

LANDSCAPE-BASIN APPROACH TO THE STUDY OF FLORISTIC DIVERSITY (HETEROGENEOUS CATCHMENTS OF STEPPE AND FOREST-STEPPE ZONES OF ALTAI KRAI, RUSSIA, AS A CASE STUDY)

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The paper describes the main ideas of the landscape-basin approach to the study of floristic diversity developed by the authors as a result of comprehensive research in heterogeneous catchments of steppe and forest-steppe zones of Altai Krai (South-East of Western Siberia, Russia). Using the particular catchments as an example, the possibilities for organization of research and the comprehensive comparative analysis of landscape structure and spatial differentiation of flora to identify the patterns of their relationship is shown.

Key words: landscape-basin approach, floristic and landscape diversity.

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INTRODUCTION

The integrated research (1995–2014) at the Ob plateau (Altai, Russia) in traditions of the Russian and Soviet schools of comparative floristics and landscape studies allowed us to test different approaches to the study of floristic diversity. Taking into account the geological and geomorphological, zonal and basin characteristics of the territory, the optimal synthetic study algorithm, which is based on the basic ideas given below, is developed.

The objectives of environmental or landscape floristics as an integrated multidisciplinary research area, were first formulated by Yu.P. Kozhevnikov (1978, 1996). Currently the

similar-oriented studies are carried out mainly in Russia and the post-Soviet space, which is associated with the specifics of the Soviet school of landscape science and comparative floristics. In particular, the investigations are conducted in the European part of Russia (Saksonov 2008), the Far North of Siberia (Pospelova 2008, 2009, Pospelova & Pospelov 2008, Telyatnikov 2009) and the Far East (Urusov & Chipizubova 2009, Schlothauer 2009). However, we have not found the complete analogs of our theoretical and practical approaches to the study of relationship between the spatial organization of flora and landscape patterns in the literature available. This was confirmed by researchers at the Congress of Russian Botanical Society (2003, 2008, 2013), the International workshop on comparative floristics (2010, 2014) and other scientific events.

The international studies are developed in line with the landscape ecology, and the most famous journal that publishes articles on the subject, is the *Landscape Ecology*. It deals with such similar issues as the species richness of the urban forest patches (Hobbs 1987); the dynamics of small biotopes in agricultural landscapes (Agger & Brandt 1987); indices of landscape pattern (O'Neill et al. 1988); biotic interactions and edge effects at the facial level (Watling & Orrock 2010) etc. A considerable number of works, including the ones listed above, refer to anthropogenic transformation of landscapes, which manifests itself, in particular, in the territory or habitat fragmentation (e.g., Lindenmayer et al. 2009). This brings together these studies with ours, since the territory of the catchments under consideration is largely changed due to economic activity.

A drastic difference from our approach is that landscape ecology traditionally uses the non-ranking term "land cover type" (e.g., Turner & Ruscher 1987, Zhou et al. 2010). The types of land cover form the landscape mosaic of a combination of single patches connected by corridors and surrounded by a matrix background or other patches. Within these patches, the interaction of organisms and communities with each other and the environment surrounding the contour is considered. In this case, there is no hierarchy of interactions, and the maps include "land covers" of various sizes belonging to different hierarchical levels according to traditions of the Russian landscape study. The hierarchical classification of the classical physical geography is found in foreign literature, but it does not deal with biogeographic differentiation at elementary regional and topological levels.

The main difference of our approach from the mentioned above is a deeper and detailed study of landscape structure at the level of types of compound urochishches groups (and higher) with the involvement of landscape specialists and carrying out the quantitative analyses. Previously the botanists performed the landscape classification in a generalized form and at a qualitative level.

I. The area of the study of floristic diversity must have natural landscape or basin boundaries, which are largely interdependent

Currently the issue of natural borders in comparative floristics is considered to be solved (Yurtsev & Kamelin 1991), since any analysis involves environmental and genetic (historical) unity of flora that can be achieved only within the natural contour. Nevertheless, the floristic checklists of arbitrary contours, for instance, the administrative units, are published. Within these administrative units, the floristic or botanical-geographical regionalization is frequently performed, and the distribution of plant species is given for these natural regions (e.g., Silantyeva 2013). Sometimes the administrative regions are considered as the natural ones, for instance, Altai Krai – Barnaul floristic region (Baikov et al. 1998).

