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Methodological techniques for identifying plant communities based on Earth remote sensing data and field research

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The possibilities of using multispectral data of remote sensing of the Earth and field research to highlight plant communities using the example of the Pizhemsky State Nature Reserve (SNR) of the Kirov region are shown. The Pizhemsky SNR is defined as a complex (landscape) reserve. It is especially valuable for maintaining the integrity, protection and restoration of aquatic biogeocenoses, preserving in the natural state of the unique natural objects of the region.

Selection of plant communities in the Pizhemsky reserve with the use of remote sensing data was carried out in several stages: pre-field cameral, field expeditionary and office generalizing. The pre-field cameral stage included the selection of satellite images from the Landsat 7 and Sentinel 2 satellites and their interpretation to isolate areas of vegetation that are homogeneous in interpretation. At this stage, several areas that were homogeneous in terms of certain features (color, microtexture of the pattern, phototones, etc.) were identified, caused by various natural objects and plant communities of the region. In the field expeditionary stage, work was carried out to identify vegetation types on the ground. The characteristic of plant communities was carried out according to generally accepted geobotanical techniques.

The peculiarities of the coenotic composition of forests in the reserve were studied. The composition of the plant communities of the Pizhemsky SNR reflects the characteristic zonal features of the vegetation of the studied region and is associated with certain landscape elements. Based on the analysis of the available cartographic material and satellite images, it has been established floodplain meadows occupy more than 60% of the study area, forests – about 20%. In order to identify plant communities, the most characteristic and most accessible direct interpretation features (phototone, shape, structure) were selected. In addition, we used the synthesis of standard combinations of "artificial colors" channels from the Landsat 7 and Sentinel 2 satellites, which made it possible to identify grassy communities, deciduous and coniferous forests. The completed classification with training provided important information on the distribution of the majority of plant communities typical for the region. The NDVI vegetation index made it possible to isolate pine, deciduous forests and meadow phytocenoses, as well as to recognize water bodies and open soils. The obtained results will allow to substantiate new approaches to environmental management.

Keywords: Pizhemsky State Nature Reserve, satellite imagery, interpretation, Normalized Difference Vegetation Index, plant communities.

УДК 528.72:004.93

Методические приёмы выделения растительных сообществ на основе данных дистанционного зондирования Земли и полевых исследований

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Показаны возможности использования мультиспектральных данных дистанционного зондирования Земли и полевых исследований для выделения растительных сообществ на примере государственного природного заказника «Пижемский» Кировской области. Государственный природный заказник (ГПЗ) «Пижемский» определён как комплексный (ландшафтный). Он имеет особо ценное значение для поддержания целостности, охраны и восстановления водных биогеоценозов, сохранения в естественном состоянии уникальных природных объектов области.

Выделение растительных сообществ на территории заказника «Пижемский» с использованием данных дистанционного зондирования Земли проводили в несколько этапов: предполевой камеральный, полевой экспедиционный и камеральный обобщающий. Предполевой камеральный этап включал в себя подбор космических снимков со спутников Landsat 7 и Sentinel 2 и их дешифрирование для выделения однородных по дешифровочным признакам участков растительности. Выделены несколько однородных по определенным признакам (цвет, микротекстура рисунка, фототон и др.) участков, обусловленных различными природными объектами и растительными сообществами района. В полевой экспедиционный этап проведены работы с целью идентификации на местности типов растительности. Характеристика растительных сообществ проводилась по общепринятым геоботаническим методикам.

Изучены особенности ценотического состава лесов заказника. Состав растительных сообществ ГПЗ «Пижемский» отражает характерные зональные черты растительности исследуемого региона и приуроченность к определённым ландшафтным элементам. На основе анализа имеющегося картографического материала и космических снимков установлено, что пойменные луга занимают более 60% исследуемой территории, леса – около 20%. Для идентификации растительных сообществ были выбраны наиболее характерные и наиболее доступные прямые дешифровочные признаки (фототон, форма, структура). Кроме того, использовали синтез стандартных комбинаций каналов «искусственные цвета» со спутников Landsat 7 и Sentinel 2, что позволило выделить травянистые сообщества, лиственные и хвойные леса. Выполненная контролируемая классификация с обучением позволила получить важную информацию о распределении большинства характерных для района исследования растительных сообществ. Использование нормализованного дифференцированного вегетационного индекса NDVI позволило выделить сосновые, лиственные леса и луговые фитоценозы, а также распознать водные объекты и открытые почвы. Полученные результаты позволят обосновать новые подходы к рациональному природопользованию.

