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RIVER VALLEYS AS THE OBJECT OF ECOLOGICAL AND GEOBOTANICAL RESEARCH

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The river valleys are characterized by high diversity of ecosystems, their originality, complex structure and dynamics. Changes in vertical displacements from the plain to channel in various parts of catena, which can be seen as an intricate complex integrating coenoses formation, geomorphological and pedogenic processes, are very important. Plant communities serve as indicators of territorial and temporal changes. Combinations of the communities within the ecological series influenced by environmental factors are characterized as ‘ecomers’, which reflect the trends of ecosystem changes, i.e. β -coenodiversity. Quantitative assessment of these plant communities is possible based on the synphytoindication methodology. There were selected three model river valleys, namely, those of the Sluch, Dniester, and Krasna rivers. Comparison of these rivers is of a special interest because they have different dimensions and flow in different natural areas. The topological differentiation in ecological series of the river valleys served for comparison of the ‘ecomers’, i.e. for assessment of β -coenodiversity differentiation towards changes of leading ecological factors.

Key words: river valley, β -coenodiversity, catena, ecomer, plant communities

Introduction

The biosphere depends on the water regime which determines distribution of ecosystems and their diversity. Rivers play important role and the way they function depends on many factors such as climate, topography, geological structure, water resources, vegetation, etc. On the other hand, rivers are difficult paragenetic systems which affect the nature of topography, landscape, soil, and biotic components of the ecosystems. These functions of the river are defined by paragenetic structure of the river valley that is formed by a complex interaction of zonal-regional location, climate impact, watercourse power, altitude, exposure and slope of the banks, geological structure, landscape structure, riverbed nature, presence of terraces, degree of floodplain inundation, vegetation, hydrological regime, etc. The movement of physical, chemical, and

biotic components of the energy flows occurs both in a horizontal direction, from the source of the river to its mouth, and vertically, from the plain to the channel. River valleys are the subject of study in many disciplines such as geography, landscape ecology, and geobotany.

Ranking of the configuration of river basins reflects particular features of their organization. The lower rank rivers are known to be more sensitive to seasonal climate change as well as other phenomena and appear to be more uniform than rivers of higher levels. In the basins of lower rank rivers, the volume of flow depends on afforestation areas, waterlogging, soil cover, and rainfall, whereas in the basins of higher rank ones these dependencies entirely disappear and are not present within the levels 6 and 7 (Hrodzynskyi, 2005).

In addition to zonal-regional characteristics, river valleys also vary from the source to the mouth and are divided into the upper, middle and lower reaches, each with its own characteristics.

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The patterns of territorial distribution, the structure of valleys, and the form of landscape components are indicators of the processes they were formed by, which can be described within the framework of fractal theory, such as sinusoidal tortuosity of channel, arborescence of hierarchical combination of tributaries, character of cirques and ravines systems on shores, linearity of alluvial sediment, shape and location of the oxbow lakes.

Apart from the patterns that reflect the nature of regional changes of river valleys and horizontal movement of the material-energy reserve, change in vertical displacements from the plain to channel in various parts of the catena including water parting, slopes, terraces, floodplain, and riverbed, is also essential.

The functioning of the catena depends heavily on geomorphological factors associated with relief, namely changes in exposure, steepness, and, consequently, heat, light, humidity, and evaporation. Significant altitudinal differentiation of relief in some catenas may result in vertical change in the altitudinal zones of vegetation and soils. In this case, the shape of slopes is important. Convex slopes indicate the presence of active deep erosion, while concave slopes indicate the reduction of soil erosion and reduction in the rate of vertical movements (Devis, 1962). Hydrological regime is greatly affected by the geological structure, which causes the internal pressure and outflow of ground water to the surface. Peculiarities of relief lead to changes in the distribution of sediments, and, consequently, formation of soil and its wealth. In the eluvial zone, the internal ecogenetic nature of successions defines the processes of natural accumulation of matter and organics, leading to autogenous pedogenesis. These processes slow down as slope steepness of the river valley increases. This transit zone is dominated by the processes of denudation and surface erosion, which cause soil depletion. In turn, soil depletion halts and even completely stops certain stages of the vegetation succession. Geological sediments and organics-rich soils tend to accumulate at the foothills of the slopes. In some places, colluvial sediments in the form of talus, landslides, and marl accumulate under the rocky outcrops. Alluvial fans of shallow sedimentary rocks are observed at the base of the slopes and occasionally can be found even in the floodplain.

All this determines complex nature of the ecosystems differentiation in the catena. The catena can be regarded as an intricate complex which integrates formation of coenoses, geomorphological and pedogenic processes.

Geomorphological processes affect the kinematics of relief, alluvial, transitive, and accumulative processes. The formation of coenoses within catena is determined by successions, which, in contrast to plakor, do not reach the final stages, but rather transition to the stable state due to the action of a specific external limiting factor on a particular succession unit, which should be interpreted as ecoclimacteric. Nodal stages (links) of plant communities form through these processes of certain direction and speed. The order in which these stages are located in the river valleys are considered as series (rows). Based on the role of a limiting factor or a group of thereof, lithosere, hydrosere, psammosere, and autogenous series can be recognized. Therefore, the catena allows for the fullest expression of natural spatial and temporal properties of ecosystems, which characterize diversity of region's ecosystems and its dynamics (Didukh, 2008). In this context, the vegetation cover is an important indicator of landscape-territorial and temporal changes. Floodplain exposes an entirely different pattern of differentiation and functioning, the one determined by the direct action of the water environment and can be considered as a terraqueous component of landscape (Lavryk (2013) includes riverbed to it). Unlike mesorelief of slopes, geomorphological differentiation of the floodplain is not as significant and is caused by microrelief, where a variegated diversity of habitats is determined by the layer of groundwater.

In addition to the changes of microrelief proper and depth of groundwater, seasonal changes in water regime are of importance as well. Together with other factors, they determine the type of plant cover. Based on the duration of flooding, short-term, middling streamside, and long-term flooding communities are recognized. Certain indicator species are present in each of these communities (Ramenskii, 1939; Mirkin 1974; Kurkin, 1976). To assess the variability of damping, there are developed appropriate integral scales (Ramenskii, 1939; Didukh, 2012).

In general, the floodplain is a highly dynamic system. Floodplain ecosystems are the least stable, because their resistant stability increases and plastic stability decreases in the direction from riverbed to slopes and eluvial plains and vice versa, with plastic stability being the highest in the ecosystems of hydrogenous type (Didukh, 2014). Accumulation of mechanical deposits and organic sediments (the highest biomass productivity leads to accumulation of highest energy reserves) and constant turnover of these alluvial deposits are charac-

teristic for the floodplain. Therefore, the floodplain can be considered as an area of perturbation of paragenetic configuration of landscape, which is characterized by high degree of seasonal fluctuation, turbulence, and even catastrophic processes that are of great interest for the research of ecosystem dynamics. Unique vegetation classes (*Bidentetea tripartite*, *Nano-Juncetea*, *Salicetea purpureae*, *Alnetea glutinosae*, *Phragmito-Magnocaricetea*) form in the floodplain. Furthermore, floodplains allow for the incursion of invasive species and often have the highest concentration of transformer species (Didukh, 2014).

The third component of the river valley is the channel proper. Its functions are determined by such factors as width, depth, water flow capacity, speed and nature of water movement, seasonal changes in its extremes, bottom sediment substrate, the presence of rapids, flatwaters, pits, chemical composition of water (in particular the degree of eutrophication), to name a few. This type of habitats is distinguished by being the most dynamic. Rapid recovery (plasticity) is the key to their stability. Specific helophyte communities (*Lemnetea*, *Potametea*, *Zosteretea*), algal and zoological complexes, such as plankton and benthos, are important components of these habitats. Indicator scales and indices developed for these communities and complexes are used in the assessment of water (Rozenberg, 1984; Didukh, 2012).

It can be concluded that the river valleys are characterized by high diversity, originality, complex structure, and dynamics of ecosystems. Plant communities serve as indicators of territorial and temporal changes. Quantitative assessment of these plant communities is possible based on the synphytoindication methodology (Didukh, 2012). The success of such research requires logical ordering of distribution of territorial and temporal components of ecosystems reflecting these patterns. Methodology-wise, it is important to shape researcher's understanding of the river valley as a complex functional system.