The method of regular graticule squares and trapezoids (e.g., Tabaka 1987, Seregin 2010), providing a uniform study of the site, makes mapping and mathematical processing and solution of some practical problems more convenient, but it does not ensure the uniformity of the contours compared. In other words, a high floristic diversity of the particular square, as well as any other arbitrary contour (e.g. administrative region) may be due to the unique features of natural contour, within which the square is marked, and the combination of different contrasting natural contours within the square. Thus, the interpretation of the study results still requires the transition from a regular graticule squares and other arbitrary contours to the natural units. Therefore, the fundamental studies of floristic diversity should be based on the natural boundaries in the transition as to a lower hierarchical level as to the higher one. The comparison of floras within natural contours, gives an indication of the floristic diversity of particular geosystems and their types to study both the topological and regional (zonal, longitudinal and altitudinal) regularities of its formation and change.

Table 1. Landscape and floristic diversity of the Barnaulka river basin

Natural zone	Steppe				Forest-steppe					
Natural subzone	Droughty		Temperate-droughty		Southern					
Landscape microregions	BLI		BLII		BLIII					
Floristic microregions	BF1		BF2		BF3		BF4		BF5	
Area, km²	2829				2944					
	1646		1183		888		1076		980	
Types of compound urochishches groups	67				58					
	32		35		45		43		34	
Types of terrains	20				16					
	9		11		13		14		13	
Individual landscapes	8				7					
	4		4		5		5		5	
Selyaninov hydrothermal coefficient	0,75–0,95				0,95–1,15					
	0,75–0,84		0,84–0,95		0,95–0,98		0,98–1,06		1,06–1,15	
Species	625				785					
	550		547		556		528		707	
Genera	292				350					
	275		271		280		276		333	
Families	85				96					
	79		82		80		79		94	
Zonal boundaries of microregions	SW	NE	SW	NE	SW	NE	SW	NE	SW	NE
differential species abundance	33	24	13	15	21	17	21	10	77	37

*The data on native flora (free from alien fraction) and restored landscapes (free from anthropogenic modifications and transformations).

Practically, the basin approach, not requiring special landscape knowledge, is the most convenient. It is convenient to compare the catchment flora with the flora of other catchments, as well as to divide and integrate them geographically according to the basin principle; this concerns both the local and relatively large regions (e.g., Kamelin 1973, Marina 1987, Silaeva 2008, Sheremetova 2013). Another thing is landscapes, which are understood by the landscape experts in different ways, not to mention the florists who do not have a background in landscape study. However, it should be noted that landscape and catchment boundaries are largely interdependent. On

the one hand, the development of catchments is determined by landscape features, on the other, the catchment functioning determines the landscape evolution. Thus, the differentiation of landscapes often depends on their belonging to different catchments, and their similarity – to the belonging to the landscape region or the individual landscape. Moreover, natural contours allow not only to compare the floras as the full territorial totalities of plant species (Yurtsev & Kamelin 1991), but also to compare the floristic diversity with the variety of other landscape components and landscape diversity within the same contours.

II. Catchments, with the exception of some of the first order, are the regionally representative combinations of landscape units of topological level, distinguished by territorial contiguity and joint functioning

In other words, the catchment is a full set of ecotopes (from automorphic to hydromorphic and aquatic) peculiar for a particular natural region (Hamilton & Bruijnzeel 1999, Kamelin 1973, Marina 1987, Didukh 1987). Ecotopes within the catchment are connected by water and substances migration, thus their biota is connected as well. In this fashion, as a particular catchment as a much larger natural region where it is located, consist mainly of the same types of ecotopes, i.e. the structure of ecotopes (geosystems) of the model catchment gives evidence of their structure within the whole region. This is true in terms of biota

and flora as a part of it. Thus, the catchment in relation to flora and landscapes is a scale model of the larger natural region.

