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Analysis of the State of Vegetation Cover in Oil Producing Complexes in the Tomsk Region

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Abstract

The state of vegetation cover at the territory of Archinskoye, Shinginskoye, Kazanskoye, Yuzhno-Tabaganskoye and Zapadno-Ostaninskoye hydrocarbon deposits in the Tomsk Region was studied using satellite data from the MODIS spectroradiometer. The time series of the values of the Enhanced Vegetation Index (EVI) were calculated for the period from 2007 to 2019. Analysis of the dynamics of changes in the average EVI values allowed us to determine the minimal and maximal values of the index for the studied territories, and to identify a trend of an increase in its values, which indicates a good (non-depressed) state of vegetation and an improvement in the environmental situation of the studied territories of oil-producing complexes in the Tomsk Region.

Keywords: vegetation dynamics, satellite data, vegetation index, geoinformation systems, oil fields, environment

INTRODUCTION

The Tomsk Region possesses enormous reserves of natural resources. Approved reserves of petroleum account for 633.8 million t, gas – 333.1 billion m^3 [1]. The total area of the land occupied by forest resources is 28 752.5 thousand ha (91 %), woodlands occupy more than 60 %, and bogs more than 30 % of the territory of the region. However, the major part (85 %) of the area of the Tomsk Region relates to so-called territories with difficult access. For example, oil pipes cross marshland or woodland in the northern part, where a serious problem for obtaining the data on the ecological state of the environment is the difficultly passable territory.

A promising and economically reasonable approach to the evaluation of the ecological state of difficult-to-reach territories is the application of the procedure for the revelation of ecological problems with the help of the data of the earth remote probing (ERP). The algorithms of the quantitative evaluation of the state of vegetation relying on the calculation of vegetation indices allow us to evaluate the dynamics of the vegetation cover during the entire vegetation period and make conclusions concerning the current state of vegetation cover at difficult-to-reach territories [2, 3]. The application of ERP is due to the spatial coverage of the territories under investigation, the time and spectral resolution of images, relevance (timely accessibility) for researchers and the possibility of the free use.

The goal of the present work was to evaluate the state of the vegetation cover of hydrocarbon deposits in the Tomsk Region (Archinskoye, Shinginskoye, Kazanskoye, Yuzhno-Tabaganskoye and Zapadno-Ostaninskoye) during the vegetation periods from 2007 to 2019 using the free satellite data.

METHODICAL PROBLEMS OF REMOTE MONITORING

Medium-resolution satellite images combine such advantages as the free access to the data and the spatial resolution which is sufficient to detect the changes in the state of vegetation cover. It was revealed that the above-listed requirements are met by the data obtained from the MODIS spectroradiometer (Moderate Resolution Imaging Spectroradiometer) mounted aboard the Terra and Aqua satellites. The data of satellite survey recorded with MODIS come from the Terra satellite every 2 days in 36 spectral zones (within the range 0.405–14.385 μm). The USA National Aeronautics and Space Administration (NASA) developed a series of MODIS products aimed at monitoring and evaluating of the state of vegetation. These products are a result of the application of corrections and calculation algorithms: analysis of orbital and mechanical differences between MODIS sensors aboard of Aqua/Terra; algorithms of preliminary treatment used to make cloud-free patterns (an original algorithm for MODIS); algorithms of post-processing, which are used to optimize the values of vegetation index obtained from the time sequences of images.

To evaluate the dynamics of vegetation at the territory of oil and gas deposits in the Tomsk Region, we used the products of MOD13Q1 – the composites of satellite images which are calculated for a 16 days long period of each year (since 2007 in our investigation) and have the spatial resolution of 250 m. The processing algorithms by NASA select the best available pixel value among all satellite images over the 16 days long period relying on the following criteria: low cloudiness, low observation angle, and the highest value of vegetation index.

In the present work, evaluation of the states of vegetation cover is carried out on the basis of MOD13Q1 product: 16 days long composites of the values of Normalised Difference Vegetation Index (NDVI) and 16 days long composites of the values of - Enhanced Vegetation Index (EVI).

