Increasing the Distinctiveness of Forest Species Composition by Satellite Images

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***Abstract*—The brightness of reflections from coniferous and foliar vegetation was studied using Landsat–7 images for different seasons of the year. Results were obtained for each of the spectral channels of the ETM + sensor, which allows forming standards for classifying forest vegetation in various phenological phases. To increase the distinctness of plant objects, information about their brightness is combined with data from another spectral channel. As a result, an additional classification feature is formed – the Euclidean distance in the space of spectral brightness. It is shown that the combination of two channels can significantly increase the number of informative classification features when mapping forest vegetation.**

Keywords—spectral brightness, coniferous and foliar vegetation, Landsat–7, combination of two spectral channels

I. Introduction

When classifying forest vegetation from satellite images, the spectral brightness coefficient is used. This coefficient is usually defined as the absolute value of the object's brightness in various spectral ranges [1]. Differences in the level of reflection from vegetation depend on its species composition in the study area, phenological phases of development and the state determined by weather conditions. The values of this parameter are also affected by the spatial, radiometric and spectral resolution of the shooting equipment; the time and season of shooting (changes in the azimuth and height of the Sun); exposure and steepness of the surface; the characteristics of atmospheric transparency.

The purpose of the study is to determine the information content of spectral brightness as a classification feature in the selection of coniferous and foliar vegetation. The relevance of this problem is confirmed by active research on the formation of spectral libraries of plant and natural objects based on satellite images [2–5], as well as monitoring their state and classification by multispectral and hyperspectral data [6,7].

II. Research Methods

Satellite images of a flat forest area were selected for the study (Fig. 1). In this drawing, a fragment of a foliar forest is highlighted in black, while a coniferous forest is highlighted in gray. The images used were obtained using ETM + equipment (Table 1) the Landsat–7 satellite [8].

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

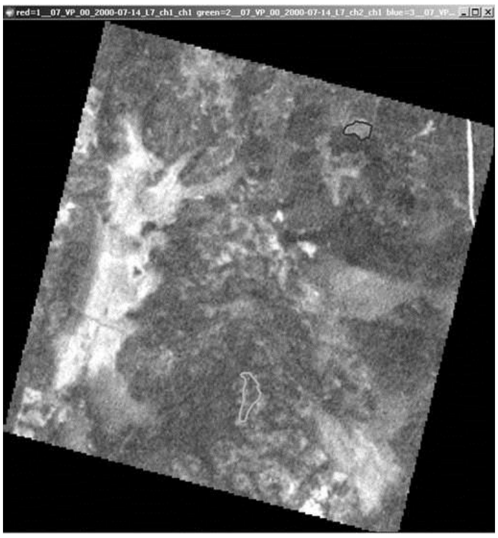

Fig. 1. Space image of the study area.

TABLE I. Characteristics of Thematic Mapper (ETM+)

Spectral Band (number)	Wave Length (μm)	Pixel size (m)
1 (1)	0.45 – 0.52	30
2 (2)	0.52 – 0.60	30
3 (3)	0.63 – 0.69	30
4 (4)	0.77 – 0.90	30
5 (5)	1.55 – 1.75	30
61 (6) Low Gain	10.40 – 12.50	60
62 (7) High Gain	10.40 – 12.50	60
7 (8)	2.08 – 2.35	30
8 (9)	0.52 – 0.90	15

In the course of the research, a specialized database was used to store the source images corresponding to the analyzed fragments [9]. This database also contains information about the composition of forest species, area, and other parameters of the study sites.

III. Experimental Results

As a result of the study, spectral curves were obtained for the winter and spring months (Fig.2), as well as for the summer and autumn months (Fig.3).

It should be noted that the use of Landsat satellite images is characterized by a large time interval (16 days) for capturing images of the same surface. At the same time, the presence of frequent clouds for the 60^0 North latitude, where the analyzed forest area is located, does not allow you to collect images corresponding to different seasons of the same year (close years). In addition, not all images for the study area are available in the Landsat system operator's database [10]. These points often limit the accuracy of obtaining quantitative results from conducted studies.

