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THE ROLE OF ALTITUDE, LATITUDE AND LONGITUDE IN THE DISTRIBUTION OF MEADOW VEGETATION IN THE FLOODPLAINS OF THE NORTHERN UKRAINE

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Abstract: This paper presents a comparison of syntaxa at alliance level from *Molinio-Arrhenatheretea, Koelerio-Corynephoretea* and *Phragmito-Magnocaricetea* classes, considering altitude, latitude and longitude. The results show that the syntaxa may be divided into two groups: one geographically specific (with a narrow distribution and propensity for certain climatic zones or regions, e.g. *Agrostio stoloniferae-Beckmannion eruciformis*) and the other non-geographically specific (with a wide distribution and occurring in several climatic zones e.g. typical *Festucion pratensis* alliance). The role of climate in the differentiation of floodplain meadow vegetation is considerable in spite of the well known azonality of such vegetation. This can be explained by the changes in environmental conditions, especially soil reaction, temperature and continentality.

Keywords: azonal vegetation, *Molinio-Arrhenatheretea* class*, Koelerio-Corynephoretea* class, *Phragmito-Magnocaricetea* class, altitude, latitude, longitude, Ellenberg indicator values.

Introduction

Azonal vegetation is the vegetation which does not form its own separate zone, but occurs in different vegetation. The term "azonal vegetation" was introduced by Y.K Pachossky in 1915 (Pachossky, 1915). Floodplain meadows are a classic example of the azonal vegetation. In contrast to the zonal types such as forest and steppe vegetation, meadow vegetation is characterized by low geographic specificity.

Some syntaxa of the meadow vegetation have a very wide distribution in Europe — from Atlantic to Ural (e.g. ass. *Anthoxantho-Agrostietum tenuis* Sillinger, 1933). Others have small ranges (e.g. *Koelerio-Agrostietum vinealis* (Sipaylova et al., 1985; Shelyag et al., 1987) or are endemic (e.g. *Trifolio (pratensis)-Brizetum elatioris* Didukh & Kuzemko in Kuzemko, 2009). Most studies focusing on the peculiarities of meadow vegetation show the influence of different ecological factors on the differentiation of flood-plain meadow vegetation to be considerable. However, as yet very little attention has been given to the influence of climatic factors on the distribution of plant communities, as the conventional view is that the flood-plain regime is the main influencing factor on the formation of the flood-plain meadow vegetation.

The aim of this study is to establish the influence of altitude, latitude and longitude on the distribution of meadow vegetation alliances in the floodplains of northern Ukraine.

Materials and Methods

The vegetation of the floodplains of the 36 large and medium sized rivers in northern Ukraine was studied during 2008-2009. The relevés were carried out along transects 5 m wide across the floodplain with plot size of 25 m^2 (in rare cases 16 m^2). There was one (in rare cases two) transect per river (Figure 1).

The relevés were carried out over a range of altitudes, latitudes and longitudes within the Forest and Forest-Steppe zones of the plains region of Ukraine. Montane areas were