Topological differentiation and temporal dynamics of the river valley ecosystems

Differentiation of ecosystems can be analyzed from three angles:

1. topological (α -diversity), reflected in classification of syntaxa;
2. topological (β -diversity), reflected in the way coenoses are connected in the landscape (phytocoenomers);

3. territorial (γ -diversity), the way coenoses are located in any given territory, and estimate the size of their areas (phytocoenokhors) (Didukh, 1995).

Phytocoenomers are understood as order of a set of communities that are linked to each other within a certain ecological series, thus reflecting a gradient of changes occurring throughout these communities, namely β -coenodiversity. When coenotic and ecological indicators are analyzed, in other words, when changes at the level of habitats are assessed, phytocoenomers are understood as *ecomers*. The terms 'phytocoenomer' and 'phytocoenokhor' were introduced by V.B. Sochava (Sochava, 1972; 1979) in the framework of mapping of vegetation, once it was determined that hierarchy of the syntaxonomic units does not correlate and cannot be used for mapping of vegetation at any scale. In Western Europe this is reflected in Symphytosociology (Tuxen, 1979) and subsequently in the dynamic-catenal phytosociology (Rivas-Martinez, 2005).

Logics behind a legend to a map differs from the logics behind classification of vegetation. The former depends primarily on the size of the plots occupied by coenoses and the way they are linked, rather than on the extent of taxonomic differences. When similar types of coenoses are merged into one, their rank is elevated to the highest syntaxonomic category they have in common. If, however, coenoses are very different, they cannot be presented as one system, since their properties expressed in khoric units are lost. Hence, there is a need to find other traits or factors that can be used as a basis to form a unified system. In this case, instead of transcending the boundaries of the coenotic (syntaxonomic) categories proper, other characteristics, such as ecological series, stages of succession are used. In contrast to the well-developed and fine-tuned syntaxonomic classification, research into underpinning such systems is in its infancy. Novel mathematical methodology that can be used to evaluate the ranks of phytocoenomers and phytocoenokhors, to determine their scope, degree of differentiation, subordination, and, first and foremost, to determine principles upon which a sound system can be formed, is urgently needed.

Ecomers can be viewed as analogous to stratigraphic columns in geology, with suites being equivalent to the link of plant communities, facies, and series being equivalent to eco-topological series of plant communities. Research on spatial heterogeneity of plant cover at the level of landscape brings to light yet another problem, namely, which elementary units (links) should be used. This problem is further complicated by the con-

tinuous mode of changes, variation in extent of difference between adjacent departments, and presence of different stages of succession.

Rivas-Martinez (2005) proposed to call series of plant communities the *sigmeta*. Depending on the structure, distribution groups and factors that determine this distribution, he proposed to allocate *geosigmeta*, *permasigmeta* and *permageosigmeta* and have even developed principles for giving them Latin names according to the syntaxon, which represented a particular link. The development of these ideas finds support in mapping complex combination of plant communities (Pedrotti, 2013).

Thus the lowest part of an ecomer is a link. All links of various stages of succession combined together are understood as series. Serial communities are the ones which are at present in the intermediate stages of development, relative to the stable (climax) state. Dynamically, each plant association belongs to one or another of initial, intermediate, mature or deviant stages out of a vegetation series (Rivas-Martinez, 1987; 2011). Combination of links which change each other in a limited area and are caused by the limiting activity of a single or several mutually dependent factors, e.g., humidity, salinity, drainage, are considered as ecological (ecotopological) series (Isachenko, 1969; Didukh, 1995). M.A. Holubets (2005) defines ecological series as a naturally occurring or imaginary arrangement of living systems according to the gradient of environment or according to selected structural and functional indicators of a system that is being studied, provided that the indicators reflect the gradual changes of the ecological gradient. The combination of regularly occurring diverse communities, which are distributed based on the particulars of micro-relief forms, occupy limited areas, and do not form elements of landscape units is called a 'complex'. Regularly located communities (or complexes) that reflect the territorial distribution of communities caused by changes in mesorelief are considered as mesocombinations. Totality of heterogeneous communities, complexes or mesocombinations which reflect change in ecological conditions of macrorelief are known as macrocombinations (Isachenko, 1969).

Since the actual slopes of the river valley, floodplain, and channel are interconnected as spatial paragenetic parts of a landscape, they are combined at the level of the macrocombination. However, because they differ in structure, influence of limiting factors, the nature of dynamic processes, they are assigned to separate mezocombinations, which may be of different size

and structure. The banks can be steep, high, slopes — precipitous, floodplains — absent, and vice versa, a wide floodplain with oxbows, low banks, and slight terraces. The same applies to the relation between these components of the river valley and the channel.

Distribution of communities across the catena of slopes and on the floodplain, direction and speed of successions are different. Changes in habitats of the slopes are defined by the changes in mesorelief and are considered as mesocombination determined by the influence of a single system-forming ecofactor, which allows to maintain the state of dynamic equilibrium within the given system. Elementary mesocombination is a combination of coenoses represented by phytokhor of landscape level (100 × 100, 200 × 200 m), and mapped on the scale of 1:100000 (Yurtsev, 1988). Mesocombination is formed by a set of eco-topological series of a given landscape, which changes depending on altitude, steepness of slopes, and geological rock (Belikovich, 2000). In a different landscape, certain series, or links of some series can vanish altogether.

In the floodplain, phytocoenosis changes are determined by microrelief. It is within microrelief that fluctuations in groundwater and type of alluvial deposits are observed, and, consequently, processes of soil formation, which determine the type of succession, transition from peat-swamp, silty-marsh to meadow alluvial type. This natural change of communities from coastal vegetation to riverine sediment manes and shafts within a microrelief are considered as *complexes*. However, great variety, large areas of similar sites (links) and complexes in the floodplain allow to consider the totality of these elements on the level of mesocombination. Patterns of change of phytocoenoses (biotopes) within the riverbed are tied to the depth of water, speed of its movement, and type of the bottom substrate. Transition from hydrotops proper to floating (*Lemnetea*), rooted (*Potametea*) and coastal hydro-aerial communities (*Phragmito-Magnocaricetea*) forms ecological series, which can be joined into mesocombinations.

Therefore, the cross-section of the river valley can be viewed as an ecosystem of landscape level, which is characterized by a conjunction of three types of mesocombinations: valley slopes are a mesocombination of pedo-lithogenic type, floodplain is the one of pedo-hydrogenous type, and channel — of hydrogenous type proper; each of these combines individual links (specific plant communities or habitats) and includes relevant complexes, series (Fig. 1). The plakor portion is consid-

