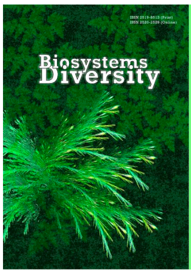

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Comparison of commonly used ecological scales with the Belgard Plant Ecomorph System

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There are several ecological scales developed both for phytoindication of ecological factors and plant ecomorphs. Among them, the scales of Ellenberg and Tsyganov are the most commonly used. L. G. Ramensky and P. S. Pogrebnyak had developed a phytoindication method; they also were founders of first ecological scale of plant species in relation to various environmental factors. One of first ecomorph systems was developed by Alexander Lyutsianovich Belgard. In 1947, Belgard presented a tabular ecomorph system in his doctoral dissertation, and later in monograph "Forest vegetation of the South-East of Ukraine". In the system he used abbreviated Latin names applying terminology proposed in the late 19th century by Dekandol, Warmin and other authors. He considered ecomorphs as adaptations of plants to environmental conditions in forests of the steppe zone of Ukraine where forest cenoses are exposed to processes of steppization, prairification, swamping, salinization, and thus clarification of relationships between forest, meadow, steppe, marsh and weed plant species was essential. Therefore, development and introduction of cenomorph terms as "adaptation of plant species to phytocenosis as a whole" were an absolutely new contribution to the concept of ecomorph system. In environmental factor scales of Ellenberg and other authors, environment characteristics based on phytoindication were underlined; in the Belgard Plant Ecomorph System, ecomorphs reflect ability of plant species to grow within certain ranges of a given factor. These approaches are quite comparable, and ecomorphs of the Belgard system correspond to certain grades of the Ellenberg and Tsyganov scales. The Belgard ecomorph system has been applied in a number of fundamental and applied works on plant ecology and phytocenology. It is convenient for characterizing ecological features of plant species growing in the steppe zone with a wide range of environment factors such as lighting, humidity, and soil richness. Other authors have expanded and supplemented the Belgard Plant Ecomorph System based on its strategy. A number of ecomorphs was introduced; they reflect intermediate or extreme gradations of factors. A new cenomorph – silvomargoant – has been proposed by the authors of this paper.

Keywords: ecological scales; environmental factors; habitats; heliomorphs; hygromorphs; trophomorphs; halomorphs; cenomorphs; ecomorphic analysis

History of phytoindication scales and ecomorph systems

A large number of environmental scales currently exist. On the one hand, they are intended for phytoindication of ecological factors, and on the other, as a system of plant ecomorphs (Diduh & Pljuta, 1994). One of first ecomorph systems was developed by Alexander Lutsianovich Belgard on the basis of concepts of D. I. Mendeleev, V. V. Dokuchaev, V. N. Sukachev. Together with his teacher G. N. Vysotsky, Belgard developed a new branch of science "Steppe Forestry". The Belgard Ecomorph System was presented by the author in his doctoral dissertation "Forests of South-Eastern Ukraine" in 1947, and then in his monograph "Forest Vegetation of South-Eastern Ukraine" (1950). In development of the ecomorph system he applied known terminology and abbreviated Latin plant names (Belgard, 1950). For nearly 70 years, this ecomorph system has been successfully applied in survey and characteristics of cenoses of both specific biotopes and landscapes. The Belgard Ecomorph System was developed in a number of fundamental works on plant ecology and phytocenology. It can be quite wide ranging: in assessment of phytocenotic structure, in ecological characteristics of flora on supracenotic levels, as well as in assessing the state of the environment with the main physical and chemical parameters.

Other authors have expanded and supplemented the Belgard Plant Ecomorph System based on its strategy. A number of ecomorphs reflecting intermediate or extreme gradations of factors have been introduced into the system. A new cenomorph – silvomargoant – has been proposed by the authors of this paper. There is a practical need for expanding the Belgard Plant Ecomorph System and further introduction of additional ecomorphs. The objective of this work was characterization of the peculiarities of the Belgard Plant Ecomorph System (including its supplemented version) and its advantages in comparison with the scales of Ellenberg and Tsyganov.

Ramensky was founder of the phytoindication method that is based on the use of species composition of vegetation. He was also originator of the first ecological scale of plant species in relation to various environmental factors (Ramenskiy, 1929). According to Tsyganov (1983), "works of Pogrebnyak and Ramensky are sources of European score-and-scale methods in ecological analysis. The first scientific work of Pogrebnyak including justification of his methodology was published in 1927. The first scientific work of Ramensky where he justified and applied in detail an ordinary coordination method was published in 1929, i.e. much earlier than similar works of Ellenberg and other European researchers." Pogrebnyak (1955) proposed an ecological scale of tree species, Ramensky (1956) developed detailed ecological scales of soil humidity, richness and salinity of meadow plant communities.

There exist a large number of ecological scales (Table 1), both phytoindications of ecological factors and plant ecomorphs. Many scales were developed by their authors based on characteristics of plant communities and biotopes surveyed. Among them, the most commonly used scales are: the Ellenberg (1950, 1974) scale, the Tsyganov (1975) scale, the Landolt (1977) scale. The Ellenberg scale is the most commonly used (Gilhaus et al., 2017; Ford et al., 2018; Goedecke et al., 2018; Hancock et al., 2018). A value set of environmental factors for vascular plants in Central Europe is defined in this scale (Ellenberg 1979, 1988; Ellenberg et al., 1991). It is widely used both in Europe and adjacent territories (Kalusová et al., 2016; Berg et al., 2017; Britton et al., 2017; Čeplová et al., 2017; Chmura et al., 2017; Hülber et al., 2017; Muir, 2017; Pruchniewicz, 2017; Santini et al., 2017; Johansen et al., 2018; Roeling et al., 2018). Its modern version was supplemented and adapted by many foreign authors (Douda et al., 2016; Dyderski et al., 2016; Ewald & Ziche, 2016; Koch et al., 2016; Van Dobben & de Vries, 2016; Elst et al., 2017; Mitchell et al., 2017; Vitasović Kosić et al., 2017; Kılıç et al., 2018; Kosanic et al., 2018).

