Assessment of urban pine forests state using the vegetation index NDVI

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Abstract. The condition of the vegetation cover in Moscow was estimated using the NDVI vegetation index. To construct synthetic images, Landsat 5, 7, and 8 multispectral satellite images taken during the active vegetation period from 1999 to 2019 were used. Index indicators are calculated for pine forests located in protected areas, in urban parks among high-rise buildings and inside private low-rise building districts. The results showed differences in the NDVI values between these three types of birch forests, however, temporal trends show similar dynamics of changes in the physiological state of trees over the studied period.

1. Introduction

Wildlife in the city and the issues of its protection have been attracting the attention of specialists and the public for several years now. Estimating the “quantity” of nature is not an easy task [1] and researchers usually use indicators of biological diversity [2] or the ratio of built-up area to ecologically efficient territories, as well as various indices expressing landscape fragmentation [3–5]. Unfortunately, the indicators of area and fragmentation cannot express the physiological state of the vegetation cover, which is the most important component of the environment. Vegetation indices (VI), which is a mathematical ratio of certain ranges of the spectrum of absorbed and reflected radiation, can fill the gap. The result is an artificial raster image, each pixel of which characterizes the state of the vegetation cover. VIs have been used since the 1970s, their number is constantly increasing, and mathematical expressions are becoming more complicated [6]. However, the most common is the relatively simple NDVI (Normalized Difference Vegetation Index), which is the ratio in the red (RED) and near infrared (NIR) parts of the spectrum [6]:

\[ NDVI = \frac{\rho(\text{NIR}) - \rho(\text{RED})}{\rho(\text{NIR}) - \rho(\text{RED})} \]

Chlorophyll absorbs light energy mainly in the red zone of the spectrum (0.62-0.75 microns), and reflects in the near infrared zone (0.75-1.3 microns). A change in the ratio indicates a change in the physiological state of plants [8-10]. The NDVI index takes values from -1 to 1. Vegetation indices are widely used in the studies of forest vegetation, for example, in order to assess the sanitary-ecological status and for other tasks common for forest management practices [11]. We set a goal to assess the state of forest vegetation in Moscow, and pine trees common in the city were chosen.
as the object of study [12]. Since VIs may vary depending on the year, the period from 1999 to 2019 is included in the work, which makes it possible to build trends and assess the dynamics of the state of forest vegetation. Pine forests within the boundaries of specially protected natural areas (SPNA), green areas in the depths of urban high-rise building districts and pine trees within the private low-rise areas preserved in the north-west of the city were selected for work.

2. Materials and methods
The Landsat 5, 7 and 8 satellite images with a resolution of 30 m in pixel were used to work with. Image obtained from the US Geological Survey website (https://earthexplorer.usgs.gov/). Satellite images were selected depending on the quality, primarily the lack of cloud cover. All space images were taken in June, i.e. they cover the general growing season.

The QGIS 3.4 environment was used to work with space images; vegetative indices were calculated using the Semi-Automatic Classification Plugin module. For all satellite imagery, radio and atmospheric corrections were performed. After obtaining the index image from the raster, the VI values are read using the Point Sampling Tool module. Statistical processing of materials was carried out in Excel. The data obtained are approximated by both linear and non-linear equations; trend lines were selected depending on the value of R2, showing the accuracy of the approximation.

3. Results and discussion
As a result of the calculation of vegetation indices for each year, synthetic images were obtained. The average NDVI and the dates on which the satellite images were taken are shown in table 1.

| Nature protected areas | 15.06.1999 | 07.06.2002 | 12.06.2004 | 14.06.2007 | 22.06.2010 | 08.06.2014 | 22.06.2016 | 06.06.2019 |
|------------------------|------------|------------|------------|------------|------------|------------|------------|------------|
| City parks             | 0.57±0.06  | 0.54±0.07  | 0.61±0.06  | 0.47±0.07  | 0.56±0.06  | 0.41±0.05  | 0.40±0.07  | 0.41±0.05  |
| Inner suburbs          | 0.52±0.08  | 0.49±0.07  | 0.54±0.07  | 0.45±0.06  | 0.50±0.07  | 0.35±0.05  | 0.37±0.06  | 0.37±0.06  |

The results showed differences in the NDVI index values for pine forests within the SPNA borders, in city parks and in private areas. To find the answer to the question about the change in this indicator over time, the average values are displayed graphically (figure 1). The graph clearly shows that the NDVI indicators vary synchronously for all studied pine forests.
To evaluate time trends, the data are approximated, and the use of a linear function gave the best results (table 2).

**Table 2.** The results of approximation of the value of NDVI by linear regression.

| Type of habitats       | Regression equation       | Multiple coefficient of determination $R^2$ |
|------------------------|---------------------------|-------------------------------------------|
| Nature protected areas | $-0.0308x + 0.7139$       | 0.749                                     |
| City parks             | $-0.0276x + 0.6203$       | 0.649                                     |
| Inner suburbs          | $-0.0254x + 0.5644$       | 0.701                                     |

As the results of approximation showed, despite the differences in the average NDVI, pine forests have similar trends in physiological state (figure 2). The values of VI significantly decreased over the entire period of research.

![Figure 2](image)

**Figure 2.** The lines of trends of dynamics NDVI in different pine forests.

4. Conclusion
The results showed differences in the physiological state of pine forests on SPNA, in park areas within multi-story building districts and within the private sector. The physiological state of trees on SPNA is better than others; and worse within private areas. Our results indirectly confirm the effectiveness of the special protection status in the city conditions. At the same time, the dynamics of the physiological state of pines, traced from 2019 to 2020, is similar regardless of the nature of the pine and its location.

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