Landscape structure of the territory of the state nature complex reserve Ichalkovsky Bor (Nizhny Novgorod region, Russia)

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Abstract. The article presents the results of landscape differentiation of the territory of the state nature complex reserve "Ichalkovsky Bor" (Nizhny Novgorod region), performed at the hierarchical level of landscapes and stows. The research territory lies in the forest-steppe zone, and characterized by a rugged karst topography relief, high biological diversity, which determined its complicated landscape structure and great environmental and recreational importance. In 2020 it was decided to organize a geopark, based on the state nature complex reserve Ichalkovsky Bor. All these circumstances determine the high demand for the landscape zoning scheme, which is necessary for the effective organization of environmental and recreational activities. In the course of the research, 4 landscapes were identified, which included 33 kinds of stows. The work was carried out on the basis of field researches, conducted in 2015-2020, materials of remote sensing of the Earth, thematic maps, literature data, processed using GIS.

1. Introduction

In the XXI century, despite the development of technologies and far-reaching progress, the problem of rational nature management and sustainable development of territories is still quite acute. For proper economic use of the conditions and resources of a particular territory, their assessment and inventory are necessary, which in turn are impossible without reliable scientific data. Knowledge of the landscape structure and landscape features of the territory is one of the most important conditions for optimal territorial planning, management, and investment in the territory's economy.

Currently, the schemes of landscape zoning of territories at the level of landscapes and stows, including for solving environmental and recreational problems, are implemented only for some few territories of the Nizhny Novgorod region [1]. There is no such scheme for the territory of the state nature complex reserve "Ichalkovsky Bor", although the need for it, due to the high scientific and environmental [2] status of this protected area is obvious. In world practice, the landscape structure of the territory, especially conservations in conditions of intensive recreational use, is the object of research of landscape scientists [3-5], pedologists [6], botanists [7], zoologists [8], ecologists [9] and specialists of recreation and tourism [10].

The purpose of the research: to make a scheme of landscape differentiation of the territory of the state nature complex reserve "Ichalkovsky Bor".
Object of research: the territory of the state nature complex reserve "Ichalkovsky Bor".
Subject of research: landscape structure of the territory of the state nature complex reserve "Ichalkovsky Bor".

2. Materials and methods
The work is based on the results of field researches, conducted by the authors on the territory of the reserve "Ichalkovsky Bor" in 2015-2020. In the course of the research work, the following research methods were used:

- Descriptive,
- Cartographic,
- GIS analysis,
- Analysis of literature and stock materials,
- Expedition,
- Remote research,
- Comprehensive physical and geographical (landscape) analysis,
- Comparative geographical analysis,
- Geographical zoning.

Generalization and spatial analysis of the data were carried out, using the geographic information system Quantum GIS. Sentinel 2 satellite images from 06/19/2020 were used. The classification was carried out, using the module Semi-Automatic Classification Plugin.

3. Results
In the course of field research, descriptions of typical stows were made. Based on the analysis of thematic maps, remote sensing data and field researches, a scheme of landscape zoning of the territory of the state nature complex reserve "Ichalkovsky Bor" at the hierarchical level of stows and landscapes was made (figure 1).

The territory of the state nature complex reserve "Ichalkovsky Bor" is located in the southern part of the Nizhny Novgorod region in the basin of the Pyana River in the south-western part of the Mezhp'yan'e upland. The area of the research area is 1.488 hectares. The lithogenic base is represented by pre-Quaternary rocks of Permian age, which include limestone, gypsum and dolomites along with clays, sands and marls, which caused the active manifestation of karst processes. Formations of Quaternary age in the north within the local watersheds and watershed slopes are represented by moraine loams; the central part, lying on the root slope of the valley of the Pyana River, is underlain by cover loams; in the southern part, facing the floodplain of the Pyana River, alluvial loams and sands are common. The relief is complicated by numerous karst forms – logs, craters, wells, caves; the slope of the valley of the Pyana River is cut by ravines and balkas, turning into hollows on the watershed slopes. The undulating floodplain is complicated by oxbow-lakes and karst craters, occupied by lakes and swamps.