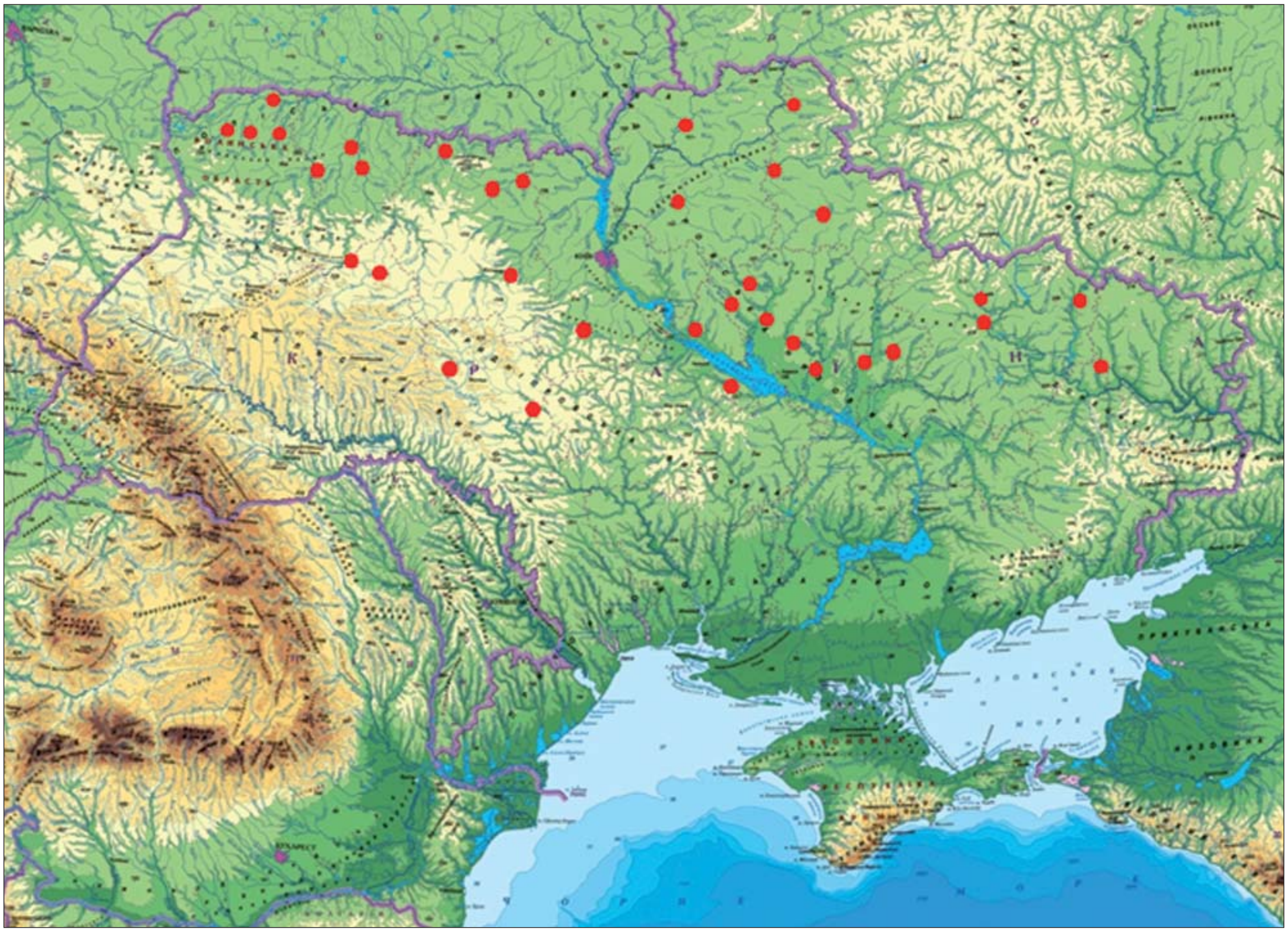

Figure 1. Location of the transects (red points) in the Forest and Forest-Steppe zones of the plains of Ukraine.

Volyno-Podilska Elevation (highest point 471 m, middle altitudes from 380-320 m on the NW side to 220-130 m on the SE, in our dataset 189-270 m), Prydniprovska Elevation (highest point 323 m, middle altitudes from 220-240 m on the N side to 150-180 m on the S, in our dataset 140-191 m). Lowland areas were Polisska Lowland (middle altitudes 100-250 m, in our dataset 126-163 m) and Prydniprovska Lowland including Prydesnianska and Poltavska plains (highest point 226 m, middle altitudes 50-160 m, in our dataset 73-125 m). The most northern point is Ivotka River valley (N 51°58´), the most southern point is Sob River valley (N 48°46´), the most western point is Vyzhivka River valley (E 24°30´) and the most eastern point is Oskil River valley (E 37°85´).

704 relevés were used for analysis and processed using the TWINSPAN modified algorithm (Hill, 1979; Roleček et al., 2009) in JUICE (Tichy, 2002) (Figure 2).

