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Landscape Catenae of Sandy Valley Plains of the Vyatka-Kama Region

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Abstract

The article shows the results of researching landscape catenae of valley-outwash plains of the Vyatka-Kama Pre-Urals by the example of the natural sanctuary "Medvedsky Bor" in the valley of the low Vyatka (the Volga basin). The catenae analysis of "Medvedsky Bor" was fulfilled on the basis of complex field and laboratory-analytical research of over 120 landscape facies. They are situated on different geomorphological layers (terraces above the floodplain of the Vyatka) and mesorelief elements (within aeolian palaeo-dunes and palaeo-knobs, interdunal and inter-knob basins, karst conical depressions, and sub-horizontal surfaces). On the basis of the analysis of horizontal interrelations of valley-outwash landscapes of "Medvedsky Bor" three models of landscape catenae for ancient-aeolian, swamp, and karstic subtypes of locality were created. The borders of catenative sets are determined; their main peculiarities on outwash valleys of the region are found out. With the help of the original methods the analysis of the power of lateral landscape links between the sets within each catena model was carried out.

As a result of the research carried out it was found out that in ancient-aeolian landscape horizontal redistribution of matter and energy is the least represented. Landscape catenae, as a rule, consist of 2 upper sets – eluvial and transit (normally of its transeluvial part). Transaccumulative part of the transit set is very seldom represented in lower positions of ancient-aeolian catenae in conditions of considerable lessening of the power of sand sediments or recurrent ground moistening. Swamp landscapes have the strongest horizontal interactions in their lower parts. Swamp landscape catenae, in case of connection with such complexes, can consist of 4 sets, such as eluvial, transit, superaqual, and subaqual. The sets considerably differ from each other as for their vegetation and soil content. Catenae of the karstic type of locality also consist of 4 sets, and strong links are characteristic not only for the upper, but also for the middle parts of this geosystem. The power of horizontal links and facies features of these catenae are strongly dependable on the evolution phase of the karst conical depression.

Keywords: landscape catenae, catenative sets, the power of horizontal links, landscape structure, valley-outwash plains, the Russian Plain, the Vyatka-Kama Pre-Urals, Medvedsky Bor.

INTRODUCTION

The structure of landscapes and soil cover of valley-outwash plains of the Vyatka-Kama Pre-Urals was studied [1] [2] [3] in the southern part of Kirov region (Nolinskiy district); the complex of 3 terraces above the floodplain of the lower Vyatka within the natural sanctuary "Medvedskiy Bor" and in its vicinity was considered (fig. 1). Mass data of morphological units of Medvedsky landscape of different taxonomic range and their placement on the mesorelief elements were got for the first time. Still horizontal links between these morphological units have not been researched enough yet. For their analysis the method of landscape catenae was used. A landscape catena is a paradynamic assembly of natural-territorial (aqual) complexes belonging to different taxonomic ranks and connected into a whole by means of mutually directed downward and upward flows of matter, energy, and information [4].

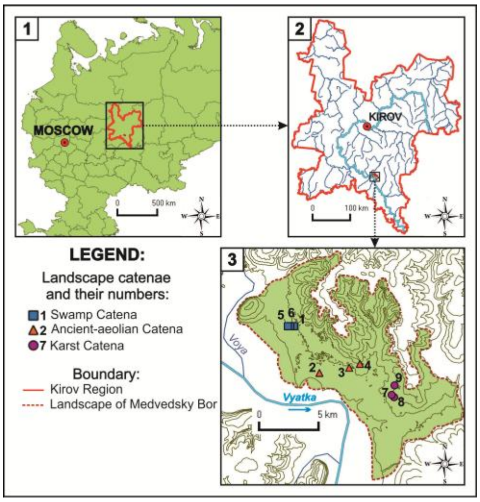

Figure 1: Geographical placement of the research area: 1) Kirov region on the map of the European part of Russia; 2) Landscape of the Medvedsky Bor on the map of Kirov region; 3) Location of catenae 1–9 within the landscape of Medvedsky Bor (the numbers of catenae are same as in fig. 2–5)

Morphological landscape units are grouped into catenative sets. They change each other down the slope: eluvial, transit, superaqual, and subaqual. Presence of all the 4 sets is viewed as a full junction within a landscape catenae; absence of at least one set indicates that the junction is not full.

For the first time catenae were described by G. Milne in 1936, these were catenae of slope soils [5]. From that time soil catenae have been of interest. Mainly research works in this field deal with geochemistry of catenae [6][7][8][9][10][11][12][13][14]. Some works touch upon the issues of formation of structures of soil cover on the catenae [15][16][17][18], other works consider catenative soil water regimes [19][20]. Landscape catenae are researched much less. The first researchers in this field are the Russian landscape geochemists B.B. Polinov [21] and M.A. Glazovskaya [22]. On the basis of their research F.N. Milkov [23] and A.V. Berezhnoy [24] were the founders of the catenative method in landscape studies. They were the first to consider the associations of areas on the slopes of mesorelief as special paragenetic complexes. Nowadays this principle serves as a basis of researching landscape catenae in Russia [25][4][26][27] and in some East-European countries [28][29]. The most works deal with the analysis of landscape catenae on heavy sediments. Horizontal redistribution of chemical elements dependable on the relief is seen to the best advantage on clays and loams. At the same time, the character of horizontal links of landscapes on sandy-loam sediments of outwash plains is not yet properly researched, and it is the aim of this research.

The hypothesis of this research: all other conditions being equal, the more the adjoining facies (soil and vegetation) differ from each other, as for their state, the stronger the horizontal links between the adjoining facies placed on catenae are.

MATERIALS AND METHODS

In the analysis of landscape catenae of valley outwash we used the research material of 28 slope areas within ancient-aeolian, swamp, and karst subtypes of the terrace of above-the-floodplain type in the landscape of Medvedsky Bor. For the analysis of catenative links for each area subtype special profiles were created (fig. 2–5). It helped to determine up to 3-4 catenative sets changing each other down the slope: eluvial (EL), transit (T), and superaqual (SuperAqua). If there were water objects, the lower parts of the catenae were occupied by subaqual sets (SubAqua). The transit set, depending on the proportion of outwash and accumulation process, was divided into 2 parts: transeluvial (TEL) and transaccumulative (TA). Within each set there is a similar character and direction of the main landscape-forming processes. There is no complete coincidence between landscape catenae and area subtypes. For example, swamp catenae include the tops of the neighboring dune complexes and their slopes facing swamp areas (fig. 2, 3). Downward set interchange in the line of landscape catenae coincides with the downward change of facios types. In this case the main and constant factor of facial differentiation is mesorelief. On outwash plains it often determines the power of the sand-loam sediments sheath and the moistening character. Moving along the catena, the facios change can be connected not only with the relief, but also with presence of well-lighted areas (forest “windows”) in the forest canopy. They make the situation more complicated.

