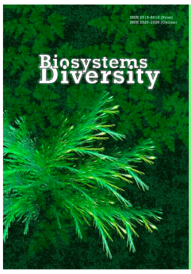

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Structural comparative analysis of forest and steppe plant communities in the south of Kryvyi Rih region

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We made a comparative analysis of the floristic structure of 11 various-aged (30–50-year-old) forest and four steppe communities in the south of Kryvyi Rih region. We ascertained that the forest communities have low specific richness (2–90 species), whereas steppe ones contain from 167 to 251 species. The ten families leading in the species number are: Asteraceae, Poaceae, Rosaceae, Fabaceae, Lamiaceae, Caryophyllaceae, Boraginaceae, Apiaceae, Brassicaceae and Polygonaceae. Specific representation of the steppe communities depends on the geomorphologic formation, grazing pressure, soil cover composition; respective order of families differs slightly: Asteraceae, Poaceae, Fabaceae, Rosaceae, Scrophulariaceae, Lamiaceae, Caryophyllaceae, Brassicaceae, Apiaceae, Boraginaceae. The core of the geographical structure of forest vegetation is the species with a palaearctic type of range (30.3–54.5%), and in the steppe, species with the Black Sea area group (15.6–24.0%). The second and the third most numerous in forest groups are groups of species of transitional areas (3.6–23.3%) and holarctic species (7.0–17.2%). In the steppe communities, almost the same proportions are formed by the species of the palaearctic group and the plants of group of transitional areas (15.8–23.1% and 18.3–21.7% respectively). We revealed that in the forest and steppe communities the most numerous group in the spectra is the biomorph of hemicryptophytes (25.6–42.4% and 45.8–47.0% respectively). According to the structure of the above-ground shoots, identical proportions are formed by rosetteless and semi-rosetted species (38.3–60.5% and 37.2–56.7% respectively) in the forest communities, and semi-rosetted species (47.4–49.1%) in the steppe ones; as for the type of structure of underground shoots in forest communities, species without special underground formations (33.3–65.1%) and caudex formations (18.6–36.4%) prevail, and, in the steppe communities – caudex species do (39.1–47.9%); xeromesophytes (33.3–100%), and mesoxerophytes (32.9–40.6%) dominate in the hygrospectra of forest and steppe communities respectively; in heliospectra, there is the predominance of heliophytes (62.3–97.1% and 50.8–67.5% respectively); in trophoscopes, the mesotrophs are prevalent (57.1–98.4% and 47.0–52.1% respectively). The ecological and coenotic spectrum of forest communities is characterized by the domination of synanthropophants (36.3–58.6%), and in steppe ones – steppants (51.8–55.0%). We revealed the similarity of the floristic composition of forest and steppe communities (6.8–39.4%), and the largest index is noted for the plot with a strict nature reserve regime (19.4–39.4%). In forest communities, this value is 15.6–66.7%, and it varies in different-aged plantations of the same species. The analysis shows that there are significant differences in the floristic and biomorphological composition of forest and steppe communities; it confirms the concept of O.L. Belgard on the environment transforming function of artificial steppe forests, changing the biotic circulation, which is inherent in the steppes.

Keywords: floristic structure; forest plantations; steppe phytocoenoses; light structure; grazing pressure

Introduction

Land afforestation in the steppe zone of Ukraine, ongoing for more than 200 years, still remains important. The problem of balance between forest and steppe is highly controversial. It predetermined the formation of the national geobotanical school and its specifics. It was at the turn of the 19th century and at the early 20th century that the scientific community focused on the problems of 'the competition' between forest and steppe, invasion of one by another, existence conditions, structure, development and typology of steppe native and introduced forests. In the discussion about the reasons for the lack of forest in steppe every scientist defended his views (Diduh, 2005). Belgard (1950) argued that artificial forests in the zone of steppes develop under conditions of geographical discrepancy and come as an extrazonal vegetation type. There are quite different views on the reasons for the lack of forest in steppe. Many scholars believe that treelessness is primarily caused by climate. Belgard (1950) associated the lack or absence of forests in steppes with the contrast, or rather non-correspondence, of biotic cycles of forest and steppe types. The function of tree plantation in steppe is environmentally important for transforming changes in the steppe biotic circle toward the forest one. Those transformations are deeper in the case of greater non-compliance of forest crop requirements with the specific environmental conditions. Steppe plantations with different species composition, crown architectonics, age and life conditions vary in their crown closure. This fact determines the light structure of plantations, playing an important role in the structural organization of vegetation. According to Belgard (1960), light structure is one of the leading factors in the environment changing effect of the forest in steppe, because the crown architectonics and density are crucial for redistributing of the sun's radiant energy, important for plant life. The changes in the qualitative and quantitative characteristics of solar radiation causes changes in other phytoclimatic parameters, observed in the litter and upper soil layer of biogeocenoses, and determining the diversity, cenomorphic, ecomorphic, biomorphological structures of plant cover (Ivanko, 1999). While the tree layer changes in order to adapt to the dry climate of the steppe zone, the formation of the grass layer is associated with adaptation to more mesophilic conditions of the phyto-climate of these plantations. The grass cover formation in introduced forests is conditioned by the adaptation process to the specific phyto-environments and severe competition for moisture with trees and shrubs (Brygadyrenko, 2015; Faly & Brygadyrenko, 2018). In the steppe conditions, forests are constantly threatened with invasion by herbaceous plants which are powerful competitors within stands

(Matveev, 2015). Interrelations between arboreal and herbaceous plants in forest phytocoenoses are among the most poorly investigated aspects of plant communities' life, as they are very complicated, variable in different ways, depending on the environmental factors, age, composition and light structure within the stands (Erdosa et al., 2017; Lashchinskiy et al., 2017). Species content, ecological structure and development of living aboveground vegetation cover in forest plantations are indicators of their health condition and the objects of research (Lebedeva et al., 2016).

The aim of this investigation is to analyze the floristic and biomorphological composition of forest plantations in terms of species diversity, type of light structure, tree age in comparison of these parameters in steppe communities (case study in the south of Kryvyi Rih area).