The interpretation of the syntaxa was made in accordance with the syntaxonomic concept for Ukraine (Solomankha, 2008; Kuzemko, 2009).

For evaluation of syntaxa and their geographical specification, statistical data were used, including arithmetic mean, standard deviation and coefficient of variation (Standard deviation / mean*100) (Table 1) that renders the variables adimensional and that can be used to calculate the extent of each alliance in relative terms by multiplying alt x lat x long.

The last value was used to identify geographically specific, relatively geographically specific and geographically non-specific alliances. Taking into consideration the fact that the coefficient of variation for altitude in each case is more than twice the analogous value for latitude and longitude, we decided to ignore that index, and to calculate the size of the geographic range we used only the extension lat × long. Thus, the alliances were arranged in order of increasing size of the geographic range and the range of values was divided into three equal parts. The group of alliances with the lowest values were considered

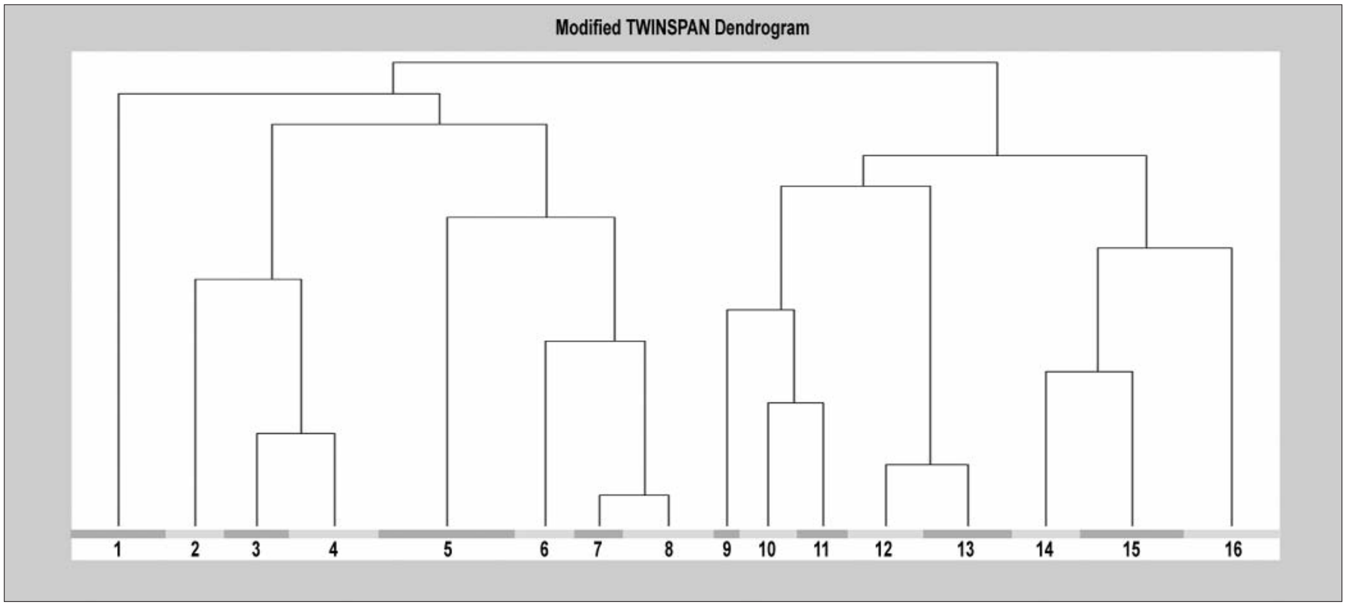

Figure 2. Dendrogram of the cluster analysis of the 704 relevés of flood-plain meadow vegetation. The code of numbers: 1 – *Corynephorion & Koelerion glaucae*; 2 – *Poion angustifoliae*; 3 – *Agrostion vinealis*; 4 – *Trifolion montani*; 5 – *Cynosurion*; 6 – *Festucion* (dry), 7 – *Festucion* (semi-halophytic); 8 – *Festucion* (typical); 9 – *Agrostio stoloniferae-Beckmannion eruciformis*; 10 – *Calthion*; 11 – *Magnocaricion*; 12 – *Sparganio-Glycerion*; 13 – *Molinion*; 14 – *Alopecurion* (semi-halophytic); 15 – *Alopecurion* (typical); 16 – *Deschampsion*.