The scales are divided into point and amplitude scales. The point scale indicates the ecological range of plant species by a particular environmental factor. The amplitude scale determines the coordinate of plant species on the axis of environmental factor.

Table 1
General characteristics of ecological scales (by Diduh & Pljuta, 1994)

Author	Total score in the scale												
	Hd	fH	Tr	Rc	Nt	Gm	Ar	Tm	Om	Kn	Cr	Lc	Dg
Ellenberg	12	–	3	9	9	–	–	9	–	9	–	9	–
Landolt	5	4	2	5	5	5	5	5	–	5	–	5	–
Zoiomi	11	–	–	6	–	–	–	7	–	2	–	–	–
Frank & Klotz	12	2	3	9	9	–	–	9	–	9	–	9	–
Zazhitskii*	6	–	3	6	5	5	5	5	–	5	–	5	–
Tsyganov*	23	11	19	13	11	–	–	17	15	15	15	9	–
Ramensky*	120	20	30	–	–	–	10	–	–	–	–	–	10
Tsatsenkin*	120	–	30	–	–	–	–	–	–	–	–	–	10

Notes: * – scales wherein factor amplitude is displayed; signs of the factors: Hd – soil moisture, W – soil moisture changes, Tr – generalized salt regime, Rc – acidity, Nt – content of mineral nitrogen, Gm – content of humus, Ar – soil aeration, Tm – thermoclimate, Om – ombroclimate, Kn – climate continentality; Cr – cryoclimate; Lc – light intensity in cenosis; Dg – pasture digression.

Belgard presented his ecomorphic system of vascular plant species in relation to the main environmental factors with the purpose of classifying ecological characteristics of forest communities in the steppe zone of Ukraine (Belgard, 1950). In 1947, A. L. Belgard presented a tabular ecomorphic system in his doctoral dissertation, and then in his monograph "Forest vegetation of the South-East of Ukraine" (1950). The author developed an ecomorphic system using terminology proposed in the late 19th century by Decandol (Dekandol, 1956), Warming (Warming, 1903), and by other authors. The Tabular Belgard Plant Ecomorph System was compiled for the main environmental factors: light intensity (heliomorphs), temperature (termomorphs), humidity (hygromorphs), soil richness (trophomorphs). The author designated names of ecomorphs with abbreviated Latin names of environmental factors. Tabulated ecomorphic analysis of plant species within a community or system of supra-cenotic level (ecological certification of species) gives insight into the ecological structure of flora (Table 2).

Table 2
Fragment of table on ecological characteristics of plant species of genus Equisetum in the steppe zone of Ukraine according to Belgard's Plant Ecomorph System

№	Species within genus	Heliomorph	Trophomorph	Hygromorph	Cenomorph
1.	*Equisetum arvense* L.	ScHe	MsTr	HgMs	RuSilPr
2.	*E. fluviatile* L.	ScHe	MsTr	HelHg	AqPal
3.	*E. hyemale* L.	ScHe	MsTr	HgMs	PrSil
4.	*E. palustre* L.	ScHe	MsTr	MsHg	PrPal
5.	*E. pratense* Ehrh.	ScHe	MsTr	HgMs	Pr
6.	*E. ramosissimum* Desf.	ScHe	MsOgTr	Ms	PrPs
7.	*E. sylvaticum* L.	Sc	MsTr	HgMs	Sil
8.	*E. telmateia* Ehrh.	HeSc	MsTr	MsHg	SilPal
9.	*E. variegatum* Schlech. ex Weber et Mohr.	He	MsTr	MsHg	Pr

Note: plant species names are given in accordance with the nomenclature of Mosyakin & Fedoronchuk (1999)

Alexander Grossheim, famous botanist, author of Angiosperm Phylogeny Group Classification (1946), emphasized the following: "The advantage of the ecological analysis method proposed by A. L. Belgard resides in the fact that it covers all the most important environmental factors affecting the existence of plant species in a phytocenosis. Usually, a more vivid impression is obtained on application of the ecomorphic method in a phytocenosis. According to A. L. Belgard, the characteristic of cenose is multisided in this case. In application of the author's formulae and graphs, interrelations existing in nature have many-sided coverage, due to which maximum approximation to the truth is obtained in comparison with the use of other, usually one-sided methods".

Correspondence of the Belgard Plant Ecomorph System to other environmental scales

Ecomorphs are considered by Belgard (1950) as adaptations, adjustments to environmental conditions (Belgard, 1950). Belgard's scheme "was made specifically for forest survey in the steppe zone of Ukraine, where forest cenoses are often exposed to processes of steppization, prairification, swamping, salinization, spread of weeds, and where it is important to find out the relationships between forest, meadow, steppe, marsh and weed species" (Belgard, 1950).

Choice of ecological scale largely depends on geographical area, biotopes studied and survey specificity. Environmental characteristics associated with phytoindication form the basis of scales of primary factor regimes developed by Ellenberg and other authors. But in the Belgard system, one or another ecomorph reflects the ability of plant species to grow in certain ranges of factors' influence, i.e. it serves as an ecological characteristic of the species. These approaches are quite comparable, and ecomorphs of the Belgard system correspond to certain gradations of the Ellenberg and Tsyganov scales (Table 3–6). Differences in these systems concerning the meaning of soil richness are based on specificity of geographical areas for which the scales have been developed. Authors apply concept of nitrogen richness to the forest zone when soils are characterized by low level of mineralization and a large amount of slowly biodegradable organic matter. For the steppe zone, the concept of soil richness reflects its total nutrient content because soils with greater mineralization and decomposition of organic matter are formed within this zone. And the presence of highly mineralized soils is reflected by the cenomorph of high salinity (alkotrophs).