III. In zonally uniform catchments or their parts, a combination of landscape and basin differentiation factors allows to identify the partial geosystems in the rank of landscape and floristic microregions

Partial geosystems (Sochava 1978) are distinguished by a more limited number of common features as compared to geosystems in the traditional sense. We have shown that the zonally uniform part (fragment) of the middle river basin is determined by a combination of zonal and basin factors (Zolotov 2009; Chernykh & Zolotov 2011) that allows us to interpret it as a landscape or floristic microregion (Fig. 1, Tab. 1).

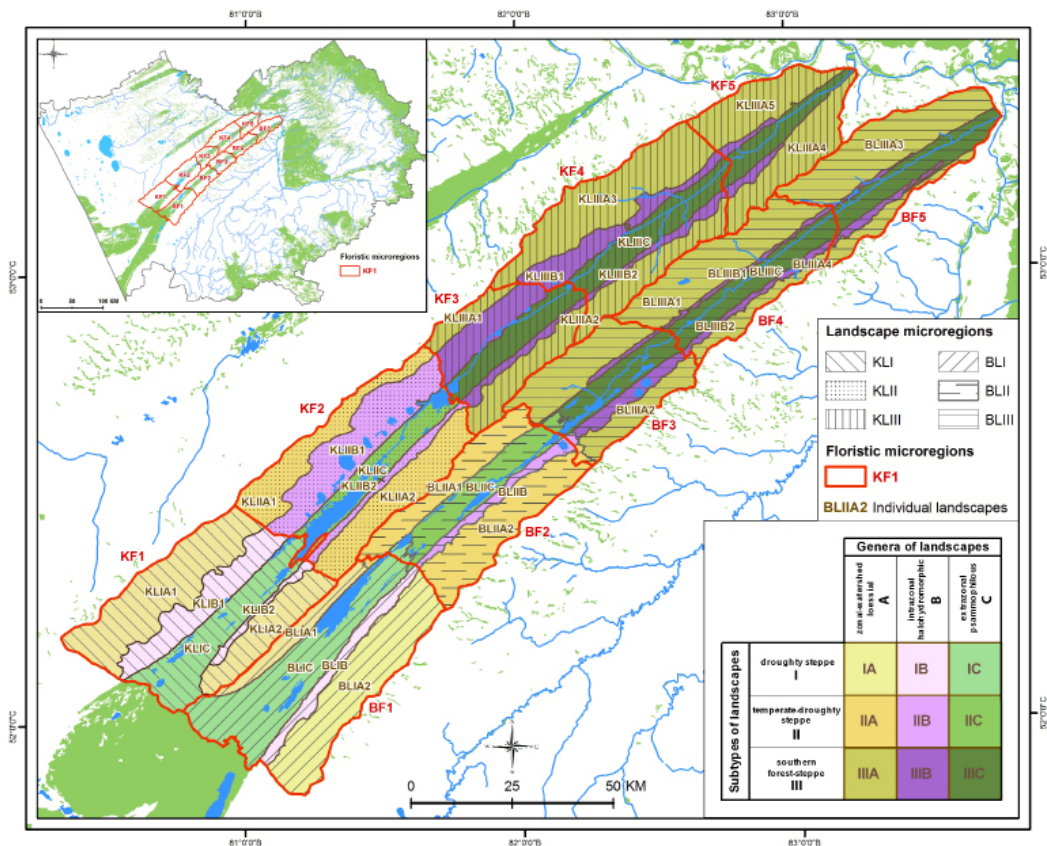


Fig. 1. Landscape and floristic regionalization of neighboring the Kasmalinsky basin and the Barnaulka river basin.

On the one hand, not only zonal, but the intrazonal and extrazonal landscapes of one basin, bordering each other, have distinct differences within different natural zones, subzones and zonal strips. These differences can be traced as in the particular components of geosystems (vegetation cover, soils, topography, etc.) or their functioning (hydrological and geochemical regimes, etc.) as in specific geosystems-indicators and their spatial organization. Particular emphasis is placed on the search for differential species (Yurtsev 1983) – zonality indicators distinguishing floras of different natural zones, subzones and zonal strips within the same catchment. It has been found that within the intrazonal and extrazonal landscapes the number of differential species is greater than in the zonal ones. Zonality of intrazonal landscapes and their vegetation cover has been reported in (Kuminova 1963, Martynenko 1987, Milkov 1990).