Materials and methods

Plantations from three forestry districts in the south of Kryvyi Rih region, namely Volodymyrivske (Lisove village, Kazankivsky District, Mykolayiv Region), Zagradivske (Zagradivka village, Vysokopilsky District, Kherson Region) and Shyrokivske (Shyroke settlement, Shyrokivsky District, Dnipropetrovsk Region) were the objects of research. There were 7 monitoring sites in the Volodymyrivske forestry: three sites in the pure stands of *Gleditsia triacanthos* L. (plots 1–3) and *Quercus robur* L. aged under 30, 40 and over 50 years (plots 4–6) and one site in the plantations of *Robinia pseudoacacia* L. older than 50 years (plot 7). In Zagradivske forestry, one monitoring site was located in the plantation with *Pinus pallasiana* D. Don aged under 30 (plot 8). In Shyrokivsky forestry, three sites were investigated: the first one with *P. pallasiana* and *P. sylvestris* L. over 50 years old (plot 9), the second one with *Q. robur* trees (aged 40 years) and the understory of *Caragana arborescens* Lam. (plot 10) and the third with *Q. robur* and shrub layer of *C. arborescens* and *Euonymus europaea* L. under 40 years old (plot 11) (Fig. 1). The area of each site is 2,500 m^2. In terms of the light structure, the communities of plots (1, 2 and 3 *G. triacanthos*) belong to light type of illumination, plots 4–6 and also 10–11 (*Q. robur*) belong to the shade type, plot 7 (*R. pseudoacacia* aged more than 50 years) is of a semi-lit type, plots 8–9 (*P. pallasiana* aged up to 30 and *P. pallasiana* and *P. sylvestris* older than 50 years) can be referred to as to the half-shade sites.

For comparison, steppe communities were investigated in four monitoring sites: in the national natural landmark named 'Urochyshche Stepok' (plot 12), 'Balka Zelena' (plot 13), 'Urochyshche Prygirye' (plot 14) and in the 'Komarova Balka' (plot 15). These sites are part of the middle steppe subzone of the Black Sea Coast landscape province. The monitoring plot 'Urochyshche Stepok' is located on the watershed between the Inhulets and Vysun Rivers, 'Urochyshche Prygirya' lies in the valley side slope to the right of the Ingulets River, the rest are the valleys of two large balkis named Zelena and Komarova.

The structural and comparative analysis of the floristic composition of the plots was carried out using the biomorphic classifications by Serebrjakov (1964), Raunkiær (1934), the linear system of life-forms of Golubev (1972). The ecological-cenotic structure was investigated according to Belgard (1950, 1960). The ecological structure of plant communities in terms of environment and water regime was determined according to the guidelines highlighted by O. L. Belgard's works. Conventionally used methods were applied to the description of phytocenoses. The similarity of the floristic composition of vegetation was calculated using Czekanowski-Sörensen's coefficient (Vasilevich, 1969). Based on this coefficient, by way of pairwise comparison of forest and steppe communities, we conducted a cluster analysis. The tree diagram of forest and steppe phytocenoses based on the composition of characteristic species combinations was constructed using the pair-group method (Oldenderfer & Bljeshfild, 1989).

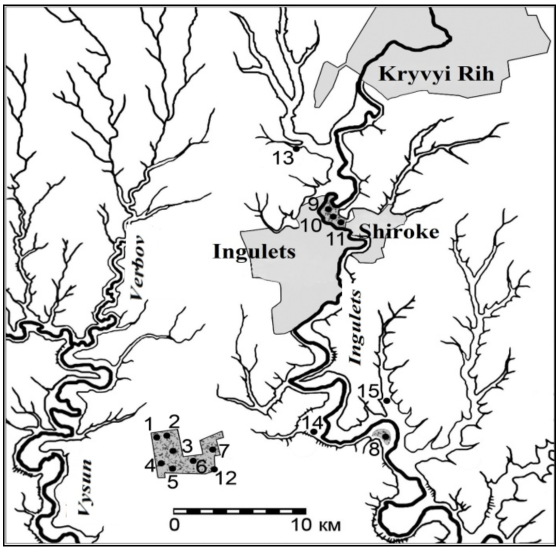

Fig. 1. Map chart scheme of monitoring sites in the forest and steppe communities of the south of Kryviy Rih region

Results

The taxonomic content reflects the internal structure and specific features of plant communities. The number of taxa of different ranks is an important indicator for its characteristic. The forest community is characterized by low species richness. The largest species diversity is detected in the plantation of *P. pallasiana* and *P. sylvestris* older than 50 years (90 species), and the smallest one was revealed in the stand of *Q. robur* with understory of *C. arborescens* (2 species) (Fig. 2). Poor species composition is characteristic of forest flora and greater diversity of vascular plant species is found in clearings or other anthropogenically transformed lands (Kryshen' et al., 2016).

The steppe communities are characterized by greater species diversity than the forest, with the maximum noted in the 'Balka Zelena' (251 species). This fact is associated with its ecotone location between two geobotanical subzones and a diverse set of ecological niches resulting from various geomorphological conditions (exposure and steepness of slopes, the presence of lateral ravines and limestone outcrops). The minimum species richness is found in the 'Komarova Balka' (167 species) and in the nature reserve 'Urochyshche Stepok' (128 species). The reasons of low diversity in these two sites are different. In the first case it is obviously due to anthropogenic load, and in the second case an indirect vegetation transformation is the manifestation of reserved land digression as a result of absolute protection for 70 years (Krasova et al., 2015). A total of 15 tree and shrub species and 31 herbaceous plant species are found in the planted forest and quite absent from steppe communities (Table 1, 2).

