PHYTOINDICATIVE ASSESSMENT OF GRASSLAND COMMUNITIES OF PASTORAL ECOSYSTEMS

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Plant communities of the 31 pastoral grasslands have been assessed using the phytoindicative analytical method of Ellenberg (1974) in order to compare the community reactions on the habitat-climatic and habitat-edaphic conditions of the following 3 physic-geographical zones of Chernivtsi Region in Ukraine: ***Plain***, ***Foothills*** *and* ***Mountains****. An average realized niche of each plant species has been assessed along the gradients of the study factors of habitat-climatic conditions, such as: insolation, thermal regime and the degree of continentality, as well as the following habitat-edaphic conditions: the soil moisture, acidity, and nitrogen content. The deviations of the pastoral plant communities from their potential climax states have been assessed.*

Key words*: phytoindication, phytocenosis, pasture, grassland, Ellenberg's analytical method*

Introduction. Near 70% of Ukraine's total land area of 60 million hectares is classified as agricultural land, which includes cultivated land (grains, technical crops, forages, potatoes and vegetables, and fallow), gardens, orchards, vineyards, and permanent meadows and pastures (US Department of Agriculture.., 2004). Due to the Ukrainian National Department of the Soil Fertility Conservation the 78% of the agricultural lands (56% of the Ukraine's total land) are arable, and it is the highest level of land plowing in a Europe (Sutton, 2008). Such increase dramatically in land arable and soil cultivation is a result of the large industrial farms shifting away from cattle toward crop production since 2000. Cattle livestock is not quickly profitable and not as attractive to investors as the other types of farming. The collapse of the Soviet Union in 1991 increased feed and production costs and reduced profitability for cattle livestock enterprises (US Department of Agriculture.., 2004). Because of reduce in cattle' inventories the demand for forage is continuing to shrink, which is followed by the transferring of the natural pastoral grasslands to the plowed lands in order to supply the crop production. These anthropogenic influences are dramatically crucial and irreversible for the native ecosystems. Ukraine's agricultural sector is estimated to cause 35-40 percent of all environmental degradation (US Department of Agriculture.., 2004).

The aim of the current paper is to define the special characteristics of the flora community reaction on habitat conditions within the three geographically different areas (***Plain***, ***Foothills*** and ***Mountains***); each one is determined by specific macroclimate and history of vegetation development. The null hypothesis is that flora composition of the grassland communities reacts the most vigorously to changes in abiotic conditions, and reflects anthropogenic influences the most quickly.

Materials and methods. The study objects are the plant communities of the 31 grassland ecosystems, which are located within the three distinct physical-geographical zones of Chernivtsi Region (47°43' – 48°41' N × 24°55' – 27°30' E) of Ukraine: ***Plain***, ***Foothills***, and ***Mountains***, each one is determined by specific characteristics of landscapes, climate, elevation, age and type of rocks. The physical-geographical zonation of Chernivtsi Region is due to mapping of Voropaj (Voropaj, 2004): ***Plain*** zone is located in a north part of a region between rivers Prut and Dniester; ***Foothill*** zone is a central before-mountain area of Chernivtsi Region; and ***Mountain*** zone is presented by Bukovina Carpathian Mountains, which are located on the south of the study region. All of the study grasslands, unmanaged since 1992, are used as commons for cattle pasturing by private household farms, which typically have two to three head of cattle per farm.

The sampling and analysis methods were performed in the same way for each of the compared ecosystems. Biological samples for phytoindication analysis were gathered during peak growing seasons (June – July) in years 2005, 2006, and 2007. Study plots for each of the compared pastures were 10m × 10m. Plant specimens were identified to species. Plant cover (C_i) in study communities was measured as a visual assessment of the relative area covered by each species i=1,…n within the composition of community in a study plot 1m × 1m, and then recorded as a continuous variable **c** between 0 and 100% and transferred into the Braun-Blanquet (Braun-Blanquet, 1965) cover classes (C_i) as follows: C_i =5, when **c** $\geq$ 75%; C_i =4, when 50% $\geq$ **c** < 75%; C_i =3, when 25 $\geq$ **c** < 50 %; C_i =2, when 5 $\geq$ **c** < 25 %; and C_i =1, when 1 $\geq$ **c** < 5 %.