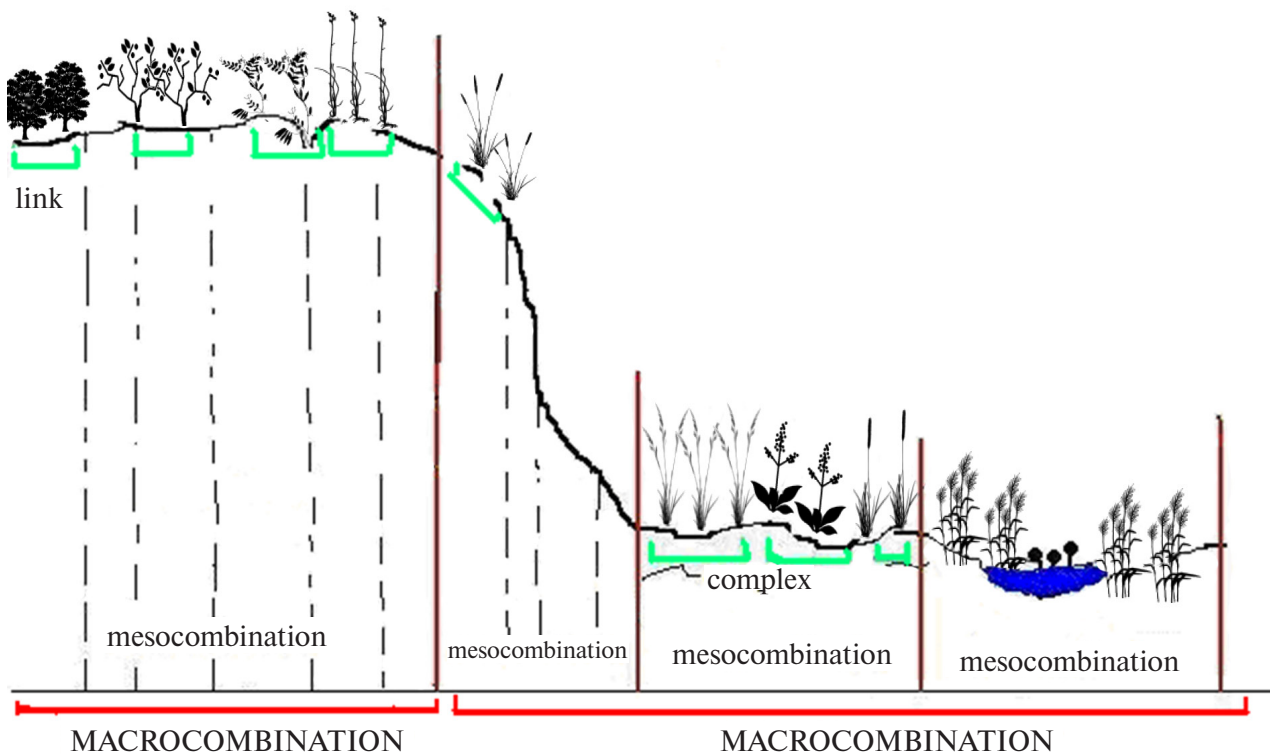











Fig.1. The cross-section of the river valley

Symbols:  — 1;  — 2;  — 3;  — 4;  — 5;  — 6;  — 7;  — 8;  — 9

Legend: 1 — *Quercus robur*; 2 — *Prunus spinosa*; 3 — *Vicia angustifolia*; 4 — *Poa angustifolia*; 5 — *Koeleria cristata*; 6 — *Festuca pratensis*; 7 — *Salvia pratensis*; 8 — *Alopecurus pratensis*; 9 — *Phragmites australis*

ered as a separate mesocombination or even a complex of thereof, and is a subject of a separate analysis. The totality of mesocombinations within given landscape is treated as a *macrocombination*.

Mesocombination changes, loss of individual series, which are observed from the upper river to its mouth characterize regional, eckhoral aspects which, albeit important, are not going to be considered here. The phenomenon of a shift in phytokhorion boundaries along river banks due to the presence, on the southern slopes, of communities of a vastly different type from the ones characteristic for the given region, is well-known. Particularly relevant is the question whether the river valley can be interpreted as a barrier (boundary) between the eckhors of regional level (zoning), or whether it is a link within the zoning units. When large rivers are considered, their differentiating role is not

questioned, whereas the role of middle rivers is up for discussion. In traditional geo-botanical zoning, when khorions were delimited based on the characteristics of plakor vegetation, boundaries between khorions were generally tied to rivers. However, eco-geo-botanical zoning of Central-Podilskyi geobotanical district, conducted by our group based on the analysis of distribution of all types of communities when plakor vegetation is violated or destroyed, has led us to question how appropriate it is to establish such boundaries strictly based on the plakor areas (Didukh, Vasheniak, 2013).

River valleys are interesting from the standpoint of dynamics, kinetics of ecosystems, which explore patterns underpinning changes in state of certain points (elements) in time. Kinematic approaches have already made their way into geomorphology (Devdariani, 1964); however, they are relevant to ecology as well. Environ-

mental kinematics is clearly a promising direction of future research, and a lot of valuable data can be gained from research on the river valley ecosystem dynamics. Of particular interest, from this standpoint, is research on positional-dynamic and paragenetic aspects, which reflect the type, speed, and magnitude of change in matter-energy processes (Hrodzynskiy, 1993), as well as direction, speed, degree of stability, risk of loss, appearance of some and disappearance of other elements, all of which are the basis for predicting future changes. Furthermore, successional development of vegetation has long been known to be complicated by the large-scale fluctuating changes, reflected in the fact that, in different years, vegetation of the same plot was recorded as belonging to different formations (Shennikov, 1924; Rabotnov, 1974).

The problem of the dynamics of ecosystems is particularly relevant due to the spread of the invasive transformer species, which change the structure of natural coenoses. The fact that river valleys serve as not only migration routes for the hydrophytes proper, which are waterborne, but also for species that, at first glance, are not directly connected to water, has been recorded in botanical literature long ago (Shennikov, 1924). Type of mezorelief provides far more diverse conditions than the plakor areas. When zonal climatic conditions are similar due to drainage, angle of slope (steepness), exposure, and baseline erosion, indicators of the thermal regime are higher and those of humidity are lower than on plakor. This, in turn, leads to a significant increase in intensity of evaporation and affects the hydrothermal regime. That said, excessively humid habitats of floodplains are the coldest. Observed elevated extent of plant cover differentiation occurs because of this high gradient of changes in hydrothermal regime. At the same time, species distributed along the border of their range are of narrower ecological amplitude relative to zonal species, and, under such diverse ecological-coenotic conditions, are able to find plots suitable for their distribution. The river valleys are highways spreading southern, more xerophytic species up north and northern, boreal species down south (Didukh, 2008).

This is of particular importance for the climate change research. We associate distribution of invasive species along the river valleys with the indirect climate changes. Temperature rise has been proven to affect ecosystems of high, 'cold' latitudes the most. Of all ecosystems of our temperate latitudes, the coldest and, thus, the most vulnerable are hydrophilic ones, and the toughest ones are the dry, lithophilic ecosystems.

Furthermore, the hydrophilic ecosystems of floodplains transformed the most through reclamation, creation of reservoirs, dams, and straightening of channels, which all cause eutrophication. Together, all of these factors determine the type of transformation of the floodplain ecosystems.

Therefore, research on the patterns of spatial-temporal changes and functioning of the river ecosystems is of utmost importance.

Methods of ecomer assessment

Field research of these aspects involves establishing a system of ecoprofiles and visual assessment of changes in plant cover based on the traits of the dominant species, which reflect the lowest level of syntaxa (variants). The geobotanical descriptions are provided for each site. If a given plot is small, several plots, with similar plant cover, relief, geology, and soil are described. Depending on the type of limit of important ecological factors and their interrelation (orographic features, height and steepness, slope exposure, outcrops of the geological rocks and their location, the impact of anthropogenic factors, type of soil, among others), each specific ecoprofile reflects this distribution, which is determined by the interaction of various factors. The task to be completed is to describe sufficient number of ecoprofiles to adequately represent all types of combinations. The next step is to process the data collected during the field research, and to create a database of geobotanical descriptions and to calculate ecofactor indicators based on phytoindication scales. Such calculations will allow to correct the position of the individual links relative to changes of indicators of ecofactors in order to construct ecological series.

In theory, these series can be constructed based on indicators of all 12 ecofactors. However, that is not necessary, and such series are constructed with respect to changes in key ecofactors or a group of thereof, or based on the corresponding structure of the coenoses (e.g. lithogenous, sylvatic, hydrogenous, psammogenous) (Sămărghișan, 2003). Ecological series should be distinguished from dynamic ones, which reflect successional development. Consequently, their links are represented by time-serial communities.

At the same time, syntaxonomic vegetation classification is constructed. Indicators evaluating similarity characteristics (floristical, ecological) between syntaxa, type of displacement of dominant species or individual groups are calculated as well.

The next step is the selection of ecomers (mesocombinations). The essence of this step lies

in construction of one or two conditional series based on actually existing profiles, ecological series, and classification data. Conditional series, in turn, characterize patterns in link distribution for a given region. Such series (mesocombinations) differ from ecological series in that the latter reflect how the links are ordered (the order of links) relative to changes in the dominant factor or several, mutually dependent dominant factors, such as change of steppe, forest, psammophyte vegetation.

Mesocombination reflects the sequence of links typical for this particular region. For example, the upper part of the slope of the bank can be composed of quaternary loess rocks, on top of which develop steppe communities (*Festucion valesiacae*, *Fragario viridis-Trifolion montani*), whereas on the slope of a bank, where the soil is washed away, steppe communities are represented either with certain differences or entirely different syntaxa. Furthermore, in the middle of the slope it is possible that the outcrops of tertiary limestone or chalk can occur in the middle part of a slope, and Devonian or Silurian sediments might be present in the bottom part of the slope. These links can be represented with *Stipo pulcherrimae-Festucion pallentis*, *Alyso-Sedetalia*, and, on the cliffs, with *Asplenietea trichomanis* communities. At the base of the slopes, where collin deposits of rocks accumulate, communities of the class *Thlaspietea rotundifolii*, shrubs (cl. *Rhamno-Prunetea*), or the edge coenoses (cl. *Trifolio-Geranietea*) form. Further down, where alluvial sandy sediments occur, *Agrostion vinealis* coenoses are present, which transition into meadow communities on the terraces and floodplains. In other cases, different pattern of alternation of coenoses may occur, e. g., typical nemoral forest coenoses (*Carpinus-Quercus*) are replaced by the thermophilic forests (*Quercion petraea*), but on the «foreheads», open edge coenoses (*Trifolio-Geranietea*) are observed. These latter coenoses transition into the meadow—steppe coenoses (*Cirsio-Brachypodion*), which, in turn, are replaced with steppe shrubs (*Prunion fruticosae*, *Berberidion vulgaris*). Forests of the *Alnion incanae* alliance are common at the bottom of the slope.

