# Increasing the distinctiveness of forest species composition by satellite images

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**Abstract**. The study of reflections from coniferous and foliar vegetation on Landsat-7 images for different seasons of the year was carried out. The results were obtained for each of the spectral channels (VIS, NIR, SWIR) of the ETM + sensor, which allow us to form standards for the classification of forest vegetation in different phenological phases. To increase the distinctness of plant objects, information about their brightness is combined with data from several spectral channels. As a result, an additional classification feature is formed - Euclidean distance in the space of spectral brightness. It is shown that the combination of several channels can significantly increase the number of classification features when mapping forest vegetation.

## 1. Introduction

When classifying forest vegetation from satellite images, a spectral brightness coefficient is used. Usually this coefficient is defined as the absolute value of the object's brightness in different 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 survey equipment; the time and season of the survey (changes in azimuth and altitude of the Sun); values of exposure and surface steepness; 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 importance of this problem is confirmed by the active development of spectral libraries of plant objects based on satellite images [2-4] for monitoring their state and classification.

## 2. Research methods

Satellite images of a flat forest area were selected for the study (figure 1). In the drawing, a fragment of foliar forest is highlighted in black, and coniferous forest is highlighted in gray. The images were obtained using the ETM + instrument (table 1) of the Landsat-7 satellite [5].

The spectral brightness of the reflection from vegetation was determined for its various phenological phases (for different seasons: winter-spring, summer and autumn). At the same time, 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.

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 about the rock composition, area and other parameters of the study sites.

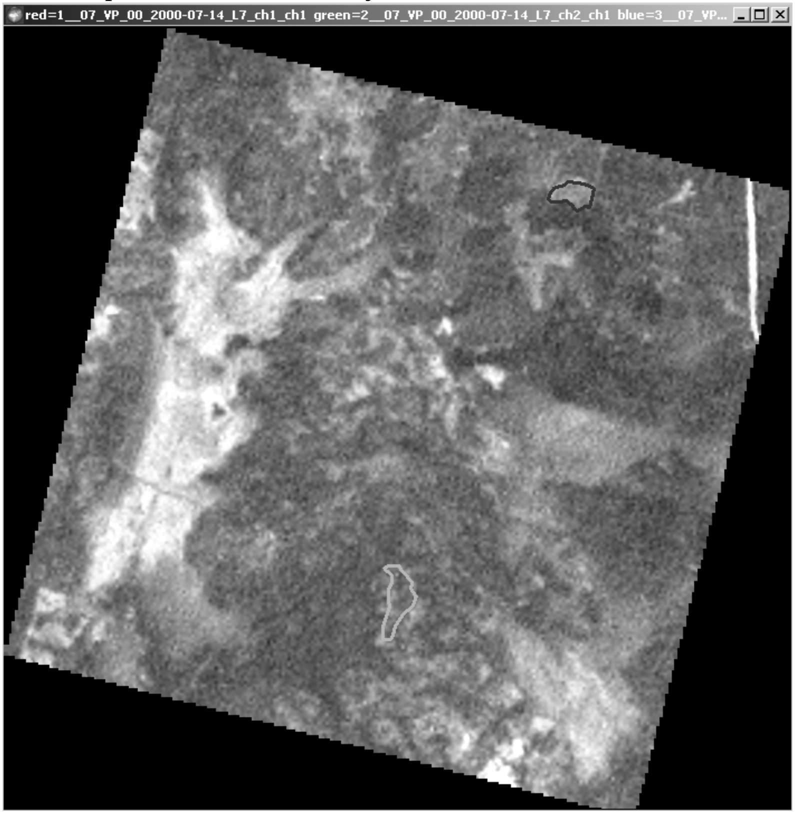


**Figure 1.** Space image of the study area.

**Table 1.** Enhanced Thematic Mapper Plus (ETM+) characteristics.

| 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 |

## 3. Experimental results

As a result of the study, it was shown that the spectral curves for the summer months are close, so the dependencies for July only are given as an example (figure 2).

