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# Interrelation of spatial changes of climatic characteristics and vegetative cover structure in Western Siberia based on space images

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The paper concerns interrelations of parameters for climatic status and spatial structure of vegetative cover in Western Siberia. The spatial structure of the vegetation cover of territory is determined on the basis of analysis of middle resolution space images. The analysis of the climatic status is carried out using data received at 99 weather stations of Western Siberia during the period of some decades from 1955 year. It is shown that the increase of space-averaged yearly temperature is accompanied by the decrease of dark-coniferous forests areas and by the growth of areas of small-leaved forests and bogs.

*Keywords:* climatic status, vegetative cover, remote sensing, geoinformation systems, Western Siberia.

## Introduction

Global warming in recent decades [1] has generated a need to study different consequences of climatic changes. Therefore one of the important problems of research in Northern Eurasia is revealing the interrelation of temporary changes of vegetation cover structure depending on climatic changes. The long duration of temporary changes of vegetation makes such studies difficult and very long-lasting. Therefore, the dependence of climatic and geobotanical changes can be studied as a relationship between changes in the spatial structure of the vegetation cover and spatial changes in climate parameters in the territory. The object of study was chosen the territory of the West-Siberian plain within six administrative formations, i.e. Jamal-Nenets and Khanty-Mansiysk autonomous okrugs and Tomsk, Omsk and Novosibirsk regions (oblasts) and the southern part of the Tyumen oblast. The aim of this paper is to study the changes of spatial structure of vegetative cover in the West-Siberian territory depending on the spatial change of climatic parameters, using remote sensing data.

## Methods

The West-Siberian plain has geobotanical zonation according to geographical latitude: subarctic tundra, sparse growth of trees, taiga and forest-steppe. It is important to notice that the taiga zone has four subzones: northern, middle and southern ones and subtaiga. Fig. 1 shows the map of geobotanical zonation of territory. Black triangles designate location of weather stations. The northern part of the investigated territory is located in the zone of subarctic tundra and sparse growth of trees. The central part is in the taiga zone. And the southern part of West-Siberian territory is in the forest-steppe zone.

Hydrometeorological data received at 99 weather stations in Western Siberia have been used to study spatial and temporal changes of climatic state. Temporal dependencies of average yearly values of air temperature, relative yearly quantity of atmospheric precipitation and maximum annual values of snow cover parameters (its height, density and stocks of water) were defined for each geobotanical zone.