In his ecomorph system, A. L. Belgard developed and first applied the term "cenomorph". Cenomorph shows the confinement of a plant species to a particular phytocenosis: Sil (*Silvaticus*) – sylvant (forest species), St (*Stepposus*) – stepant (steppe species), Pr (*Pratensis*) – pratant (meadow species), Pal (*Paludosus*) – paludant (marsh species), Aq (*Aqantus*) – aquant (aquatic species), Ps (*Psammophyton*) – psammophant (species of sandy ecosystems), Pt (*Petrophyton*) – petrophyte (petrant) (species of stony ecosystems), Ru (*Ruderatus*) – ruderant (weed species), H (*Halophyton*) – halophyte (species of saline soil), Cu (*Cultus*) – culturant (cultivated species), etc. (Table 7). Belgard also applied intermediate values to cenomorphs. For example, a complex coenomorph SilPr (forest-meadow) shows the species belonging to different phytocenoses, i.e. its cenotic amplitude.

The systems of Ellenberg and Tsyganov were developed for phytoindication of forest plant communities within the forest zone. And Belgard's system of ecomorphs was developed for survey of forest plant communities in the steppe zone. On the one hand, it meets the requirements of these ecosystems, and on the other hand, it is more suitable for phytoindication of different types of plant communities (forest, steppe, meadow, marsh, aquatic, etc.). The Belgard Plant Ecomorph System has a wider range of environmental factors in forest phytocenoses of the steppe zone. It is particularly convenient and can be successfully applied for data processing in ecological analysis both of individual plant communities and flora in large areas (supracenotic level) having considerable species richness. For a more convenient analysis, Matveev suggested a numerical equivalent of ecomorphs (Matveev, 2006).

Application and development of Belgard's Plant Ecomorph System

The Belgard Plant Ecomorph System was applied in several fundamental and applied scientific works on plant ecology and phytocenology (Tarasov, 1981, 2012; Matveev, 1995, 2006; Baranovsky, 2000; Ekoflora Ukrajiny, 2000; Brygadyrenko, 2016; Baranovsky et al., 2017). Belgard's scale is applied to characterize the environmental features of plant species in the steppe zone with a wide influence range of environmental factors such as moisture, soil richness, mineralization.

In a multi-volume edition "Ekoflora Ukrajiny" (2000–2010), Tsyganov's scheme was underpinned by the ecomorph system with numerical gradations of environmental factors, although Belgard's cenomorph system was used in section "Cenotop" of the monograph (Belgard, 1950). The Belgard Plant Ecomorph System is applied in tabular form (Table 2), so it is convenient for computer data processing in performing ecological analysis of flora of large areas with significant species richness (Baranovsky et al., 2017). The letter designation of ecomorphs allows one to calculate quantitative relationships between ecomorphs using the software Microsoft Excel and even Microsoft Word (using "replacement" option).

Table 3
Light intensity factor according to Belgard's Plant Ecomorph System in comparison with other ecological scales

Complemented Belgard scale (**) (point)				Ellenberg scale (point)		Tsyganov scale (amplitude)			
letter designation	ecological optimum, points (by Matveev)	ecomorphs	relation to environment factor	points	relation to environment factor	identification	relation to environment factor	points	relation to environment factor
USc**	0–1 (0.5)	ultra-sciophytes	ultra-shade species	1	Extreme shade-loving plants (growing at light intensity up to 1%, rarely at light intensity more than 30%)	S	ultra-shadow	9	of particularly shady forests
Sc	1	sciophytes	obligate shade-loving plant species	2	From strongly shade-loving to shade-loving (between 1 and 3 units)	+	thicket-shadow	8	of shady forests/particularly shady forests
				3	Shade-loving plants (grow in light intensity up to 5%, but can grow in lighter places)	s	shady-forest	7	of shady forests
HeSc	2	helio-sciophytes	facultative shade-loving plants	4	From shade-loving to shade-tolerant (between 3 and 5 units)	+	thick light forest	6	of light forests/shady forests
				5	Shade-tolerant plants (in most cases grow at light intensity more than 10%, as an exception at total illuminance)	M	light forest	5	of light forests
ScHe	3	scio-heliophytes	facultative sun-loving plants	6	From shade-tolerant to light-loving (between 5 and 7 units, rarely grow at light intensity less than 20%)	+	sparse forest	4	of semi-open spaces/light forests
				7	Sun-loving plants (in most cases grow in total light, but can grow in shade – up to 30%)	g	shrubby	3	of semi-open spaces
He	4	heliophytes	obligate sun-loving plants	8	From sun-loving plants to extremely sun-loving (exceptionally the plants can grow at light intensity up to 40%)	+	forest meadow (sublight)	2	of open spaces/semi-open spaces
UHe**	5	ultra-heliophytes	ultra sun-loving species	9	Extremely sun-loving plants (growing only in lighted places, in open areas, at light intensity no less than 50%)	G	outside-forest (sun)	1	of open spaces

Note: ** – amendments of Matveev (2006).

