Formation of evolutionary landscape science in Russia

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Abstract. In contrast to paleogeography and evolutionary geography, evolutionary landscape science is only a few decades old. This paper traces the history of paleogeographic research and, on this basis, the development of the methodology and methods of evolutionary landscape science. In this country, paleogeographic research began with the reconstruction of vegetation cover based on the edaphic approach. Later, such work started to be based on the integration of palynological data and reconstructions of climatic changes. Actual papers on evolutionary landscape science appeared only in the last decades of the XX century. At the turn of the millennium, work on paleolandscape reconstructions and paleolandscape mapping commenced. The main methods for large-scale paleoreconstructions of landscapes, which constitute the basis for works on evolutionary landscape science, are presented in the given paper. An essential part of the research is the application of the landscape-edaphic approach to specific chronological sections and the compilation of maps of conditionally restored (indigenous) landscapes. Detailed paleolandscape studies in the key areas of forest zones in the European Territory of Russia (ETR) made it possible to reveal some patterns in the evolution of their landscapes in the Holocene.

1. Introduction
In contrast to paleogeography and evolutionary geography, which formed in the middle of the XIX century, paleolandscape science and evolutionary landscape science do not possess such an extensive historiography and are only a few decades old. The first person to mention the need for proper paleolandscape studies was V.A. Nikolaev [1]. He also emphasized that retrospective (paleolandscape) analysis of modern geosystems is one of the most important methods of implementing the principle of historicism in landscape research. And that scientists should strive to use a bilateral approach: ‘from the fossil past to the present, and from the present to the past’.

The innumerable paleogeographic studies, both at the regional and local levels, focus mainly on individual components of nature: relief, climate, vegetation, soil and, in some cases, ‘bundles’ of these components, especially that of vegetation and climate. To date have accumulated certain experience in paleolandscape research. The research is based on the basic principles of classical paleogeography. Furthermore, the works by many paleogeographers repeatedly mention the need to use the principle of the interconnectedness between evolutionary and specific-territorial approaches when studying the formation of landscapes. It should be noted that, unfortunately, in many publications on this topic, the landscape component is present mainly only through the use of specific terminology.
2. Development methodology and methods
One of the most difficult paleogeographic tasks is the reconstruction of natural conditions in certain chronological sections of specific territories and, primarily, the ‘restoration’ of the vegetation cover. The first reconstructions of primary (indigenous) vegetation were essentially based on the assessment of the edaphic properties of habitats and the distribution of indicator plants. It is worth mentioning the pioneering works by V.V. Alekhin [2] on the compilation of maps of the restored vegetation of the Nizhny Novgorod and Moscow regions, based on the analysis of the distribution of modern vegetation and the edaphic approach. Later, such work began to be based on the integration of palynological data, starting with the first integrations carried out by F. Firbas [3], M.I. Neustadt [4] and V.P. Grichuk [5] and N.A. Khotinsky [6] for the postglacial period.

Recently, a substantial number of papers have been devoted to the reconstruction of vegetation and climate during the Holocene at the regional level, based on the palynological data from various sections of alluvial, lacustrine and bog deposits [7-11]. Among the works by foreign scientists, reconstructions of landscape and climatic changes in the Baltic countries, Poland, Germany and, Belarus are close in terms of geography [12-16].

Noteworthy ones are the complex paleoreconstructions of natural conditions and the evolution of vegetation of Valday by A.A. Tishkov [17-18], A.L. Aleksandrovsky and Yu.G. Chendev [19] devoted their monographs to the reconstructions of the soil evolution, reflecting rather conditionally the changes in the natural conditions of specific territories.

A major disadvantage of many papers is that the description and characteristics of the restored vegetation or soils are presented in general terms without any specific landscape references or attribution. And little attention is paid to the anthropogenic impact as a factor of evolutionary development. At best, a certain degree of vegetation and soil disturbance under the influence of the anthropogenic factor is mentioned.

We may also cite very successful geobotanical reconstructions based on the palynological method, carried out in collaboration with specialists of different profiles, especially archaeologists, geomorphologists and soil scientists. Recently there have been conducted quite many of such interdisciplinary and sometimes complex studies both in our country and abroad. As a rule, paleogeographic reconstructions are performed at a very high level and led by a certain specialist (or two). We can single out the following works on reconstruction (of relief, vegetation, soil, climate), that are closely related to the given paper: research with the participation of A.V. Panin, E.G. Ershova, A.L. Aleksandrovsky [20-21] and a number of other researchers.

At the local level, the study of the issues regarding the interaction between the natural environment and humans in different epochs of the Holocene is often based on archaeological material and paleoecological reconstructions. These and similar works deserve due attention; the use of such research’s results significantly increases the conditionality of landscape reconstructions. However, the key difference of such works is either a narrow component focus or, in most cases, the fact that they are of a point, local or generalized nature.