To assess the power of catenative interactions we carried out the analysis of soil and vegetation change from the upper to the lower sets in each of 28 catenae under research. Qualitative character of changes of facial states was presented in points. Points were given taking into account the amount of classification differences of soils and plant associations (table 1).

Table 1. Points of the difference of soils and plant associations of the adjoining sets and landscape catenae of the Medvedsky Bor

Soils		**Plant associations**	
Difference in…	Point	Difference…	Point
department	5	plant type (forest /swamp)	5
type	4	dominant species of the Ist tree layer	4
subtype	3	sodominant species of the Ist tree layer	3
species	2	dominant species in the ground layer	2
variety	1	sodominant species in the ground layer	1
not present	0	not present	0

For example, in case there is a difference in soil departments, the corresponding border between catenative sets is given 5 points, if soils coinside – 0 points. If there are differences on several levels the border between the sets is given the highest point.

The indices F_{cat}(EL/TEL), F_{cat}(TEL/TA), F_{cat}(TA/SuperAqua) which we got at addition of points of soils and vegetation characterize the power of interaction of the corresponding adjoining sets of the catena. Their value can vary from 0 to 10. The following scale of F_{cat} indices assessment can be suggested: $0 \le F_{cat} \le 3$ – weak interaction; $3 < F_{cat} \le 7$ – medial interaction; $7 < F_{cat} \le 10$ – strong interaction. Average F_{0cat} indices of adjoining sets of ancient-aeolian, swamp, and karst catenae were calculated.

RESULTS AND DISCUSSION

Ancient-aeolian subtype of locality in the research area is characteristic of the IInd, IIId terraces above the floodplain of the Vyatka River and partially for the periphery zone, which is attributed to alluvial-fluvioglacial formations (fig. 2). This subtype is background in character and it occupies a small area. It unites the areas which are the most typical of Medvedsky landscape – sand dunes (knobs) and interdunal (inter-knob) basins under different types of pine forests on podzols developed on light sediments. Their height within the subtype varies from several centimeters to 20–30 m and more. This fact determines considerable heterogeneity of eolian relief within ancient-aeolian type of locality.

Edge eastern area of the subtype (fig. 2) is covered by weak alluvial-fluvioglacial formations. It has a flatten relief with height range of about 2 m, seldom more than that. The relief is complex and pit-and-mound, with a general tendency of decreasing westwards and southwards (to the Vyatka basin). There are many aeolian forms there, but they are not high (up to 2 m) and not long (30–50 m), they are of low sinuosity, represented by duny crests and separate dunes. According to the classification of B. A. Fedorovich [30], they can be attributed to rectilinear transverse ones and crescent-shaped ones. Round and oval deflation basins are also not big in size.

On the contrary, the territory of edge northern area of ancient-aeolian subtype of locality consists of high alluvial sediments of the IIId terrace above the floodplain. They directly contact with fluvioglacian sediments of the Vyatka valley slope. Here dunes are unusually large, up to 20 m high or more, they are divided by deep round basins. The dunes are mostly parabolic ones, but there are also enclosed aeolian formations, called “circular” dunes by B. A. Fedorovich [30]. North orientation of the arc point, together with considerable steepness of northern slopes (35–40º), indicates that they were formed mainly under the influence of southern winds. It looks like the northern valley slope of the Vyatka formed an obstacle for dunes further moving and contributed to collecting rich amounts of sand.

The relief of the central part of ancient-aeolian subtype of locality within the IIId terrace above the plain of the Vyatka (fig. 2) is characterized by circular dunes. Their diameter is up to 120 m, with deep deflation basins in the middle. In this part sands are high; dunes are well-defined, up to 5 m high. Steepness of inner slopes (25–30º) exceeds steepness of outer ones (15–20º). Circular dunes could be developed under the influence of the uniform system of wind blowing from the opposite directions [30], south-eastern and north-western ones.

The relief of the central part of the Medvedsky Bor within the IInd terrace above the floodplain is the most typical for the ancient-aeolian type of locality (fig. 2). Aeolian forms were developed here on powerful (20–30 м) sands, they are considerable in size, both vertically and in plan. Dunes are up to 10 m high, sometimes more than that. Separate dunes often merge into continuous dune ridges 500 m long, parallel to each other. In some places ridges get connected with each other in walls and form a cellated relief. Forms and orientations of dunes are quite diverse; on the whole, classical parabolic and complex parabolic dunes prevail. At merging they are often transformed into dune ridges and complex ridgy dunes [30]. The most parabolic dunes appear due to prevailing south winds. Asymmetry of slopes steepness is typical for aeolian forms in this part of the forest: low-sloped (15–20º) windward, and steeple (25–30º) leeward. Dune ridges and complex ridgy dunes usually stretch north-eastwards and are parallel to each other. Deflation basins, which separate parabolic dunes, are rounded in form, while interring basins are “8-shaped”.

In ancient-aeolian landscape horizontal redistribution of matter and energy is usually not considerable. Thus landscape catenae are not well-defined, they are similar to mesocatenae in size. They occupy the mesoform of the aeolian relief and usually they consist of 2 landscape sets. The top positions of aeolian mesorelief are occupied by eluvial sets, while slopes and the most basins with good drainage – by the transeluvial part of the transit set (fig. 2). Due to high sand sediments they almost do not differ in soil and vegetation. And any difference is caused by different lightening, microclimate, etc., rather than by catenative interactions.

Eluvial set includes facies of tops of aeolian knobs and dunes on surface haplic sandy podzol (Po_1Hs) under different types of pine forests (NMed-14, 40, 67), including lichens (NMed-18). In certain cases (they are not shown in fig. 2 due to scale restrictions) special conditions are created for formation of carbic podzols (NMed-74) or sod podzols (NMed-15).