Table 1
The species list of vegetation cover in forest plantations from the south of Kryvyi Rih region

Species	Plantation of *Gleditsia triacanthos*			Plantation of *Quercus robur*			Plantation of	Pine plantation		Plantation of *Quercus robur* with undergrowth of	
	aged under 30	aged under 40	aged over 50	aged under 30	aged under 40	aged over 50	*Robinia pseudoacacia* aged over 50	*Pinus pallasiana* aged under 30	*Pinus pallasiana* and *P. sylvestris* aged over 50	*Caragana arborescens* aged under 40	*C. arborescens* and *Euonymus europaea* aged under 40
1	2	3	4	5	6	7	8	9	10	11	12
Acer campestre L.	+	–	–	–	–	–	–	–	–	–	–
Acer tataricum L.	+	+	++	+	++	+++	–	–	–	–	–
Achillea submillefolium Klok. et Krytzka	+	–	–	+	–	–	–	+	++	–	–
Achillea nobilis L.	–	–	–	–	–	–	–	–	+	–	–

Continuation of Table 1

1	2	3	4	5	6	7	8	9	10	11	12
Adonis wolgensis Steven	+	+	–	–	–	++	–	–	–	–	–
Agrimonia eupatoria L.	–	–	–	–	–	–	–	–	+	–	–
Ajuga genevensis L.	–	+	–	–	–	+	–	–	–	–	–
Alliaria petiolata (M. Bieb.) Cavara et Grande	–	–	–	–	+	+	+	–	–	–	–
Anisantha tectorum (L.) Nevski	+	+++	+++	–	+	+	+++	+	++	–	+++
Anthriscus cerefolium (L.) Hoffm.	++	++	–	–	++	–	++	–	+	–	++
Anthriscus sylvestris (L.) Hoffm.	+	++	+++	+++	++	++	+	–	+	–	++
Anthemis ruthenica M. Bieb.	–	–	–	–	–	–	–	+	+	–	–
Amaranthus retroflexus L.	–	–	–	–	–	–	+	+	+	–	–
Amygdalus nana L.	–	–	–	+	–	–	–	–	–	–	–
Ambrosia artemisiifolia L.	–	–	–	–	–	–	–	–	+	–	–
Arctium tomentosum Mill.	+	–	+	+	+	+	+	–	+	–	+
Arenaria uralensis Pall. ex Spreng.	–	–	+	–	–	–	–	–	+	–	–
Artemisia absinthium L.	–	–	–	–	–	–	–	+	+	–	–
Artemisia austriaca Jacq.	–	–	–	–	–	–	–	–	+	–	–
Artemisia marschalliana Spreng.	–	–	–	–	–	–	–	+	–	–	–
Astragalus varius S. G. Gmel.	–	–	–	–	–	–	–	+	+	–	–
Atriplex tatarica L.	+	++	+	++	–	++	++	+	+	–	–
Ballota nigra L.	+	+	+	++	++	+	++	–	+	–	+++
Bellevalia sarmatica (Pall. ex Georgi) Woronow	–	+	+	–	–	–	–	–	–	–	–
Berberis vulgaris L.	+	–	–	+	–	–	–	–	–	–	–
Berteroa incana (L.) DC.	–	–	–	–	–	–	–	–	+	–	–
Buglossoides arvensis (L.) I. M. Johnst.	+	++	–	–	–	–	+	–	–	–	+++
Cannabis ruderalis Janisch.	–	–	–	–	–	–	+	–	–	–	–
Calamagrostis epigeios (L.) Roth	–	–	–	–	–	–	–	–	+	–	–
Capsella bursa-pastoris (L.) Medik.	–	–	–	–	–	–	–	+	+	–	–
Caragana arborescens Lam.	–	–	+	–	–	++	+	–	–	+++	–
Cardaria draba (L.) Desv.	–	+	–	–	–	–	–	–	+	–	–
Carduus acanthoides L.	–	+	+	++	–	–	+	+	+	–	+
Carex spicata Huds.	–	–	–	–	–	–	–	–	–	–	++
Chamerion angustifolium (L.) Holub	–	–	–	–	–	–	–	–	+	–	–
Chelidonium majus L.	–	–	–	–	–	–	–	–	+++	–	++
Chenopodium album L.	–	–	–	–	+	–	–	+	++	–	++
Chondrilla juncea L.	–	–	–	–	–	–	–	+	++	–	–
Chorispora tenella (Pall.) DC.	–	–	–	–	–	–	–	–	+	–	–
Celtis caucasica Willd.	+	–	–	–	–	–	–	–	–	–	–
Centaurea diffusa Lam.	–	–	–	–	–	–	–	–	+	–	–
Cerasus mahaleb (L.) Mill.	–	–	+	–	–	–	–	–	–	–	–
Cerastium pseudobulgaricum Klokov	–	–	–	–	–	–	–	+	–	–	–
Cirsium setosum (Willd.) Besser	–	–	+	++	–	++	++	+	++	–	++
Conyza canadensis (L.) Cronq.	–	+	–	–	–	–	–	+	+++	–	–
Convolvulus arvensis L.	–	–	–	++	–	++	–	–	+	–	–
Crataegus fallacina Klokov	+	–	–	–	–	+	–	–	–	–	–
Cotinus coggygria Scop.	+	+	+	–	+++	–	–	–	–	–	–
Crepis tectorum L.	–	–	–	–	–	–	–	+	++	–	–
Cynoglossum officinale L.	–	–	–	–	+	–	+	–	++	–	++
Descurainia sophia (L.) Webb et Prantl	–	–	–	–	–	–	–	–	+	–	–
Dianthus pseudoarmeria M. Bieb.	–	–	–	–	–	–	–	+	–	–	–
Digitaria sanguinalis (L.) Scop.	–	–	–	–	–	–	–	+	–	–	–
Echium vulgare L.	–	–	–	–	–	–	–	–	+	–	–
Elytrigia repens (L.) Nevski	–	–	–	+++	+	++	–	+	–	–	–
Euonymus europaea L.	+	–	+	–	–	–	–	–	–	–	+++
Euphorbia virgata Waldst. et Kit.	–	–	–	–	–	–	–	–	++	–	–
Eragrostis minor Host	–	–	–	–	–	–	–	+	+	–	–
Erophila verna (L.) Besser	–	–	–	–	–	–	–	+	–	–	–
Eryngium campestre L.	–	–	–	–	–	–	–	+	+	–	–
Falcaria vulgaris Bernh.	–	–	–	++	++	++	+	–	+	–	–
Fallopia convolvulus (L.) A. Love	+	+	+	++	++	++	+	–	++	–	++
Festuca valesiaca Gaudin	–	–	–	–	–	–	–	+	–	–	–
Fumaria schleicheri Soy.-Willem.	–	–	–	–	–	–	+	–	++	–	++
Fraxinus lanceolata Borkh.	–	–	–	–	–	–	–	–	–	–	+
Fraxinus excelsior L.	+	+	–	–	–	+	+	–	–	–	–
Galium aparine L.	+	++	++	++	–	++	+	–	+++	–	++
Galinsoga parviflora Cav.	–	–	–	–	–	–	–	+	+	–	–
Geranium robertianum L.	++	+	++	–	+	++	++	–	+	–	++
Geum urbanum L.	+	++	+++	+++	++	+++	+	–	+	–	+++
Gleditsia triacanthos L.	+++	+++	+++	++	++	+	++	–	+	–	++
Gypsophila paniculata L.	–	–	–	–	–	–	–	+	–	–	–
Helichrysum arenarium (L.) Moench	–	–	–	–	–	–	–	+	+	–	–
Hieracium virosum Pall.	–	–	–	–	–	–	–	–	+	–	–
Hypericum perforatum L.	–	–	–	+	–	–	–	–	–	–	–
Juglans regia L.	+	–	–	–	–	–	–	–	–	–	–
Jurinea salicifolia Grun.	–	–	–	–	–	–	–	–	+	–	–
Koeleria cristata (L.) Pers.	–	–	–	–	–	–	–	–	+	–	–
Lactuca serriola L.	+	+	++	+	+	++	++	+	+++	–	–

