. Sciences. 2015. P. 417–423. doi: 10.5194/isprsarchives-XL-7-W3-417-2015

11. Borzov S.M., Potaturkin O.I. Classification of vegetation types based on hyperspectral data of remote sensing of the earth // Vestnik Novosibirskogo gosudarstvennogo universiteta. Seriya: Informacionnye tekhnologii. 2014. V. 12. No. 4. P. 13–22 (in Russian).

12. Afonin A.N., Sokolova Yu.V., Bardakov N.N., Sakharov I.O. Deciphering the vegetation of the northwestern Ladoga area from high-resolution satellite images using ordination based on a complex of morphological and physiological parameters // Sovremennye problemy distancionnogo zondirovaniya Zemli iz kosmosa. 2018. V. 15. No. 1. P. 147–156 (in Russian). doi: 10.21046/2070-7401-2018-15-1-147-156

13. Rees W.G., Tutubalina O.V., Tømmervik H., Zimin M., Mikheeva A., Golubeva E. Mapping of the Eurasian circumboreal forest-tundra transition zone by remote sensing // Proceedings of the Fifth International Workshop: Conservation of Arctic Flora and Fauna (CAFF) Flora Group. Circumboreal Vegetation Mapping (CBVM) Workshop, Helsinki, Finland, November 3–6th, 2008. CAFF International Secretariat, CAFF Flora Expert Group (CFG), CAFF Technical Report No. 21 / Eds. S. Talbot, T. Charron, T. Barry. Helsinki, 2010. P. 144–150.

14. Kravtsova V., Tutubalina O., Hofgaard A. Aerospace mapping of the status and position of northern forest limit // Geography, Environment, Sustainability. 2012. No. 5 (3). P. 28–47. doi: 10.24057/2071-9388-2012-5-3-28-47

15. Kurbanov E.A., Vorob'ev O.N., Lezhnin S.A. Thematic mapping of vegetation cover from satellite imagery: validation and assessment of accuracy: monograph. Yoshkar-Ola: Povolzhskiy gosudarstvenniy tekhnologicheskiy universitet, 2015. 132 p. (in Russian).

16. Davranchea A., Lefebvreb G., Poulinb B. Wetland monitoring using classification trees and SPOT-5 seasonal time series // Remote Sensing of Environment. 2010. V. 114. No. 3. P. 552–562. doi: 10.1016/j.rse.2009.10.009

17. Ranson K.J., Sun G., Kharuk V.I., Kovacs K. Assessing tundra–taiga boundary with multi-sensor satellite data // Remote Sensing of Environment. 2004. V. 93. No. 3. P. 283–295. doi: 10.1016/j.rse.2004.06.019

18. Zhang Y., Xu M., Adams J., Wang X. Can Landsat imagery detect tree line dynamics? // Int. J. Rem. Sens. 2009. V. 30. No. 5–6. P. 1327–1340. doi: 10.1080/01431160802509009