Ключевые слова: государственный природный заказник «Пижемский», космические снимки, дешифрирование, нормализованный дифференцированный вегетационный индекс, растительные сообщества.

To ensure the necessary ecological balance and maintain the qualitative state of the biosphere as the environment of human life, it is necessary to preserve the maximum biological diversity of ecosystems including the animal and plant world [1]. Russia's unique natural diversity is protected by a system of specially protected natural areas (SPNA) which play a huge role in the preservation of natural ecosystems and the ecological conditions of the regions.

The implementation of environmental management is impossible without monitoring forest biodiversity providing an assessment of its current state, analysis and forecast of possible changes against the background of natural processes and under the influence of anthropogenic factors [2]. Studying plant communities in SPNAs is of paramount importance. At the same time, the use of satellite images of the Earth surface obtained from spacecrafts and related ground-based research is indispensable [3].

The use of remote methods allows you to quickly get a fairly complete amount of information about the state of plant ecosystems in the study area [4, 5].

The purpose of these research is to develop a methodology for selecting various types of plant communities on the territory of the Pizhemsky state reserve in the Kirov region based on remote sensing data (RSD) in combination with field studies.

Objects and methods of research

The “Pizhyemsky” State Natural Reserve (SNR) of regional importance was created as a hydrological reserve in 1990 on the territory of Kotelnichsky, Tuzhinsky, Pizhansky, Arbazhsky and Sovetsky municipal districts of the Kirov region along the Pizhma River and its right tributary – the Nemda River with a width of 0.5 to 3.5 km (on average about 1.7–2.0 km) and a length of 173 km.

The natural reserve “Pizhemsky” has a particularly valuable significance for maintaining the integrity, protection and restoration of aquatic biogeocenoses, preserving the unique natural objects of the region in the natural state. In accordance with the objectives of creating the reserve, its profile is defined as a complex (landscape) reserve.

The Pizhemsky reserve is located in the belt of southern taiga forests. Its vegetation is described only on the plot of the Nemda River. It is noted that the native vegetation in this area is spruce-fir and fir-spruce forests in some places with linden undergrowth, with open moss cover, boreal grasses and shrubs [6].

Studies on the selection of plant communities in the framework of this work were conducted in areas located along the Pizhma Piver in the territory of the SNR and directly adjacent to it.

Selection of plant communities of the Pizhemsky reserve on the basis of RSD was carried out in several stages: pre-field cameral, field expeditionary and cameral generalizing stage.

The pre-field stage included the selection of satellite images using the SAS. Planet Internet resource (Google, Bing and Yandex maps) with 1 m resolution, as well as imagery from Landsat 7 and Sentinel 2 satellites (30 m and 10 m resolution, respectively), and their interpretation for selection homogeneous vegetation areas in accordance with interpreting signs [7, 8].

According to the results of the pre-field cameral stage, several "plots" uniform for certain features (color, microtexturing of the pattern, photo tone, etc.) due to various natural objects and plant communities of the area were identified in the spring and summer Bing maps and Yandex satellite images. These sites were selected for field research.

During the field expeditionary stage in July 2017, the authors carried out work aimed at searching on the ground the types of vegetation identified in the cameral interpretation of satellite images. The characteristic of plant communities was carried out according to generally accepted geobotanical techniques [9].

Geobotanical descriptions were performed within plant communities, homogeneous in floristic composition, composition of dominants of each tier, community appearance (aspect, community structure) and habitat conditions, on sample plots of 20 × 20 m using GPS positioning.

The cameral generalizing stage included the process of interpretating satellite images in order to isolate different plant communities. In this work, direct interpretation signs of objects (photo tone, shape, structure) were used. In addition, we used the synthesis of standard channel combinations, classification with the training of multi-zone high and medium resolution images, the calculation and estimation of the NDVI vegetation index.

