Difference of Reflections from Coniferous and Foliar Vegetation According to Spectrozonal Remote Sensing Data

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Abstract. The paper presents results of the spectral brightness study of coniferous and foliar forests on the satellite images Landsat-7 for different seasons. Spectral channels, in which reflections from such species most differ from each other, are determined. The obtained results allow one to form standards for the classification of forest vegetation cover in different phenological phases. To increase the distinctiveness of the analyzed objects, information about their brightness was merged for different combinations of two spectral channels. This allows one to form two additional classification features: the Euclidean distance and spectral angle in two-dimensional brightness space. It is shown that the combination of two channels can significantly increase the number and quality of the formed features for the selection of coniferous and foliar vegetation.

Keywords: Coniferous and foliar vegetation, satellite images, spectral brightness coefficient, classification features.

INTRODUCTION

The spectral brightness coefficient is used to classify the forest vegetation cover by the satellite images. As a rule, it is defined as the absolute value of the object brightness in different spectral ranges [1]. Differences in the level of reflection depend on the species composition of the vegetation of the study area and are determined mainly by its phenological phases. The values of this parameter are also affected by the spatial, radiometric, and spectral resolution of the equipment; the shooting season (changes in the azimuth and altitude of the Sun); exposure values, surface steepness; and characteristics of the atmospheric transparency. The aim of the study is to determine the information content of the spectral brightness as a classification feature in the allocation of coniferous and foliar vegetation. The importance of the problem is confirmed by the active development of the spectral libraries of plant objects for their interpretation by the satellite images [2–4].

RESEARCH METHODS

Space images of the flat forest area were chosen for the study. The images were obtained using the ETM+ of the Landsat-7 [5].

The spectral brightness of reflection from vegetation was determined for its various phenological phases (for different seasons: winter-spring, summer, and autumn). The expectation and standard deviation of the reflection brightness in each spectral channel were determined by a set of image pixels corresponding to the known type of the vegetation cover.

During the research, a specialized database was used to store the original images and images corresponding to the analyzed fragments [6]. This database also contains information on the species composition, area, and other parameters of the study sites.

International Conference of Numerical Analysis and Applied Mathematics ICNAAM 2019
AIP Conf. Proc. 2293, 140024-1–140024-4; https://doi.org/10.1063/5.0027365
Published by AIP Publishing. 978-0-7354-4025-8/$30.00

EXPERIMENTAL RESULTS

As a result of the study, it was shown that the spectral curves for the summer months are close, so, as an example, the dependences are only taken for July (Fig. 1). In this figure, the dependencies for a foliar forest are shown in red and for a coniferous forest in green. Here, the upper curve corresponds to the expected brightness, to which its doubled standard deviation is added. The lower curve corresponds to the expected brightness, from which its doubled standard deviation is subtracted.

As follows from the results, the spectral characteristics of the reflection from the coniferous and foliar areas in the spectral channels of the Landsat-7 differ from each other in the different seasons of the year. These differences were quantified (Table 1) as follows:

$$D_{FC} = (M_F - 2\sigma_F) - (M_C - 2\sigma_C) . \quad (1)$$

In this expression, the values M_F and M_C are the mathematical expectations of the brightness of deciduous and coniferous species, σ_F and σ_C are their standard deviations.