Table 4
Temperature factor according to Belgard's Plant Ecomorph System in comparison with other ecological scales

Complemented Belgard scale (**) (point)				Ellenberg scale (point)		Tsyganov scale (amplitude)			
letter designation	ecological optimum, points (by Matveev)	ecomorphs	relation to environment factor	scores	relation to environment factor	identification	relation to environment factor	scores	relation to environment factor
UOgT**	1	ultra-oligo-thermophytes	cryophytic species of the polar zone	1	cold climate – Arctic and high-mountain (alpine and nival) species	K	hyper-cryothermic 1st	1	of very harsh winters (average temperature of the coldest month < –32)
						+	hyper-cryothermic 2nd	2	of very harsh winters/harsh winters
						L	percryothermic 1st	3	of severe winters (average t of the coldest month –24 to –32)
OgT	2	oligo-thermophytes	cryophytic species of taiga and tundra	2	from cold to cool (1–3 units)	+	percryothermic 2nd	4	of harsh winters/moderately harsh winters
				3	cool climate (subalpine heights)	M	cryothermic 1st	5	of moderately harsh winters (average t of the coldest month –16 to –24)
				4	cool to moderate (4–5 units)	+	cryothermic 2nd	6	of moderately harsh winters/moderate winters
MsT	3	meso-thermophytes	moderately cryophytic species of broadleaf forest zone	5	temperate (warm-temperate) climate	N	subcryothermic 1st	7	of moderate winters (average t of the coldest month –8 to –16)
				6	from moderately warm to warm (5–7 units)	+	subcryothermic 2nd	8	of moderate winters/mild winters
				7	warm climate	O	hemi-cryothermic 1st	9	of mild winters (average t of the coldest month 0 to –8)
MgT	4	mega-thermophytes	heat-loving plants of steppes and deserts	8	from warm to extremely warm, sub-Mediterranean (7–9 units)	+	hemi-cryothermic 2nd	10	of mild winters/warm winters
						P	acryothermic	11	of warm winters (average t of the coldest month 0 to +8)
						+	sub-thermophilic 1st	12	of warm winters/very warm winters
						Q	sub-thermophilic 2nd	13	of very warm winters (average t of the coldest month +8 to +16)
UMgT**	5	ultra-mega-thermophytes	heat-loving plants of the tropical zone	9	extremely warm, Mediterranean	+	thermophilic 1st	14	of very warm winters/unpronounced winters
						R	thermophilic 2nd	15	of unpronounced winters (average t of the coldest month is above + 16)

Note: ** – amendments of Matveev (2006).

Table 5
Moisture factor according to Belgard's Plant Ecomorph System in comparison with other ecological scales

Complemented Belgard scale (**, ***) (point)					Ellenberg scale (point)	Tsyganov scale (amplitude)			
letter designa-tion	ecological optimum, points (by Matveev)	ecomorphs	relation to environment factor	po int s	relation to environment factor	identi-fication	relation to environment factor	po-ints	relation to environment factor
UX**	–	ultra-xerophytes	species of very dry habitats	1	very dry habitats (plants growing on dry soils, often on slob habitats)	D	dry desert	1	desert
						+	middle desert	2	desertic/semidesertic
						d	semidesertic	3	semidesertic
						+	desert-steppe	4	semi-desertic/dry steppe
X	0-1 (0.5)	xerophytes	species of dry habitats	2	from very dry to dry (between 1 and 3 degrees)	s	sub-steppe	5	dry steppe
						+	dry steppe	6	dry steppe/medium steppe
MsX	1	meso-xerophytes	species of preferably dry places occurring also on fresh soils	3	dry habitats (plants occur on dry soils more frequently than on fresh soils)	S	middle-steppe	7	middle-steppe
XMs	1-2 (1.5)	xero-mesophytes	species on fresh soils occur also on dry habitats	4	from dry to fresh habitats (between 3 and 5 units)	+	fresh-steppe	8	fresh-steppe/meadow-steppe
						C	moist-steppe	9	meadow-steppe
						+	sub-forest-meadow	10	meadow-steppe/dry-forest-meadow
Ms	2	mesophytes	inhabitants of fresh soils	5	fresh habitats (medium-moist)	c	dry-forest-meadow	11	dry-forest-meadow
						+	fresh-forest-meadow	12	dry-forest-meadow/moist-forest-meadow
HgMs	2-3 (2.5)	hygro-mesophytes	species of fresh soils occurring also in wet habitats	6	from fresh to moist habitats (between 5 and 7 units)	f	moist-forest-meadow	13	moist-forest-meadow
MsHg	3	meso-hygrophytes	species of wet soils occurring also in fresh habitats	7	moist habitats (well-saturated with water but not wet)	+	not quite wet-forest-meadow	14	moist-forest-meadow/wet-forest-meadow
						F	wet-forest-meadow	15	wet-forest-meadow
Hg	4	hygrophytes	species of wet soils	8	from moist to wet habitats (between 5 and 7 units)	+	watery-forest-meadow	16	wet-forest-meadow/swampy-forest-meadow
						p	swampy-forest-meadow	17	swampy-forest-meadow
UHg**	5	ultra-hygrophytes	species of watery habitats	9	wet habitats (mainly oxygen-poor soils)	+	sub-swampy	18	swampy-forest-meadow/swampy
						P	swampy	19	swampy
HelHg***		helo-hygrophytes	species of temporarily flooded wetlands	10	temporarily flooded habitats (plants of intermittent water bodies)	+	wetland	20	swampy/shore
HgHel***	6 (Hd) ** hydrophytes	hygro-helophytes	species of semi-aquatic habitats			a	water near the shoreline	21	shore
Hel***		helophytes	species of shallow-water habitats	11	shallow-water environment (amphibious plants)	+	shallow-water	22	shore/aquatic
Pl***		pleistophytes	species floating on the water's surface	12	underwater environment (underwater plants)	A	water	23	water
Hy***		hydatophytes	underwater plant, mostly totally immersed in water						

Notes: ** – amendments of Matveev (2006); *** – amendments of Baranovsky (2000, 2017).