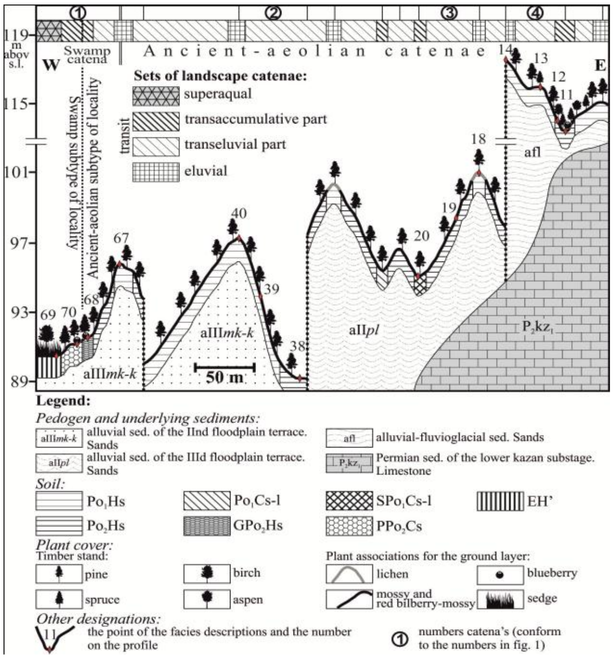

Figure 2: Landscape catenae of ancient-aeolian type of locality of Medvedsky valley-outwash landscape (interpretation of soil indexes: **Po_1Hs** – superficial haplic sandy podzol; **Po_2Hs** small haplic sandy podzol; **Po_1Cs-l** – superficial carbic sandy podzol; **GPo_2Hs** – small haplic sandy gleyic podzol; **SPo_1Cs-l** – superficial carbic sandy-loam sod podzol; **PPo_2Cs** – small carbic sandy peat podzol; **EH’** – eutric histosols)

Transit set of catenae is most often represented by the transeluvial part that occupies the largest area in the landscape. It includes sub-areas of dune slopes and ridges, as well as the most areas of interdune and some interridge basins. Depressions of mesorelief are attributed to this set because sand sediments are high. They let water and dissolved materials go through vertically. Transeluvial set occupies the biggest area in the landscape. Facies in the transeluvial set are noted for absence of both superficial and small sandy podzols (Po_2Hs) mostly haplic, in some basins – cabric, as a rule, under green mosses pine forests. Small podzols start dominating in lower parts of slopes, especially in basin areas. The reason of that is small increase of soil moistening in this direction and increase in the content of fine granulometric fractures which are good at holding in water.

The analysis of the power of catenative interactions within the upper parts of 20 ancient-aeolian catenae has shown that the catenative links between eluvial and transit sets are weak. The index F_{0cat}(EL/TEL) was 2.8. The power of horizontal interactions in individual catenae (F_{cat}) varied from 0 to 6. The only catena with the highest index (through facies NMed-7 – NMed-6 – NMed-5) belongs to the periphery part of the ancient-aeolian subtype of locality of Medvedsky Bor with a low power cover of sand sediments.

Transaccumulative part of the transit set is present only in separate mesocatenae. It includes some areas of interdune basins of the rear part of the IInd terrace over the floodplain of the Vyatka with the water stream due to neighboring upper parts (NMed-24, 28). For podzols in these areas (not shown in fig. 2) soil gleization is often characteristic. Pine forest of local plant associations includes white birch (*Betula pubescens*) which prefers moistened soil. Besides, the areas of basins of the IIId terrace over the floodplain inside circular dunes belong to the transaccumulative part of the transit area, for example, NMed-20 (not shown in fig. 2 of the facies NMed-86, 90). High level of accumulation of organic and mineral colloids is shown in soils, one of the reasons of its growing is the input from the upper facies. The soils of the areas are sod cabric sandy podzols, and in certain cases (NMed-20), sandy-loam (SPo_1Cs-l). Dense underlying sediments are situated not deeply (in the site NMed-86 they were opened with hand drilling 3.2 m deep). Plant associations are various – from green mosses pine forests (NMed-20) to pine-aspen green mossy-litter forests with spruce (NMed-86, 90).

Most often areas of interridge basins with a low-power cover of alluvial-fluvioglacial sediments (0.4 m in the point NMed-11) play the role of a transaccumulative part of a transit set in landscape mesocatenae of ancient-aeolian locality type. From the upper positions of mesorelief there is a stream of water and mineral and organic colloids. Still, on the whole, due to the fact that underlying limestone is covered with cracks, drainage is good and the facies are not over-moistened. On small haplic sandy podzol (Po_2Hs) one can often meet pine-birch spruce forests with blueberry-litter (fig. 2). Domination of spruce indicates comparative richness of soil, and domination of blueberry – hygromesophyte environment.

Only 6 out of 20 ancient-aeolian catenae have a transaccumulative part. There are catenative links of mid-power F_{0cat}(EL/TEL) = 6.2 between transeluvial and transaccumulative parts.

Swamp subtype of locality occupies the laid-out surface of the Ist terrace over the floodplain of the Vyatka and its left tributary the Voya River to the west and to the south from the ancient-aeolian one at the datum level 78–88 m (fig. 3). Downwards it is adjoined by floodplain landscape of the Vyatka. This subtype is also characterized by "insular" distribution in interdune lowlands of ancient-aeolian type, mostly within the edgy part of the II above-the-floodpain terrace of the Vyatka. The point NMed-76, whith the datume level 88.42 m (fig. 3), marks the contact of the IId and Ist above-the-floodplain terraces of the Vyatka and the Voya.

Due to flattened relief, the swamp subtype is characterized by a set of microcatenae consisting of facies which occupy hypsographic positions, low in contrast. Meanwhile, even inconsiderable differences in height (about 1 m), in conditions of high level of subsoil water, cause facies contrast and strong catenative interactions. Within the swamp subtype landscape catenae consist only of lower sets – of the transaccumulative part of transit, superaqual, and subaqual. The last link including the lakes of the edgy part of the IInd above-the-floodplain terrace and draining ditches of the Ist above-the-floodplain terrace, is not included in this paper.