Continuation of Table 1

1	2	3	4	5	6	7	8	9	10	11	12
Lactuca tatarica (L.) C.A. Mey.	–	–	+	+	–	–	–	–	++	–	–
Lamium amplexicaule L.	+	++	–	–	–	–	+	–	++	–	–
Lathyrus tuberosus L.	–	–	–	+	–	+	–	–	–	–	–
Leonurus villosus Desf. ex D'urv.	–	–	–	++	–	+	–	–	+	–	–
Ligustrum vulgare L.	–	–	+	–	+	–	–	–	–	–	–
Limonium platyphyllum Lincz.	–	–	–	+	–	–	–	–	–	–	–
Linaria genistifolia (L.) Mill.	–	–	–	–	–	–	–	+	+	–	–
Linaria vulgaris Mill.	–	–	–	–	–	–	–	–	+	–	–
Lithospermum officinale L.	–	+	–	–	–	–	–	–	–	–	++
Lonicera tatarica L.	–	+	+	–	++	+	–	–	–	–	–
Medicago romanica Prodan	–	–	–	–	–	–	–	–	+	–	–
Melandrium album (Mill.) Garcke	–	–	+	+	–	+	–	–	+	–	–
Melica altissima L.	+	+	+	–	++	++	+	–	–	–	–
Melica transsilvanica Schur	–	–	+	–	–	–	–	–	+	–	–
Morus nigra L.	–	–	–	–	–	–	–	–	++	–	–
Myosotis arvensis (L.) Hill	+	++	–	+	++	+	+	–	–	–	–
Nonea rossica Steven	–	–	–	–	–	–	–	–	+	–	–
Ornithogalum boucheanum (Kunth) Asch.	–	+	+	–	–	–	+	–	–	–	–
Otites borysthenicus (Grun.) Klokov	–	–	–	–	–	–	–	+	–	–	–
Padus avium Mill.	–	+	+	++	–	–	–	–	–	–	–
Phalacroloma annuum (L.) Dumort.	–	–	–	–	–	–	–	+	+	–	–
Phlomis tuberosa L.	–	–	+	–	–	–	–	–	–	–	–
Picris hieracioides L.	–	–	–	–	–	–	–	–	+	–	–
Pilosella echioides (Lumn.) F. Schultz et Sch. Bip.	+	–	–	–	–	–	–	–	–	–	–
Pilosella officinarum F. Schult. et Sch. Bip.	–	–	–	–	–	–	–	–	+	–	–
Pinus pallasiana D. Don	–	–	–	–	–	–	–	+++	+++	–	–
Pinus sylvestris L.	–	–	–	–	–	–	–	–	+++	–	–
Poa angustifolia L.	–	++	+	++	–	+	–	–	++	–	++
Poa bulbosa L.	+	++	+	–	–	–	–	+	+	–	–
Poa nemoralis L.	+	–	++	–	+	+++	–	–	–	–	–
Polygonum arenarium Waldst. et Kit.	–	–	–	–	–	–	–	+	–	–	–
Polygonum aviculare L. s.str.	–	–	–	–	–	–	–	–	+	–	–
Populus nigra L.	–	–	–	–	–	–	–	+	–	–	–
Potentilla neglecta Baumg.	–	–	–	–	–	–	+	–	+	–	++
Prunus stepposa Kotov	+	–	–	–	+	++	–	–	–	–	–
Quercus robur L.	++	–	+	+++	+++	+++	+	–	+	+++	+++
Reseda lutea L.	–	–	–	–	–	–	–	–	+	–	–
Rhamnus cathartica L.	+	–	–	+	++	–	–	–	–	–	–
Ribes aureum Pursh	++	+	–	–	–	–	–	–	–	–	–
Robinia pseudoacacia L.	+	++	–	–	+	+	+++	–	+	–	++
Rosa canina L.	++	+	+	++	–	–	–	–	+	–	–
Rumex confertus Willd.	–	+	–	–	–	–	+	–	–	–	–
Salvia nemorosa L. aggr.	–	–	–	–	–	–	–	–	+	–	–
Sambucus nigra L.	+	–	–	–	–	–	+	–	+	–	–
Securigera varia (L.) Lassen	+	–	–	–	+	–	–	–	–	–	–
Sedum ruprechtii (Jalas) Omelcz.	–	–	–	–	–	–	–	–	+	–	–
Senecio erucifolius L.	–	–	–	–	–	+	–	–	–	–	–
Senecio jacobaea L.	–	–	–	–	–	–	–	+	+	–	–
Senecio vernalis Waldst. et Kit.	–	+	–	–	–	–	–	+	+++	–	–
Setaria glauca (L.) P. Beauv.	–	–	–	–	–	–	–	+	+	–	–
Sisymbrium loeselii L.	–	–	–	–	–	–	–	+	+	–	–
Solanum nigrum L.	–	–	–	–	–	–	–	+	++	–	–
Sonchus arvensis L.	–	++	+	+	+	++	+	+	++	–	–
Syrenia cana (Piller et Mitterp.) Neilr.	–	–	–	–	–	–	–	+	–	–	–
Stellaria media (L.) Vill.	–	+	++	–	–	–	++	+	+	–	++
Taraxacum officinale Wigg. aggr.	+	+++	+++	++	+	++	++	+	+++	–	++
Taraxacum serotinum (Waldst. et Kit.) Poir.	–	–	–	–	–	–	–	–	+	–	–
Thlaspi perfoliatum L.	+	++	–	–	–	–	+	–	+	–	+++
Tragopogon major Jacq.	+	–	–	–	–	–	–	–	–	–	–
Trifolium arvense L.	–	–	–	–	–	–	–	+	+	–	–
Tussilago farfara L.	–	–	–	–	–	–	+	–	–	–	–
Ulmus minor Mill.	+	–	+	–	–	–	+	+	–	–	+
Urtica dioica L.	–	–	–	–	–	–	–	–	+	–	–
Verbascum lychnitis L.	–	–	–	–	–	–	–	+	–	–	–
Vicia cracca L.	–	+	++	+	–	++	–	–	–	–	–
Viola ambigua Waldst. et Kit.	–	–	–	–	–	–	–	–	+	–	–
Viola accrescens Klokov	–	–	+	–	–	–	–	–	–	–	–
Viola kitaibeliana Schult.	+	++	–	–	–	–	–	–	+++	–	–
Vinca herbacea Waldst.et Kit.	–	–	–	–	–	+	+	–	–	–	–
Xanthium albinum (Widder) H. Scholz	–	–	–	–	–	–	–	+	–	–	–
Total species	43	41	40	33	29	38	39	47	90	2	29