It is known that NDVI is widely used in the monitoring of the state of vegetation cover [3, 4]:

$$\mathrm{NDVI} = \frac{\rho_{\mathrm{nir}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{nir}} + \rho_{\mathrm{red}}} \qquad (1)$$

where ρ_{nir} is the spectral radiance of the surface in the near IR range; ρ_{red} – in the red range.

The methodical problems of the monitoring of vegetation cover state over oil and gas mining territories of West Siberia with the application of NDVI values using MOD13Q1 products are described in the works published by the authors previously [5, 6]. One of the disadvantages of the use of NDVI is the necessity (for the majority of tasks) to compare the results with the data for background territories (references) collected preliminarily, which are to take into account seasonal ecological and climatic parameters of the image itself and of the background territories at the moment of data collection. These data become especially significant for the calculations of productivity, biomass resources and other quantitative parameters [7].

In the present work, we use EVI, which has some advantages over NDVI for the monitoring of changes in vegetation because the effect of soil and atmosphere it minimized in its values.

The data on EVI values are taken from the MOD13Q1 product, where the enhanced index EVI is expressed as [8]:

$$\mathrm{EVI} = \frac{\rho_{\mathrm{nir}} - \rho_{\mathrm{red}}}{(\rho_{\mathrm{nir}} + C_1)(\rho_{\mathrm{red}} - C_2)(\rho_{\mathrm{blue}} - L)}(1 + L) \qquad (2)$$

where ρ_{blue} is the spectral radiance of the surface in the blue region; L is a correcting coefficient taking into account the effect of soil; C_1, C_2 are coefficients of aerosol stability using the blue channel for the correction of aerosol effect in the red channel. The range of EVI values is –1 to 1; for green vegetation, this index is within 0.2 to 0.8.

Evaluation of the state of vegetation cover of the territories of hydrocarbon deposits of the Tomsk Region (Archinskoye, Shinginskoye, Kazanskoye, Yuzhno-Tabaganskoye and Zapadno-Ostaninskoye) during vegetation periods since 2007 till 2019 was carried out with the help of EVI.

A collection of the satellite data from MODIS for the territory of the Tomsk Region for 2000-20019 has been formed at the Research Information Centre of the Institute of Petroleum Chemistry SB RAS. It should be stressed that the satellite data from MODIS system are free to access, which allows rapid and timely evaluations of the state of the environment [9, 10]. To test the correctness of calculations, the territory of the State Natural wildlife Oglatskiy preserve in the Kargasok district of the Tomsk Region was included as the background (reference) territory. The area of the preserve is 100 thousand ha, and the significant dominating vegetation is mixed forest. The polygonal vector layers of the territories of hydrocarbon deposits and background territory were created by means of ArcGis 10.2.2 geoinformation system. The territories of oil deposits un-