Each of plant species *i* within the study communities was analyzed using the analytical method of Ellenberg [5] in order to assess the factors *f* of habitat-climatic conditions, such as: insolation ***L***, thermal regime ***T*** and the degree of continentality ***K***, as well as the following habitat-edaphic conditions: the soil moisture ***F***, acidity ***R***, and nitrogen content ***N***. The index for each factor *f* (*n=1…6*) is a continuous variable f_i, which is assessed for each species *i*, as follows in table 1.

The phytoindication measure X_f of a total community reaction on a factor *f* was calculated as follows: $X_f = \sum C_i f_i, / \sum C_i$, where C_i is a plant cover class (C_i=1…5) of species *i*=1,…n assessed by the Braun-Blanquet method; f_i is a value of factor *f* of each species *i*=1,…n within the community, where *f* is 1 of the following 6 factors analyzed using the analytical method of Ellenberg (Ellenberg, 1947): ***L***, ***T***, ***K***, ***R***, ***F***, ***N***. The X_f expresses an average realized niche of species along the gradients of the study factors *f*.

The reference value for each factor *f* is linked to its mean ($\mathbf{m}_f$) assessed across all pastures within each of study physic-geographical zone of Chernivtsi Region (fig. 1). Due to Didukh e al. (Didukh and Gaiova, 2008) the reference value expresses potentially the reference climax state of the study community.

Relative deviation r_f of the measured values of *f* from the reference value was assessed as follows [6]: $r_f = X_f - \mathbf{m}_f / \max_f * 100\%$, where X_f is a phytoindication measure of a total community reaction on a factor *f*; $\mathbf{m}_f$ is a mean value of X_f assessed across all pastures within each of study physic-geographical zone of Chernivtsi Region; $\max_f$ is a maximum possible value within the scale of factor *f*.

An overall deviation of plant community relatively to the reference point was quantified as an average of relative deviations r_f of the measured values of *f* from the reference values: $r = \sum r_f / n$, where n is a number of factors *f* (n=6).

Results and Discussions. Within the study area the measure of phytocenosis reaction on the soil humidity $\mathbf{X_F}$ varies from 3.4 to 5.3 with an average value m=4.2 (*SD*($\pm$)=0.4). In general these data expresses the high level of the soil humidity within the study pastures from the prospective of the phytoindication analysis. It can be explained by the the leaching (permacidous) type and periodic leaching type of soil moister regimes, where the soil returns less moisture to the atmosphere than it receives. Comparative analysis of the X_F within each of the three physic-geographical zones of Chernivtsi Region shows the following minimum, maximum, and mean values respectively: for ***Plain*** zone ($3.6 \leq X_F \leq 4.8$; **m** = 4.2, *SD*($\pm$)=0.4); for ***Foothills*** zone ($3.4 \leq X_F \leq 5.3$; **m**=4.2, *SD*($\pm$)=0.5); and for ***Mountains*** ($3.7 \leq X_F \leq 4.7$; **m**=4.2, *SD*($\pm$)=0.3). Grasslands of wet foothills from time to time are perched by groundwater, because the excess moisture is percolated down to the dead horizon of desiccation.

Table 1.

Description and abbreviation of the factors f under assess driven from the analytical method of Ellenberg [5].

Factor *f*, abbreviation	$\max_f$	Description
		Habitat-climatic conditions:
insolation, ***L***	9	indicates the relative strength of insolation; vary from 1 (species requiring full shade) to 9 (plant species requiring full light).
degree of continentality, ***K***	9	describes the resistance of a species to the frequency and length of occurrence of dry periods in the growing season, as well as to the length of the pre-frost period; vary from 1 (the most features of an Atlantic climate) to 9 (the most continental features).
degree of the temperature regime, ***T***	9	indicates the resistance of a plant species to the thermal regime; vary from 1 (species requiring low temperatures) to 9 (species requiring high temperatures).
		Habitat-edaphic conditions:
soil moisture, ***F***	12	expresses the ecological reaction of species in relation to the humidity of the substrate in the growing season; vary from 1 (species requiring extremely dry soils) to 12 (aquatic plants that are mostly completely submerged in water).
soil acidity, ***R***	9	reflects biologically the acidity of the substrate experienced by plants from; vary from 1 (species requiring highly acid soil [pH < 3.5]) to 9 (species requiring neutral or basic soils [pH > 6.5]).
nitrogen content in the soil, ***N***	9	expresses the ecological reaction of species to the content of nitrogen in the soil; vary from 1 (species only occurring in soils poor in nitrogen) to 9 (species only occurring in soils with high content of nitrogen).