Note: + – the species occurs in this monitoring area individually, ++ – the species is frequent in this monitoring area, +++ – the species dominates this monitoring area, the dash stands for the absence of a species in this monitoring area.

Table 2
The species list of steppe vegetation in the south of Kryvyi Rih region

Species	Monitoring areas			
	Urochychshe Stepok	Balka Zelena	Urochyshche Prygirya	Balka Komarova
1	2	3	4	5
Acer platanoides L.	–	–	+	–
Acinos arvensis (Lam.) Dandy	–	+	+	+
Achillea nobilis L.	–	+	+	++
Achillea pannonica Scheele	+	+	+	+
Achillea submillefolium Klok. et Krytzka	+	+	+	+
Adonis vernalis L.	–	++	+	–
Adonis wolgensis Stev.	+	+	+	–
Agrimonia eupatoria L.	–	+	+	+
Agropyron pectinatum (M. Bieb.) P. Beauv.	+	+	+	+
Ajuga chia Schreb.	–	+	+	+
Ajuga genevensis L.	–	+	–	–
Alliaria petiolata (M. Bieb.) Cavara et Grande	–	–	+	–
Allium flavescens Besser	–	+	+	+
Allium inaequale Janka	–	+	+	+
Allium paczoskianum Tuzs.	+	+	+	+
Allium sphaerocephalon L.	–	+	+	+
Alopecurus pratensis L.	+	–	–	–
Alyssum desertorum Stapf	–	+	+	+
Alyssum tortuosum Waldst. et Kit.	–	++	+	+
Ambrosia artemisiifolia L.	+	+	+	+
Amygdalus nana L.	–	+	+	–
Anchusa officinalis L.	–	+	–	+
Anemone sylvestris L.	–	+	–	–
Anisantha tectorum (L.) Nevski	–	–	+	–
Anthriscus cerefolium (L.) Hoffm.	–	–	+	–
Anthriscus sylvestris (L.) Hoffm.	+	–	+	–
Anthemis tictoria L. subsp. *subtinctoria* (Dobrocz.) Soo	–	+	+	–
Arrhenatherum elatius (L.) J. Presl et C. Presl	+	–	–	–
Arabidopsis toxophylla (Bieb.) N. Busch	–	–	+	–
Arenaria uralensis Pall. ex Spreng.	–	+	+	+
Aristolochia clematitis L.	–	+	+	–
Artemisia absinthium L.	+	+	+	+
Artemisia austriaca Jacq.	+	+	+	+
Artemisia pontica L.	+	–	–	–
Artemisia santonica L.	–	+	+	+
Artemisia vulgaris L.	+	+	+	–
Asparagus pallasii	+	+	+	–
Asparagus verticillatus L.	–	–	+	–
Asperula montana Waldst. et Kit.	–	++	+	++
Astragalus abruptus Krytzka	–	+	+	–
Astragalus austriacus Jacq.	–	+	+	+
Astragalus dasyanthus Pall.	+	–	–	–
Astragalus onobrychis L.	+	+	++	+
Astragalus odessanus Besser	–	–	+	–
Astragalus pallescens M. Bieb.	–	+	+	+
Astragalus pubiflorus DC.	+	–	–	–
Astragalus ponticus Pall.	–	–	+	–
Astragalus ucrainicus M. Pop. et Klokov	–	+	+	+
Asyneuma canescens (Waldst. et Kit.) Griseb. et Schenk	–	+	+	–
Aster amelloides Bess.	–	–	+	–
Atriplex sagittata Borkh.	–	–	+	–
Atriplex tatarica L.	–	+	–	–
Ballota nigra L.	+	+	+	–
Bellevalia sarmatica (Pall. ex Georgi) Woronow	+	–	–	–
Berberis vulgaris L.	–	–	+	–
Berteroa incana (L.) DC.	+	–	+	+
Botriochloa ischaemum (L.) Keng	–	++	+	+
Bromopsis inermis (Leyss.) Holub	++	+	+	+
Bromopsis riparia (Rehman) Holub	+	++	++	++
Bromus squarrosus L.	+	+	+	+
Bulbocodium versicolor (Ker Gawl.) Spreng.	–	+	+	–
Bunias orientalis L.	–	–	+	–
Bupleurum rotundifolium L.	–	+	–	–
Calamagrostis epigeios (L.) Roth	–	+	–	+
Camelina microcarpa Andrz.	–	–	+	–
Campanula glomerata L.	–	+	+	–
Campanula sibirica L.	–	+	+	+
Capsella bursa-pastoris (L.) Medik.	–	–	+	–
Caragana frutex (L.) K. Koch	–	+	–	–
Caragana scythica (Kom.) Pojark.	–	+	+	–
Cardaria draba (L.) Desv.	+	–	+	–
Carduus acanthoides L.	+	+	–	+
Carduus thoermeri Weinm.	–	–	–	+
Carex melanostachya M. Bieb. ex Willd.	+	+	–	–
Carex caryophyllea Latourr.	++	+	–	–
Carex supina Willd. ex Wahlenb.	–	+	+	+
Centaurea adpressa Ledeb.	–	+	–	–
Centaurea diffusa Lam.	–	+	+	+
Centaurea jacea L.	–	+	–	–
Centaurea marschalliana Spreng.	–	++	+	+
Centaurium pulchellum (Sw.) Druce	–	–	–	+
Centaurea orientalis L.	–	+	+	–
Centaurea trinervia Stephan	–	+	+	+
Cephalaria uralensis (Murray) Roem. et Schult.	–	+	++	++
Cerasus mahaleb (L.) Mill.	–	+	+	–
Cerinthe minor L.	–	+	+	–
Chamaecytisus ruthenicus (Fisch. ex Wol.) Klaskova	–	+	–	–
Chamaecytisus graniticus (Rehman) Rothm.	–	++	++	+
Chelidonium majus L.	–	–	+	–
Chenopodium album L.	+	–	–	–
Chondrilla juncea L.	–	+	–	+
Cichorium intybus L.	+	+	+	+
Cirsium setosum (Willd.) Besser	+	+	–	+
Cirsium ucrainicum Besser	–	+	+	+
Cleistogenes bulgarica (Bornm.) Keng	–	++	+	+
Clematis integrifolia L.	–	+	+	–
Consolida regalis S. F. Gray	+	+	+	+
Convolvulus arvensis L.	++	+	+	+
Convolvulus lineatus L.	–	+	+	+
Crepis rhoeadifolia M. Bieb.	–	–	–	+
Conyza canadensis (L.) Cronq.	+	+	–	+
Cotinus coggygria Scop.	–	+	+	–
Crataegus fallacina Klokov	+	+	+	–
Cuscuta epithymum (L.) L.	+	–	+	–
Cymbochasma borysthenica (Pall. ex Schlecht.) Klokov et Zoz	–	–	+	+
Cynoglossum officinale L.	+	+	+	+
Daucus carota L.	–	+	–	–
Descurainia sophia (L.) Webb ex Prantl	–	–	+	–
Dianthus pseudoarmeria M. Bieb.	–	+	+	+
Dianthus euponticus Zapal.	–	++	–	–
Dianthus carbonatus Klokov	+	+	+	+
Dianthus quttatus M. Bieb.	+	–	–	–
Diplotaxis tenuifolia (L.) DC.	–	+	–	+
Echinops ruthenicus M. Bieb.	–	–	+	–
Echinops sphaerocephalus L.	–	+	–	–
Echium vulgare L.	–	+	+	+
Elaeagnus angustifolia L.	–	–	–	+
Elytrigia intermedia (Host) Nevski	++	+	+	–
Elytrigia repens (L.) Nevski	++	+	+	+
Elytrigia stipifolia (Czern. ex Nevski) Nevski	+	++	+	+
Elytrigia trichophora (Link) Nevski	+	+	–	–
Ephedra distachya L.	–	+	–	+
Eremogone biebersteinii (Schlecht.) Holub	–	+	+	+
Eremogone cephalotes (M.Bieb.) Fenzl	–	+	–	–
Erodium cicutarium (L.) L'Her.	–	–	+	–
Erodium ruthenicum M. Bieb.	–	–	+	–
Erigeron acris L.	–	+	–	+
Erophila verna (L.) Besser	–	+	–	–
Erucastrum armoracioides (Czern. ex Turcz.) Cruchet	–	+	–	+
Eryngium campestre L.	+	++	+	++
Erysimum diffusum Ehrh.	–	+	++	+
Euonymus europaea L.	–	–	+	–
Euonymus verrucosa Scop.	–	–	+	–
Euphorbia agraria M. Bieb.	–	–	–	+
Euphorbia semivillosa Prokh.	–	+	–	–
Euphorbia sequieriana Neck.	+	+	++	++
Euphorbia stepposa Zoz ex Prokh.	–	+	++	++
Euphorbia virgata Waldst. et Kit.	+	+	+	+
Falcaria vulgaris Bernh.	++	+	+	–
Fallopia convolvulus (L.) A. Love	+	–	–	–
Festuca regeliana Pavl.	–	+	+	–