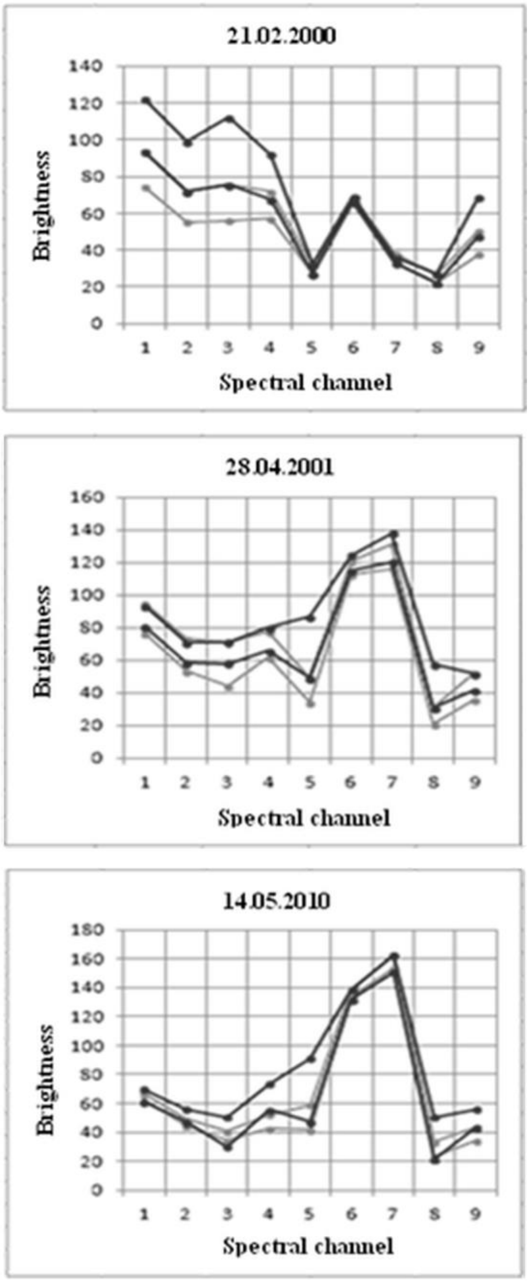

Fig. 2. Spectral brightness of coniferous and foliar trees in winter and spring.

In the figures below, dependencies for foliar forests are shown in black, while for coniferous forests they are shown in gray. Here, the upper curve corresponds to the mathematical expectation of brightness, to which is added to its doubled standard deviation. The lower curve corresponds to the mathematical expectation of brightness, from which its doubled standard deviation is subtracted.

As follows from the results, the spectral characteristics of reflection from coniferous and foliar areas in the spectral channels of Landsat–7 differ from each other in different seasons of the year. A quantitative assessment of the brightness differences of the vegetation under study for spectral channels with a resolution of 30 meters is given in table 2.

These differences in one channel were determined as follows

$$D_1^i = B_{Fi} - B_{Ci}, \quad (1)$$

$$\Delta_1^i = M\{D_1^i\} - 2\,\sigma\,\{D_1^i\}. \quad (2)$$

Here B_{Fi} and B_{Ci} is the brightness of foliar and coniferous species, respectively, for images of the same size in the *i*-th spectral channel.

D_1^i the difference in brightness of species, and Δ_1^i the measure of their difference is determined by mathematical expectation and standard deviation.

Negative numbers in the table below correspond to the overlap of the brightness values of coniferous and foliar vegetation in accordance with the criterion defined (2). At the same time, coniferous and foliar vegetation differ most in spectral brightness in the following channels: 1, 2, 3 of the February image, 5 – April, 4 – May, 4, 5 – July, 1, 3 – October. The results obtained can be explained by the absence of foliage and reflection from the snow through the crown of foliar trees in February and reflection from the litter in April, the appearance and presence of foliage that differs in tone from the needles in May and July, the change in color of the foliage and its fall in October.

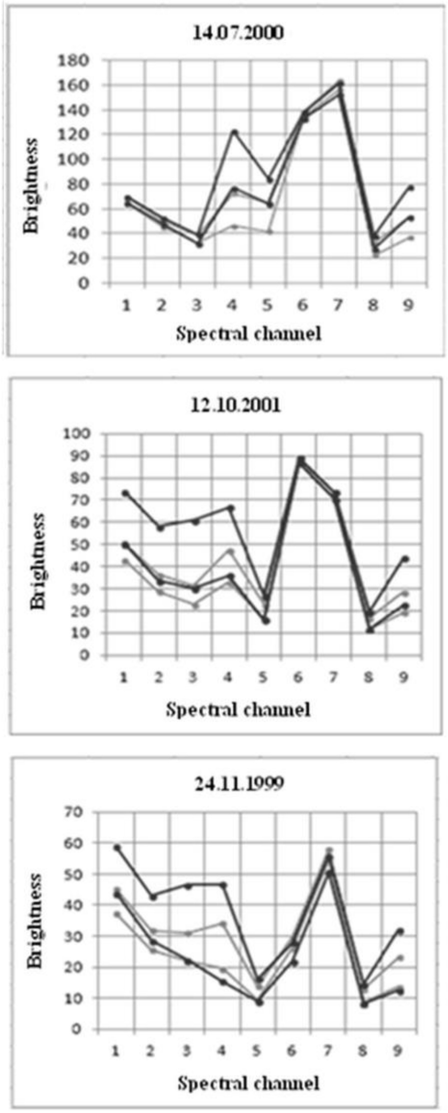

Fig. 3. Spectral brightness of coniferous and foliar trees in summer and autumn.