Table 6
Trophicity factor according to Belgard's Plant Ecomorph System in comparison with other ecological scales

Complemented Belgard scale (**) (point)					Ellenberg scale (point)	Tsyganov scale (amplitude)			
letter design-nation	points of eco-logical optimum (by Matveev)	ecomorphs	relation to environment factor	po-ints	relation to environment factor	desig nati-on	relation to environment factor	po-ints	relation to environment factor
1	2	3	4	5	6	7	8	9	10
UOg Tr**	0–1 (0.5)	ultra-oligotrophs	species growing on oligotrophic soils	1	extremely nitrogen-poor habitats	j	nitrogen-free soil	1	anitrophilous
OgTr	1	oligotrophs	species growing on nutrient-poor soils	2	from extremely poor to poor soils (between 1 and 3 units)	+	intermediate between j and k	2	subnitrophilous 1st
						k	soils very poor in nitrogen	3	subanitrophilous 2nd
MsOgTr		meso-oligotrophs	species that grow on poor soils, but can also occur on soils medium in fertility	3	nitrogen-poor habitats (plants occur on nitrogen-rich soils only as an exception)	+	intermediate between k and l	4	heminitrophilous 1st
OgMsTr	2	oligo-mesotrophs	plants growing on soils medium in fertility but can occur on poor soils	4	plants growing on soils rich in nitrogen from poor to moderately (between 3 and 5 units)	l	soils poor in nitrogen	5	heminitrophilous 2nd
MsTr		mesotrophs	species growing on soils medium in fertility	5	soils moderately rich in nitrogen (moderately rich)	+	intermediate between l and m	6	subnitrophilous 1st
MgMs Tr		mega-mesothophs	plants growing on soils moderate in fertility, but can occur on rich soils	6	plants growing on soils from moderately to high rich in nitrogen (between 5 and 7 units)	m	soils sufficiently rich in nitrogen	7	subnitrophilous 2nd
MsMg Tr	3	meso-megathophs	species that grow on rich soils, but can also occur on soils medium in fertility	7	nitrogen-rich habitats (plants occur on nitrogen-poor soils only as an exception)	+	intermediate between m and n	8	nitrophilous 1st
MgTr	–	megatrophs	species tending to prefer soil high in fertility	8	from rich to very rich in nitrogen soils (between 7 and 9 units)	n	nitrogen-rich soils	9	nitrophilous 2nd

1	2	3	4	5	6	7	8	9	10
UMgTr	–	ultra-megatrophs	species tending to prefer the highest-fertility soil	–	–	+	intermediate between n and o	10	nitrophilous 3rd
Nitr	–	nitrophilic group	species that grow on soil enriched in nitrogen	9	extremely nitrogen-rich habitats (nitrogen-contaminated)	o	extremely nitrogen-rich soils	11	nitrophilous 4th
AlkTr (not currently developed)	4 (HMg Tr) ** 5 (Hal) **	alkotrophs	species tending to prefer saline soils low in fertility	not provided because the lack of analogues in Belgard system		not provided because the lack of analogues in Belgard system		not provided because the lack of analogues in Belgard system	
Ac (not currently developed)	–	acidophilic group	species that grow in more acidic environment	not provided because the lack of analogues in Belgard system		not provided because the lack of analogues in Belgard system		not provided because the lack of analogues in Belgard system	
Ca	–	calciphilous group	species that grow on soil enriched in lime						
Spr	–	saprophytes	heterotrophic species	–		–		–	
Par	–	biophytes	heterotrophic species	–		–		–	
S/Par	–	semi-biophytes	myxotrophic species	–		–		–	

Note: ** – amendments of Matveev (2006).

Table 7
Cenomorphs according to Belgard's Plant Ecomorph System in comparison with other ecological scales

Letter designation	Points of ecological optimum (by Matveev)	Ecomorphs	Relation to environment factor
Aq	–	aquant	aquatic species
Pal	–	paludant	swamp species
Pr	–	pratant	meadow species
Sil	–	sylvant	forest species
SMn***	–	sylvomargoant	forest margin species
St	–	stepant	steppe species
Ps	–	psammophyte	species of sandy soils
Pt	–	petrophyte	species of stony biotopes
Ru	–	ruderant	ruderal species
Hal	–	halophyte	species of saline soils
Cul*	–	culturant	cultural species

Notes: "–" is not provided by this system; * – amendments of Tarasov (1981, 2005); *** – amendments of Baranovsky (2000, 2017).

Like any other scientific concepts, Belgard Plant Ecomorph System can be developed and expanded. Other authors have expanded and supplemented the Belgard Plant Ecomorph System based on its strategy. Several ecomorphs have been later introduced; they reflect intermediate or extreme gradations of factors for terrestrial ecosystems (Tarasov, 1981, 2012; Matveev, 1995, 2006), as well as for aquatic ecosystems (Baranovsky, 2000). Multi-year analysis of ecological features of plant species in their native environment (Baranovsky, 2000, 2008; Belgard, 1950; Matveev, 1995, 2006; Tarasov, 1981, 2012) generated the need to introduce a new cenomorph – sylvomargoant (species of forest margins, from Latin words: margo – edge, boundary, border, margino – edged, framing (Dvoreckij, 1976), margo – forest margin, ad margines silvarum – at margins of deciduous forests (Kirpichnikov & Sabinkova, 1977). The "Sylvomargoant" cenomorph applies to species that can grow on forest margins or forest clearings, but not in the shady areas of forest plant communities (Baranovsky, 2017; Baranovsky et al., 2017).