On the other hand, the adjacent fragments of different basins but of the same zonal strip differ in their basin functioning. Such hydrological differences also influence on the landscape structure. For instance, the adjacent microregions of the Kasmalinsky basin (KLII) and Barnaulka river basin (BLII) belong to the temperate-droughty steppe (II) subzone; the first is occupied by drainless lake Gorkoye, while the second – an intermittently-flowing section of the middle river basin (Fig. 1). In the first case (KLII), intrazonal halohydromorphic landscapes are represented by larger areas that together with the drainless regime provide greater salification and preservation of large salty and bitter-salty lakes. That is why the temperate-droughty steppe microregions of the Kasmalinsky basin (KLII) and the Barnaulka river basin (BLII) significantly differ in landscape structure, vegetation cover and differential species. In the temperate-droughty steppe microregion of the Kasmalinsky basin (KLII) obligate halophytes of sor (salt-marsh), i.e. *Halocnemum strobilaceum* (Pall.) M.Bieb., *Limonium suffruticosum* (L.) O.Kuntze and others grow on the shores of the salt lakes. These species are not found in the Barnaulka river basin in temperate-droughty steppe (BLII) and more southwestern and salted droughty steppe (BLI)

microregions and even in the droughty steppe microregion of the Kasmalinsky basin (KLI). In Altai Krai, the mentioned species are confined mainly to the dry steppe subzone with dominant kastanozems.

Obviously, the combination of zonal and basin factors creates the conditions for landscape and floristic differentiation at the elementary regional level. Differences in landscape structure and geosystems functioning regime allow us to specify landscape microregions. The presence of differential species and differences in the structure of elementary regional floras makes it possible to define such areas as floristic microregions, i.e. the smallest regional units. It should be noted that the boundaries of floristic and landscape microregions correlate being at the same time not strictly uniform. In our case, floristic microregions are equal to or smaller than landscape ones. Note, only one landscape microregion is identified in the southern forest-steppe of Kasmalinsky and Barnaulka river basins since the landscape differences in their different parts is insufficient for splitting into several microregions. The flora in these landscape microregions (they cross three zonal strips of the southern forest-steppe subzone) changes significantly that makes it possible to identify three floristic microregions with various landscape structure here (Fig. 1, Chernykh & Zolotov 2011). The determination of microregions as elementary regions based on landscapes and vegetation cover features has been made in (Kuminova 1956; Tumadzhyanov 1963; Zolotukhin 1987).

IV. The most important criterion for identification of elementary natural regions (microregions) is the representativeness for the region of the next higher hierarchical rank

It is generally accepted (Yurtsev 1992) that a particular or an elementary regional flora is the flora of one specific landscape; in a similar manner, a landscape is understood sometimes as an elementary region (Krauklis 1979). However, in the regions where sharply contrasting environments occur within a small area, an elementary region includes several

individual landscapes. It is typical for the Altai Mountains and heterogeneous catchments of the Ob plateau (Altai Krai). The surface of the plateau is cut by the ancient flow gullies and succeed them catchments in each natural subzone have a set of multiple individual landscapes: 1) 1 extrazonal psammophilous landscape of the first accumulative terrace or the bottom of the ancient flow gully with strip pine forests and wetland complexes; 2) 1 or 2 intrazonal halohydromorphic landscapes of the second erosion-accumulative terrace with large-scale salinification and waterlogging caused by high groundwater levels; 3) 2 zonal-watershed loessial landscapes of the third and fourth erosion terraces and inter-gully plateau fragments with zonal steppe and forest-steppe nature complexes. In this case, the efforts to specify a strip pine forests area as a separate structurally homogeneous region (Alexandrova et al. 1958) brings to its disjunctiveness and presence in two natural zones, not to mention the subzones. Thus, traditional basic requirements to regionalization, i.e. zonal homogeneity and territorial integrity of a region are not met. Moreover, such a region do not include a complete set of landscape units characteristic of the Ob plateau or its part within the natural zone or subzone, hence it does not represent a regionally representative sampling of landscapes and floras.