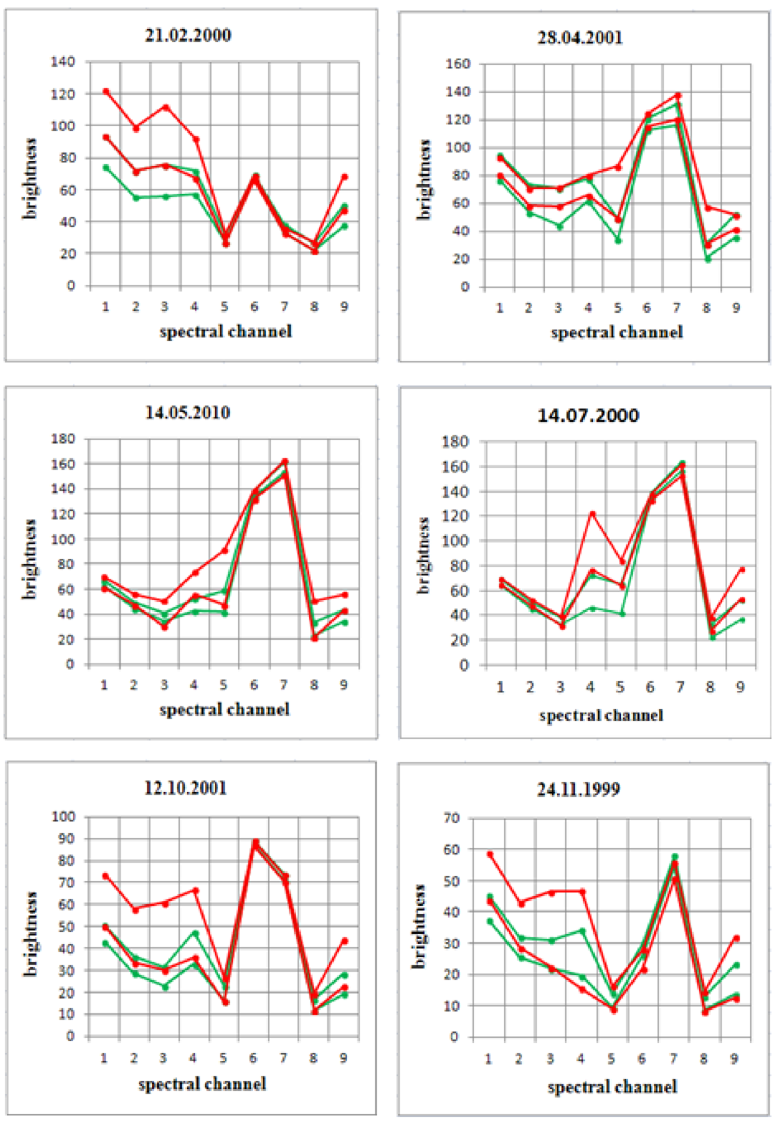

FIGURE 1. Spectral brightness of coniferous and foliar species.

The negative numbers in Table 1 correspond to the overlap of the brightness values of the coniferous and foliar vegetation in accordance with the criterion adopted in form (1). As follows from the presented results, reflections in 1–3 channels of the February image and reflections in the 4th channel for images of May, June, July, and August can be used as signs for distinguishing the coniferous and foliar vegetation by the spectral brightness. In addition, one can use the June pictures of the 6th and 7th channels and the July pictures of the 9th channel. However, it should be noted that the pixel size of the image in the 6th and 7th channels is twice as large as in 1–5th and 8th channels, and in the 9th channel, on the contrary, twice as small. This complicates the integration of classification results using information from the 6th, 7th and 9th spectral channels.

TABLE 1. Differences in brightness of coniferous and foliar vegetation.

Shooting date	Spectral channel number								
	1	2	3	4	5	6	7	8	9
21.02.2000	0.35	0.07	0.48	–4.60	–4.50	–2.10	–2.66	–4.50	–2.73
28.04.2001	−14.24	−14.93	−12.98	−11.66	−0.38	−5.80	−10.69	−0.02	−10.72
14.05.2010	−5.29	−2.11	−10.52	3.48	−11.23	−4.57	−8.48	−11.51	−0.04
23.06.2013	−2.29	−2.83	−2.21	4.07	−18.07	0.64	1.83	−6.40	−2.43
14.07.2000	−4.44	−2.54	−6.55	4.64	−1.05	−3.33	−5.24	−4.84	1.26
13.08.2014	−2.36	−2.51	−2.49	5.40	−16.58	−0.31	−0.67	−7.51	−1.98
10.09.2001	−5.83	−3.77	−6.14	−1.12	−2.92	−2.87	−3.56	−4.09	−7.17
12.10.2001	−0.12	−2.69	−1.26	−11.43	−7.18	−1.81	−2.67	−4.64	−5.78
24.11.1999	−1.40	−3.25	−8.67	−18.87	−4.91	−1.74	−1.46	−4.68	−10.60