Table 2.

The phytoindication measures X_f of the study communities' reactions on factors f

Zone	Study grasslands	F	N	R	L	T	K
Plain zone	*Vikno*	4.6	4.7	3.6	7.3	3.8	2.4
Plain zone	*Kostryzhivka*	4.3	3.9	5.0	7.4	4.3	3.3
Plain zone	*Luzhany*	4.3	4.0	4.4	7.2	7.2	3.0
Plain zone	*Polyana*	3.6	3.2	2.5	6.2	2.1	3.0
Plain zone	*Chornyvka*	3.9	4.3	3.3	6.9	2.9	3.8
Plain zone	*Zelena*	4.3	3.0	2.8	7.3	3.3	3.2
Plain zone	*Vovchynec*	3.8	4.0	5.0	7.9	5.0	3.5
Plain zone	*Stavchany*	3.6	3.5	3.7	6.9	2.5	2.6
Plain zone	*Grushivcy*	4.4	5.6	2.3	6.8	3.3	3.2
Plain zone	*Myhalkove*	4.4	5.1	3.5	7.3	3.9	4.0
Plain zone	*Magala*	4.8	4.3	4.6	7.2	2.9	3.3
Plain zone	*Zarozhany*	4.4	2.8	3.2	7.1	2.6	3.1
Foothills	*Ternavka*	3.7	3.5	5.0	7.5	3.7	3.7
Foothills	*Gorbovo*	4.3	4.1	4.3	7.1	3.6	3.2
Foothills	*Valya Kuzmyna*	4.1	3.6	4.6	7.2	4.3	3.9
Foothills	*Myhalcha*	3.4	2.3	5.7	7.0	3.1	4.1
Foothills	*Cher. Dibrova*	4.2	3.9	4.6	7.2	4.3	3.4
Foothills	*Dubovo*	4.1	3.7	5.0	7.5	3.2	3.8
Foothills	*Kostynsy*	4.6	3.9	4.3	6.9	3.1	2.7
Foothills	*Brusnyca*	4.1	3.4	4.4	7.5	3.5	3.6
Foothills	*Chereshenka*	5.3	5.2	3.0	7.5	2.1	2.4
Foothills	*Banyliv Pidgirnyj*	4.4	3.1	3.2	6.9	2.8	3.1
Foothills	*Krasnoyilsk*	4.6	3.6	4.6	7.4	3.5	3.0
Foothills	*Staryj Vovchynec*	4.1	4.6	4.5	6.5	3.4	3.4
Mountains	*Stebnyk*	3.7	3.4	4.1	3.9	3.2	3.5
Mountains	*Lopushna*	4.0	3.0	4.4	6.4	3.1	3.8
Mountains	*Selatyn*	4.1	3.8	3.8	7.0	3.8	3.1
Mountains	*Shepit*	4.0	2.8	3.5	7.2	2.6	3.5
Mountains	*Dolyshnij Shepit*	4.2	3.7	3.6	6.6	2.3	2.9
Mountains	*Percalab*	4.7	4.4	4.5	6.9	3.2	3.5

The important property of soils is also their acidity. The reaction of plant communities on the soil acidity ***R*** expressed by the measure X_R varies in general within the study area as follows: $2.3 \leq X_R < 5.7$, **m**=4.0, (*SD(+)*=0.8). Within 12 pastures of ***Plain*** area X_R vary between a low of 2.3 and a high of 5.0 with the mean value **m** = 3.7 (*SD(+)*=0.9). Within 12 pastures of ***Foothills*** the measure X_R ranges from 3.0 to 5.7 values (**m** = 4.4, *SD(+)*=0.7). The minimum, maximum, and mean values are respectively $3.5 \leq X_R \leq 4.5$, **m** = 3.9 (*SD(+)*=0.4) for the measure X_R within 7 pastures of ***Mountain*** area. Plain area has a high diversity of soil types, which may explain the high variety in values of measure X_R within the plant communities of ***Plain*** zone. Foothill area has acidic soils, but also it is an ecoton between two other zones, which may explain the high range of values of X_R. Mountain soils are mostly acidic, that is expressed by mountain plant communities as low range and variation in plant reaction to the soil acidity.