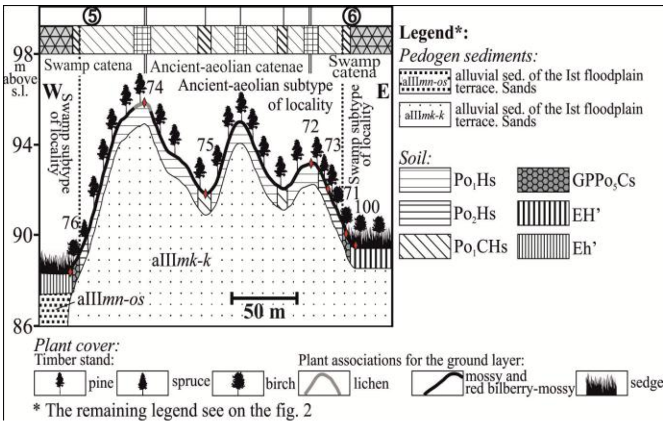

Figure 3: Swamp and ancient-aeolian catenae of Medvedsky valley-outwash landscape in the sone of contact of the I and IInd above-the-plain terraces of the Vyatka and the Voya (interpretation of soil indexes, which are not given in fig. 2**:** **Po_1CHs** – superficial carbic haplic sandy podzol; **$GPPo_5Cs$** – superdeep carbic sandy gleyic peat podzol; **Eh'** – eutric histosols)

The contact of swamp and ancient-aeolian subtypes presupposes absence of swamp mesocatenae which include transeluvial parts of transit and eluvial sets, as in fig. 2. As for their facies content and other peculiar features, these upper sets are actually similar to the corresponding parts of ancient-aeolian catenae. The analysis of 4 swamp catenae has shown that the link index F_{0cat}(EL/TEL) is 4.3.

The transaccumulative part of swamp catenae includes facies of two types of areas belonging to the swamp type of locality. Areas of spacious drained peat-deposits of the Ist above-the-floodplain terrace (not shown in fig. 3) occupy the most part of the transaccumulative set of swamp catenae of Medvedsky Bor. They provide influx of water and mineral compounds into lower-lying subaqual areas of draining ditches. Peat-humus eutrophic soil of the area accumulates much compost rich in ash-content (64%) neutral in reaction (pH_{KCl} = 6.8). The dominating phytocenosis is represented by drained bentgrass–reedgrass swamps with a mesophytic content (for example, facies NMed-101) with a big amount of megatrophic species, such as meadowsweet (*Filipendula ulmaria*), nettle (*Urtica dioica*), veronika (*Veronica officinalis*), orobus (*Lathyrus vernus*), thistle (*Cirsium vulgare*), ground ivy (*Glechoma hederaceae*), wheat grass (*Elytrigia repens*), including nitrophils, such as nettle, rosebay willow-herb (*Chamaenerion angustifolium*), wheat grass, knot grass (*Polygonum aviculare*), goose grass (*Potentilla anserine*). Other facies of the transaccumulative set have forest (or underwood, as for NMed-77) associations. They have developed on podzols and on gley peat-podzol (drypeat as for NMed-92), they have little drain to the lower positions and they differ in moistening degree. The most hydromorphic facies are placed on sub-horizontal surfaces of the Ist and IInd terraces above the floodplain (NMed-60, 77), even there the share of meso-hygrophytes and hygrophytes does not exceed 38% species of grass-small shrub layer.

In areas of interdune peat bogs of upper terraces the transaccumulative set of landscape catenae embraces the facies of the dune lower slope parts at their change into sedge (NMed-68, 70, 71). At these sites (fig. 2, 3) the species with completely different moistening regimes are close neighbors: stiff clubmoss (*Lycopodium* annotinum), red bilberry (*Vaccinium vitis-idaea*), etc. Such facies of the lower slope parts on the border of different types of locality have highly intensive catenative links and a variety of environmental conditions. This fact allows attributing them to the range of a landscape mesoecotone, or a transition band between geosystems [31]. Here strong two-side catenative interactions take place in tight space. On the one hand, the upper ancient-aeolian facies provides entry of organic and mineral colloids and determines the mesophyte image of the local association (92% species). On the other hand, the lower swamp facies contributes to flow of ground water and development of hydromorphic soils. Such are superdeep carbic sandy gleyic peat podzols ($GPPo_5Cs$) characteristic of the facies NMed-71 (fig. 3), or small carbic sandy peat podzols (PPo_2Cs) in the site NMed-70, which up the slope are changed by small haplic sandy gleyic podzols (GPo_2Hs) in the site NMed-68 (fig. 2). Bottoms of some interdune basins of the IIId above-the-floodplain terrace on drypeat podzols underlied from 1 m deep by Permian sediments are the least hydromorphic transaccumulative facies. Upper facies supply input of humus, mineral substances into water, which periodically leads to sinter overmoistening and formation of drypeat horizon. As for the vegetation, only some rare plants of haircap serve as sings of overmoistening. Accumulation of biophylic elements leads to growth of megatrophic plant species, such as Siberian fir (*Abies sibirica*) in timber stand, bird cherry (*Padus avium Mill.*), Norway maple (*Acer platanoides*), mountain ash (*Sorbus aucuparia*), fly honeysuckle (*Lonicera xylosteum*) in the underwood. For swamp catenae middle and high power of interaction is characteristic between transeluvial and transaccumulative sets on the border of ancient-aeolian and swamp subtypes of locality. The average index of F_{0cat}(TEL/TA) was 7.0.

The superaqual set of landscape catenae includes overmoistened facies which belong to interdune peat-bogs. Geosystems are definitely hydromorphic in conditions of highly restricted drainage at the dune bottoms or on flat-concave surfaces in interdune depressions. These positions collect water, mineral and organic connections from the surrounding ancient-aeolian complexes, as well as from transaccumulative sets of swamp catenae, and they are characterized by a higher level of groundwater – 50-110 cm. Facies of flattened dune bottoms (НМед-69) on eutric histosols are less hydromorphic within the set. There are few species of hygrophytes and megatrophs (marsh sedge (*Carex acuta*), etc.), but they occupy a big plant cover, which is caused by affluent water inflow and by input and accumulation of organic colloids and mineral salts of calcium, ferrum, magnesium, etc. (fig. 2). Facies of flat-concave surfaces in imterdune depressions are the most hydromorphic (fig. 3). Here groundwater is 50–80 cm deep. Vegetation is represented by reed swamps, sedge swamps, sphagnum-sedge swamps on eutric histosols. Sedge swamps are the most typical of these locations (NMed-76, 100). Inflow of groundwater rich in fertilizer elements provides hygrophytic vegetation in these facies (67%), beaked sedge (*Carex rostrala*) is dominating. Microcatenative interactions between facies are seen inside the superaqual set under sphagnum-sedge swamps on eutric histosols (NMed-109) and under reed swamps placed lower (by 0.5 m) on eutric histosols (NMed-57). Because of geographical scale these facies were not reflected on the catenative profiles. In this microcatena reed swamps occupy rather superaqual-subaqual position as they are periodically occupied by a lake. Groundwater rich in biophylic elements changes its level, depending on the season, but it is always available to the plants of the facies, and, first of all, to reed (*Phragmites australis*), which requires mineral