Results and discussion

Based on the analysis of the available cartographic material and satellite images of different seasons, it has been established that in most sections the Pizhma River intensively meanders. There are numerous channels and many old lakes. Floodplane of the Pizhma River occupies more than 70% of the area of the SNR. During the spring floods, the reserve's territory is flooded by 50–80% (Fig. 1, see color insert).

In geomorphological terms, the SNP covers the floodplain of the Pizhma and Nemda rivers, the first and second terraces above the floodplain, and also partly the indigenous shores represented by Upper Permian terrigenous-carbonate sediments. This circumstance determines the nature of the vegetation. There are mainly floodplain meadows (more than 60%). The banks of the mainstream, channels and lakes are covered with thickets of shrubs (mainly willow). Forests within the boundaries of the SNR occupy about 20% (Fig. 2, see color insert).

In the process of deciphering the plant communities of the Pizhemsky reserve, direct interpretation signs were taken into account. The photo tone acts as the main interpretive sign that forms the outlines of the boundaries, the size and structure of the image of the object [10]. In the photographs, water spaces that absorb light are displayed dark to black. Vegetation is displayed in various shades of green, while the darker the green, the darker its color in nature. So, pine and spruce forests in the Pizhemsky reserve are distinguished by a darker color in the picture than mixed and deciduous forests.

Another important interpretation is the form. The form sets both the presence of the object and its basic properties. For natural objects of the areal nature, such as meadows, forests, areas of thickets, there is an indefinite form, and for anthropogenic, they are regular (arable land, roads, buildings, etc.).

The structure of the image is the most stable direct interpretive feature, practically independent of the shooting conditions. It is a complex trait that combines some other direct interpretive signs, such as shape, tone, size, shadow. The sign of the structure is the most stable of the direct signs, less dependent on shooting conditions than others [11]. When interpreting complex objects, especially in pictures of relatively small scales, as in our case, this feature became one of the defining features.

The grain structure is characteristic for the image of forests. The pattern is created by gray round-shaped spots (crowns of trees) on a darker background created by shaded spaces between the trees. The forest vegetation of the Pizhemsky reserve is characterized by an irregular image structure.

Fragments of images for Figures 1 and 2 (Fig. 3, see color insert) clearly demonstrate the differences in color, photo tone and microtexture in different parts of the Pizhemsky SNR (SAS. Planet Internet resource: Yandex (top row) and Bing maps (bottom row)).

At the same time, synthesized images (standard combinations of channels "artificial colors" 6, 5, 2 or 5, 6, 4 from Landsat 7 and spectral bands 2, 3, 4 from Sentinel 2 satellites) were used to isolate various types of vegetation. However, the resolution of these images does not allow to select homogeneous areas with a size of less than 150 m in one dimension (without taking into account transition zones).

A synthesized image of the territory of the Pizhemsky reserve, obtained from the Landsat 7 apparatus using a combination of spectral channels 7-5-3, is shown in Figures 4, 5 (see color insert).

This combination gives an image close to the natural colors. The undisturbed vegetation looks bright green, the grass communities are green, the pink areas detect open soil. Dry vegetation looks orange, water as blue [12]. Olive-green color is characteristic of forests, and a darker color is an indicator of conifer admixture.

Classification of high-resolution multichannel images with the training provided important information on the distribution of the majority of plant communities observed in the region (Fig. 6, 7, see color insert).

The classes of vegetation obtained in the analysis of satellite images coincided quite well with those that were identified during field work. At the same time, the accuracy of determining certain classes turned out to be rather low. The highest separation accuracy is obtained for water bodies and areas without vegetation.

The paper assesses the values of NDVI. This index helps to identify pine, deciduous forests and meadow phytocenoses, as well as to identify water bodies and open soil [13] (Fig. 8, see color insert).