Thus, on one hand, each mesocombination combines elements, links of various ecological series, and, on the other hand, includes elements that could be absent from any given actually existing profile due to various reasons.

Research results

Let us consider this approach on the example of specific valleys, namely, those of the Sluch, Dniester, and Krasna rivers. Comparison of these rivers is of a special interest because they have different dimensions and flow in different natural areas. However, we did not intend to provide an exhaustive description or comparison of the ecomers of these rivers, which would require more extensive data collection. In the present study, we were merely trying to illustrate how the methodology of this approach could be practically applied.

The **Sluch** river takes its source in the Forest-Steppe zone of Podillya Upland near the village Chervony Sluch of Teofipol District, Khmelnytsky Region, flows through Polissya lowlands, and falls into the Horyn river. Based on the peculiarities of physical and geographical characteristics, the river is divided into upstream, middle part, and downstream. The upper part of the river stretches from the source in Khmelnytsky Region to the town of Myropil (Romaniv District, Zhytomyr Region), where the banks of Sluch are composed of loess rocks. The middle part of the river cuts through the Ukrainian Crystalline Massif from Myropil to Sosnove village (Bereznovsky District, Rivne Region), and the downstream part stretches from Sosnove to the confluence into the Horyn river in Rivne Region. The Sluch is a stream of the fourth order, with length of 451 km (Hrodzynskyi, 2007). Width of its valley is from 0.2 to 0.8 km in the upper part, to 5 km downstream. Width of the channel is from 5 to 50 m, with a maximum of 110 m. The slope of the river is 0.4 m / km.

Studies were conducted in the upstream and in the middle part of the river. Eco-coenotic profiles were established in the environs of the town of Staryi Ostropol (Starokostiantyniv District, Khmelnytsky Region). The South-Eastern slope of the left bank of the Sluch river is 20 m high. Its upper part is occupied by coenoses of *Artemisio marschalliani-Elytrigion intermediae* alliance (dominated by *Elytrigia intermedia* (Host) Nevski, *Bromopsis inermis* (Leyss.) Holub, and occasional *Chamaecytisus ruthenicus* (Fisch. ex Wöl.) Klask.). Coenoses of *Festucion valesiacae* alliance with dominant species *Festuca valesiaca* Schleich. ex Gaudin, *Medicago falcata* L., and some *Carex humilis* Leyss. are present in the middle part of the slope, and bottom part of the slope is occupied by the *Koelerio-Corynephoretea* coenoses, with *Sedum acre* L., *Euphorbia cyparissias* L. → *Melica transsylvanica* Schur being the dominant species. This

series combined meadow-steppe vegetation in the upper part, and psammo-pteridophytic in the bottom part.

Another profile was established near the village Mala Tokarivka (Romaniv District, Zhytomyr Region) on the left bank of Sluch, whose height reached 15 m, where the conditions are more mezophytic than in the previous site. Upland area was represented by the meadow coenoses of *Cynosurion cristati*, the well-heated and well-drained upper part of the slope — with *Cariceto praecocis-Thymetum marschalliani*, the middle part of the slope (with the 20° steepness) — by *Artemisio marschalliani-Elytrigion intermediae* (with dominant *Elytrigia intermedia*), and the bottom part — by *Arrhenatherion* (with dominant species *Briza media* L.).

Geobotanical descriptions of these plots were used to develop syntaxa classification and to perform their comparison based on the indicators of 12 ecofactors according to the method of synphytoindication.

Dniester is one of the longest rivers in Ukraine, with length of 1362 km. It originates in the north-eastern slopes of the Ukrainian Carpathians, flows through the Pre-Carpathian basin, Lviv basin, southern Podillya Plate, slopes of the Ukrainian Crystalline Massif, Black Sea lowlands, and falls into the Black Sea. Based on the peculiarities of orographic characteristics, Dniester is divided into upper (Carpathian), middle (Podolian), and lower (Black Sea plain) parts. The middle part of the river is the most interesting and unique. Here, the valley narrows and deepens, acquiring the canyon-like shape, with steep slopes (30—70°), cliffs (over 80°) up to 250 m high, and winding meanders.

On the cross-section profile of the banks, three parts can be clearly distinguished. Upper part, usually a gentle slope composed of Quaternary loam, clay, and Miocene deposits; middle part, with cliffs composed of solid rocks of middle Baden (gypsum, limestone), chalk (limestone, sandstone), Silurian and Devonian (limestone, dolomite, mudstone and marl) deposits; and lower part, where products of these rocks accumulate. This three-tiered profile of the Dniester Canyon plays an important role in the development of exogenous processes in the valley. The upper and middle parts of slopes are affected by such processes as erosion, sheet flood, in the middle part water denudation and landslides occur, and at the bottom part accumulative processes take place (talus, colluvial deposits and alluvial fans are formed).

Dniester valley is presented by the complex of heterochronous terraced levels. Of the 7—11 currently recognized levels of the terraces (Herenchuk, 1980),

only terraces of the levels 1—5 are present within the canyon. Fourth Middle Pleistocene terrace is located at the height of 70—60 m, third — at the height of 50—45 m. Narrow bottom of the valley is formed by Late Pleistocene terraces, the second one at the height of 35—25 m, and the first one at the height of 15—10 m. Terraces are expressed fragmentarily on convex, sloping areas of meanders.

Floodplain is rather narrow and clearly separated from the terraces by steep ledges. It can be divided into high (7—5 m) and low (3.5—0.5 m) parts.

Gray-forest and black-forest soils have formed in loess-loam and loess areas; sod-carbonate soils (rendzinas) formed on carbonate rock weathering products. Rendzinas are typically washed away on steep slopes. Certain peculiarities of the climatic characteristics of the Dniester Canyon can be attributed to the Orographic heterogeneity surfaces. A specific microclimate forms on the slopes and near foot of the slope. This microclimate causes the effect of Transdnistrian «warm Podillya». The effect is caused by the canyon-like valley that serves as a barrier that protects from the wind and retains heat accumulated by the slopes from solar radiation. Consequently, elevated temperatures are observed within the canyon. Winter period here is 20—25 days shorter, and the average temperature of air 1.5—2.0° C higher than that of the uplands. This difference in temperature has a marked effect on vegetation of plants (Herenchuk, 1980; Denysyk, 2007).

Warm and mild climate, diversity of geological and geomorphological structures, and edaphic conditions contributed to formation of nemoral forests with elements of Mediterranean flora, Central and Eastern European steppe coenoses, and petroglyphic vegetation within the canyon, which includes a large number of endemic, relict and rare species. Accordingly, diverse plant communities, which form certain ecological series, are present in the valley. Steppe-petroglyphic ecological series occurs on the southern slopes: *Festuca valesiaca* and *Bothriochloa ischaemum* (L.) Keng are dominant in the upper part of the slope near plakor → *Teucrium chamaedrys* L., *Festuca ovina* L. — in places of quaternary rocks denudation on convex slopes → *Seseli hippomarathrum* Jacq, *Teucrium pannonicum* A.Kern. are dominant on petrous limestone screes → *Teucrium chamaedrys*, *Melica transsylvanica* — further down, on the colluvial deposits. Another Steppe series is represented by the following change of dominants: *Poa angustifolia* L. on plakor (upland) → *Festuca valesiaca*, *Bothriochloa ischaemum* dominate dry areas