TABLE II. DIFFERENCES IN THE BBRIGHTNESS IN ONE CHANNEL

Shooting date	Spectral channel number					
	1	2	3	4	5	8
21.02.2000	12.95	11.50	14.25	5.25	–2.24	–2.56
28.04.2001	–7.16	–7.29	–2.39	–5.13	11.28	7.33
14.05.2010	–2.74	0.86	–4.18	8.25	1.37	–2.30
14.07.2000	–2.36	–0.66	–3.69	18.22	8.77	–1.37
12.10.2001	5.32	2.55	5.19	–0.45	–3.85	–2.60
24.11.1999	4.04	0.69	–3.39	–12.01	–2.93	–2.64

To increase the number of informative features that distinguish coniferous and foliar vegetation, spectral channels were combined in pairs. Spectral channels with the same spatial resolution of 30 meters were also used. Then the Euclidean distance in brightness and the measure of the difference between coniferous and foliar species was calculated between the channels

$$D_2^{ij} = \left[\left(B_{Fi} - B_{Ci}\right)^2 + \left(B_{Fj} - B_{Cj}\right)^2 \right]^{1/2}, \quad (3)$$

$$\Delta_2^{ij} = M\left\{D_2^{ij}\right\} - 2\,\sigma\left\{D_2^{ij}\right\}. \quad (4)$$

Here D_2^{ij} is the difference in brightness and Δ_2^{ij} a measure of distance of coniferous and foliar vegetation when using the *i*–th and *j*–th spectral channels.

The result of combining the brightness of these objects in two spectral channels is a significant increase in the number of informative features for their classification (table 3).

TABLE III. CHANNEL NUMBERS WITH DIFFERENCES OF SPECIES IN TWO CHANNELS

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

This table shows the numbers of spectral channels, the combination of which does not lead to overlap by the introduced measure of difference (4) of coniferous and foliar vegetation. In this case, for example, for July images, you can add nine additional classification features to the existing two by combining them 1–4, 1–5, 2–4, 2–5, 3–4, 3–5, 4–5, 4–8, and 5–8 channels. This increases the total number of features for classifying coniferous and foliar vegetation.

To demonstrate the increase in the measure of the difference between breeds, the parameter with the highest value for the channel (shown in parentheses) combined with the original one (table 4) is calculated.

For the February image, for example, the greatest differences in plant species are obtained when the first and third channels are combined. When combining two channels, the difference between coniferous and foliar vegetation, as a rule, increases significantly.

TABLE IV. DIFFERENCES IN THE BRIGHTNESS OF SPECIES IN TWO CHANNELS

Shooting date	Spectral channel number				
	1	2	3	4	5
21.02.2000	20.15 (3)	17.10 (3)	16.36 (4)	6.11 (5)	–9.14 (8)
28.04.2001	9.34 (5)	10.78 (5)	11.07 (5)	12.83 (5)	14.63 (8)
14.05.2010	1.88 (5)	3.69 (4)	6.10 (4)	9.18 (5)	3.37 (8)
14.07.2000	17.03 (4)	19.67 (4)	19.46 (4)	23.08 (5)	2.52 (8)
12.10.2001	9.81 (3)	6.30 (3)	8.03 (4)	–1.42 (5)	–2.50 (8)
24.11.1999	5.45 (2)	–0.01 (3)	–0.61 (4)	–1.90 (8)	–0.12 (8)

IV. CONCLUSION

Based on Landsat–7 satellite data for different seasons, a fragment of the spectral library of coniferous and foliar vegetation of the forest area located in the area of 600 North latitude of the European part of the Russian Federation was formed.

Based on the introduced criterion based on the calculation of mathematical expectation and the doubled mean square deviation for the difference in spectral brightness between the studied vegetation types, the following conclusions are formulated. Coniferous and foliar species differ the most in channels 1, 2, 3 of the February image, 5 – April, 4 – May, 4, 5 – July, 1, 3 – October. The results obtained are explained by the absence of foliage and reflection from the snow through the crown of foliar trees in February and reflection from the litter in April, the appearance and presence of foliage that differs in tone from the needles in May and July, the change in color of the foliage and its fall in October.

To increase the number of informative features that distinguish coniferous and foliar vegetation, spectral channels were combined in pairs. In this case, as in the case of a single channel, spectral channels with the same spatial resolution of 30 meters were used. Then the Euclidean distance in brightness and a similar measure of the difference between coniferous and foliar species were calculated between the channels. It is shown that combining information from two channels can significantly increase the number of informative vegetation classification features for the selected seasons. We also selected pairs of channels, combining which allows you to get the maximum difference between coniferous and foliar vegetation. Thus, the effectiveness of combining spectral brightness channels in the formation of classification features for forest vegetation has been quantitatively demonstrated.

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