Table 1. Altitude and geographical coordinate data for the flood-plain meadow vegetation alliances. The highest means (not more than 3) are indicated in bold, lowest means are underlined.

№	Syntaxa	Number of relevés	Altitude Mean Std.	Dev.	Latitude Mean Std.	Dev.	Longitude Mean Std.	Dev.
1	*Corynephorion & Koelerion glaucae*	55	137.4±4.25	31.49	50.9±0.11	0.81	28.6±0.53	**3.93**
2	*Poion angustifoliae*	34	119.8±7.29	42.49	50.0±0.17	**0.98**	32.4±0.31	1.79
3	*Agrostion vinealis*	52	91.2±1.96	14.11	49.9±0.11	0.80	**33.9±0.25**	1.81
4	*Trifolion montani*	38	113.3±5.48	33.80	50.3±0.14	0.86	32.6±0.54	**3.34**
5	*Cynosurion*	79	**156.3±3.84**	34.11	**51.1±0.06**	0.57	27.3±0.30	2.69
6	*Festucion* (dry)	35	104.9±4.94	29.22	50.3±0.14	0.85	**35.0±0.47**	2.76
7	*Festucion* (semi-halophytic)	28	96.4±6.85	36.23	49.6±0.05	0.29	**33.8±0.34**	1.78
8	*Festucion* (typical)	53	122.5±5.50	40.01	50.1±0.13	**0.92**	31.2±0.44	3.17
9	*Agrostio stoloniferae-Beckmannion eruciformis*	15	86.3±3.21	12.44	49.6±0.14	0.53	33.3±0.37	1.45
10	*Calthion*	33	148.0±9.36	**53.76**	50.1±0.14	0.80	30.0±0.52	2.96
11	*Magnocaricion*	30	146.1±11.95	**65.48**	49.9±0.13	0.69	30.4±0.47	2.59
12	*Sparganio-Glycerion*	44	136.7±5.19	34.45	50.9±0.11	0.75	29.3±0.56	**3.71**
13	*Molinion*	51	148.4±3.83	27.36	**51.0±0.11**	0.76	27.0±0.39	2.76
14	*Alopecurion* (semi-halophytic)	40	106.2±7.20	45.57	49.7±0.09	0.55	33.0±0.36	2.27
15	*Alopecurion* (typical)	60	115.8±5.16	39.95	50.3±0.12	**0.95**	32.0±0.41	3.16
16	*Deschampsion*	56	**152.6±4.78**	35.79	**51.1±0.09**	0.64	27.4±0.37	2.77
	Total	703	127.7±1.62	42.86	50.4±0.03	0.92	30.6±0.14	3.83

Table 2. The distribution of syntaxa according to their geographic specificity based on the size of the geographic range.

№	Syntaxa	coefficient of variation x 100			lat × long	alt × lat × long
		alt	lat	long		
	geographically specific syntaxa					
7	*Festucion* (semi-halophytic)	37.58	0.58	5.27	3.08	115.72
9	*Agrostio stoloniferae-Beckmannion eruciformis*	14.41	1.07	4.35	4.65	67.07
14	*Alopecurion* (semi-halophytic)	42.91	1.11	6.88	7.61	326.64
3	*Agrostion vinealis*	15.47	1.60	5.34	8.56	132.43
	relatively geographically specific					
2	*Poion angustifoliae*	35.47	1.96	5.52	10.83	384.06
5	*Cynosurion*	21.82	1.12	9.85	10.99	239.86
11	*Magnocaricion*	44.82	1.38	8.52	11.78	528.00
16	*Deschampsion*	23.45	1.25	10.11	12.66	296.96
6	*Festucion* (dry)	27.86	1.69	7.89	13.33	371.19
13	*Molinion*	18.44	1.49	10.22	15.23	280.85
	geographically non-specific					
10	*Calthion*	36.32	1.60	9.87	15.76	572.30
4	*Trifolion montani*	29.83	1.71	10.25	17.52	522.57
15	*Alopecurion* (typical)	34.50	1.89	9.88	18.65	643.43
12	*Spargano-Glycerion*	25.20	1.47	12.66	18.66	470.19
8	*Festucion* (typical)	32.66	1.84	10.16	18.66	609.38
1	*Corynephorion* & *Koelerion glaucae*	22.92	1.59	13.74	21.87	501.16