near plakor → *Stipa capillata* L. is dominant on convex slopes → *Elytrigia intermedia* — in areas with loess deposits → *Poa versicolor* Besser is a dominant species on the outcrops of limestone with intense denudation → *Teucrium chamaedrys*, *Melica transsilvanica* — on the colluvial deposits → *Agrostis tenuis* Sibth., *Briza media* — on alluvial sediments. Presence of the Central European Steppes, forming a following ecological series of changing of dominants on the northern slopes, is a peculiar feature of this part of the valley: *Brachypodium pinnatum* (L.) P. Beauv. is a dominant species on the even areas → *Carex humilis* (*Sesleria heufleriana* Schur) — in the upper part of the convex slopes → *Seseli hippomaranthrum*, *Teucrium pannonicum* — in the middle part and on carbonate cliffs → *Inula ensifolia* L., *Anthericum ramosum* L. — further down, in areas with intense denudation and flushing carbonates → *Melica transsilvanica*, *Teucrium chamaedrys*, *Bupleurum falcatum* L. — in the bottom part, on colluvial and diluvial deposits. Shrub series on dry slopes is characterized by *Prunus spinosa* L. growing on the top → *Lembotropis nigricans* (L.) Griseb. is a dominant species further down → *Caragana frutex* (L.) K. Koch — in the dry conditions of middle part → *Swida sanguinea* (L.) Opiz, *Ulmus minor* Mill. — in the bottom part. Forest series is represented with *Fraxinus excelsior* L., *Carpinus betulus* L., and *Quercus robur* L. on flat plakor areas → *Carpinus betulus* — on slopes near the top → *Carpinus betulus*, *Quercus robur*, and *Stellaria holostea* L. → *Quercus petraea* (Matt.) Liebl., *Cornus mas* L., and *Aegonychon purpurea-coeruleum* Holub. — on the convex southern slopes → *Fraxinus excelsior*, *Aegopodium podagraria* L. — in the bottom part, on accumulative soils. These examples do not exhaust the list of series of the middle Dniester, which are presented by various combinations and require further study.

The **Krasna** river is a left feeder of the Seversky Donets and flows within the southern part of Central Russian Upland (Steppe zone) from north to south. The length of the river is 124 km, the drop height of riverbed is 0.5 m/km. River valley is quite wide and its length is 3.5 km, while the width of the floodplain is 200–250 m. The river is fed predominantly by meltwater. Geomorphologically, the area is located 150–200 m above the sea level and is composed of cretaceous rocks, which are well developed here. Carbon rocks form the base of this territory, with Upper Cretaceous deposits further up, and, finally, the Quaternary loess. Relief is dominated by the denudation forms. The right bank of the river is fairly high (up to 60 m), steep (30–35°),

sometimes scarp, frequently dissected by ravines mostly in the west-east direction. The ravines are fairly long for the most part, and assume the shape of a «circus» along the banks of the Krasna river. Outcrops of Cretaceous rocks, sand, and loess deposits are observed here. The left bank of Krasna is gently sloping (3–7°). Three wide terraces can be traced within the right bank: floodplain, sandy terrace, and a terrace above the sandy terrace proper. The latter terrace transitions into plakor (Ekomerezha, 2013).

In regard to climate, the investigated area is characterized by average rainfall of 450–500 mm. The average annual temperature is 7–8° C, average January temperature is from –8 to –6° C, average July temperature is from 21 to 22° C, indicating subcontinental (subarid) climate with deficit of moisture and drought in August and September.

Medium-humic blackearth predominate in the soil mantle. Rendzinas (sod-calcareous soils) or chalk outcrops occupy the slopes of the right bank (Hrytsenko, 2004).

The vegetation of the valley is represented by deciduous ravine forests, with plakor occupied by sites of forb-fescue-feather-grass steppe. Chalk outcrop vegetation is present on the steep right bank, along with forb-herb-grass meadows which form a patchy complex of combinations in the catena and are characterized by high gradient of changes of various ecological factors.

The nature of the chalk outcrops (the presence or absence of soil cover, the mobility of the substrate, chemical and physical properties of the chalk) is one of the leading factors of formation of ecological series in the valley of the Krasna river.

Forest vegetation in the floodplain areas is represented by communities with dominance of *Alnus glutinosa* (L.) Gaertn., *Salix alba* L., and *Populus nigra* L., whereas communities with *Fagetalia sylvaticae* (*Scillo sibericae-Quercion roboris*) are present on the slopes of ravines and areas adjacent to plakor. Shrub steppe, with dominant species *Caragana frutex* and *Prunus stepposa* Kotov, can often be encountered on the slopes of the valley and ravines. Communities of *Amygdalus nana* L. and *Spiraea hypericifolia* L. are more rare. In more humid conditions, at the bottom, thickets of *Acer tataricum* L., *Rhamnus cathartica* L., *Padus avium* Mill. occur.

Steppe series form on rendzinas and on the blackearth soils with underlying loess. Gentle slopes of the upper part are occupied by forb-grass steppe of *Fragario viridis-Trifolion montani* alliance. *Festucion valesiacae* steppe coenoses are common in drier areas adjacent

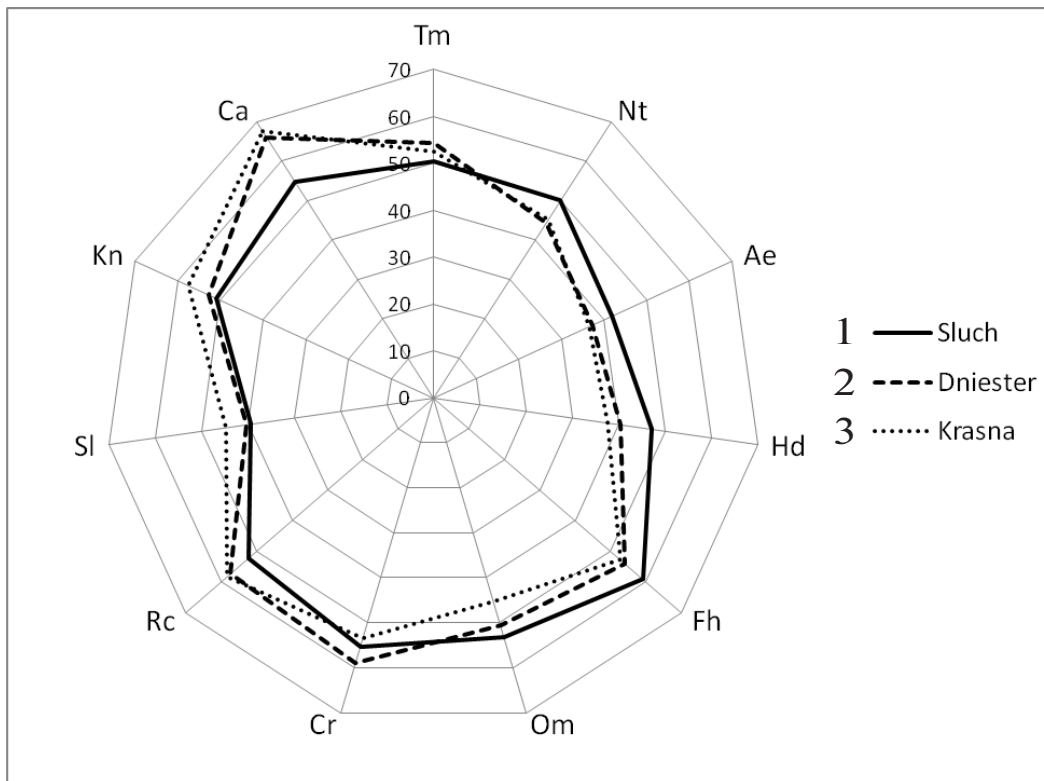


Fig. 2. Patterns of distribution of the mean values of leading ecological factors in river valley catena: 1 — Sluch; 2 — Dniester; 3 — Krasna

to plakor. In places with good drainage, communities of *Artemisia marschalliani-Elytrigion intermediae* alliance are formed, and, further down, typical steppe communities *Stipion lessingianae* are present.

In the middle reaches of the Krasna river, the right bank is very steep and is characterized by the most flushing regime. Chalk outcrops are observed here, and the ravine system is represented by narrow ravines with steep slopes. From upland to foot of the slope, the following series is usually formed: *Stipion lessingianae* → *Centaureo carbonatae-Koelerion talievii* → *Artemisia hololeuca-Hyssopion cretacei* → *Festucion valesiaca* → *Artemisia marschalliani-Elytrigion intermediae*.