In this figure, the dependencies for a foliar forest are shown in black, and for a coniferous forest in gray. Here the upper curve corresponds to the mathematical expectation of brightness, to which is added its double standard deviation. The lower curve corresponds to the mathematical expectation of brightness, from which its doubled standard deviation is subtracted.

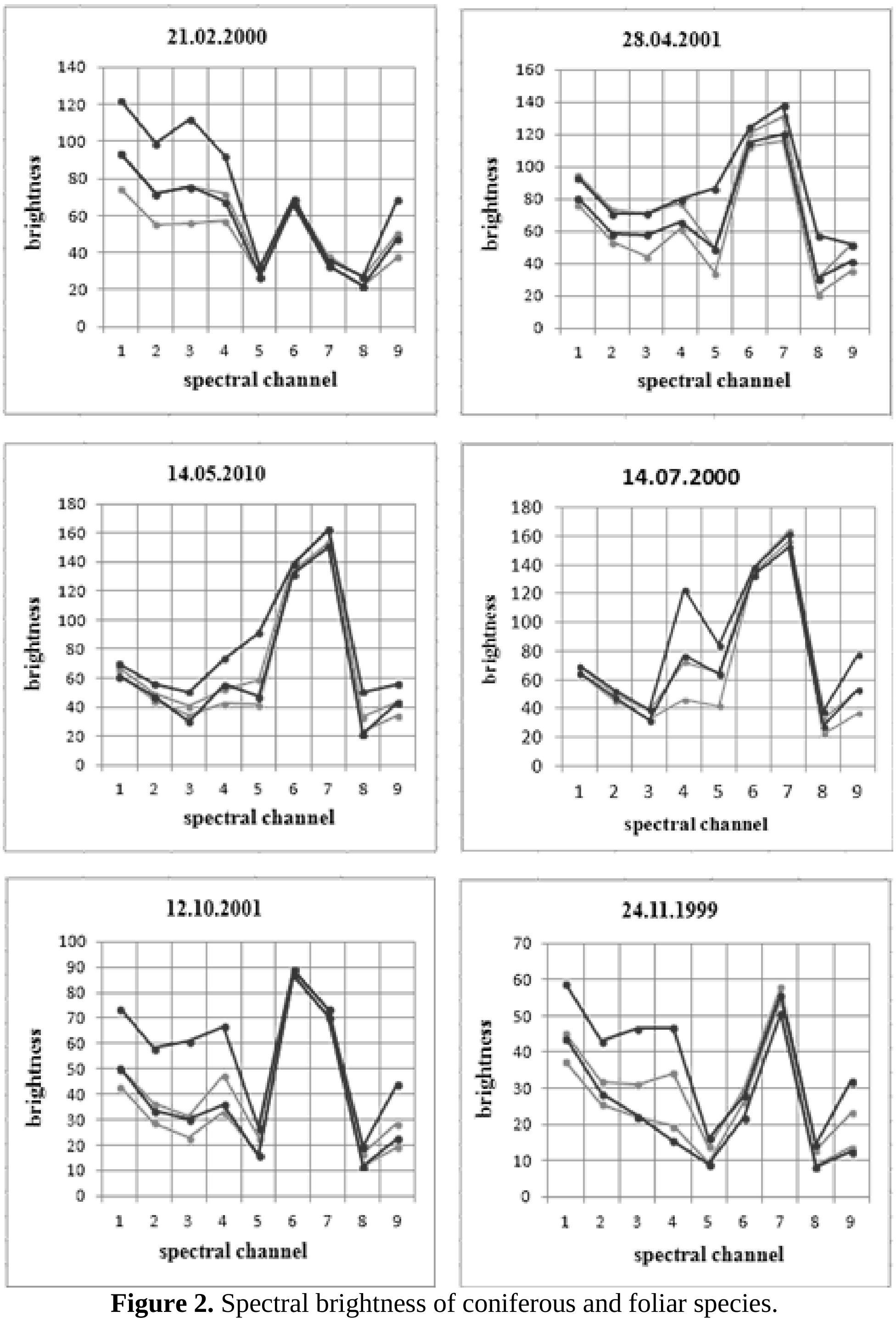


**Figure 2.** Spectral brightness of coniferous and foliar species.

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. The quantitative assessment of these differences was defined as:

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

and is shown for spectral channels with a resolution of 30 m in table 2.