An analysis of the obtained values of the NDVI vegetation index revealed that for coniferous and deciduous forests the index values range from 0.32 to 0.68 [14, 15]. This suggests a poor and sparse tree and shrub vegetation, since dense forest vegetation corresponds to an NDVI value of more than 0.67–0.80. The same trend is characteristic of plant communities (from 0.68). Low NDVI values for these types of vegetation can be associated with a rather low monthly average air temperature and heavy rainfall. Rather low temperatures for the vegetation period of plants disrupt the flow of biochemical processes in cells, and thus can cause irreversible changes in them, leading to the cessation of plant growth and even their death.

In the course of field studies within the Pizhemsky SNR, the following plant communities were identified: floodplain meadows, coniferous, deciduous and mixed forests.

Meadows, depending on their location in the floodplain of the Pizhma River, were characterized by different species composition. The meadows of the high floodplain were attributed to the formation of true mixed grass and cereals. Their total projective cover was 95%. In the herbage prevailed: *Deschampsia cespitosa*, *Alopecurus pratensis*, *Galium boreale*. Formations of the lower floodplain were large-grass with a projective cover of 60–70%. Their herbage was represented by the *Filipendula ulmaria*, *Thalictrum flavum*, *Phalaris arundinacea*, *Carex nigra*, and others.

The forests in the reserve are mostly mixed, characterized by different ratios of coniferous and deciduous trees. We have described oxalis spruce-birch-fir forest and oxalis-carex birch-fir forest.

Among the coniferous forests in the Pizhemsky SNR the following community options are noted: cowberry pine forest with may-lily and cowberry-green moss pine forest. Pine forests occupy the high banks of the Pizhma River and stretch along them in a narrow strip or create significant arrays in elevated areas.

In the study area there are sites of both small-leaved and broad-leaved forests. They are located in the depressions and along the river. These forests occupy small areas, so they are hardly visible on the map. During the field studies, 2 oak forests were described within the territory under study: oyster oakwood with may-lily and ostrich oakwood. Phytocenoses formed by linden are marked along the low bank of the river. On moist soils the forest cuttings are overgrown with birch and aspen.

Conclusion

The processing of Earth remote sensing data is an up-to-date and important method of biological research. Satellite images are indispensable in the selection of plant communities. They are very effective in studying forest communities.

On the basis of ground and remote data, floodplain meadows occupying more than 60% of the area and forests (about 20%) were allocated in the territory of the Pizhemsky State Natural Reserve in the Kirov region. When deciphering forests were divided into mixed and coniferous (pine). Unfortunately, the areas of deciduous