The steeper are the slopes, the bigger is the area occupied by communities with dominance of *Artemisia hololeuca* M. Bieb. ex Besser (predominantly on the slopes with eastern exposure), and by communities with *Hyssopus cretaceus* Dubj. as a dominant species. The latter communities favor slopes with eastern and southern exposure, composed of denser chalk. On more gentle slopes, less affected by erosion and land-loss, the communities of tomillares are either fragmented or do not form at all. Under such conditions, lower alpine communities *Centaureo carbonatae-Koelerion*

talievii with dominant species *Thymus cretaceus* Klokov & Des.-Shost. and *Pimpinella tragium* Vill. occur on the loose chalk substrate. *Centaureo carbonatae-Koelerion talievii* communities alternate with xerophyte communities, such as *Festucion valesiaca* or *Artemisia marschalliani-Elytrigion intermediae*. At the bottom of the slopes, in the area with talus material accumulation, xerophytic communities with considerable share of *Krascheninnikovia ceratoides* (L.) Gueldenst. are formed. These coenoses transition into *Artemisia marschalliani-Elytrigion intermediae* grass communities, followed by meadow-steppe communities of the floodplains.

Thus the following series of coenoses is formed: *Stipa capillata* + *Festuca valesiaca* → *S. lessingiana* L. + *F. valesiaca* → *Artemisia hololeuca* → *Thymus cretaceus* + *Pimpinella tragium* → *Bromopsis inermis* + *Elytrigia intermedia* → *Krascheninnikovia ceratoides*. Coenoses of tomillares are not present when this series occupies gentle slopes. Shrub communities with dominance of *Caragana frutex* are often formed on plakor and upper parts of the steppe slopes of the northern, northeastern, and eastern exposures. The latter species is adapted to steppe conditions and can withstand considerable grazing and mowing. Therefore, its communities often develop

where grass communities would have otherwise thrived. An example of ecological series involving *Caragana frutex* is as follows: *Stipa capillata* + *Festuca valesiaca* → *Festuca valesiaca* + *Poa angustifolia* → *Caragana frutex* + *Poa angustifolia* + *Elytrigia intermedia* → *Bromopsis inermis* + *Elytrigia intermedia* → *Thymus cretaceus* + *Pimpinella titanophylla*, and further down → *Ceratoides papposa*.

Comparative analysis of ecomers on river's slopes.

The examples of changing links in ecological series of the valleys of three model rivers served for comparison of ecomers i.e. for assessment of β -coenodiversity differentiation towards the changes of leading ecological factors.

Ecological factors by the nature of the mean value of bias can be divided into two groups: the first in which the highest rates associated with the moisture regime (soil humidity, variability of moisture, aeration, mineral nitrogen's content in soil, humidity) are characteristic for the Sluch valley, and the second, with the chemical properties of soil (salt regime, acidity, carbonate content and continental climate), typical of the Krasna valley (Fig. 2). Indicators of the Dniester valley occupy an intermediate position, except thermal climate and crioclimate, which are the highest ones here, leading to the effect of «warm Podillya». Thus, the mean values in general depend on regional location of the valleys and in the system of global ecological space according to climate indicators occupy the optimal position (50–60 % of the scale), except for humidity of the Krasna which is at around 45 %.

By the indications of soil humidity (*Hd*) ecomers of the Krasna (6.5–9.3 points) and Sluch (9.2–11.4 points) river valleys are characterized by the widest gradient among groups of grassy slopes and of the Dniester valley — by the narrowest one (8.0–9.2 points). Although given forest communities, the picture changes dramatically and gradient of ecomers of Sluch is the narrowest and the widest is on valley Krasna (Fig. 3, *a*). The stabilizing role of forests is to increase the ecosystem humidity by two points approximately as it can be seen on these data. This is also confirmed by indicators of soil aeration (*Ae*), which is closely correlated with the previous one (Fig. 3, *c*). Important role in the accumulation and nitrogen mineralization play the forests, where the figures differ significantly from those of herbaceous communities (Fig. 3, *h*). Herewith, among grass habitats the wettest indicators

Hd are for the Sluch, accordingly, the driest ones are for the Dniester and Krasna valleys, while the driest forests are characteristic for the Dniester valley. With regard to the variability of damping, these figures for all valleys have similar amplitudes (2 points); however, they are naturally reduced from the Sluch to Dniester and to the Krasna valley (Fig. 3, *b*).

Indicators of chemical properties of soil vary in the opposite direction. The lowest and the narrowest parameters *Rc*, *Sl* and *Ca* are characteristic for the Sluch, the larger and wider ones — for the Dniester and the highest gradient — for the river Krasna, where the biotopes from loess and arid slopes to tomillares are represented. The indicators *Rc*, *Sl*, *Ca* of these coenoceses does not overlap with other and differ significantly, indicating a different type of conditions of their existence (Fig. 3, *d–f*).

Estimating of ecomers by the climatic indicators is important. The warmest biotopes (*Tm*, *Cr*) are characteristic for the canyonlike Dniester valley, not for the open steppe of the Krasna river valley (Fig. 3). As for those environmental parameters that are associated with precipitation (*Om*, *Kn*), a clear zonal pattern of their changes is observed (Fig. 3, *a*, *i*). Forests increase these figures in the first case and reduce in the second, although not essential, wherein range of amplitudes of all four climatic factors increases from the forest zone to the steppe.

The next stage of analysis of the biotopes in river valleys was to assess their similarities-differences by complex of ecological performance. For this purpose, a dendrogram was built by Ward method that reflects Linkage Distance. Dendrogram at $D > 30$ is divided into two large clusters according to the habitat specifics, not to the river valley grounds. The «A» cluster can be called a «humid» and the «B» cluster an «arid» (Fig. 4). The first in its turn is divided into two groups at level $D > 10$: A_1 — nemoral deciduous forests of river basins, A_2 — grassy meadows communities (A_{21} , A_{22}), which at the highest level ($D > 5$) are adjacent to xerophytic forests *Quercetalia pubescenti-petraeae* and rock communities *Asplenion rutae-murariae* (A_{23}). This strange combination can be explained by the fact that petrophytic rock communities were not available elsewhere except the Dniester valley. Instead, A_{21} and A_{22} clusters include strictly speaking biotopes of the Sluch valley. The «arid» «B» cluster has a lower degree of differentiation and at the level ($D > 5$) is divided into three parts: B_1 — steppe biotopes, B_2 —