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nourishment. The neighboring upper sphagnum-sedge facies has a definite deficit of groundwater with mineral salts available to plants, it happens due to drainage provided by reed lake-swamp complex. At the same time, peat has a high value of acidity (pH = 4) and a low degree of decomposition (OB = 90%). As for the requirements to mineral nourishment, the most species are mesotrophic, while such as cranberry (*Oxycoccus palustris*), sundew (*Drosera rotundifolia*), and scheuchzeria (*Scheuchzeria palustris*) are typical oligotrophic plants. Lack of mineral salts and high acidity in the upper part of the peat horizon could be proved even more by the fact that sphagnum (*Sphagnum*) is dominating in mossy-lichen cover (40–80%). Such facies could be tenuously attributed to lower swamp ones, according to the place they take in mesorelief: their soil and vegetation have definite features of upper ones, or, at least, of intermediate swamp geosystems. The lower sets of swamp catenae are characterized by strong horizontal links: F_{0cat}(TA/SuperAqua) = 9.7.

Karst subtype of locality is differentiated within the IInd and IIId above-the-floodplain terraces of the Vyatka, as well as in the belt of alluvial-fluvioglacial sediments in the left bank area of the Yurtik River and the Klyuka River.

The forms of mesorelief within the karst subtype are rather various. Among them 2 types of karst conical depressions prevail: cone-shaped and saucer-shaped. Cone-shaped depressions do prevail (fig. 4), their ratio of depth (h) to the upper diameter (d) is about 1/5. For example, the Karst conical depression 1 (fig. 4), which is 50.0 m in diameter and is 11.4 m deep, with h/d equal to 1/4,4.

Within the subtype, apart from the typical conical depressions with symmetrical borders and small bottoms, one can also meet conical depressions with a broad flattened bottom and asymmetric borders, such as the Karst conical depression 2 (fig. 4), with d = 52, and h = 12.7 m. The ratio h/d of such conical depressions is similar to the typical one and is equal to 1/4.1. On the bottom of such conical depressions one can usually finds swamp facies. For them it is typical to have a small daughter depression nearby the parental one. They are divided by a thin barrier which disappears in course of their growth, which leads to development of karst basins with transverse riffles on the bottom.

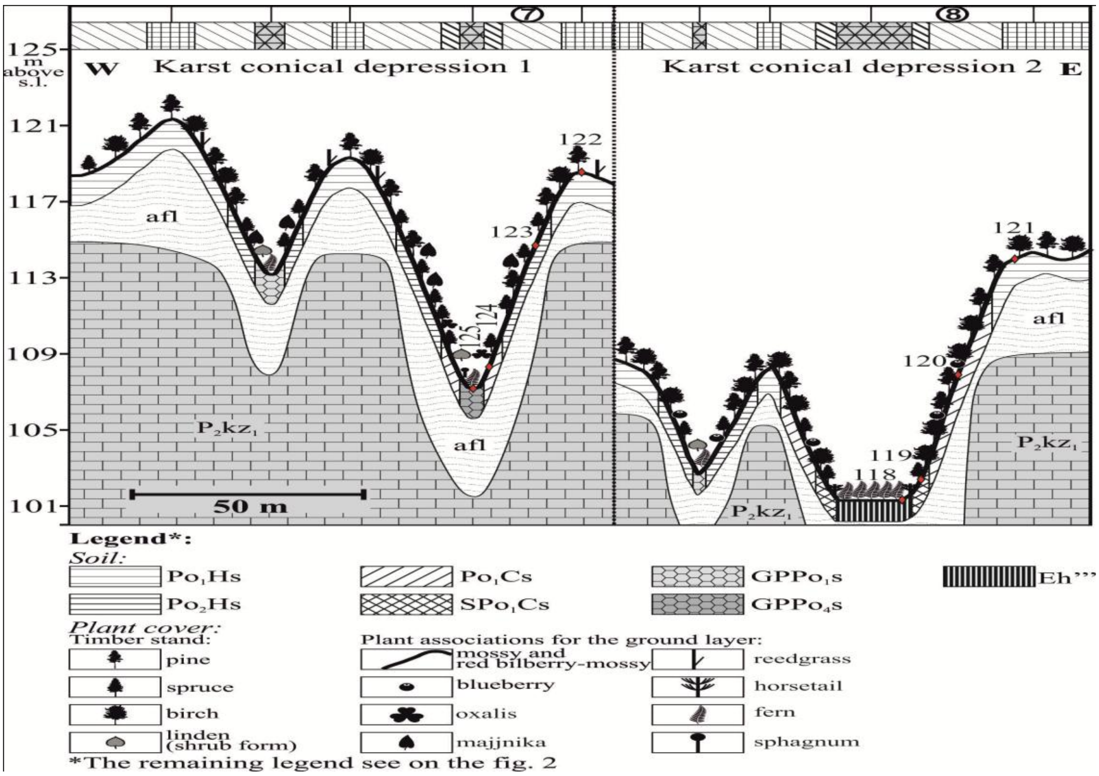

Figure 4: Landscape catenae of cone-shaped karst conical depressions: 1 – typical; 2 – with a broadened bottom and asymmetric slopes

(interpretation of soil indexes, which are not given in fig. 2, 3: **Po_1Cs** – superficial carbic sandy podzols;

$GPPo_1s$ – superficial sandy gleyic peat podzol**;** **$GPPo_4s$** – deep sandy gleyic peat podzol; **Eh'''** – Eutric Histosols)

Cone-shaped karst conical depressions are the youngest karst formations. In the process of desalination and suffusion carrying-out they broaden and the sides gradually flatten out, the bottom gets peatified, and the karst conical depression becomes saucer-shaped. And evolution of karst conical depressions goes on this way: 1) a typical cone-shaped karst conical depression (fig. 4, Karst conical depression 1) – 2) a cone-shaped karst conical depression with a broadened bottom (fig. 4, Karst conical depression 2) – 3) a saucer-shaped karst conical depression (fig. 5).