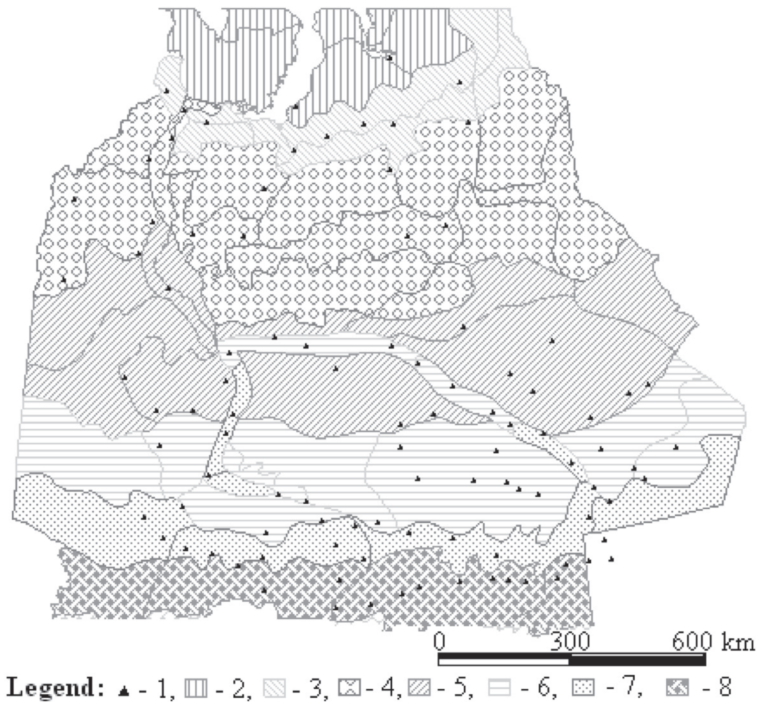


Fig. 1. Map of geobotanical zonation of West-Siberian territory. Symbols: *1* – weather stations, *2* – subarctic tundra, *3* – sparse growth of trees, *4* – northern taiga, *5* – middle taiga, *6* – southern taiga, *7* – subtaiga, *8* – forest-steppe

We used middle resolution space images from Russian satellite Resources-O1-3 (scanner MSU-SK) to determine the spatial structure of vegetative cover. These space images have the spatial resolution of about 150 m in a 600 km strip of the investigated site. The images from the MSU-SK scanner were received in spectral channels of the visible range and the near infrared zone. Vegetation cover structure was determined using the synthesized images. Coniferous and small-leaved forests are distinctly determined in the space images owing to differences of spectral brightness. Light-coniferous (pine) and dark-coniferous forests were separated by classification analysis using the «teachers» obtained on the base of forest management data [2, 3].

Space images were processed by means of the ERDAS Imagine software. Then the data were exported to the format supported by the software of geoinformation system ArcGIS 9.3. We used the ArcGIS system to determine relative areas of each landscape structural unit. To solve this problem, it is necessary to take into account spatial properties of the objects under study [4]. It allows one to use additional spatial information, which can be used within the frames of geoinformation approach [5] to analyze multidimensional heterogeneous data. This approach requires the use of geoinformation systems enabling to manipulate the spatial data stored in the form of thematic layers, which are geographically certain relative to digital map-basis.

## Results

### 1. Studying climatic changes in territory of Western Siberia

The analysis of changes in the climatic status of West-Siberian plane has been carried out for the central and the southern parts because these territories are located in taiga zone. The analysis was based on using time dependencies of average annual values of air temperature, quantity of atmospheric precipitation and a stock of water in snow cover. Figs 2 and 3 below present the results of the analysis of climatic changes for the central part (Khanty-Mansyisk autonomous okrug) and the southern part of Western Siberia (Tomsk, Omsk and Novosibirsk oblasts). Every black square spot on the graphs in Fig. 2 and 3 is a result of space-averaging yearly data taken from all weather stations in the corresponding territory.

Fig. 2 shows temporal dependencies of average annual air temperature (T). Space-averaged values of T for two time intervals 1955–1970 and 1975–1992 are shown in Fig. 2 by dashed lines. Confidence intervals for the average values calculated with 90% probability are represented in Fig. 2 by dash-dot lines. As may be seen in Fig. 2, the average value of temperature in the second period has increased approximately 0.9 – 1°C in comparison with the period 1955–1970.

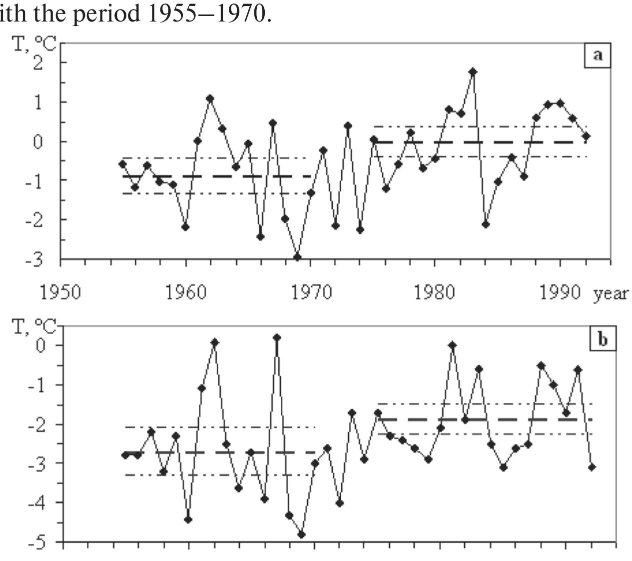


Fig. 2. Temporal dependencies of air temperature in the southern (*a*) and the central (*b*) parts of Western Siberia