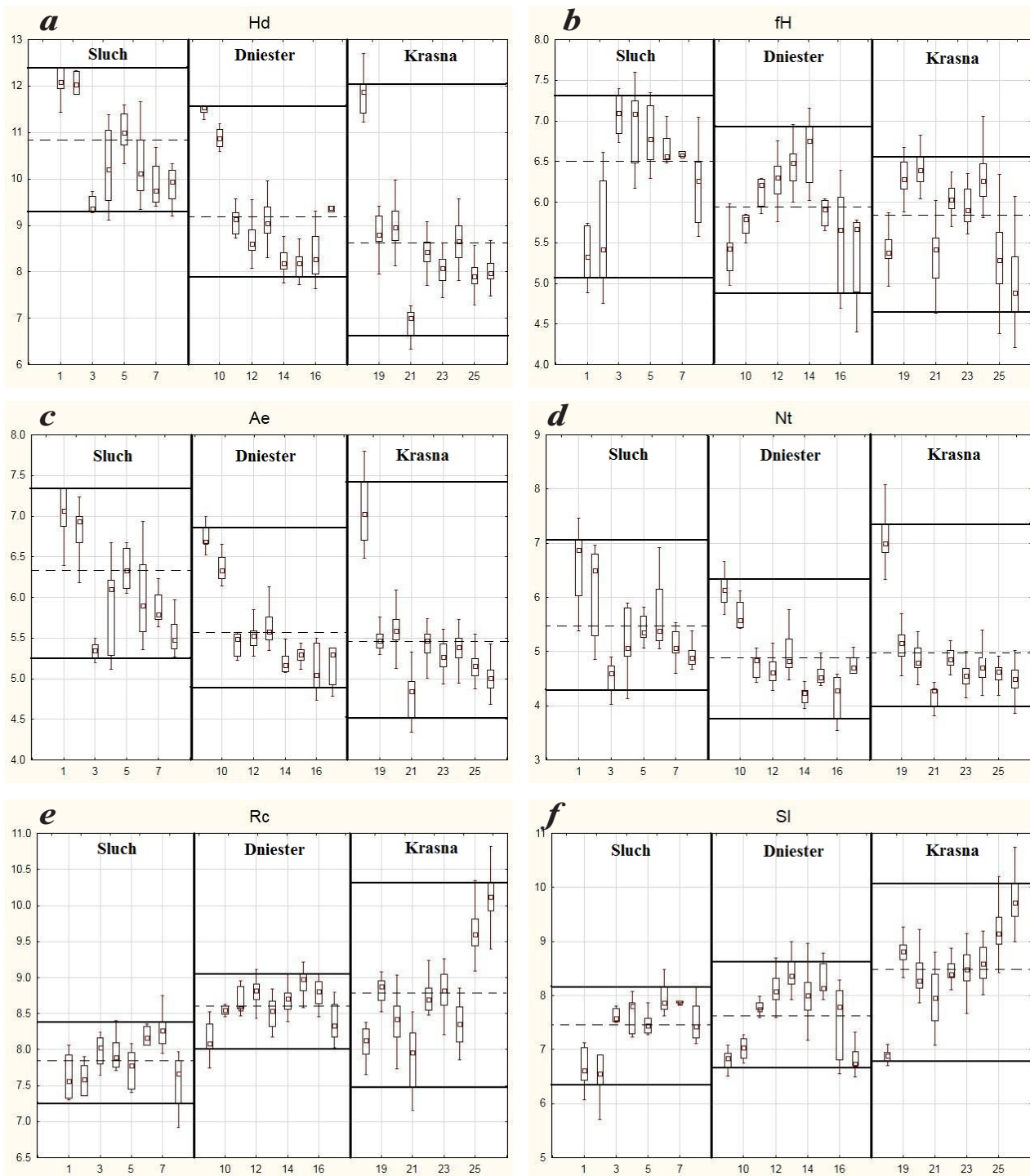
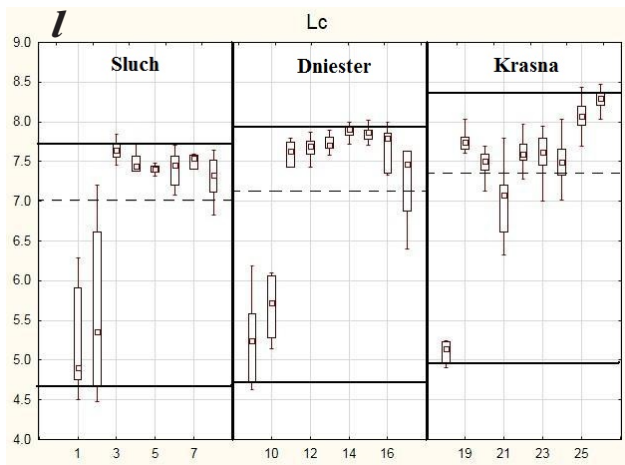
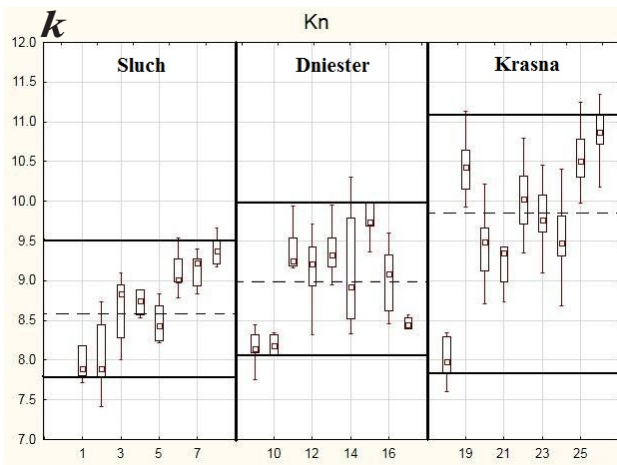
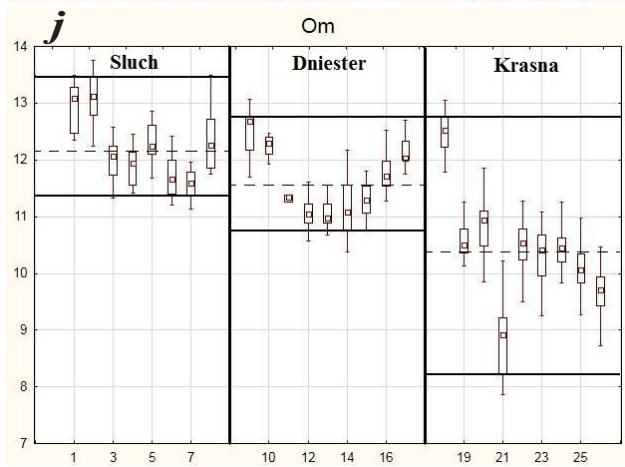
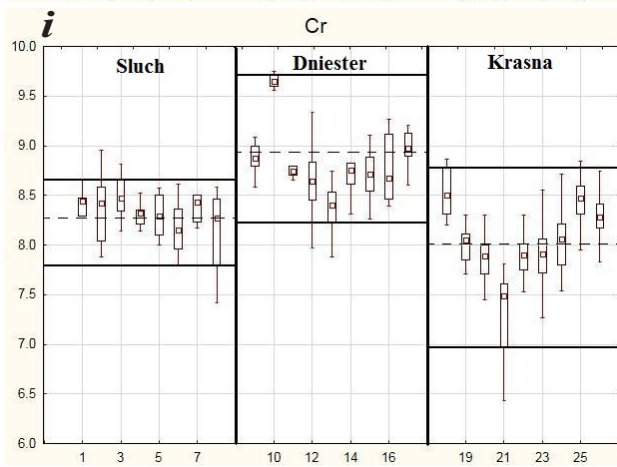
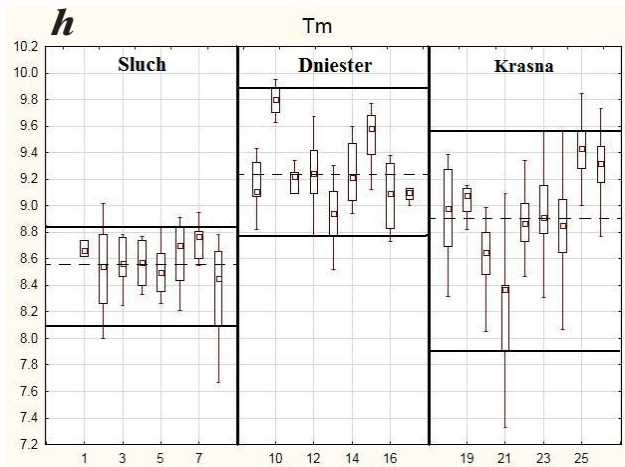
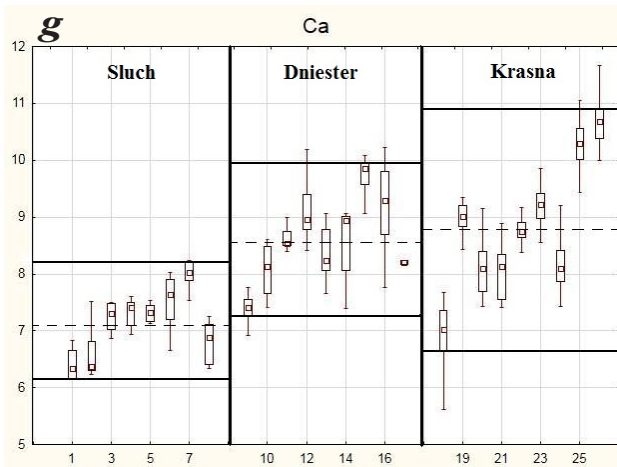


Fig.3. Distribution of xerophytic steppe communities depending on ecological scales: *a* — soil humidity; *b* — variability of damping; *c* — aeration of soil; *d* — nitrogen content; *e* — acidity; *f* — total salt regime



Continuation fig.3. Distribution of xerophytic steppe communities depending on ecological scales: *g* – carbonate content in soil; *h* – thermal climate; *i* – cryo-climate; *j* – humidity; *k* – continental climate; *l* – light in community