The average annual precipitation is 530 mm. The maximum monthly average wind speed values occur in spring (2.8 m/s), the minimum – in summer (2.2 m/s). Dominates westerly and south-westerly winds. The average temperature in January is -9°C, in July +22°C.

The annual flow modulus of rivers is 3-4 litre/second/km2. The hydrographic network is represented by the Pyana River, which runs along the southern border of the research area, a complex of oxbow-lakes karst lakes and small-scale lowland swamps.
The research area is characterized by 3 types of soils: gray wood loamy on moraine and cover loams in the north of the reserve, alluvial-sod on the floodplain – in the southern part, the soil of the ravine-balka complex in the central part of the reserve.

Most part of the territory is covered with mixed forest, locally with the presence of spruce and pine crops, in the northern and north-western parts – a fallow land with the recovery of pine and birch. In the course of field descriptions, we compiled a floristic list, that includes 106 species of vascular plants in 50 families of 5 classes.

The territory of the state nature complex reserve "Ichalkovsky Bor" lies in the north of the forest-steppe zone within the Privolzhskaya landscape province, in the Central Stepped landscape district. During the research, the landscape structure of the territory was detailed (figure 1) to the level of
landscapes and stows. Below is a list of landscapes (highlighted in bold) and stows in their composition. The boundaries of the stows are indicated in figure 1.

1. Humid undulating floodplain of the middle river on alluvium of Quaternary age, complicated by oxbow-lakes and karst lakes, under ruderal-mixed grass meadows and willows on alluvial-sod soils of different texture of soil:
   1.1. Eutrophied oxbow-lake on a low floodplain.
   1.2. Karst eutrophied lake on a low floodplain.
   1.3. Humid low floodplain under a meadow on alluvial-sod soils.
   1.4. Humid low floodplain under willow on alluvial-sod soils.
   1.5. Easily moistened high floodplain under an oak community with sparse ground cover on alluvial-sod soils.
   1.6. Easily moistened high floodplain under a community of pine trees with sparse ground cover on alluvial-sod soils.

2. Easily moistened bedrock slope of the middle river valley, complicated by ravines, balkas and karst forms, composed of water-glacial sands and loams, under mixed forests on gray wood loamy heavily washed away soils:
   2.1. Easily moistened bedrock slope of the middle river valley under the meadow community of Calamagrostis epigejos on gray wood loamy strongly washed-off soils.
   2.2. Easily moistened bedrock slope of the middle river valley under the community of silver birch and Calamagrostis epigejos on gray wood loamy strongly washed-off soils.
   2.3. Ravine in easily moistened bedrock slope of the middle river valley under the community of oak and elm trees with nemoral herbaceous ground cover on the soils of the ravine-balka complex.
   2.4. Easily moistened bedrock slope of the middle river valley under the community of aspen with sparse herbaceous ground cover on gray wood loamy strongly washed-off soils.
   2.5. Easily moistened bedrock slope of the middle river valley under the community of birch trees with sparse herbaceous ground cover on gray wood loamy strongly washed-off soils.
   2.6. Easily moistened bedrock slope of the middle river valley under the community of maple trees with nemoral herbaceous ground cover on gray wood loamy strongly washed-off soils.
   2.7. Quarry in the easily moistened bedrock slope of the middle river valley with destroyed vegetation and soil cover.
   2.8. Easily moistened bedrock slope of the middle river valley under the community of pine trees with nemoral herbaceous ground cover on gray wood loamy strongly washed-off soils.
   2.9. Easily moistened bedrock slope of the middle river valley under plantings of pine and spruce with sparse herbaceous ground cover on gray wood loamy strongly washed-off soils.
   2.10. Easily moistened bedrock slope of the middle river valley under the community of linden and pine trees with asarabacca in herbaceous ground cover on gray wood loamy strongly washed-off soils.
   2.11. Balka in the easily moistened bedrock slope of the middle river valley under the community of linden and pine trees with nemoral herbaceous ground cover on the soils of the ravine-balka complex.