Such a succession of development phases of karst conical depressions in the Medvedsky Bor can be proved by measurement of datum level of their bottoms which get smaller as the phase of development of karst conical depression changes: 1) 107.15 m above s.l. – 2) 101.30 m above s.l. – 3) 100.75 m above s.l. At the same time, overlying sand sediments contribute to the karst conical depressions staying longer at the conical stage of their development [32]. That’s why such karst forms prevail in the valley-outwash landscape of the Medvedsky Bor. Saucer-shaped form of karst conical depressions is characterized by the ratio of depth and the upper diameter from 1/5 to 1/10. Such karst conical depressions are usually more spacious that cone-shaped ones. The example of such a karst conical depression is given in fig. 5. Its depth is 17.3 m, its diameter is 158 m, ratio h/d = 1/9.1. On the bottom of the karst conical depression a facies of a sedge-sphagnum swamp is described (NMed-110).

Evolutional stage of development in many ways determines landscape catenative links inside areas of karst conical depressions. Landscape mesocatenae develop the characteristic space of karst landscape. A set of catenative links is not absolutely complete; still it is represented well enough. Eluvial, transit (the transeluvial part), and superaqual sets change each other downwards. Separate catenae, mostly those of old mesoforms of karst relief, have a transaccumulative part of the transit set, which is restricted in area, in the lower slopes (NMed-111). The ultimate (subaqual) catenative link, which in itself represents aqualandscape, is in most cases absent, but in some cases it is occupied by a karst lake.

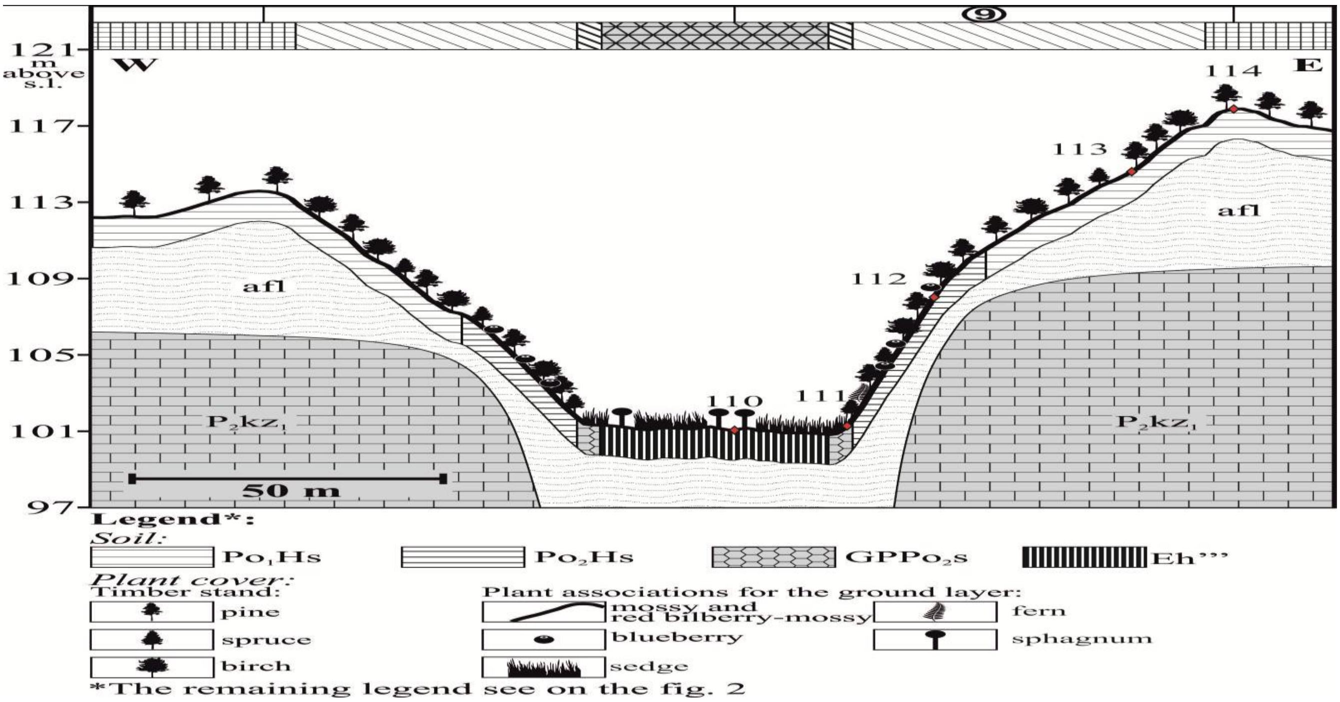

Figure. 5. Landscape catenae of saucer-shaped karst conical depressions of Meddvedsky valley-outwash landscape (interpretation of soil indexes, which are not given in fig. 2–4:

$GPPo_2s$ – small sandy gleyic peat podzol)

The eluvial set consists of upper facies with atmospheric moistening and with dominance of birch-pine forests on superficial haplic sandy podzols. Eluvial facies on high sand sediments have almost no influence on the lower complexes. Good drainage contributes to strong drying out of soil and a high degree of mesophytes (first of all, red bilberry) in the grass-small shrub layer.

The transit set in the most young cone-shaped karst conical depressions is represented only by the transeluvial part. It includes sub-areas of steeple (up to 40°) slopes with atmospheric moistening under birch-pine forests usually mixed with spruce. The soils of the set are either small haplic sandy podzols (NMed-123, fig. 4), or carbic sandy podzols (NMed -120, fig. 4). In conditions of closely placed underlying sediments soil moistening is higher, that is why presence of podzol is morphologically better expressed. The higher level of moistening contributes to absolute dominating of hygro-mesophytes (first of all, blueberry) in grass-small shrub layer of plant associations. In middle and, especially, in lower parts of slopes, in timber stand of the facies the importance of spruce grows, spruce requires mineral elements. It is provided by inflow of mineral and organic colloids from the upper positions, and by the fact that primary carbon-bearing underlying sediments are positioned not deeply, due to driftage of some part of sand. Flat-lying upper parts of slopes of saucer-shaped karst conical depressions within the transit set, like the upper facies, are occupied by superficial haplic sandy podzols (NMed-113, fig. 5). Even facies of bottoms of not deep young karst conical depressions with good drainage can be attributed to the transeluvial part of the transit set. As the research of 3 conical depressions belonging to different evolutional plases has shown, the power of interactions of the upper sets of karst catenae is not great (F_{0cat}(EL/TEL) = 4.3), still it exceeds the same index for the ancient-aeolian ones.