Vascular plant species of forest clearings present a special ecomorph due to the specificity of natural conditions in this biotope. This is especially true of forest clearings of the steppe zone where the lack of moisture as a limiting factor is more significant and manifests itself in more distinct gradations. Vegetation of forest margins and clearings had previously been allocated in a separate group (Rastenija lesnih poljan i opuschek, 1986). Previously, in ecomorphic analysis the authors attributed these plants to steppe or forest species (Baranovsky, 2000; Matveev, 2006; Tarasov, 2012). However, the majority of these species classified as stepants are not typical representatives of steppe biotopes, and species classified as sylvants almost never occurred in the undergrowth.

Conclusion

The Belgard Plant Ecomorph System has its own characteristics, but it corresponds to the more widespread systems of Ellenberg and Tsyganov. It includes fewer gradations of environmental factors, so it is more applicable for phytoindication of different plant associations, especially for large areas. Its advantage is that the letter designation of ecomorphs gives the possibility to tabulate calculation of ratio between plant species of different habitats. The Belgard Plant Ecomorph System is especially suitable for characterizing ecological features of higher plant species in biotopes of the steppe zone with a wide range of such factors as moisture and mineralization. The Belgard scale covers specifically a wide range of influence of environmental factors. In his ecomorph system, A. L. Belgard first used the term "cenomorph" which indicates the confinedness of a species to a particular phytocenosis. Multi-year studies and analysis of reported and archival scientific materials allow us to propose new ecomorphs for extreme values of factors and separate a new cenomorph – sylvomargoant – in the context of development of the Belgard Plant Ecomorph System. Botanists and ecologists of Oles Honchar Dnipro National University are successors of Belgard's scholarly traditions. Currently, "ecological passports" have been developed for almost 2,000 vascular plant species of the steppe zone of Ukraine. In this paper, we set ourselves the task of acquainting our colleagues and revealing as fully as possible the essence of Belgard's Plant Ecomorph System. Application of the methodology of this system, as well as the ecomorph system itself, can be useful and applicable by our foreign colleagues.

References

Baranovsky, B. A. (2000). Rastitel'nost' ruslovogo ravninnogo vodohranilishha [Vegetation of the channel of a lowland reservoir]. Izdatel'stvo DNU, Dnepropetrovsk (in Russian).

Baranovsky, B. A. (2005). Rastitel'nost' pojmennyh vodoemov Prisamar'ja Dneprovskogo [The vegetation of floodplain reservoirs in the Prisamarya Dnieper]. Pytannja Stepovogo Lisoznavstva ta Lisovoi' Rekul'tivacii' Zemel', 34, 90–94 (in Russian).

Baranovsky, B. A., Ivanko, I. A., Kotovych, A. V., Karmyzova, L. A., & Roschina, N. O. (2017). Analiz trofichnoji struktury flory lisiv dolyny r. Oril' [Analysis of trophic structure of forest flora in the Oril river valley]. Gruntoznavstvo, 18(3–4), 37–50 (in Ukrainian).

Baranovsky, B. A., Manjuk, V. V., Ivan'ko, I. A., & Karmyzova, L. A. (2017). Analiz flori nacional'nogo prirodnogo parku "Oril's'kij" [Analysis of the flora of the Orilsky National Park]. Lira, Dnipro (in Ukrainian).

Baranovsky, B. O. (2008). Analiz florystychnogo riznomanittja richkovyh dolyn Prysamar'ja na suchasnomu etapi doslidzhen' [Analysis of floristic diversity of river valleys of the Prysamarya at the current stage of research]. Pytannja Stepovogo Lisoznavstva ta Lisovoi' Rekul'tivacii' Zemel', 37, 91–94 (in Ukrainian).

Baranovsky, B. O. (2009). Fitoindikacijna ocinka ekologichnogo stanu vodojm basejnu r. Samari [Phytoindication assessment of the ecological state of the River Samara water basin]. Pytannja Stepovogo Lisoznavstva ta Lisovoi' Rekul'tyvacii' Zemel', 38, 52–58 (in Ukrainian).

Baranovsky, B. A. (2017). Vydelenie novoj cenomorfy v kontekste razvitija sistemy ekomorf A. L. Bel'garda [Differentiation of a new coenomorph in the context of the development of Belgard's ecomorph system]. Ecology and Noospherology, 28(3–4), 16–26 (in Russian).

Bel'gard, A. L. (1950). Lesnaja rastitel'nost' jugo-vostoka USSR [Forest vegetation of southeast of Ukrainian SSR]. Lesnaja Promyshlennost', Kiev (in Russian).

Berg, C., Welk, E., & Jaeger, E. (2017). Revising Ellenberg's indicator values for continentality based on global vascular plant species distribution. Applied Vegetation Science, 20, 482–493.

Britton, A. J., Hewison, R. L., Mitchell, R. J., & Riach, D. (2017). Pollution and climate change drive long-term change in Scottish wetland vegetation composition. Biological Conservation, 210, 72–79.

Brygadyrenko, V. V. (2016). Evaluation of ecological niches of abundant species of *Poecilus* and *Pterostichus* (Coleoptera: Carabidae) in forests of the steppe zone of Ukraine. Entomologica Fennica, 27(2), 81–100.

Čeplová, N., Kalusová, V., & Lososová, Z. (2017). Effects of settlement size, urban heat island and habitat type on urban plant biodiversity. Landscape and Urban Planning, 159, 15–22.

Chmura, D., Żarnowiec, J., & Staniaszek-Kik, M. (2017). Do Ellenberg's indicator values apply to the vascular plants colonizing decaying logs in mountain forests? Flora, 234, 15–23.

Cyganov, D. N. (1974). Ekomorfy i ekologicheskie svity [Ecomorphs and ecological suites]. Byuleten MOIP, 79, 2 (in Russian).