Soil fertility is characterized by bioavailable macronutrients' supply, including mineral nitrogen (N). The ecological reactions of plant communities to the soil content of nitrogen X_N vary from 2.3 to 5.6 (**m** = 3.8, *SD(+)* = 0.7) in general within the study pastures of Chernivtsi Region. The minimum, maximum and mean values of X_N assessed separately within each of the three physic-geographical zones of the study area are as follows: $2.8 \leq X_N \leq 5.6$; **m** = 4.0, *SD(+)*=0.8 within the ***Plain*** zone; $2.3 \leq X_N \leq 5.2$; **m**=3.7, *SD(+)*=0.7 within the ***Foothills***; and $2.8 \leq X_N \leq 4.4$; **m**=3.6, *SD(+)*=0.5 within the ***Mountains***. This data are consistent with the studies of soils of Chernivtsi Region that show in general the decrease in soil fertility while moving in direction from ***Plain*** to ***Mountains*** physical-geographical zones.

Habitat-climatic conditions of the study 31 pastoral plant communities are expressed by their reaction on the relative strength of insolation X_L, thermal regime X_T, as well as by the community resistance X_K to the frequency and length of occurrence of dry periods in the growing season, as well as to the length of the pre-frost period.

The resistances of the study plant communities to the thermal regime X_T vary from 2.1 to 7.2 (**m**=3.4, *SD(+)*=0.9) within the study grassland of the study area. In term of physic-geographical zoning of Chernivtsi Region the analysis of range and variability of X_T values in grasslands under study shows the following results for each of physic-geographical zones: for ***Plain*** zone ($2.1 \leq X_T \leq 7.2$; **m** = 3.7, *SD(+)*=1.4); for ***Foothills*** ($2.1 \leq X_T \leq 4.3$; **m** = 3.4, *SD(+)*=0.6); and for ***Mountains*** ($2.1 \leq X_T \leq 3.8$; **m** = 2.9, *SD(+)*=0.6). Our data are consistent with the general data related to the climate thermal regimes of the study physical-geographical zones showing the decrease in mean daily temperatures while moving in direction from ***Plain*** to ***Mountains***.

The communities' reactions to the relative strength of insolation is expressed by measure X_L which varies between a low of 3.9 and a high of 7.9 with the mean value **m** = 7.0 (*SD(+)*=0.7). Our phytoindication data show that the ***Mountain*** communities experience lower insolation ($3.9 \leq X_L \leq 7.2$; **m** = 6.4, *SD(+)*=0.4) in comparison to the ***Plain*** ($6.2 \leq X_L \leq 7.9$; **m** = 7.1, *SD(+)*=0.3) and ***Foothills*** ($6.5 \leq X_L \leq 7.5$; **m** = 7.2, *SD(+)*=1.2). These data are expected due to increase in elevation, which is followed by increase in transparency of atmosphere. It increases an effective radiation, especially at night. Furthermore, during the summer seasons, while the solar radiation is highly intensive, the probability of clear skies in the mountains is at 10-15% less than in the area between the revers Prut and Dniester. That highly reduces the direct solar radiation reaching the Earth's surface of the Mountain area.

The measure X_K expresses the community resistance to the frequency and length of occurrence of dry periods in the growing season, as well as to the length of the pre-frost period. It changes its values from 2.4 to 4.1 (**m** = 3.3; *SD(+)*=0.4) within the study grasslands throughout the Chernivtsi Region. The grassland communities assessed separately within the ***Plain*** and ***Foothill*** areas show the close results in the minimum, maximum, mean values, and variations of the measure X_K (**m** ≈ 3.2; *SD(+)*≈0.4)., while the mountain grassland communities show the comparatively lower range and variability of values: $2.9 \leq X_K \leq 3.8$; **m** = 3.3, *SD(+)*=0.3. That can be driven by intensification of the extreme external conditions. In general the study area experiences the Temperate Continental Climate which is highly influenced by the humid air masses from Atlantic. Complex terrain of Chernivtsi Region causes variety in climate of different zones: in the east it is more continental, and while moving in direction from foothills to mountains it becomes more severe due to the cold and short summer.