The transaccumulative part of the transit set of landscape catenae includes the facies which occupy the lower, comparatively flat (5–15°) slope parts with atmospheric-groundwater moistening. As a rule, in this set facies of spruce-birch forests dominate on carbic sod podzols, in which humus content gradually decreases with depth (NMed-119, fig. 4). Humus substances of the illuvial horizon are partially flown over from the upper facies. The increased content of humus contributes to spruce growth in the timber stand and many megatrophic grasses in the grass-small shrub layer, such as orobus (*Lathyrus vernus*) and goatweed (*Aegopodium podagraria*). Inflow of groundwater and the increased sinter moistening in the lower part of the slope causes dominating of birch in the timber stand and disappearance of pine. Grass-small shrub layer of the association becomes meso-hygrophytic due to high projective cover of horsetail (10%).

Even more a hygromorphic variant of the facies, which are restricted within the set, is represented by sedge swamps on small gley peat podzolds (NMed-111, fig. 5). These facies are found on flat lower parts of slopes of old saucer-shaped karst conical depressions and they are under two-side influence. The upper sets of the catenae provide water inflow, while lower overmoistened geocomplexes broaden their geographical range up the slope by means of expansion of hygrophyte sedge phytocenoses (fig. 5). Grasses which need moistening are neighboring here with mesophytic groups which are typical for the transit catenative set. Such environmental variety, together with a high intensity of matter and energy interchange, allows attributing the transaccumulative set to the range of a landscape ecotone. The power of catenative links between the upper and the lower parts of the transit set is maximum (for this boundary) among all the landscape of the Medvedsky Bor (F_{0cat}(TEL/TA) = 8.0). It is explained, evidently, by very steeple slopes and the fact that the underlying sediments are close by.

The superaqual set of karst catenae includes bottom facies of deep karst conical depressions with swamps, as a rule, on eutric histosols (Eh'''). In some cases the soil of the set is represented by peat gley podzols (NMed-125, fig. 4). These placements are notable for problematic drainage and the main influence of the upper facies, because of inflow of water, organic and mineral connections. Strong overmoistening leads to development of a high layer of poorly-decomposed acid peat. Plant cover of the set consists completely of hygrophytes, of beaked sedge and of hairy-fruited sedge (*Carex lasiocarpa*), shuttlecock fern (*Matteuccia struthiopteris*), water dragon (*Calla palustris*), sphagnum, hair-cap moss, etc. Only in some facies on peat podzols mesophytes play a comparatively more important role. The position of the set in the very bottom of the landscape catena contributes to accumulation of organic and mineral connections there. Thus hygrophilous species which form the background of bottom facies vegetation are usually megatrophic, which prefer soils rich in organic matter. On the whole, the area of the superaqual set increases with the age of the karst conical depressions (fig. 4, 5). There take place strong horizontal interactions between the transaccumulative part of the transit set and the superaqual set of karst katenae (F_{0cat}(TA/SuperAqua) = 8.7), though the index is less than the average one for swamp catenae.

CONCLUSIONS

As a result of landscape research of the territory of the Medvedsky sandy valley plain, difference in the character of catenative links was stated: from their being completely absent to their being strong and various. In ancient-aeolian landscapes on high sandy sediments catenative interactions are rather weak (F_{0cat}(EL/TEL) = 2.8). Landscape catenae are separated just nominally and they consist just of 2 upper sets: eluvial and transeluvial parts of the transit set. Difference in soil and vegetation of the sets is not considerable and it is usually not connected with catenative interactions. The factor of lightening is even more important here. Catenative links considerably increase (F_{0cat}(TEL/TA) = 6.2) only on the periphery of the ancient-aeolian subtype, where the height of the sand sediments decreases, and in some close interdune basins at the back part of the IInd terrace above the floodplain of the Vyatka, where groundwater rises from time to time. In these sites the lower part of landscape catenae is represented by a transaccumulative part of the transit set. Due to the high level of groundwater, swamp landscapes are characterized by considerable horizontal redistribution of matter and energy even in conditions of weak compartmentalization of the relief. Swamp catenae can consist of connection of 4 links: eluvial, transit, superaqual, and subaqual. The upper sets of swamp catenae on the border of ancient-aeolian and swamp subtypes of locality are represented by dune complexes. Only the transaccumulative part of the transit set, subaqual (and superaqual) sets with strong catenative interactions (F_{0cat}(TA/SuperAqua) = 10) are attributed to properly swamp landscapes. Karst landscapes represent one of the examples of geosystems with the fullest connection of catenative sets: in some karst conical depressions there are at the same time eluvial, transit, superaqual and subaqual (a kast lake) sets. On the whole, horizontal redistribution of matter in karst landscapes is stronger than in ancient-aeolian ones, and in many cases it depends on the age of the karst conical depression: its power increases with age, from young karst conical depressions to old ones, and then again it decreases during considerable flattening of karst relief. The power of catenative interactions in the lower sets of karst catenae (F_{0cat}(TA/SuperAqua) = 8.7) is, on the whole, smaller than the same index for swamp catenae, and their upper and middle sets, as for the power of interaction (4.3–8.0), can even exceed the same parts of the swamp ones (4.3–7.0).

Thus, horizontal interaction between morphological elements of sandy valley landscape is quite complex. The power of such an interaction is determined, first of all, judging by the height of the cover of light sandy-loam sediments. Their high power neutralizes catenative links, which always grow from the upper sets to the lower ones and from the central part of the sandy valley to its periphery. The factor that contributes to lateral influence of natural-territorial complexes on each other consists in composition of compartmentalized mesorelief with local hydromorphism of geosystems.

REFERENCES

[1] Matushkin, A.S., Baranov, A.I., 2015, “The Soil Covers Structure of Sandy Valley Plains of the Vyatka-Kama Region”, Proc. 5th International Scientific Conference “Reflection Bio-Geo-Antroposferal Interactions in Soils and Soil Cover”, Tomsk State University, Tomsk, Russia, September 7-11, 2015, pp. 142-146.

[2] Matushkin, A.S., Prokashev, A.M., 2012, The Sandy Valley Landscapes of Medvedok Pine Forest, Raduga-Press, Kirov, Russia.

[3] Matushkin, A.S., Prokashev, A.M., 2012, “The Comparative Analysis of Structure Ancient-Winds Landscapes of the Nature Sanctuary “Medvedsky Bor”, Geographicheskiy Vestnik PGU, vol. 20(1), pp. 15-31.

[4] Berezhnoi, A.V., Berezhnaya, T.V., 2004, “Landscape-Ecological District of the Voronezh Region and their Catenas”, Proceedings of Voronezh State University Series: Geography. Geoecology, vol. 1, pp. 110-117.

[5] Milne, G.,1936, “A Provisional Soil Map of East Africa”, Geograf Review, vol. 26, pp. 522–523.