1	2	3	4	5
Festuca rupicola Heuff.	+	+	+	–
Festuca valesiaca Gaudin	+	++	++	++
Filipendula vulgaris Moench	–	+	+	–
Fumaria schleicheri Soy.-Willem.	+	–	–	–
Galatella linosyris (L.) Rchb.f.	–	++	–	–
Galatella villosa (L.) Rchb.f.	+	++	+	+
Galium aparine L.	+++	+	+	+
Galium humifusum M. Bieb.	–	+	–	+
Galium octonarium (Klokov) Soo	++	+	+	–
Galium ruthenicum Willd.	+++	+	+	+
Galium volhynicum Pobed.	–	+	+	–
Genista scythica Pacz.	–	++	+	–
Geum urbanum L.	+	+	+	–
Geranium robertianum L.	+	–	–	–
Glechoma hederacea L.	–	–	+	–
Goniolimon besserianum (Schult.) Kusn.	–	+	+	–
Grindelia squarrosa (Pursh) Dunal	–	+	–	–
Haplophyllum suaveolens (DC.) G. Don f.	–	+	+	+
Helichrysum arenarium (L.) Moench	–	++	+	–
Heracleum sibiricum L.	–	–	+	–
Herniaria besseri Fisch. ex Hornem.	–	–	+	+
Hesperis tristis L.	+	+	–	–
Hieracium virosum Pall.	–	+	–	–
Holosteum umbellatum L.	–	–	+	–
Hyacinthella leucophaea (K.Koch) Schur	–	+	+	–
Hypericum elegans Stephan ex Willd.	+	+	+	++
Hypericum perforatum L.	+	–	–	–
Hylotelephium polonicum (Blocki) Holub	–	–	+	–
Inula aspera Poir.	–	–	+	–
Inula britannica L.	–	+	–	+
Inula ensifolia L.	–	+	+	–
Inula oculus-christi L.	+	+	+	–
Inula germanica L.	+	–	–	–
Iris halophila Pall.	–	+	–	–
Iris pumila L.	–	+	+	+
Iris pontica Zapal.	–	–	–	+
Jurinea arachnoidea Bunge	–	+	+	–
Jurinea brachycephala Klokov	–	++	+	++
Jurinea multiflora (L.) B. Fedtsch.	–	+	–	+
Kochia laniflora (S.G.Gmel.) Borbas	–	–	+	–
Kochia prostrata (L.) Schrad.	–	+	+	+
Koeleria cristata (L.) Pers.	+	+	+	++
Lactuca serriola L.	++	–	–	+
Lamium amplexicaule L.	+	–	–	–
Lappula squarrosa (Retz.) Dumort.	–	–	+	–
Lathyrus tuberosus L.	+	+	–	–
Lavatera thuringiaca L.	+	+	–	+
Leontodon biscutellifolius DC.	–	++	+	–
Leonurus villosus Desf. ex D´Urv.	++	+	–	–
Ligustrum vulgare L.	–	+	+	–
Limonium alutaceum (Steven) O. Kuntze	–	+	–	–
Limonium bungei (Claus) Gamajun.	+	+	–	+
Limonium platyphyllum Lincz.	++	–	–	–
Linaria biebersteinii Besser	++	+	+	+
Linaria macroura (M. Bieb.) M. Bieb.	–	–	+	–
Linaria vulgaris Mill.	–	–	–	+
Linaria genistifolia (L.) Mill.	+	+	–	–
Linum czerniaevii Klokov	–	–	–	++
Linum hirsutum L.	–	++	+	–
Linum linearifolium Jav.	–	++	+	–
Linum perenne L.	–	+	+	+
Linum tenuifolium L.	–	++	+	+
Lithospermum officinale L.	+	+	+	–
Lonicera tatarica L.	–	+	+	+
Lotus ucrainicus Klokov	–	+	+	+
Malus praecox (Pall.) Borkh.	–	+	–	+
Marrubium praecox Janka	+	++	+	+
Medicago lupulina L.	–	+	+	+
Medicago minima (L.) Bartal.	–	–	–	+
Medicago romanica Prodan	++	+	+	+
Melandrium album (Mill.) Garcke	+	+	+	+
Melica altissima L.	+	–	+	–
Melica transsilvanica Schur	+	+	+	–
Melilotus albus Medik.	–	+	–	+
Melilotus officinalis (L.) Pall.	+	+	+	+
Minuartia leiosperma Klokov	–	+	+	+
Minuartia glomerata (M. Bieb.) Degen	–	–	–	+