Cyganov, D. N. (1975). Sistema jekomorf i indikacija osnovnyh ekologicheskih rezhimov mestoobitanij [The system of ecomorphs and indication of the main ecological regions of habitats]. Ekologija, 6, 15–22 (in Russian).

Cyganov, D. N. (1983). Fitoindikacija jekologicheskih rezhimov v podzone hvojno-shirokolistvennyh lesov [Phytoindication of ecological regimes in the subzone of coniferous-broadleaf forests]. Nauka, Moscow (in Russian).

Dekandol, A. (1956). Geografija rastenij [Geography of plants]. Vestnik Imperatorskogo Russkogo Geograficheskogo Obshchestva (in Russian).

Diduh, Y. P. (2012). Osnovy bioindykacii' [Basics of bioindication]. Naukova Dumka, Kyiv (in Ukrainian).

Douda, J., Boublík, K., Doudová, J., & Kyncl, M. (2016). Traditional forest management practices stop forest succession and bring back rare plant species. Journal of Applied Ecology, 54(3), 761–771.

Dvoreckij, I. H. (1976). Latinsko-Russkij slovar' [Latin-Russian Dictionary]. Russkij Jazyk, Moscow (in Russian).

Dyderski, M. K., Wrońska-Pilarek, D., & Jagodziński, A. M. (2016). Ecological lands for conservation of vascular plant diversity in the urban environment. Urban Ecosystems, 20(3), 639–650.

Diduh, Y. P., & Pljuta, P. G. (1994). Fitoindikacija ekologichnih faktoriv [Phytoindication of environmental factors]. Kyiv (in Ukrainian).

Ekoflora Ukrai'ny [Ecoflora of Ukraine] (2000). Fitosociocentr, Kyiv (in Ukrainian).

Ellenberg, H. (1950). Uncrautgtmeinschaften als Zeigen Fir Clima und Boden. Landwirtschafliche Pflancensociologie, 1. Stutgart.

Ellenberg, H. (1979). Zeigerverte der Gefassphlancen Mitteleuropas. Scripta Geobotanica, 9, 1–121.

Ellenberg, H. (1988). Vegetation ecology of Central Europe. Cambridge University Press, Cambridge.

Ellenberg, H., Weber, H. E., Dull, R., Wirth, V., Werner, W., & Paulissen, D. (1991). Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica, 18, 1–248.

Elst, E. M., De Boeck, H. J., Vanmaele, L., Verlinden, M., Dhliwayo, P., & Nijs, I. (2017). Impact of climate extremes modulated by species characteristics and richness. Perspectives in Plant Ecology, Evolution and Systematics, 24, 80–92.

Ewald, J., & Ziche, D. (2016). Giving meaning to Ellenberg nutrient values: National Forest Soil Inventory yields frequency-based scaling. Applied Vegetation Science, 20(1), 115–123.

Flora USSR (1935–1965). [Flora of USSR]. Kyiv (in Ukrainian).

Ford, H., Healey, J. R., Markesteijn, L., & Smith, A. R. (2018). How does grazing management influence the functional diversity of oak woodland ecosystems? A plant trait approach. Agriculture, Ecosystems and Environment, 258, 154–161.

Gilhaus, K., Boch, S., Fischer, M., Hölzel, N., Kleinebecker, T., Prati, D., Rupprecht, D., Schmitt, B., & Klaus, V. (2017). Grassland management in Germany: Effects on plant diversity and vegetation composition. Tuexenia, 37, 379–397.

Goedecke, F., Jahn, R., & Bergmeier, E. (2018). Quantified ecology and co-occurrence of Mediterranean woody species in a landscape context. Plant Ecology, 219(5), 481–496.

Hancock, M. H., Klein, D., Andersen, R., & Cowie, N. R. (2018). Vegetation response to restoration management of a blanket bog damaged by drainage and afforestation. Applied Vegetation Science, 21(2), 167–178.

Hülber, K., Moser, D., Sauberer, N., Maas, B., Staudinger, M., Grass, V., Wrbka, T., & Willner, W. (2017). Plant species richness decreased in semi-natural grasslands in the Biosphere Reserve Wienerwald, Austria, over the past two decades, despite agri-environmental measures. Agriculture, Ecosystems and Environment, 243, 10–18.

Johansen, O. M., Andersen, D. K., Ejrnæs, R., & Pedersen, M. L. (2018). Relations between vegetation and water level in groundwater dependent terrestrial ecosystems (GWDTEs). Limnologica, 68, 130–141.

Kalusová, V., Čeplová, N., & Lososová, Z. (2016). Which traits influence the frequency of plant species occurrence in urban habitat types? Urban Ecosystems, 20(1), 65–75.

Kılıç, D. D., Kutbay, H. G., Sürmen, B., & Hüseyinoğlu, R. (2018). The classification of some plants subjected to disturbance factors (grazing and cutting) based on ecological strategies in Turkey. Rendiconti Lincei. Scienze Fisiche e Naturali, 29(1), 87–102.

Koch, M., Schröder, B., Günther, A., Albrecht, K., Pivarci, R., & Jurasinski, G. (2016). Taxonomic and functional vegetation changes after shifting management from traditional herding to fenced grazing in temperate grassland communities. Applied Vegetation Science, 20(2), 259–270.

Kosanic, A., Anderson, K., Harrison, S., Turkington, T., & Bennie, J. (2018). Changes in the geographical distribution of plant species and climatic variables on the West Cornwall peninsula (South West UK). PLoS One, 13(2).

Landolt, E. (1977). Okologische Zeigerwerts zur Sweizer Flora. Veroffentlichungen des Geobotanischen Institutes der ETH, 64, 1–208 (in Germany).