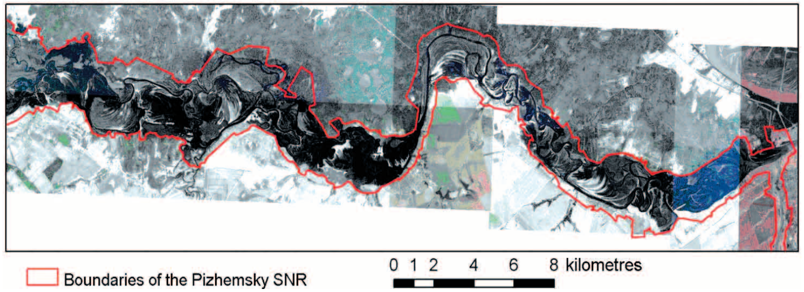

Fig. 1. Satellite image of the eastern part of the Pizhemsky SNR

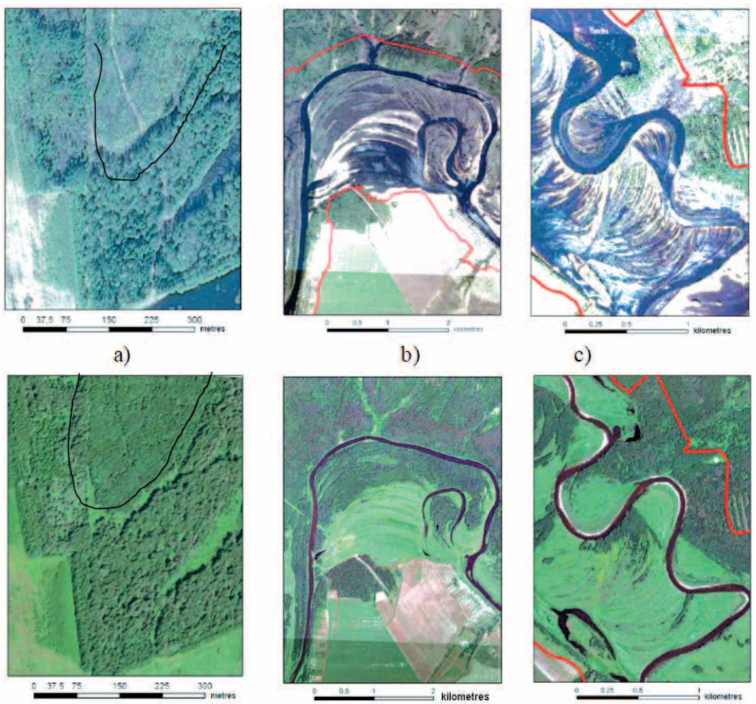

Fig. 3. Fragments of images for Figures 1 and 2

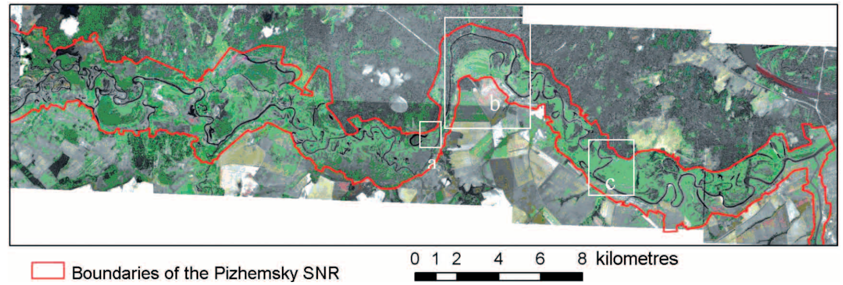

Fig. 2. Satellite image of the eastern part of the Pizhemsky SNR (the Pizhma River) in summer. Dark color refers to the Pizhma River and floodplain lakes, light green – to meadow communities, dark green – to forests

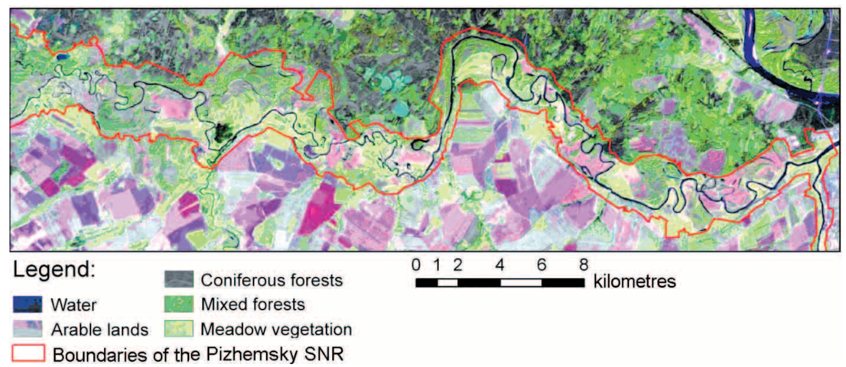

Fig. 4. Synthesized image obtained from the Landsat 7 satellite. Channel combination 7-5-3, resolution 30 m