To increase the number of informative features that distinguish the coniferous and foliar vegetation, the spectral channels were combined in pairs. The channels with the same spatial resolution are selected. After that, the Euclidean distance and spectral angle between the brightness of the coniferous and foliar species are calculated the

$$D_2 = \sqrt{(B_{nF} - B_{nC})^2 + (B_{mF} - B_{mC})^2}\ , \tag{2}$$

$$U_2 = arctg\frac{B_{mF}}{B_{nF}} - arctg\frac{B_{nC}}{B_{mC}}\ . \tag{3}$$

In expressions (2) and (3), the values B_{nC} and B_{mC} are the brightness of coniferous trees, and B_{nF} and B_{mF} are brightness of the foliar ones in the *n*th and *m*th spectral channels, respectively.

The result of combining the brightness of these objects is a significant increase in the number of informative features for their classification (Table 2) and (Table 3).

TABLE 2. Numbers of spectral channels differing in Euclidean distance in two-dimensional brightness space for coniferous and foliar vegetation.

Shooting date	Numbers of the combined spectral channels				
	1	2	3	4	5
21.02.2000	2–5, 8	3–5, 8	4, 5, 8	5, 8	–
28.04.2001	3, 5, 8	3, 5, 8	4, 5, 8	5, 8	8
14.05.2010	4	4	4	5, 8	–
23.06.2013	4	4	4	5, 8	–
14.07.2000	4, 5	4, 5	4, 5	5, 8	8
13.08.2014	4	4	4	5, 8	–
10.09.2001	4, 5	4, 5	4, 5, 8	5, 8	8
12.10.2001	2–5, 8	3–5, 8	4, 5, 8	5, 8	–
24.11.1999	2–5, 8	5, 8	–	–	–

TABLE 3. Channel numbers differing in spectral angle in two-dimensional brightness space for coniferous and foliar vegetation.

Shooting date	Numbers of the combined spectral channels				
	1	2	3	4	5
21.02.2000	3, 5, 8	3, 5, 8	4, 5, 8	5, 8	–
28.04.2001	5, 8	5, 8	–	5, 8	–
14.05.2010	2, 4, 5	4	5	–	–
23.06.2013	4	4	4	5, 8	8
14.07.2000	2, 4, 5	4, 5	4, 5	–	–
13.08.2014	4	4	4	5, 8	8
10.09.2001	4, 5	4, 5	4, 5	–	–
12.10.2001	3	3	4, 5, 8	–	–
24.11.1999	–	–	–	–	–

Tables 2 and 3 show the numbers of spectral channels, the combinations of which do not lead to overlap in the Euclidean distance and spectral angle in brightness between the coniferous and foliar vegetation. In this case, the absence of overlap is determined by the absence of overlapping of these parameters in the range of two of their standard deviations from the corresponding mathematical expectations. For example, using spectral brightness for the June images, five additional classification features can be formed by combining 1–4, 2–4, 3–4, 4–5 and 4–8 channels (Table 2). As for the spectral angle between the brightness vectors, six additional classification features can be obtained by combining 1–4, 2–4, 3–4, 4–5, 4–8 and 5–8 channels (Table 3).

CONCLUSION

Using the Landsat 7 satellite images, a fragment of the spectral library of the forest area located in the region of 60^0 North latitude of the European part of the Russian Federation was formed. The experimental dependences of the spectral brightness of coniferous and foliar vegetation for different shooting seasons were obtained from the remote sensing data. Calculation of the Euclidean distance and spectral angle by brightness between these forest species for different combinations of two spectral channels is made. It is shown that in this case, the formation of a greater number of features for the classification of vegetation in the performance of forest management and forest monitoring by satellite images is possible.

ACKNOWLEDGMENTS

This work was supported by the Center of Excellence “Geoinformation technologies and geophysical data complex interpretation” of the Ural Federal University Program (Act 211 Government of the Russian Federation, contract № 02.A03.21.0006).

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