Temporal dependencies of yearly relative (per month) quantity of atmospheric precipitation (Q) and yearly stock of water (SW) in a snow cover are shown in fig. 3. Space-averaged values of Q and SW and its confidence intervals calculated with 90% probability for two time intervals 1955–1970 and 1975–1992 are shown in fig. 3 by dashed and dash-dot lines accordingly. As fig. 3-a shows, the yearly relative quantity of atmospheric precipitation in the second period in comparison with the period 1955–1970 has increased approximately 2 %. Change in the volume of water-stock in snow cover for the second period makes 12,8 mm (Fig. 3-b), i.e. the increase in comparison with the first period is 12.4 %. Hence, rise of air temperature is accompanied by growth of water-stock volume in snow cover though the level of atmospheric precipitation changes insignificantly. This shows explicit climatic change in West-Siberian territory. Below are some results of studying interrelations in the parameters of climatic state and spatial structure of vegetative cover in West-Siberian territory.

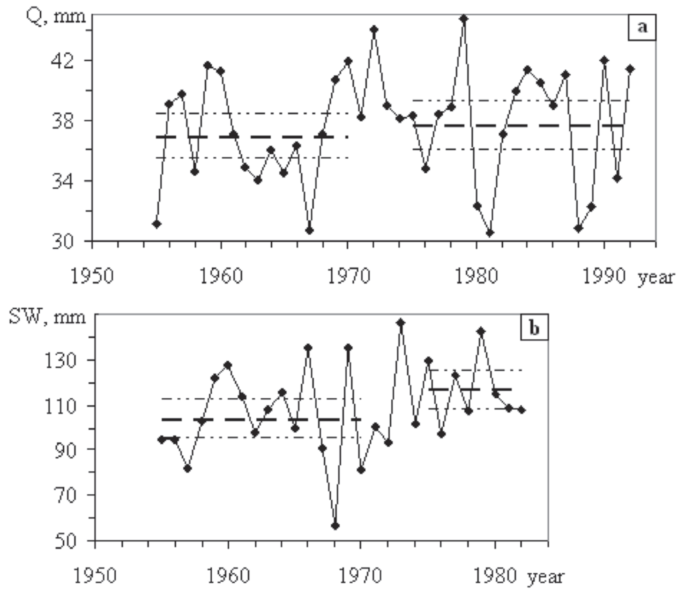


Fig. 3. Temporal dependencies of the yearly relative quantity of atmospheric precipitation (*a*) and yearly stock of water in a snow cover (*b*) in a southern part of Western Siberia

## 2. Determination of vegetation structure on the basis of interpretation of space images

Study of vegetative cover structure is carried out using space images of the southeast and the central parts of Western Siberia within Tomsk region and Khanty-Mansyisk autonomous okrug. Fig. 4 presents the map-scheme of landscape zonation in the investigated territory created on the basis of the atlas [6]. Below is a list of landscape provinces, shown in fig. 4:

1) Severo-Sosjvinskaya;
2) Nadymskaya;
3) Polujskaya;
4) Belogorskaya;
5) Numtovskaya;
6) Kondo-Tavdinskaya;
7) Kondinskaya;
8) Nazym-Lyaminskaya;
9) Lyamin-Aganskaya;
10) Yugan-Larjeganskaya;
11) Kazymskaya;
12) Nizhne-Obskaya;
13) Sredne-Obskaya;
14) Irtyshskaya;
15) Alexandrovskaya;
16) Vasyuganskaya;
17) Ket-Tymskaya;
18) Pojmennaya
19) Tomskaya;
20) Chulymskaya.