Mitchell, R. J., Hewison, R. L., Britton, A. J., Brooker, R. W., Cummins, R. P., Fielding, D. A., Fisher, J. M., Gilbert, D. J., Hester, A. J., Hurskainen, S., Pakeman, R. J., Potts, J. M., & Riach, D. (2017). Forty years of change in Scottish grassland vegetation: Increased richness, decreased diversity and increased dominance. Biological Conservation, 212, 327–336.

Mosyakin, S. L., & Fedoronchuk, M. M. (1999). Vascular plants of Ukraine (Nomenclatural checklist). Naukova Dumka, Kyiv.

Muir, C. D. (2017). Light and growth form interact to shape stomatal ratio among British angiosperms. New Phytologist, 218(1), 242–252.

Opredelitel' vysshih rastenij Ukrainy [Identification guide to higher plants of Ukraine] (1987). Kiev (in Russian).

Pogrebnjak, P. C. (1955). Osnovy lesnoj tipologii [Basics of forest typology]. Kiev (in Russian).

Pruchniewicz, D. (2017). Abandonment of traditionally managed mesic mountain meadows affects plant species composition and diversity. Basic and Applied Ecology, 20, 10–18.

Ramenskiy, L. G. (1929). K metodike sravnitel'noj obrabotki i sistematizatsii spiskov rastenij i drugikh ob'yektov, opredelyayemykh neskol'kimi neskhodno deystvuyushchimi faktorami [On the method of comparative processing and systematization of lists of plants and other objects, determined by several dissimilar factors]. Sel'khozgiz, Moscow. Pp. 11–36 (in Russian).

Ramenskiy, L. G. (1971). Problemy i metody izuchenija rastitel'nogo pokrova [Problems and methods of studying vegetation]. Nauka, Leningrad (in Russian).

Ramenskiy, L. G., Tsatsenkin, I. A., Chizhikov, O. N., & Antipov, N. A. (1956). Ekologicheskaja ocenka kormovyh ugodij po rastitel'nomu pokrovu [Ecological assessment of fodder land by vegetation cover]. Sel'khozgiz, Moscow (in Russian).

Rastenija lesnyh poljan i opushek [Plants of forest glades and fringes] (1986). Schtiinca, Kischinjov (in Russian).

Roeling, I. S., Ozinga, W. A., Dijk, J., Eppinga, M. B., & Wassen, M. J. (2018). Plant species occurrence patterns in Eurasian grasslands reflect adaptation to nutrient ratios. Oecologia, 186(4), 1055–1067.

Santini, B. A., Hodgson, J. G., Thompson, K., Wilson, P. J., Band, S. R., Jones, G., Charles, M., Bogaard, A., Palmer, C., & Rees, M. (2017). The triangular seed mass-leaf area relationship holds for annual plants and is determined by habitat productivity. Functional Ecology, 31(9), 1770–1779.

Schindler, S., O'Neill, F. H., Biró, V., Damm, C., Gasso, V., Kanka, R., Sluis, T., Krug, A., Lauwaars, S. G., Sebesvari, Z., Pusch, M., Baranovski, B., Ehlert, T., Neukirchen, B., Martin, J. R., Euller, K., Mauerhofer, V., & Wrbka, T. (2016). Multifunctional floodplain management and biodiversity effects: A knowledge synthesis for six European countries. Biodiversity and Conservation 25, 1349–1382.

Tarasov, V. V. (1981). Ob ekologicheskoj pasportizacii trav lesnyh kul'tur biogeocenozov stepi (v predelah Dnepropetrovskoj oblasti) [On the ecological certification of grasses of forest cultures of biogeocenoses of the steppe (within the Dnepropetrovsk region)]. DGU, Dnepropetrovsk, 122–138 (in Russian).

Tarasov, V. V. (2012). Flora Dnipropetrovs'koi' ta Zaporiz'koi' oblastej [Flora of Dnipropetrovsk and Zaporizhia regions]. Lira, Dnipropetrovsk (in Ukrainian).

Van Dobben, H. F., & de Vries, W. (2016). The contribution of nitrogen deposition to the eutrophication signal in understorey plant communities of European forests. Ecology and Evolution, 7(1), 214–227.

Vitasović Kosić, I., Juračak, J., & Łuczaj, Ł. (2017). Using Ellenberg-Pignatti values to estimate habitat preferences of wild food and medicinal plants: An example from northeastern Istria (Croatia). Journal of Ethnobiology and Ethnomedicine, 13(1).

Warming, E. (1902–1903). Raspredelenie rastenij v zavisimosti ot vneschnih uslovij [Distribution of plants depending on external conditions]. Brokhaus – Efron, 1–3, Sankt-Peterburg (in Russian).

Kirpichnikov, M. E., & Sabinkova, N. N. (1977). Russko-latinskij slovar' dlja botanikov [Russian-Latin Dictionary for Botanists]. Nauka, Leningrad (in Russian).

Mirkin, B. M., & Naumova L. G. (2012). Sovremennoe sostojanie osnovnyh koncepcij nauki o rastitel'nosti [The current state of the basic concepts of the science of vegetation]. Ufa (in Russian).

Matveev, N. M. (1995). Ob osnovnyh tipah cenoticheskoj struktury etalonnyh dlja stepnogo Zavolzh'ja estestvennyh lesov [On the main types of the cenotic structure of the reference forests for the steppe Zavolzhye]. Voprosy Ekologii i Ohrany Prirody v Lesostepnoj i Stepnoj Zonah, Samara, 1, 29–41 (in Russian).

Matveev, N. M. (2006). Biojekologicheskij analiz flory i rastitel'nosti (na primere lesostepnoj i stepnoj polosy) [Biecological analysis of flora and vegetation on the example of the forest-steppe and steppe strip]. Samara (in Russian).