geographically specific, those with average values as relatively geographically specific, and those with maximum values as geographically non-specific (Table 2).

To reveal the dependencies between the geographic coordinates and the environmental factors, the average means of Ellenberg indicator values for each alliance were calculated (Table 3), followed by a calculation of the correlation coefficient between average means of geographic coordinates and environmental factors (Table 4).

For comparison of syntaxa relating to altitude, latitude and longitude a box & whiskers plot was used.

RESULTS

Using cluster analysis (TWINSPAN modified algorithm) we obtained 16 groups of relevés. The clusters were interpreted in terms of alliances, resulting in the identification of 16 alliances (Figure 2). The number of relevés in each cluster is presented in the Table 4. The *Koelerio-Corynephoretea* class is represented by 2 alliance, which were assigned into one cluster, *Molinio-Arrhenatheretea* class by 10 alliances (and 13 cluster) *Phragmito-Magnocaricetea* class by 2 alliances (and 2 cluster). *Festucion* and *Alopecurion* alliances are represented by several clusters: the first alliance by three clusters which were interpreted as dry, semi-halophytic and typical types, and the second alliance by two clusters — the typical and semi-halophytic types.

The results of the analysis of the meadow vegetation syntaxa distribution in relation to the means of altitude, latitude and longitude are presented in Table 1.

Distribution of the syntaxa in relation to altitude revealed that the ‘high’ alliances, i.e. occurring mainly at upper elevations are *Cynosurion* and *Deschampsion*, and the ‘low’ alliances, i.e. distributed mainly on lowlands are *Agrostion vinealis, Festucion* (semi-halophytic), *Agrostio stoloniferae-Beckmannion eruciformis*. Alliances with the widest altitudinal amplitudes are *Calthion* and *Magnocaricion*. Alliances with narrowest altitudinal amplitudes are *Agrostion vinealis* and *Agrostio stoloniferae-Beckmannion* (Table 1, Figure 3a).

The distribution of floodplain vegetation depending on latitude showed that the most ‘northern’ syntaxa, i.e. founded in more northern region of Ukraine are *Cynosurion, Molinion*

Table 3. Average means of Ellenberg indicator values for syntaxa.