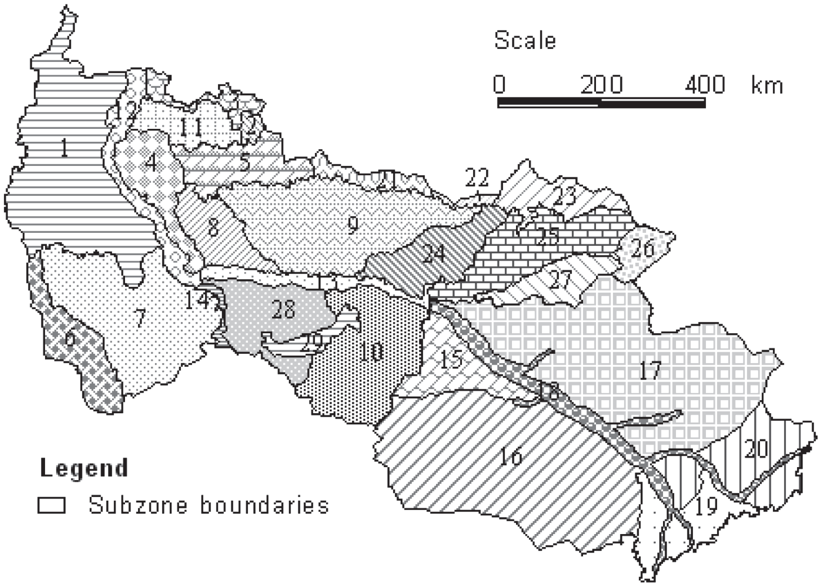


Figure 4. Map of landscape provinces of the central and the southeastern parts of Western Siberia

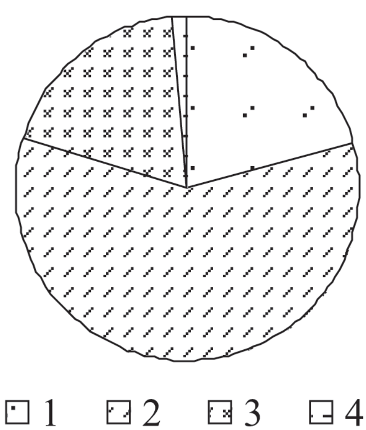


Fig. 5. The relative areas of landscape units of Sredne-Obskaya landscape province. Symbols: *1* – dark-coniferous forests, *2* – light-coniferous forests, *3* – small-leaved forests, *4* – water-bog lands

As a result of processing middle resolution space images, there have been determined relative areas of landscape structural units related with certain forest type for each landscape province shown in Fig. 4. It is known [4], that four classes of landscape structural units are the most typical for the Siberian taiga zone: dark-coniferous (fir, spruce, cedar), small-leaved (birch, aspen) and light-coniferous (pine, larch) forests and water-bog lands. In our paper, the spatial structure of vegetative cover will be determined by the ratio of relative summarized areas of landscape structural units. For instance, Fig. 5 presents the diagram displaying spatial structure of vegetative cover in the territory of Sredne-Obskaya landscape province. The diagram shows the prevalence of light-coniferous forests in this landscape province.

## 3. Analysis of interrelation of vegetative cover structure and climatic characteristics

For studying the interrelation between climatic characteristics and vegetative cover structure, a table of climatic parameters and data on relative areas of landscape units for different landscape provinces shown in Fig. 4 has been composed. For illustration, Fig. 6 represents the dependence of the relative areas of dark-coniferous forests (S) on average air temperature (T) for each landscape province. Arabic numerals in fig. 6 correspond to numbers of landscape provinces shown in Fig. 4.