[6] Gennadiev, A.N., Zhidkin, A.P., 2012, “Typification of Soil Catenas on Slopes from the Quantitative Manifestations of the Accumulation and Loss of Soil Material”, Eurasian Soil Science, vol. 45(1), pp. 12–21.

[7] Samonova, O.A., Aseyeva, E.N., 2013, “Distribution of Metals in Particle Size Fractions in Soils of Two Forested Catenas (Smolensk-Moscow Upland)”, Geography, Environment, Sustainability, vol. 6(2), pp. 28–33.

[8] Owliaie, H., 2014, “Soil Genesis Along a Catena in Southwestern Iran: a Micromorphological Approach”, Archives of Agronomy and Soil Science, vol. 60(4), pp. 471–486.

[9] Jauss, V., Lehmann, J., Johnson, M., Krull, E., Daub, M., 2015, “Pyrogenic Carbon Controls Across a Soil Catena in the Pacific Northwest”, Catena, vol. 124, pp. 53–59.

[10] Semenkov, I.N., Kasimov, N.S., Terskaya, E.V., 2015, “Vertical Geochemical Structure of Soils of the Forest-Steppe Loamy Catenas of a Balka Water Catchment Area in the Centre of the Srednerusskaya Upland”, Vestnik Moskovskogo Unviersiteta, Seriya Geografiya, vol. 5, pp. 42–52.

[11] Derbentseva, A.M., Chernovalova, A.V., Nesterova, O.V., Semal, V.A., Ribachuk, N.A., Surzhik, M.M., Mayorova, L.P., 2015, “Podgorodenka Natural-Technogenic Soil Catena: Morphological, Physicomechanical, and Chemical Properties”, Contemporary Problems of Ecology, vol. 8(1), pp. 99–111.

[12] Semenkov, I.N., Kasimov, N.S., Terskaya, E.V., 2016, “Lateral Distribution of Metal Forms in Tundra, Taiga and Forest Steppe Catenae of the East European Plain”, Vestnik Moskovskogo Unviersiteta, Seriya Geografiya, vol. 3, pp. 29–39.

[13] Konarbaeva, G.A., 2016, “The Contents and Distribution Patterns of Bromine in Soils of the Catena on Baraba Plain”, Agricultural Chemistry, vol. 2, pp. 60–64.

[14] Pasquini, A.I., Campodonico, V.A., Rouzaut, S., Giampaoli, V., 2017, “Geochemistry of a Soil Catena Developed From Loess Deposits in a Semiarid Environment, Sierra Chica De Córdoba, Central Argentina”, Geoderma, vol. 295, pp. 53–68.

[15] González-Arqueros, M.L., Vázquez-Selem, L., Gama Castro, J.E., Sedov, S., McClung de Tapia, E., 2013, “History of Pedogenesis and Geomorphic Processes in the Valley of Teotihuacán, Mexico: Micromorphological Evidence from a Soil Catena”, Spanish Journal of Soil Science, vol. 3(3), pp. 201–216.

[16] Lisetskii, F.N., Goleusov, P.V., Moysiyenko, I.I., Sudnik-Wójcikowska, B., 2014, “Microzonal Distribution of Soils and Plants Along The Catenas of Mound Structures”, Contemporary Problems of Ecology, vol. 7(3), pp. 282–293.

[17] Sewerniak, P., Jankowski, M., Dąbrowski, M., 2017, “Effect of Topography and Deforestation on Regular Variation of Soils on Inland Dunes in The Toruń Basin (N Poland)”, Catena, vol. 149, pp. 318–330.

[18] Hartemink, A.E., Bockheim, J.G., Bero, N., Gennadiyev, A.N., 2017, “Short-Range Variation in a Wisconsin Soilscape (USA)”, Eurasian Soil Science, vol. 50(2), pp. 198–209.

[19] Muromtsev, N.A., Anisimov, K.B., 2015, “The Peculiar Formation of the Water Regime in Soddy-Podzolic Soil in Different Positions of Soil Catena”, Bul. Pochv. Inst. im. V.V. Dokuchaeva, vol. 77, pp. 78–93.

[20] Shabanov, V.V., Soloshenkov, A.D., 2016, “Differentiation of Moistening Types and Types of Soils Water Feeding on the Catane”, Prirodoobustroystvo, vol. 1, pp.97–101.

[21] Polinov, B.B., 1956, Selected works, Akademiya nauk SSSR, Moscow, USSR.

[22] Glazovskaya, M.A., 1964, Geochemical Fundamentals of Typology and Methodology of the Study of Natural Landscapes, MGU, Moscow, USSR.

[23] Milkov, F.N., 1974, “Microtonalist Slope of Landscapes”, Nauchniye Zapiski Voronezhskogo Otdeleniya GO SSSR, vol. 1, pp. 3-9.

[24] Berezhnoi, A.V., 1983, Microtonalist Slope of the Central Russian Forest-Steppe Landscapes, VGU, Voronezh, USSR.

[25] Volkova, N.I., 2001, “Landscape Structure of Opol'e-Poles'e Catena as a Result of its Functioning”, Ekologia Bratislava, vol. 20(3), pp. 118–124.

[26] Avessalomova, I.A., 2014, “Landscape Neighborhood as a Factor Transforming Lateral Flows”, Voprosi Geografii, vol. 138, pp. 233–250.

[27] Khoroshev, A.V., 2015, “Landscape-Geochemical Basis of Designing the Ecological Network of Agrolandscapes (Case Study of a Middle Taiga Landscape in the Arkhangelsk Oblast)”, Vestnik Moskovskogo Unviersiteta, Seriya Geografiya, vol. 6, pp. 19–27.

[28] Malinowska, E.,Ároglińska, K., 2011, “Spatial Variability of Soil Properties in the Slope Catenas in the Vicinity of Murzynowo (Central Poland)”, Prace i Studia Geograficzne, vol. 46, pp. 77–92.

[29] Malinowska, E., Szumacher, I., 2013, “Application of the Catena Concept in Studies of Landscape System Dynamics”, Miscellanea Geographica, vol. 17(4), pp.42–49.

[30] Fedorovich, B.A., 1983, Dynamics and Regularities of Morphogenesis of Deserts, Nauka, Moscow, USSR.

[31] Sochava, V.B., 1975, The Doctrine about Geosystems, Nauka, Novosibirsk, USSR.

[32] Stupishin, A.V., 1967, Lowland Karst and its Development on the Example of the Middle Volga Region, KGU, Kazan, USSR.