V. The landscape-basin structure determines the differentiation of flora both at elementary regional and topological levels, therefore landscape microregions correspond to floral ones, and the hierarchy of landscape units (facies (microecotope) – urochishche (mesoecotope) – terrain (macroecotope) – landscape (megacotope) corresponds to the hierarchy of partial floras.

In each specific case, the hierarchy can be considered at different levels depending on the objectives of the study. Total mapping of all areas in natural undisturbed regions at the level of the facies (their types or groups, classes) including binding of geobotanical (floristic) description to the contours is possible, while for anthropogenically transformed landscapes (e.g., plowing) it is impossible because of

transformation-induced blurriness of facies boundaries. Hence, it is better to start with a higher level, namely: urochishches, terrains or landscapes. The most strict determination is used at the level of facies – a partial flora of microecotope because facies are typically the most contrasting landscape units. Nevertheless, strict determination can be also found at higher levels up to landscape ones, e.g. the presence of specific halohydromorphic landscape in Kasmala temperate-droughty steppe microregion (KLIIB1) with differential species (see III, Fig. 1).

VI. The selection of sites with maximum floristic diversity for field research is based on the landscape-basin approach. The comprehensive analysis of remote sensing data, topographic and thematic maps allows to estimate the occurrence of units (dominant, subdominant, secondary, rare, unique) and their preservation under the anthropogenic fragmentation of vegetation cover (flora-isolates)

Since the total survey of large areas is hardly feasible, thorough planning of field research is a must. The landscape-basin approach allows to identify both the most typical and the most unique units for a given area. It saves time when making field research and identifying similarities and differences of adjacent territories (e.g. neighboring microregions or individual landscapes). In other words, at a preliminary stage we plan to test certain landscape units and concurrently formulate the hypotheses on landscape structure and spatial organization of the flora to be confirmed or rejected in the following field research.

VII. The comparative analysis of floristic diversity (differential species, taxonomic and typological structure, spatial organization) is carried out concurrently with the analysis of the author's landscape maps of basins to identify the cause-and-effect relations and to compare the regularities

The comprehensive comparative landscape and floristic analysis within the natural contours is

performed to correlate landscape and floristic diversity. Table 1 gives an example of such a comparison for the Barnaulka river basin. The steppe zone of the basin is much poorer in flora at substantially greater landscape diversity and slightly smaller area. The microregion BF5 contribution to the flora of the southern forest-steppe of the basin is the greatest. Floras of BF3+BF4 include 613 species from 299 genera and 80 families, whereas addition of BF5 gives more 172 (21.9% of the southern forest-steppe flora) new species, 51 (14.6%) of genera and 16 (16.7%) of families. Besides, BF5 is most clearly demarcated from the adjacent microregions by its differential species abundance, however, by the number of types of compound urochishches groups it is the poorest microregion in the southern forest-steppe zone of the Barnaulka river basin. At the level of floristic microregions other regularities work. The microregions of the southern forest-steppe in the Barnaulka basin are much smaller in size than the steppe ones, but their landscape and floristic diversity is higher or almost equal to that of the steppe microregions. Note that the number of differential species marking the southwestern boundaries of microregions is normally much higher than that for the northeastern boundaries because the forest-steppe flora is generally richer than the steppe one.

Table 1 demonstrates non-linear and mixed relationships between landscape and floristic diversity at different hierarchical levels. Probably, the most strict relationship between floras and landscapes does exist at the facies level (see V), however, the construction of detailed maps for large areas is time consuming; moreover, for the anthropogenically transformed areas it can be hardly done at all. In our opinion, the presented interdisciplinary approach is productive for systematization of the accumulated information, planning and conducting research, making a comprehensive comparative analysis of the collected data as well as practical application of the obtained results for landscape planning, optimization of nature management, environment protection and the establishment of system of specially protected natural territories.

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