In this expression $M_F$ and $M_C$ mathematical expectations of brightness of foliar and coniferous species, and $\sigma_F$ и $\sigma_C$ their standard deviations.

**Table 2.** Differences in the brightness of coniferous and foliar vegetation in one channel.

| Shooting date | Spectral channel number | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 8 |
| 21.02.2000 | 0.35 | 0.07 | 0.48 | -4.60 | -4.50 | -4.50 |
| 28.04.2001 | -14.24 | -14.93 | -12.98 | -11.66 | -0.38 | -0.02 |
| 14.05.2010 | -5.29 | -2.11 | -10.52 | 3.48 | -11.23 | -11.51 |
| 23.06.2013 | -2.29 | -2.83 | -2.21 | 4.07 | -18.07 | -6.40 |
| 14.07.2000 | -4.44 | -2.54 | -6.55 | 4.64 | -1.05 | -4.84 |
| 13.08.2014 | -2.36 | -2.51 | -2.49 | 5.40 | -16.58 | -7.51 |
| 10.09.2001 | -5.83 | -3.77 | -6.14 | -1.12 | -2.92 | -4.09 |
| 12.10.2001 | -0.12 | -2.69 | -1.26 | -11.43 | -7.18 | -4.64 |
| 24.11.1999 | -1.40 | -3.25 | -8.67 | -18.87 | -4.91 | -4.68 |

The negative numbers in the table below correspond to the overlap of the brightness values of coniferous and foliar vegetation in accordance with the criterion adopted in the form (1). As follows from the presented results, as features that distinguish coniferous and deciduous vegetation by spectral brightness, you can use reflections in the 1-3 channels of the February image and reflections in the 4th channel for images of May, June, July and August.

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

$$D_2 = \left[ \left( B_{nF} - B_{nC} \right)^2 + \left( B_{mF} - B_{mC} \right)^2 \right]^{1/2}, \qquad (2)$$

In the ratios (2) and (3) $B_{nC}$ и $B_{mC}$ – brightness of coniferous trees, and $B_{nF}$ и $B_{mF}$ – foliar in $n$ and $m$ 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 3).

This table shows the numbers of spectral channels, the combination of which does not lead to overlap in the Euclidean distance between the brightness of coniferous and foliar vegetation. In this case, the absence of overlap is determined by the absence of overlapping corresponding brightness in the range of two standard deviations from the difference in their mathematical expectations. For example, using spectral brightness for August images, six additional classification features can be formed by combining 1-4, 2-4, 3-4, 4-5, 4-8, and 5-8 channels.

**Table 3.** Channel numbers with differences in coniferous and foliar species by Euclidean distance.

| 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 |
| 23.06.2013 | 3, 4 | 4 | 4, 5, 8 | 5, 8 | - |
| 14.07.2000 | 4, 5 | 4, 5 | 4, 5 | 5, 8 | 8 |
| 13.08.2014 | 4 | 4 | 4 | 5, 8 | 8 |
| 10.09.2001 | 4, 5 | 4, 5 | 4, 5, 8 | 5, 8 | 8 |
| 12.10.2001 | 2, 3, 4, 5 | 3, 4, 5, 8 | 4, 5, 8 | - | - |
| 24.11.1999 | 2, 3, 4, 8 | - | - | - | - |

## 4. Conclusion

Using images of the Landsat 7 satellite, a fragment of the spectral library of a forest area located in the region of $60^0$ North latitude of the European part of the Russian Federation was formed.

Experimental dependences of the spectral brightness of coniferous and foliar vegetation for different shooting seasons were obtained using remote sensing data. The Euclidean brightness distance between these forest species was calculated for different combinations of two spectral channels. In this case, the possibility of forming a larger number of features for vegetation classification during forest management and forest monitoring using satellite images is shown.

## 5. Acknowledgments

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## 6. References

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