№	Syntaxa	Ellenberg indicator values											
		Light		Temperature		Continentality		Moisture		Soil Reaction		Nutrients	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1	*Corynephorion & Koelerion glaucae*	7.72	0.30	6.18	0.23	4.60	0.53	2.91	0.42	4.73	0.84	2.52	0.54
2	*Poion angustifoliae*	7.30	0.29	5.98	0.19	5.12	0.57	4.39	0.55	6.76	0.67	4.73	0.80
3	*Agrostion vinealis*	7.32	0.26	6.16	0.21	4.60	0.45	4.14	0.43	6.16	0.85	3.92	0.52
4	*Trifolion montani*	7.59	0.31	6.24	0.26	4.46	0.65	3.74	0.53	5.71	0.98	3.50	0.76
5	*Cynosurion*	7.11	0.19	5.66	0.28	3.58	0.46	5.14	0.73	5.18	0.78	4.18	0.83
6	*Festucion* (dry)	7.03	0.27	5.87	0.20	4.43	0.48	5.24	0.66	6.80	0.63	4.79	0.82
7	*Festucion* (semi-halophytic)	7.32	0.19	5.81	0.26	4.01	0.62	4.97	0.65	7.05	0.58	4.41	0.61
8	*Festucion* (typical)	7.04	0.22	5.76	0.26	3.93	0.45	5.11	0.56	6.66	0.72	4.92	0.80
9	*Agrostio stoloniferae-Beckmannion eruciformis*	7.11	0.33	5.75	0.11	4.35	0.41	7.50	0.51	6.88	0.38	6.08	0.58
10	*Calthion*	6.90	0.24	5.55	0.22	4.34	0.53	7.81	0.47	6.39	0.63	5.81	0.75
11	*Magnocaricion*	7.00	0.29	5.49	0.31	4.64	0.53	8.46	0.49	6.47	0.48	5.88	0.81
12	*Sparganio-Glycerion*	7.02	0.31	5.58	0.27	4.22	0.50	8.18	0.56	6.06	1.06	5.65	0.76
13	*Molinion*	6.82	0.31	5.32	0.22	3.96	0.53	8.06	0.48	5.47	0.88	4.85	0.73
14	*Alopecurion* (semi-halophytic)	7.10	0.30	5.82	0.17	3.95	0.64	6.31	0.61	6.94	0.70	5.57	0.61
15	*Alopecurion* (typical)	6.78	0.22	5.63	0.23	4.18	0.48	6.62	0.45	6.69	0.56	5.51	0.68
16	*Deschampsion*	6.88	0.24	5.47	0.22	3.68	0.79	6.89	0.44	5.32	0.82	4.59	0.58

Table 4. The values of the correlation coefficient between average means of geographic coordinates and environmental factors.

	Light	Temperature	Continentality	Moisture	Soil Reaction	Nutrients
altitude	-0.31	-0.56	-0.30	0.33	-0.65	-0.03
latitude	-0.12	-0.29	-0.38	0.03	-0.85	-0.37
longitude	0.24	0.55	0.43	-0.30	0.78	0.12

and *Deschampsion*. The most ‘southern’ syntaxa, distributed in Forest-Steppe of Ukraine are *Festucion* (semi-halophytic), *Agrostio stoloniferae-Beckmannion eruciformis,* and *Alopecurion* (halophytic type). Syntaxa with widest amplitudes according to latitude are *Poion angustifoliae, Festucion* (typical), *and Alopecurion* (typical). Syntaxon with narrowest amplitude according to latitude is *Festucion* (semi-halophytic) (see Table 1 and Figure 3b).

The analysis of the distribution of floodplain meadow vegetation depending on longitude showed that the most ‘western‘ syntaxa are *Cynosurion, Molinion, Deschampsion*; the most ‘eastern’ syntaxa are *Agrostion vinealis, Festucion* (dry), and *Festucion* (semi-halophytic). The syntaxa with the widest longitudinal amplitudes are *Corynephorion & Koelerion glaucae, Sparganio-Glycerion, and Trifolion montani*; the syntaxon with narrowest longitudinal amplitude is *Agrostio stoloniferae-Beckmannion eruciformis* (see Table 1 and Figure 3c).

The size of the geographic range considering latitude and longitude varies between 3.08 units (for *Festucion*