The deviation "r" of plant communities from the reference value, which is assessed relative to the physical-geographical zone, varies from 1.9 to 11.4 and shows how far each one of the study phytocenosis is from its climax state (fig. 1). Average values of the deviations assessed separately for each of physical-geographical zones show the decrease in deviation of plant communities from the reference value while moving from ***Plain*** area toward the ***Mountains*** (fig. 1). It can be explained by the decrease of anthropogenic influence on the study grasslands in direction from plain to mountains.

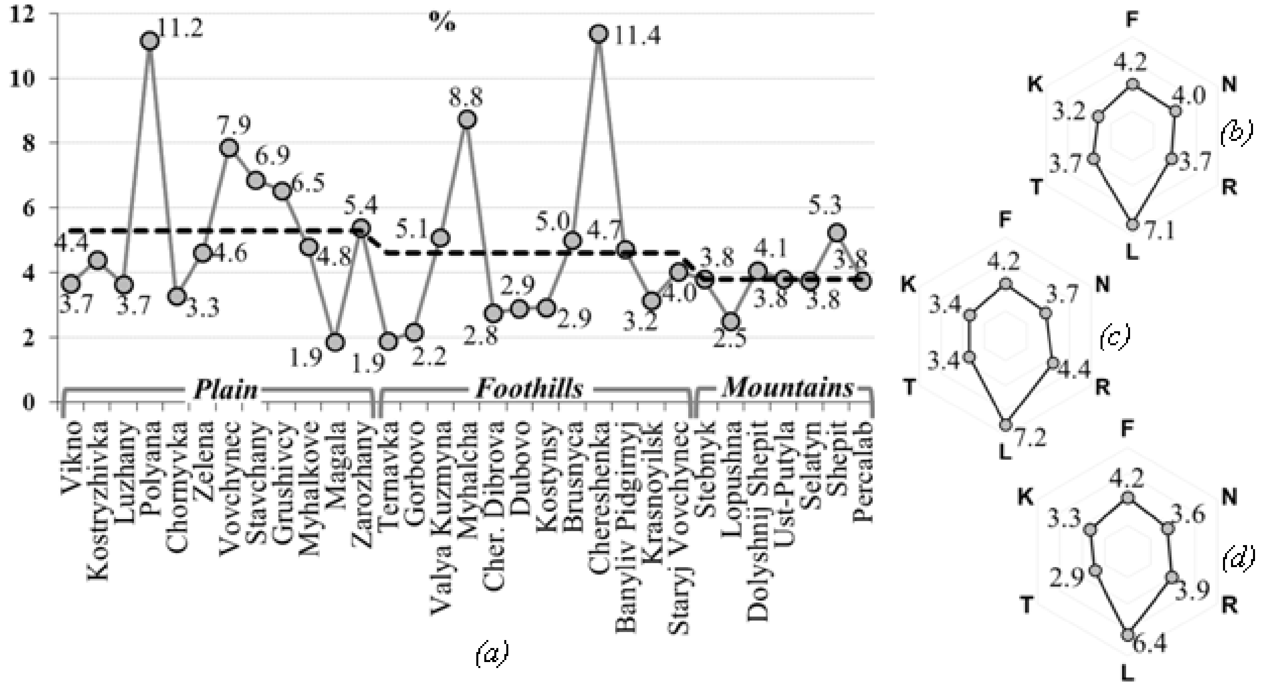

Fig. 1. Overall deviation "r" of plant communities (a) of the study pastoral grasslands from the relative reference values, which are the mean values m_f of the study factors f assessed respectively for each of study physic-geographical zone: Plain (b), Foothills (c), and Mountains (d). Dashed line indicates the average deviation of plant communities within each of the study zones.

Conclusions. An average realized niche of species along the gradients of the study factors of habitat-climatic conditions, such as: insolation, thermal regime and the degree of continentality, as well as the following habitat-edaphic conditions: the soil moisture, acidity, and nitrogen content shows plant communities to be vigorous indicator of external ecosystem conditions. The deviation of the pastoral plant communities from their potential climax states increases while moving in direction from the Carpathian Mountains through the Foothills to the Plain physical-geographical zone of Chernivtsi Region that can be driven by anthropogenic influence increase in the direction from plane area to mountains.

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Одержано редколегією 09.10.2013