1	2	3	4	5
Minuartia hypanica Klokov	–	–	–	+
Morus nigra L.	–	–	–	+
Nepeta parviflora M. Bieb.	–	+	+	–
Nigella arvensis L.	–	+	+	+
Nonea rossica Steven	–	+	+	+
Oberna cserei (Baumg.) Ikonn.	–	+	+	+
Odontites luteus (L.) Clairv.	–	++	+	–
Odontites vulgaris Moench	–	+	+	++
Onobrychis tanaitica Spreng.	–	+	+	+
Onopordum acanthium L.	–	+	+	+
Onosma macrochaeta Klokov et Dobrocz.	–	++	+	+
Origanum vulgare L.	–	+	+	–
Ornithogalum kochii Parl.	+	–	–	+
Orobanche alba Stephan ex Willd.	+	–	–	–
Otites chersonensis (Zapal.) Klokov	+	+	–	–
Otites hellmannii (Claus) Klokov	–	+	+	+
Oxytropis pilosa (L.) DC.	–	+	+	+
Paronychia cephalotes (M. Bieb.) Besser	–	–	–	+
Pastinaca clausii (Ledeb.) M.Pimen.	+	–	–	–
Pastinaca sylvestris Mill.	+	–	–	–
Peucedanum lubimenkoanum Kotov	–	–	+	–
Peucedanum ruthenicum M. Bieb.	–	+	–	–
Phleum phleoides (L.) H. Karst.	–	+	–	–
Phlomis pungens Willd.	+	+	+	+
Phlomis tuberosa L.	++	+	+	–
Phragmites australis (Cav.) Trin. ex Steud.	–	+	+	–
Picris hieracioides L.	+	+	+	+
Pilosella echioides (Lumn.) F. Schultz et Sch. Bip.	+	+	–	–
Pimpinella saxifraga L.	–	+	+	–
Plantago urvillei Opiz	–	++	+	+
Plantago lanceolata L.	–	+	+	+
Poa angustifolia L.	+++	++	+	++
Poa bulbosa L.	–	+	+	+
Poa compressa L.	+	+	+	+
Polycnemum majus A.Braun	–	+	+	–
Polygala podolica DC.	–	++	+	–
Polygonatum multiflorum (L.) All.	–	+	–	–
Polygonum aviculare L. s.str.	+	+	–	+
Polygonum bellardii All. s.str.	+	–	–	–
Potentilla incana P. Gaerth., B. Mey. et Scherb.	–	++	++	++
Potentilla astracanica Jacq.	–	+	+	+
Potentilla neglecta Baumg.	+	+	+	+
Potentilla obscura Willd.	+	+	+	+
Potentilla patula Waldst. et Kit.	–	+	+	–
Poterium polygamum Waldst. et Kit.	–	+	++	+
Prunus stepposa Kotov	+	+	+	+
Pulsatilla pratensis (L.) Mill.	–	+	–	–
Pyrus communis L.	+	–	–	–
Pyrethrum corymbosum (L.) Scop.	–	–	+	–
Ranunculus polyanthemos L.	–	+	–	–
Reseda lutea L.	–	++	+	+
Rhamnus cathartica L.	+	+	+	–
Rosa bordzilowskii Chrshan.	–	+	+	–
Rosa canina L.	+	–	–	–
Rosa corymbifera Borkh.	+	+	+	+
Rosa lapidosa Dubovik	–	+	–	–
Rosa jundzillii Besser	–	–	+	–
Rubus caesius L.	–	–	+	–
Rumex confertus Willd.	+	+	+	–
Rumex crispus L.	+	+	–	–
Salvia aethiopis L.	–	+	+	+
Salvia austriaca Jacq.	–	+	+	+
Salvia nemorosa L. aggr.	+	+	+	+
Salvia nutans L.	–	++	++	++
Salvia verticillata L.	–	+	–	–
Sambucus nigra L.	–	–	+	–
Scabiosa ochroleuca L.	–	+	–	+
Scorzonera mollis M. Bieb.	–	–	+	+
Scorzonera taurica M. Bieb.	–	–	+	–
Senecio jacobaea L.	–	+	+	+
Securigera varia (L.) Lassen	+	+	+	+
Serratula bracteifolia (Iljin ex Grossh.) Stank.	–	+	+	–
Serratula erucifolia (L.) Boriss.	–	+	–	–
Seseli campestre Besser	++	+	+	+
Setaria viridis (L.) P. Beauv.	–	–	+	–
Sideritis montana L.	–	+	+	+
Silene dichotoma Ehrh.	+	–	–	–