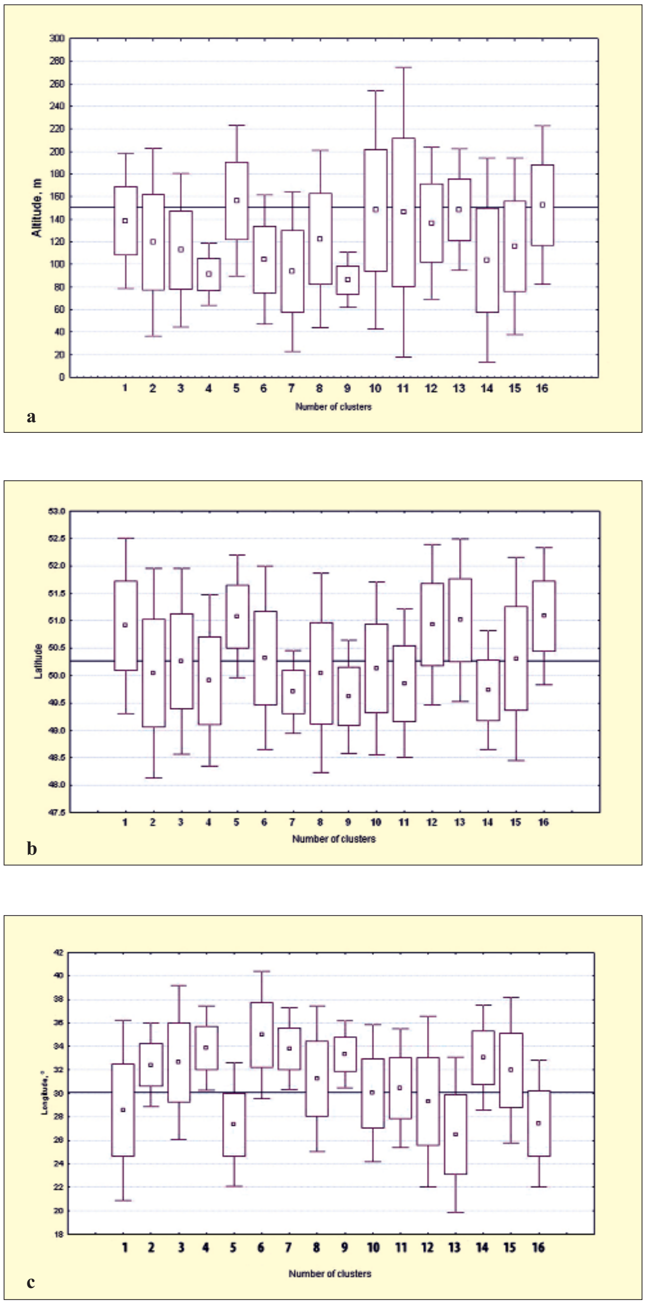

Figure 3. A comparison of syntaxa relating to altitude (a), latitude (b) and longitude (c). Number of clusters corresponds to explanation for Figure 2.

(semi-halophytic)) to 21.87 (for *Corynephorion* & *Koelerion glaucae*) (Table 2). The obtained scale was divided into three equal parts, and then the stride parameter was determined with formula: mean min + mean max / 3, i.e. in this case is 6.26. Consequently, the first group (geographically specific syntaxa) contained the syntaxa with the means of lat × long from 3.08 to 9.34, the second group (relatively geographically specific) from 9.35 to 15.60, and the third group (geographically non-specific) from 15.61 to 21.87. The first group contains 4 syntaxa: *Festucion* (semi-halophytic), *Agrostio stoloniferae-Beckmannion eruciformis, Alopecurion* (semi-halophytic), and *Agrostion vinealis*; the second group — 6 syntaxa: *Poion angustifoliae, Cynosurion, Magnocaricion, Deschampsion, Festucion* (dry), and *Molinion* and the third group — 6 syntaxa: *Calthion, Trifolion montani, Alopecurion* (typical), *Sparganio-Glycerion, Festucion* (typical), *Corynephorion* & *Koelerion glaucae.*

The calculation of the correlation coefficient between the average means of geographic coordinates and the average means of Ellenberg indicator values (Table 3) revealed that altitude has a negative correlation with all factors except moisture. The largest values of correlation coefficients were for soil reaction (-0.65) and temperature (-0.56). The lowest value was for nutrients (-0.03) (Table 4).

Similar results were obtained for latitude, but with some minor differences. The only positive value of the coefficient for moisture was also the lowest (0.03). The largest value, as in previous case, we seen for soil reaction (-0.85).

In contrast, the results for longitude show a positive correlation coefficient for all factors except moisture. The largest value, as in the two previous cases, was obtained for soil reaction (0.78), and the lowest for nutrients (0.12).

Discussion

The results of the analysis allowed us to divide the syntaxa of the floodplain meadow vegetation into 3 groups: geographically specific, relatively geographically specific and geographically non-specific.