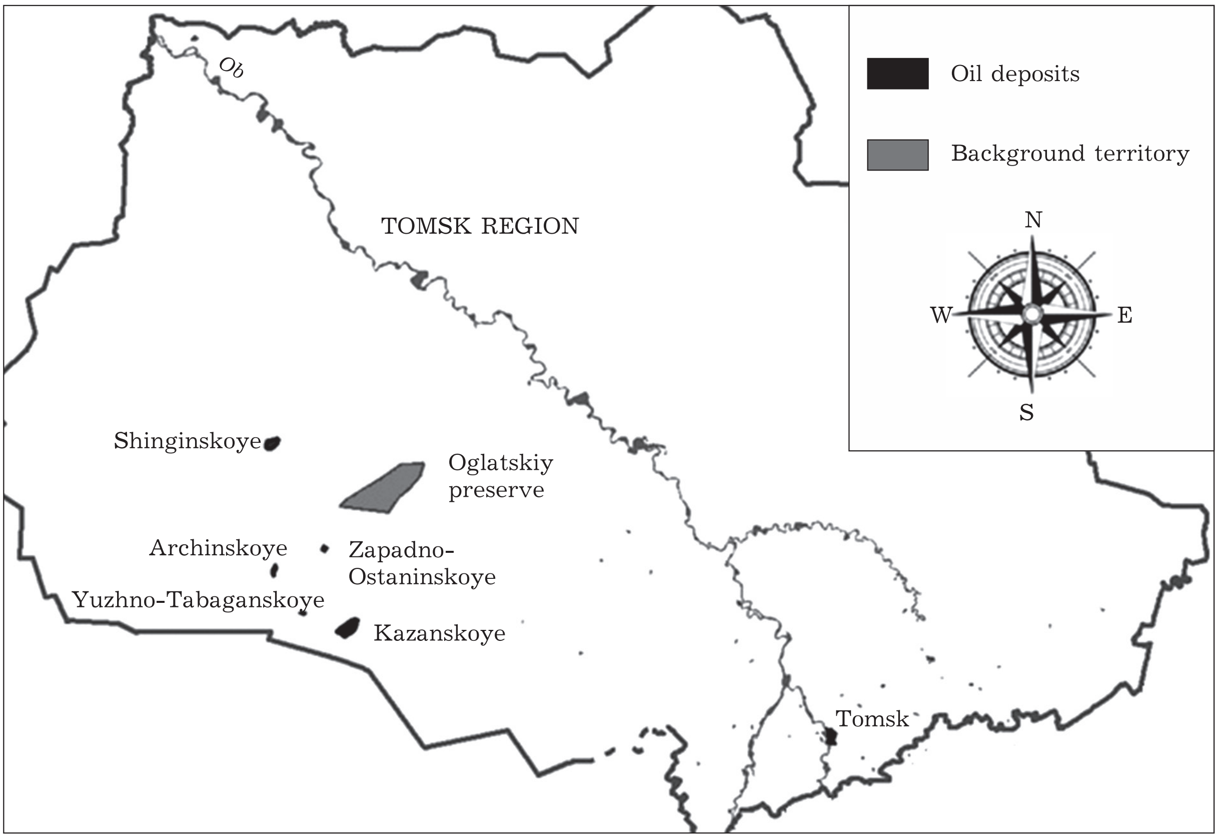

Fig. 1. Territories of the Tomsk Region under investigation.

der investigation and a background region are shown in Fig. 1.

To analyze the dynamics of EVI, the satellite data from MOD13Q1 were taken as the 16-Day Vegetation Indices with the spatial resolution of 250 m since July 13 till July 28 of each year. The calculation of EVI was carried out over 12 years from 2007 to 2019 except for 2015 because of the low quality of satellite data.

RESULTS AND DISCUSSION

Calculation of EVI value was carried out by superposition of vector models of the polygons of territories occupied by hydrocarbon deposits and background territory on diversified satellite MOD13Q1 images with the information on EVI value. The calculated average values of EVI for each territory under investigation for the 12 year period are presented in Table 1. One can see that the maximal value (marked with bold type) of EVI corresponds to the state of vegetation in 2009 at the background territory of the Oglatskiy preserve, which confirms the correctness of the obtained EVI values.

The dynamics in the change of average values of EVI is presented in Fig. 2. Calculation of the average values for each territory was carried out with the help of the Zonal Statistics tool of the ArcGis 10.2.2 geoinformation system.

It may be noted that the lowest values of EVI over the 12 years long period correspond to the Zapadno-Ostaninskoye deposit, and in 2011 the value was minimal (0.2810) for the entire set of data shown in Table 1. This fact may be explained greatly by the position of the Zapadno-Ostaninskoye deposit and the features of its landscape: the territory is heavily waterlogged, with many small lakes, which causes a substantial decrease in EVI value.

The highest EVI values correspond to the Yuzhno-Tabaganskoye deposit; they exceed some values for the background territory of the Oglatskiy preserve in 2008, 2012, 2016 and 2017.