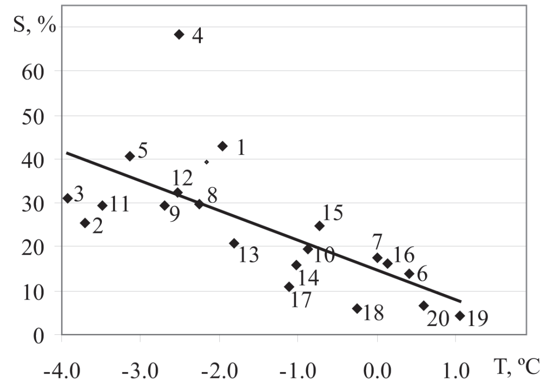


Fig. 6. The relative areas of dark-coniferous forests with respect to air temperatures

Apparently from Fig. 6, increase of average annual temperature in the West-Siberian territory is accompanied by a decreasing share of dark-coniferous forests in the structure of vegetation cover. This dependence is satisfactorily approximated by the equation of a linear trend.

Fig. 7 gives graphs of dependencies of the relative areas of landscape units on different climatic parameters. Lines of the resulting trends in Fig. 7 represent the relative areas of different landscape units depending on climatic parameters. Increase of average air temperature corresponds to moving in direction from the north to the south in Western Siberia. As follows from Fig. 7, the spatial structure of West-Siberian forest-swamp territories essentially depends on climatic status parameters. The areas of dark-coniferous and light-coniferous forests shrink from 35–40 % in the north up to 10–15 % in the south, where birch forests become dominant.

The Fig. 7, *b* shows, that with increase SW, i.e. in a direction from the south to the north, the areas of dark-coniferous and light-coniferous forests increase from 5–12 % in the south up to 35–40 % in the north. The area of small-leaved forests and

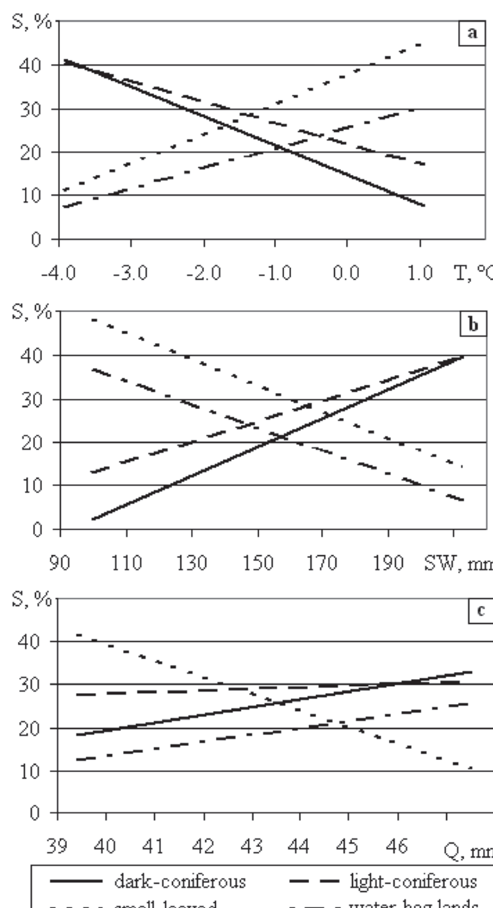


Fig. 7. Interrelations between the relative areas of landscape units and climatic parameters

water-bog lands decreases. Growth in the areas of dark-coniferous forests and boggy territories and shrinking in the areas of small-leaved forests are marked in Fig. 7, *c* with increasing of the yearly sum of atmospheric precipitation.

## Conclusion

Thus, the result of quantitative analysis carried out let us to establish an explicit interrelation between spatial changes in parameters of the climatic status and spatial structure of vegetative cover in Western Siberia. In particular, the increase of air temperature is accompanied by a shrinking area of dark-coniferous forests and a wider area of small-leaved forests and bogs. The area of dark-coniferous forests, on the contrary, increases and the areas of small-leaved forests and water-bog lands are reduced with a growth in the average value of water-stock in a snow cover. These results can be used to predict changes of geobotanical structure of vegetation cover of Western Siberia in conditions of global warming.

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