The first group contains syntaxa with a propensity for certain climatic zones or regions, i.e. occur only in northern, southern, western or eastern regions of the Forest and Forest-Steppe zones of the plain region of Ukraine.

Among investigated syntaxa, *Agrostio stoloniferae-Beckmannion eruciformis, Festucion* (semi-halophytic) and *Alopecurion* (semi-halophytic), which were distributed only in the lowlands of the southern and eastern regions, are the most geographically specific. Such specificity is caused by edaphic factors, because these communities occur on the ecotopes with chloride salinization of the soil, which are spread just to the South-East of the study area and formed by the conditions of weak flood regime of the Prydniprovska lowland and semi-arid continental climate. The first group also contains the *Agrostion vinealis* alliance, with relatively local distribution of the communities in Dnipro flood-plain and the lower reaches of its tributaries. The last alliance has a narrow distribution, only occurring in Ukraine and Belarus (Korotkov et al., 1991; Stsepanovich, 2001). Alliance

Agrostio stoloniferae-Beckmannion eruciformis was described in middle Don River basin (Korotkov et al., 1991) and occurs also in some regions of the Russian Federation (Bulokhov, 2001; Semenischenkov, 2009; Averinova, 2010). *Festucion* (semi-halophytic) and *Alopecurion* (semi-halophytic) have uncertain syntaxonomic status, therefore it is not obviously possible to consider their geographical distribution.

Some syntaxa we consider as relatively geographically specific, e.g. *Molinion* and *Deschampsion* syntaxa which are generally found at high elevations and in northern and western regions, although they have quite a wide amplitude for each factor. In most cases they widespread from the West on the East, but only within one geographical zone: Forest (*Cynosurion, Deschampsion, Molinion*) or Forest-Steppe (*Poion angustifoliae, Festucion* (dry)).

An example of geographically non-specific syntaxa is the typical *Festucion* alliance which is characterized by intermediate means and a wide amplitude, i.e. indifferent for each factor.

The analysis of the influence of environmental factors on the geographic distribution of the syntaxa revealed that increasing altitude corresponds to increasing soil acidity, decreasing temperature, insignificant reduction of illumination and little increase in habitat moisture. A correlation with soil nutrient content is, however, almost absent. As the study area includes only plain regions, the influence of altitude on the distribution of syntaxa is poorly marked.

The investigation of the correlation of latitude with environmental factors showed that from south to north the soil acidity increased considerably, but the nutrient content, continentality, temperature and illumination slightly reduced. Moisture was nevertheless barely correlated with latitude.

Increasing longitude (from west to east) lead to a significant reduction of the soil acidity, a slight decrease in moisture, and an increase in illumination, temperature, continentality of communities and also nutrient contents of the soil.

This means that the factors which have the most influence on the geographic distribution of the flood-plain vegetation in Northern Ukraine are soil reaction, temperature and continentality. The leading role of the soil reaction can be explained by podzol process within a Forest zone that in combination with high humidity permeability of soil leads to washing away of ions of hydrogen from these soils in flood-plains, thus raising their acidity. In a Forest-Steppe zone such process is not observed. As investigations were carried out in flood-plain conditions where irrespective of geographical zone superfluous humidification is observed, moisture does not have much influence on geographic differentiation. This phenomenon is connected to the known azonality of the flood-plain vegetation.

CONCLUSIONS

Geographical specificity of syntaxa in the floodplains of the Northern Ukraine is mainly caused by edaphic factors, the greast of wich is salt content in soil.

Geographical position along latitudinal and longitudinal gradients is more important than altitude for differentiation of grassland alliances within the plains of Ukraine.

The role of climate in the differentiation of the floodplain meadow vegetation is important, in spite of the well known azonality of such vegetation. This can be explained by the changes in environmental conditions, especially soil reaction, temperature and continentality.

The presented analysis can be applied to a wider range of investigated factors. Probably, a comparison of the meadow vegetation from mountain and plain regions also from all natural zones of Ukraine (Forest, Forest-Steppe and Steppe zones) will reveal different patterns.

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