It was established that the trend of EVI changes is of the same type for the majority of the territories under investigation: the highest values were observed in 2009 and 2012, while the minimal values were observed in 2011. In general, it may be concluded that positive trends to an increase in EVI are observed for the indicated territories over a 12 year long period of monitor-

TABLE 1

EVI values

Year	Territories of hydrocarbon deposits of the Tomsk Region					Oglatskiy preserve
	Archinskoye	Shinginskoye	Zapadno-Ostaninskoye	Yuzhno-Tabaganskoye	Kazanskoye	
2007	0.4109	0.3222	0.3227	0.4169	0.4570	0.4576
2008	0.4215	0.3796	0.3076	0.4589	0.4688	0.4479
2009	0.4104	0.3554	0.3544	0.4834	0.4294	**0.5429**
2010	0.4185	0.4450	0.3058	0.4453	0.4541	0.4863
2011	0.3796	0.3473	0.2810	0.4210	0.4194	0.4254
2012	0.5266	0.3495	0.3095	0.5417	0.4676	0.4668
2013	0.4469	0.3578	0.3572	0.4439	0.4683	0.5376
2014	0.4909	0.3906	0.2989	0.4859	0.4804	0.4671
2016	0.4762	0.3613	0.3181	0.5228	0.4606	0.4305
2017	0.4667	0.4014	0.3557	0.4944	0.4667	0.4884
2018	0.4506	0.4112	0.3441	0.4759	0.5086	0.4815
2019	0.4539	0.4542	0.3665	0.4783	0.4915	0.4895

ing studies. For a more detailed analysis of the results, EVI values were presented in the form of linear trends for the Zapadno-Ostaninskoye (Fig. 3, *a*) and Yuzhno-Tabaganskoye (see Fig. 3, *b*) deposits.

The maximal values of EVI in 2012 are connected, with a high probability, with high average temperatures for July, and the minimal values of the index in 2011 may be explained by the lowest average temperatures in July of that year (Table 2).

The effect of temperature on EVI values is confirmed by the results of correlation analysis. The degree of correlation between monthly average air temperature and EVI values for the indicated deposits varies within the range of 0.27–0.51 and is ranked as medium. The effect of relative humidity on EVI value is more complicated.

For the Shinginskoye deposit, an inverse relationship between monthly average air temperature and EVI values was revealed (the correlation coefficient was equal to −0.46), while for other deposits a direct relationship was revealed, with the coefficient varying between 0.05 and 0.51. Correlation analysis of EVI values and the parameters of ‘the number of days with precipitation’ and ‘atmospheric precipitation’ revealed an insignificant (very weak) correlation between the data.

It is necessary to stress that the legislation in the RF made a contribution to the improvement of the ecological state of oil and gas mining territories. In 2012, the Government of the RF adopted Regulation No. 1148 “on the features of calculation of the charge for the negative action on the environment through the environmental emission of pollutants formed during the flare combustion or dispersal of associated petroleum gas”. For instance, according to the information submitted by Tomskneft PC, expenses for nature-saving measures are permanently increasing from one year to another [12].

CONCLUSIONS

The diagnostics of the state of vegetation in difficult-to-access territories of the West Siberian oil and gas-bearing province was carried out with