Legend: 1. *Carpinion betuli*; 2. *Quercio-Fagetea, Quercetalia robori-petraeae*; 3. *Agrostion vinealis*; 4. *Brizetomediae-Anthoxantheum (Cynosion cristati)*; 5. *Artemisio marschalliani-Elytrigion intermediae*; 6. *Festucion valesiacae*; 7. *Thymo pulegioides-Sedion sexangulare*; 8. *Asplenietea trichomanis, Androsacetalia vandellii* (with dominant species *Asplenium trichomonas*); 9. *Carpinion betuli*; 10. *Quercion petraeae*; 11. *Prunion fruticosae*; 12. *Festucion valesiacae*; 13. *Artemisio marschalliani-Elytrigion intermediae*; 14. *Allyso-Sedion* (with dominant species *Sedum acre*); 15. *Allyso-Sedion*; 16. *Galio campanulatae-Poion versicolor*; 17. *Asplenion rutae-murariae*; 18. *Scillo sibericae-Quercion roboris*; 19. *Prunion fruticosae*; 20. *Fragario viridis-Trifolion montani*; 21. *Artemisio-Kochion*; 22. *Artemisio marschalliani-Elytrigion intermediae*; 23. *Festucion valesiacae*; 24. *Stipion lessingianae*; 25. *Centaureo carbonatae-Koelerion talievii*; 26. *Artemisio hololeucaae-Hyssopion cretaceae*

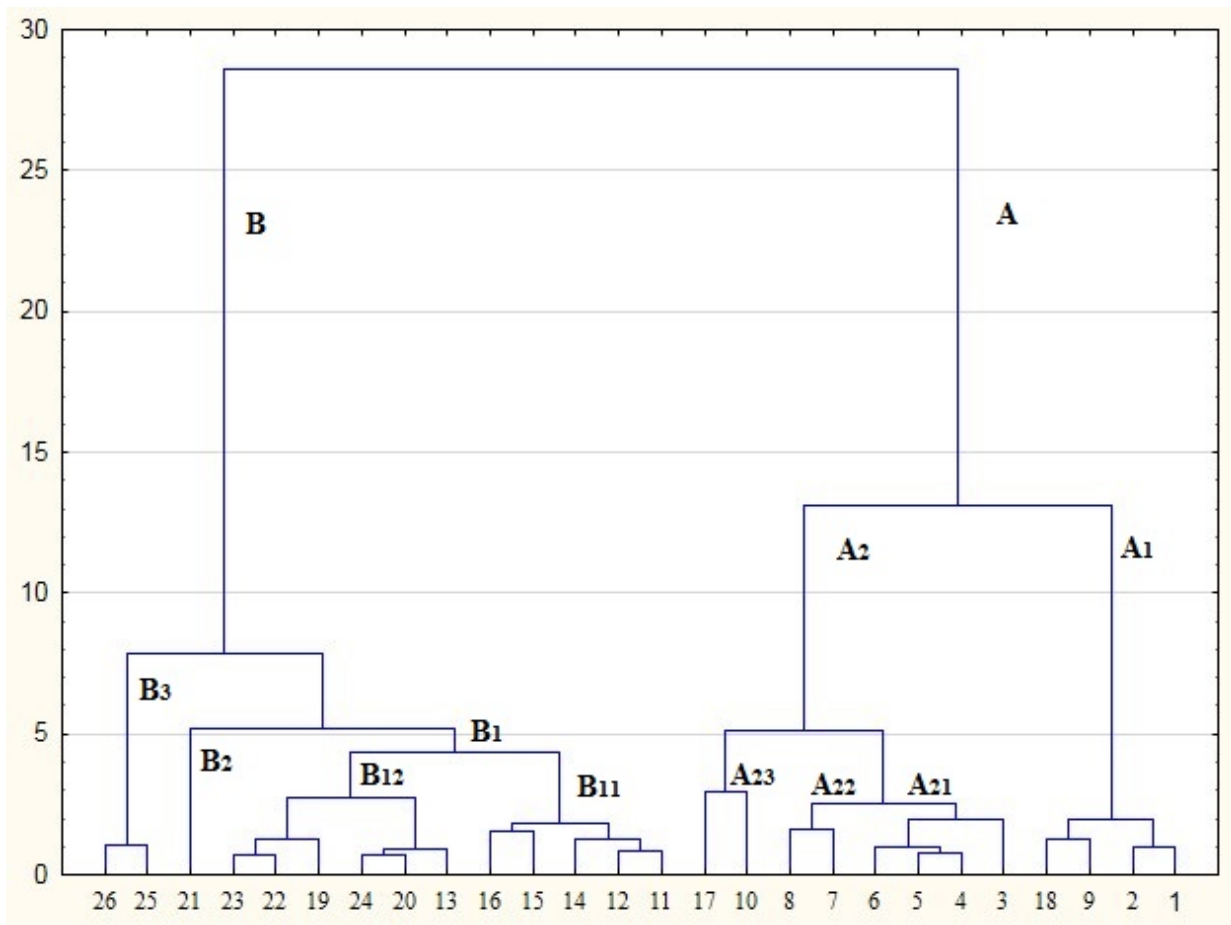


Fig. 4. Distribution of communities in relation to the cumulative influence of ecological factors (Euclidean distances, Ward method)

Legend: see Fig. 3

desert steppes *Artemisio-Kochion*, B_3 — tomillares *Artemisio hololeucae-Hyssopion cretaceae* and petrophytic steppes *Centaureo carbonatae-Koelerion talievii*.

In turn, B_1 is divided into two clusters at the level $D > 4$: B_{11} — steppes and petrophytic communities of the Dniester river and B_{12} — steppe communities of the Krasna river, adjacent to loess outcrops biotopes *Artemisio marschalliani-Elytrigion intermediae* (13) of the Dniester valley, which are also represented on the slopes of the Krasna valley (22). At the same time, we note that communities of this union are also present in the Sluch valley (5) although they are quite different from the south ones.

Conclusions

Analysis of ecomers of the river valleys indicates that each valley includes diverse, enough differentiated by

the ecological conditions habitats, which analogues may occur in different areas and different by structure and size river valleys. This confirms the high diversity of river valleys as important ecological corridors providing biodiversity conservation. At the same time, the technique permits to conduct quantitative comparative analysis both of individual habitats and ecomers of the valleys entirely, to assess their topological structure that reflects change in β -coenodiversity. Such studies are important for developing specific habitat conservation measures and forecasting their possible changes.

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Дідух Я.П., Чусова О.О., Ольшевська І.А.,
Поліщук Ю.В. **Річкові долини як об'єкт еколого-
геоботанічних досліджень.** — Укр. ботан. журн. — 2015. —
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Долини річок характеризуються високою різноманітністю екосистем, їх оригінальністю, складною структурованістю і динамічністю. Важливе значення у формуванні закономірностей територіального розподілу цих екосистем мають вертикальні переміщення від плакору до русла на різних ділянках катени, яку можна розглядати як складний комплекс, де інтегруються геоморфологічні, ґрунтовірні процеси та ценозоутворення. Індикаторами цих територіально-часових змін виступають відповідні рослинні угруповання, поєднання яких у межах екологічного ряду під впливом екологічних чинників трактується як екомери, що відображає градієнт змін, тобто β -різноманіття. Кількісна оцінка цих рослинних угруповань можлива на основі методики синфітоіндикації. Для роботи було обрано три модельні річки (Случ, Дністер і Красна), які мають різну розмірність і протікають у різних природних зонах. На їхньому прикладі проведено порівняння екомерів, тобто оцінено диференціацію β -ценорізноманіття щодо зміни провідних екофакторів.

К л ю ч о в і с л о в а: річкова долина, β -різноманіття, катена, екомери, рослинні угруповання.

Дидух Я.П., Чусова О.А., Ольшевская И.А.,
Полищук Ю.В. **Речные долины как объект эколого-
геоботанических исследований.** — Укр. ботан. журн. —
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Долины рек характеризуются высоким разнообразием экосистем, их оригинальностью, сложной структурированностью и динамичностью. Важное значение в формировании закономерностей территориального распределения этих экосистем имеют вертикальные перемещения от плакора до русла на разных участках катены, которую можно рассматривать как сложный комплекс, где интегрируются геоморфологические, почвообразующие и процессы ценозообразования. Индикаторами этих территориально-временных изменений выступают соответствующие растительные сообщества, сочетание которых в пределах экологического ряда под влиянием экологических факторов трактуется как экомеры, что отражает градиент изменений, то есть β -ценоразнообразие. Количественная оценка этих растительных сообществ возможна на основе методики синфитоиндикации. Для работы были выбраны три модельные реки (Случ, Днестр и Красная), которые имеют разную размерность и протекают в разных природных зонах. На их примере проведено сравнение экомеров, т. е. дана оценка дифференциации β -ценоразнообразия по отношению к изменению ведущих экофакторов.

К л ю ч е в ы е с л о в а: речная долина, β -разнообразие, катена, экомеры, растительные сообщества.