Most often, these reconstructions are areal in nature, but they rarely ‘go beyond’ the relief reconstruction. As in similar archaeological and historical studies, the landscape component is present mainly in the use of landscape-specific terminology. Often the name contains the term ‘landscape’, but the paper contains no research of the landscape structure, especially not its reconstruction. Therefore, as V.A. Nikolaev emphasizes, ‘as a result, only a generalized paleogeographic zonal-provincial background is recreated, not a specific landscape structure of the territory’ [1].

In the 1990s, the first papers devoted to paleolandscape reconstructions were published [22]. A significant turn in detailed paleolandscape studies of a particular region is associated with the works by G.I. Yurenkov and his followers at the Herzen State Pedagogical University in St. Petersburg. Properly speaking, G.I. Yurenkov introduced the concept of ‘evolutionary landscape science’ into scientific circulation (1997) and published the first (and so far, the only) monograph of this kind (titled correspondingly): Introduction to Evolutionary Landscape Science [23]. It should be noted that within the Herzen State Pedagogical University, two scientific schools within this scientific direction are
being formed: spearheaded by professors D.A. Subetto and E.M. Nesterov. And for almost two decades there has been a similar international seminar.

Almost around the same time, large-scale work on the evolution of landscapes of the Center of the Russian Plain was launched at the Faculty of Geology of Lomonosov Moscow State University. Both in paleogeographic and paleolandscape studies, the basis of the research is the compilation of various types of reconstructive maps. The first provisions of the paleolandscape concept based on large-scale studies of the Holocene evolution of Meshchera forest landscapes were formulated by T.A. Abramova and K.N. Dyakonov [24]. Research conditions were the following: the definition of a regional integral physical-geographical process (bog formation, desertification, salt accumulation (halogenesis), glaciation, etc.), which should be described through mass balance and characterized by speed; the identification of specific physical and geographical features of the region: its modern climate, geological and geomorphological structure, biotic factors.

At the end of the XX century, I.I. Mamai [25] developed an evolutionary-dynamic concept of changing geosystems. Throughout their life, geosystems go through stages of emergence and formation, stable existence, slow development and replacement of one complex by another, while forming evolutionary-dynamic series, under the influence of morpholithogenic, thermal, hydrological, geochemical factors. That is, the development of NTC (natural territorial complexes), leading to the replacement of the old complex with a new one, is carried out through changes in their states. The replacement of one complex by another occurs due to a change in its lithogenic base, a climate change or self-development. In the first case, the landscape pattern is transformed. In the second case, the change of the invariant occurs without changing the pattern of the morphological structure. In the case of self-development of geosystems, both a change in the morphological structure and its preservation can be observed. The new NTC inherits the features of the former NTC, which is the manifestation of the landscape heterochronicity.

In the natural conditions and over large areas, such changes usually occur over long periods of time – thousands and tens of thousands of years, which complicates their study. At the same time, it is possible to trace the changes of natural complexes of a large rank: landscapes of a high typological level (type, subtype, etc.). Unfortunately, I.I. Mamai also does not consider the specific landscape structure of a territory.

3. Results

Actual papers on evolutionary landscape science appeared only in the last decades of the XX century. At the turn of the millennium, work on paleolandscape reconstructions and paleolandscape mapping was launched.

In 2004, the first thesis on this topic was written by L.A. Nesterova [26]. This was the “Formation and Evolution of Landscapes in the Eastern Part of the Leningrad Region”. It is worth noting the study of the paleovegetation of the Late Glacial and Holocene in Eastern Fennoscandia, by G.A. Elina et al. [27], which, in terms of content and presented cartographic materials, is a landscape research. Among the works on paleolandscape science published in the recent years, one of the latest works by E.Yu. Novenko et al. [28] can be singled out. It is dedicated to the reconstruction of natural landscapes in the Meshchera lowland that existed before the beginning of their anthropogenic transformation.

The early experiments in large-scale paleolandscape mapping were carried out by V.A. Nizovtsev, by the example of the Dubna paleolake system on a large scale. A paleolandscape reconstruction of this territory was carried out in 2001-2002 [29]. An essential part of the research is the application of the landscape-edaphic approach in the reconstruction of the landscape structure of territories in specific chronosections and the compilation of maps of conditionally restored (indigenous) NTCs [30]. The main element of these studies is the assessment of the edaphic properties of the NTCs, the compilation of the ecological and dynamic series of indigenous plant communities, the reconstruction of the lithogenic (geological and geomorphological) base and native vegetation for the main types of the NTCs, and based on this, the reconstruction of the indigenous landscape structure. The
identification and study of the evolutionary series of landscapes and their morphological units in the field make it possible to restore the stages of their development through spatial transition.