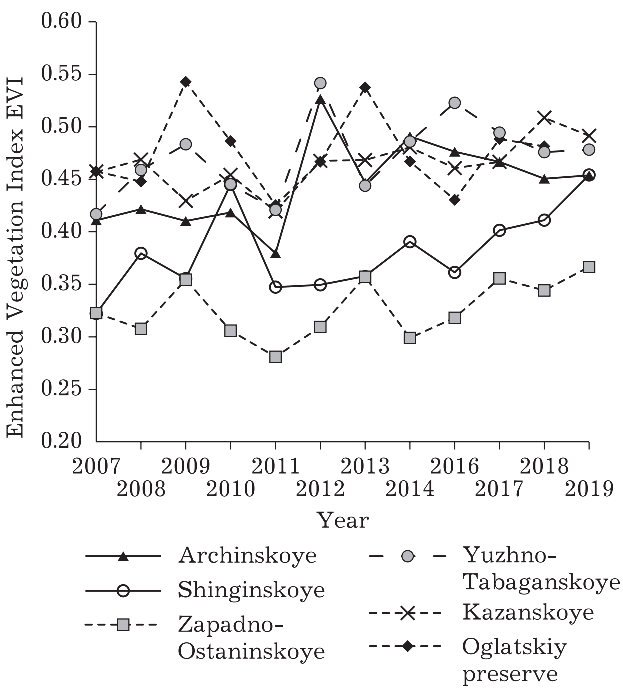

Fig. 2. Dynamics of changes in the average values of EVI.

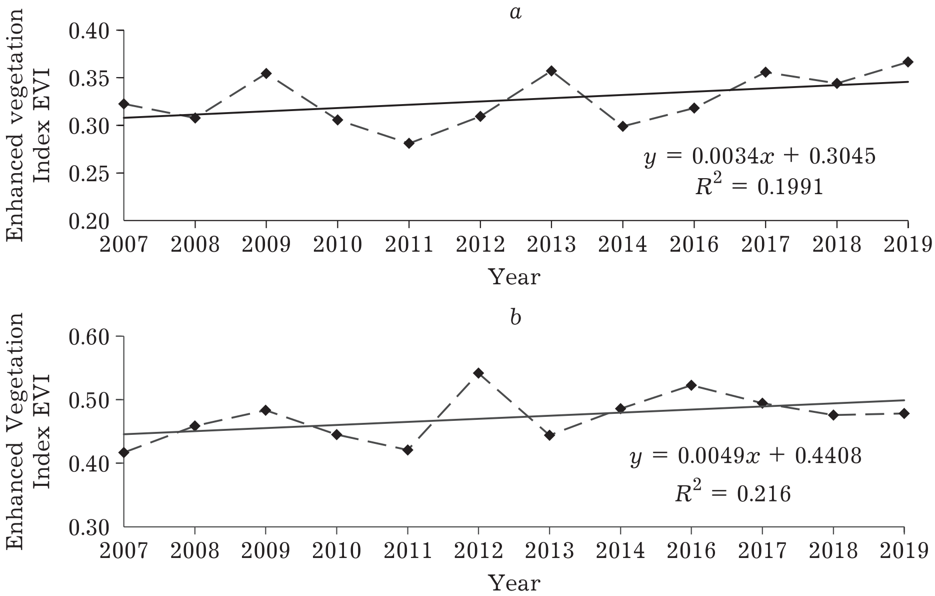

Fig. 3. Dynamics of changes of the average values of EVI at the Zapadno-Ostaninskoye (*a*) and Yuzhno-Tabaganskoye (*b*) deposits. The continuous line is the linear trend, dash line connects the average values of EVI.

the application of satellite data without carrying out an expensive land-based survey. On the basis of the analysis of the dynamics of changes exhibited by the values of enhanced index EVI, the minimal and maximal values of the index for the territories under investigation were determined, and a trend to increase its values was revealed over a 10 years long period, which is the evidence of the recovery of vegetation cover, its non-suppressed state, and improvement of the ecological situation over oil mining territories. A dependence of EVI values on meteorological data (temperature and relative humidity) was established, but the correlation has a complicated and unstable nature, which requires a continuation of monitoring studies.

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TABLE 2

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Year	Monthly average temperature, °C	Number of days with precipitation	Atmospheric precipitation, mm	Relative air humidity, %
2007	19.6	10	82.6	75.9
2008	19.0	12	90.0	75.3
2009	17.7	14	–	77.2
2010	15.9	10	79.3	75.9
2011	14.5	10	96.4	76.8
2012	20.9	3	28.6	71.8
2013	18.7	10	38.9	71.3
2014	16.7	12	83.6	76.1
2016	19.0	10	189.7	76.8
2017	16.7	13	132.2	75.5
2018	17.5	6	40.5	62.0

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