3. Easily moistened near-watershed slope on cover loam, complicated by ravines, balkas and karst forms, under mixed forests on gray wood loamy soils:
   3.1. Balka in the easily moistened near-watershed slope under fallow land on the soils of the ravine-balka complex.
   3.2. Easily moistened near-watershed slope under the community of pine trees with nemoral herbaceous ground cover on gray wood loamy strongly washed-off soils.
   3.3. Easily moistened near-watershed slope under the community of aspen with sparse herbaceous ground cover on gray wood loamy strongly washed-off soils.
   3.4. Easily moistened near-watershed slope under the community of birch trees with sparse herbaceous ground cover on gray wood loamy strongly washed-off soils.
   3.5. Easily moistened near-watershed slope under the community of oak trees with nemoral herbaceous ground cover on gray wood loamy strongly washed-off soils.
3.6. Easily moistened near-watershed slope under the community of oak and pine trees with nemoral herbaceous ground cover on light gray wood fine-sandy-loamy strongly washed-off soils.

3.7. Easily moistened near-watershed slope under the community of pine trees with nemoral herbaceous ground cover on light gray wood fine-sandy strongly washed-off soils.

3.8. Easily moistened near-watershed slope under the community of linden trees with Hairy sedge in herbaceous ground cover on gray wood fine-sandy loam strongly washed-off soils.

3.9. Easily moistened near-watershed slope under the community of Norway maple trees with the recovery of Finnish spruce and Hairy sedge in herbaceous ground cover on gray wood loamy strongly washed-off soils.

3.10. Easily moistened near-watershed slope under the community of linden and pine trees with asarabacca in herbaceous ground cover on gray wood loamy strongly washed-off soils.

3.11. Balka in the easily moistened near-watershed slope under the community of linden trees with nemoral herbaceous ground cover on the soils of the ravine-balka complex.

3.12. Balka in the easily moistened near-watershed slope under the community of linden and pine trees with nemoral herbaceous ground cover on the soils of the ravine-balka complex.

4. Easily moistened near-watershed slope on cover loam under fallow land on gray wood loamy soils:

4.1. Easily moistened near-watershed slope under the meadow community of Calamagrostis epigejos, overgrowing with silver birch and Scots pine, on gray wood loamy strongly washed-off soils.

4.2. Easily moistened near-watershed slope under the meadow community of Calamagrostis epigejos with the recovery of Scots pine on gray wood loamy strongly washed-off soils.

4.3. Easily moistened near-watershed slope under plantings of pine with the community of Calamagrostis epigejos on gray wood loamy strongly washed-off soils.

4. Discussion
The research area characterized by significant landscape diversity, which has led to high biological diversity and diversity of ecological-cenotic groups (ECG) of plant species. ECG of plant species are united species, that are similar in their natural habitat (similar in terms of physico-geographical conditions – climatic and soil-edaphic – and phytocenotic conditions – similar plant communities). In the course of the research it was found, that 21% of plant species relevant to the ECG of the edge of the forest (edges of the forests of nemoral and pine forests communities); 15% to the ECG of meadows; 11% to the nemoral ECG; 11% to the ECG of natural outcrops; 7% to the ECG of black alder and coastal communities; 7% to the ECG of pine forests communities; 5% to the ECG of nemoral and pine forests communities; 4% to the boreal and pine forests ECG; 4% to the coastal ECG; 3% to the ECG of black alder community; 3% to the steppe ECG (including ECG of the southern pine forests); 3% to the ECG of nemoral and pine forests; 2% to the water ECG. 4% of plant species relevant to wild cultivated plants outside of ECG.

The character of the vegetation cover structure indicates, that the territory of the state nature complex reserve "Ichalkovsky Bor" is already exposed to a high recreational pressure and needs a more uniform allocation of recreational influence.

5. Conclusion
The results of the research can be used for territorial planning, scientific, environmental and recreational activities on the territory of the state nature complex reserve "Ichalkovsky Bor", especially in connection with the prospect of creating a geopark on its basis.

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