Particular attention is paid to the analysis of the anthropogenic changes in the terrain (artificial terracing, planation, ‘anthropogenic’ erosive forms, etc.), the accumulation and distribution capacity of the cultural layer and the changes in the hydrological regime across a given territory. From a significant number of natural factors, on which the growth of phytocenoses depends, the most important ones are selected: the relief and location, substrate fertility, the nature of moistening and the degree of moisture. Knowing the natural properties of the NTC, it is possible to establish its main edaphic properties (a specific edaphotope) and, accordingly, the primary type of forest or steppe vegetation, which most fully corresponds to these properties, and to foresee the successional alternation of modern phytocenoses. Each specific type of NTC is also characterized by a certain specific series of successions of plant communities. According to the ecology of phytocenoses and indicator plants (eco-dominants), conjugate series of forest or steppe phytocenoses and habitats are compiled. The climatic background is restored for the chronosection under study, and anthropogenic changes in the relief, the accumulation and distribution capacity of the cultural layer, etc. are analyzed. The established patterns of confinement of modern plant communities and soil varieties to certain landforms and lithology of the parent rocks of sediments can be extrapolated to certain chronosections, with adjustments for climatic changes (the principle of actualism). Then an adjustment is carried out, based on detailed paleoecological (spore-pollen and carpological) data. Therefore, the NTC data are highlighted on the map with a certain degree of conditionality.

It should be understood that the reconstruction of landscape changes based on climate fluctuations could be misleading, since intra-landscape changes in reality are not synchronous with the changes in climatic conditions. This technique for reconstructing the paleolandscape structure at the local level is consistent with the concept developed by G.A. Isachenko and A.I. Reznikov [31]. According to them it is proposed to divide the characteristics of elementary landscapes into location features (relatively stable parameters of the relief and bedding rock that determine the moisture regime) and state features (more dynamic parameters, vegetation and soils). At the same time, the boundaries of modern tracts, identified in the course of mapping the modern landscape, are the so-called ‘rigid frame’ that predetermines the spatial distribution of plant communities and soil varieties. A similar approach in studying the dependence of the vegetation cover distribution on the landscape structure can be found in the geobotanical work by A.P. Gromtsev, carried out in the taiga zone of Fennoscandia [32], and a number of other studies.

Detailed paleolandscape studies in the key areas of forest zones in the European Territory of Russia (ETR) made it possible to reveal some patterns in the evolution of their landscapes in the Holocene [33]. Rhythmic climate fluctuations, which led to repeated changes in the typological (zonal) affiliation of the areas under study, were crucial in the evolution of landscapes. The specific pattern of the distribution of landscapes of the highest rank, as well as those of the local level, is caused by a group of structural and geomorphological factors. For the territory of the Moscow glaciation, a distinctive feature is the lesser variegation of the morphological structure of landscapes, in contrast to the area of the Valdai glaciation, which is characterized by landscape complexes of the local level with rough boundaries, predetermined by a significant ‘variegation’ of micro- and mesorelief forms. During the Holocene, landscapes of mixed forests changed their typological affiliation four times (taiga – mixed forests – deciduous forests – mixed forests), and there was a succession of six subtypes of landscapes. The duration each type functioned (its particular age) averaged about 3 thousand years. Southern taiga landscapes and northern taiga landscapes went through a succession of four types of zonal affiliation, and at the level of subtypes, there happened from five to eleven shifts, respectively. The northern taiga landscapes have the lowest particular age: 2 thousand years.

Starting from the Eneolithic – Bronze age, the anthropogenic factor was added to the natural factors of landscape evolution; and already in the Bronze Age, at the local level, it became one of the key factors in some types of landscapes, associated with the peculiarities of the distribution of the first settlers’ population and their methods of land and resources management. In the Bronze Age, from the
Subboreal period, anthropogenic transformation of landscapes began, which sharply increased only during the last 300-400 years in the area of the Moscow glaciation and 200-300 years in the area of the Valday glaciation. At the zonal-provincial level, several main types of landscape exploration and exploitation developed, represented by the spatial pattern of combinations of natural and anthropogenic landscape complexes. For the southern-taiga and middle-taiga landscapes of the Valday glaciation, a small-scale (point) type of landscape development is characteristic, due to the fact that small tracts of developed land were confined to elevated drained areas: moraine and kame hills or residual mountains of ‘sunken moraine relief’. Linear and tree-like subtypes of patterns characteristic of the valley type of land development are common. The combination of small-scale and linear development is common in areas of end-moraine ridges. The mosaic type of development with an approximately equal combination of forest and treeless areas is more typical of landscapes of mixed forests in the territory of the Moscow glaciation. A more homogeneous spatial pattern of land exploration and development is specific to the background type of development with the watershed type of settlement, prevalent mainly in the broad-leaved zone.

4. Conclusion
The formation of evolutionary landscape science relies on the extensive methodological and methodical base of paleogeography and evolutionary geography. At the turn of the XX-XXI centuries, work on evolutionary landscape science in specific territories, based on paleolandscape reconstructions and large-scale paleolandscape mapping, started. For greater reliability of the results of the ‘restoration’ of landscapes of the past, their evolutionary development, cross-spectrum paleolandscape and paleoecological reconstructions are necessary. Generating paleolandscape maps, based on landscape-edaphic interpretations of spore-pollen spectra and data from paleopedological studies, will provide a comprehensive visual presentation of the development of the main types of landscape complexes at the local level in model areas (at the tract-subtract level of the hierarchy of morphological landscape units). Such detail and complexity of paleolandscape reconstructions will significantly increase the conditionality of the research results and will make it possible to identify short-term changes in the landscape structure.

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