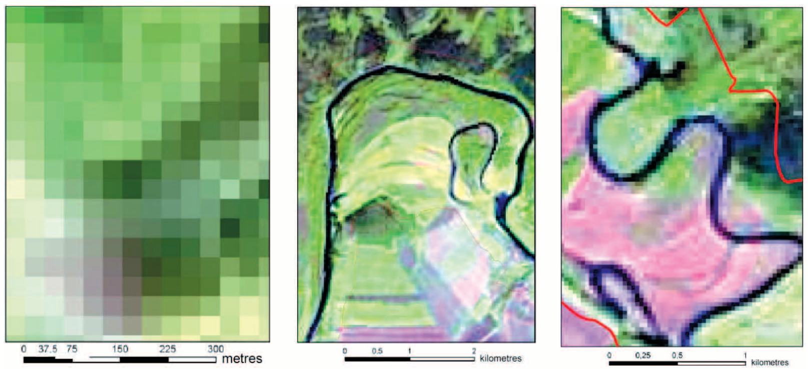

Fig. 5. Fragments of images to Figure 4

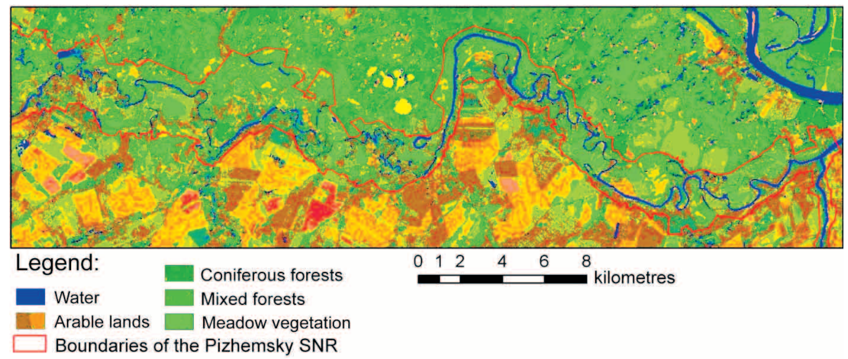

Fig. 6. Landsat 7 snapshot classification by maximum likelihood method. Resolution is 30 m

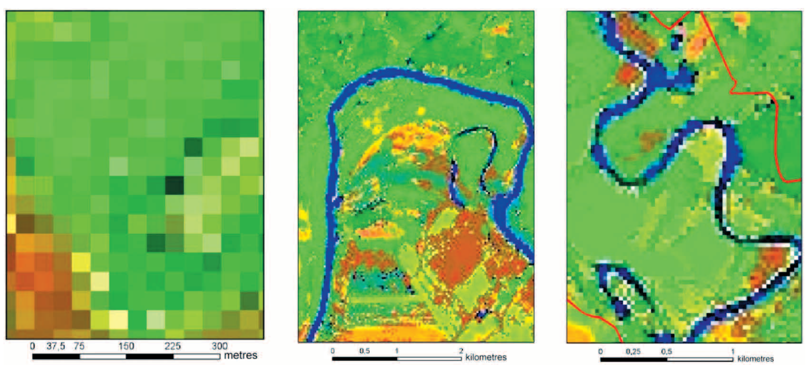

Fig. 7. Fragments of the image for Figure 6

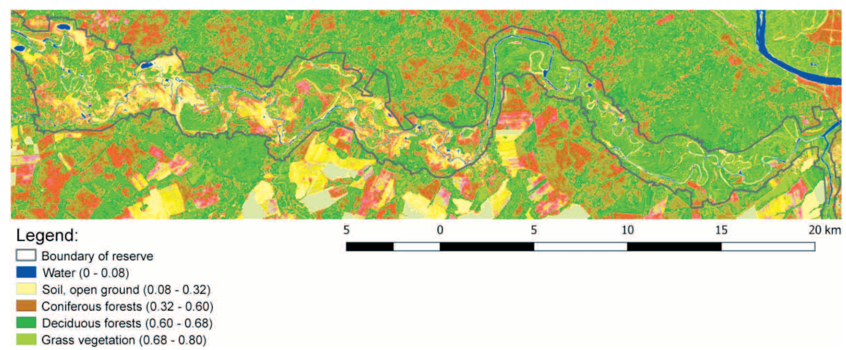

Fig. 8. NDVI map of the Pizhemsky reserve

forests occupying small areas were not identified on the map.

For identification of plant communities, the most characteristic and most accessible direct interpretive features were selected. Synthesis of standard combinations of channels "artificial colors" from satellites of high and medium resolution allowed us to distinguish grassy communities, coniferous and deciduous forests. The classification carried out by the maximum likelihood method yielded important information on the distribution of the majority of plant communities characteristic for the region. Maps obtained in the calculation of the vegetation index demonstrate the possibilities of using NDVI for the isolation and subsequent classification of plant communities.

The results of the interpretation of satellite images by the proposed methods can be used to compile different-time vegetation maps and to study the dynamics of plant communities. The obtained results will allow to substantiate new approaches to environmental management.

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