1	2	3	4	5
Silene bupleuroides L.	–	+	+	+
Sisymbrium loeselii L.	+	+	+	+
Sisymbrium polymorphum (Murray) Roth	+	–	–	–
Sonchus arvensis L.	+	–	–	–
Stachys recta L.	++	+	++	+
Stellaria graminea L.	+	–	–	–
Stipa capillata L.	+	++	++	+
Stipa lessingiana Trin. et Rupr.	–	++	++	–
Stipa ucrainica P. Smirn.	+	–	–	–
Stipa pulcherrima K. Koch	–	+	+	–
Swida sanguinea (L.) Opiz	–	+	–	–
Tanacetum millefolium (L.) Tzvelev	–	+	+	+
Tanacetum vulgare L.	–	–	+	+
Taraxacum officinale Wigg. aggr.	+	+	+	–
Taraxacum serotinum (Waldst. et Kit.) Poir.	+	++	+	+
Teucrium chamaedrys L.	–	++	++	+
Teucrium polium L.	–	+++	++	++
Thalictrum minus L.	+	+	+	+
Thesium arvense Horv.	–	+	+	+
Thlaspi perfoliatum L.	–	+	–	+
Thlaspi praecox Wulf	–	+	–	–
Thymelaea passerina (L.) Coss. et Germ.	–	+	+	+
Thymus ×dimorphus Klokov et Des.–Shost.	+	++	++	+
Tragopogon major Jacq.	++	+	+	+
Tragopogon podolicus (DC.) Artemcz.	++	–	–	–
Trifolium arvense L.	–	–	–	+
Trifolium ambiguum M. Bieb.	–	+	–	–
Trifolium pratense L.	–	–	–	+
Trigonella monspeliaca L.	–	–	–	+
Tripleurospermum parviflorum (L.) Sch. Bip.	–	–	–	+
Ulmus laevis Pall.	–	+	+	–
Urtica dioica L.	–	+	–	–
Valeriana stolonifera Czern.	–	–	+	–
Valeriana tuberosa L.	–	–	+	–
Verbascum austriacum Schott ex Roem. et Schult.	+	+	+	–
Verbascum densiflorum Bertol.	–	–	–	+
Verbascum lychnitis L.	+	+	+	+
Verbascum phoeniceum L.	+	+	+	–
Veronica austriaca L.	+	+	+	–
Veronica prostrata L.	–	+	+	–
Veronica barrelieri Schott	+	++	+	++
Veronica verna L.	+	–	+	–
Veronica teucrium L.	+	+	–	–
Viburnum lantana L.	–	+	+	–
Vicia cracca L.	+++	–	–	–
Vicia tetrasperma (L.) Schreb.	+	+	–	–
Vinca herbacea Waldst.et Kit.	+	+	+	–
Vincetoxicum hirundinaria Medik.	–	+	+	–
Vincetoxicum intermedium Taliev	–	+	+	–
Viola ambigua Waldst. et Kit.	–	++	+	+
Viola suavis M. Bieb.	–	+	+	–
Viola kitaibeliana Schult.	+	–	–	–
Xeranthemum annuum L.	–	+	+	+
Total species	128	251	236	167

Note: + – the species occurs in this monitoring area individually, ++ – the species is frequent in this monitoring area, +++ – the species dominates this monitoring area, the dash stands for the absence of a species in this monitoring area.

It should be noted that it is quite difficult to quantify the standard for naturalness of vegetation in forests planted in steppe, as such standards do not exist (Bölöni et al., 2008). On the other hand, the species composition of plant communities may indicate degradation of their habitat (Erdös et al., 2015). In the study of artificial steppe forests, loss of genetic diversity in the course of planting should be evaluated in comparison with native populations of the species (Korshikov & Mudrik, 2006).

As a rule, distribution of plant families by species representation in the Holarctic floras follows a certain pattern. A total of 10–15 leading families are known to form the basis of the spectrum. According to previous studies, the descending order of families in terms of species numbers in the zonal steppe communities of the research area is as follows: Asteraceae, Poaceae, Brassicaceae, Fabaceae, Caryophyllaceae, Scrophullariaceae, Euphorbiaceae, Liliaceae, etc. (Kucherevskyj, 2004). The Asteraceae family is in the first place according to the number of species in all forest communities, and its share is not sufficiently stable, ranging from 13.8 to 38.3%. The family Poaceae is the second according to the species number (5.3–15.8%). The families Rosaceae (4.4–12.1%) and Fabaceae (4.3–50.0%) are the third and fourth among leading families. Families of Lamiaceae and Apiaceae also play a significant role (5th and 8th place, respectively, in most plantations). The richest families within the spectra of all steppe communities are as follows: Asteraceae (16.5–21.0%), Poaceae (9.0–14.8%), Fabaceae (7.0–10.2%). The first dozen leading families in all areas include such families as Lamiaceae, Rosaceae, Caryophyllaceae, Brassicaceae, Scrophulariaceae, Ranunculaceae with slight variations in their positions within the spectrum.

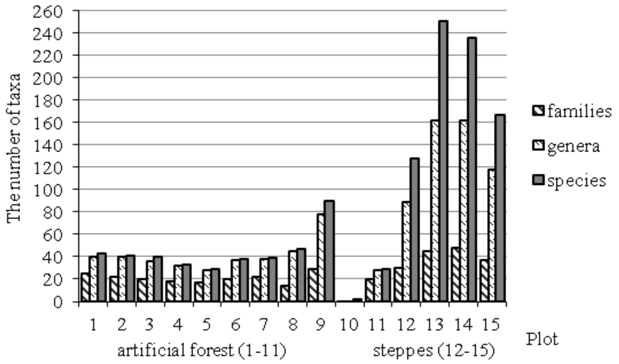

Fig. 2. Taxonomic structure of floristic composition of vegetation in forest and steppe communities from the south of Kryvyi Rih region, names of monitoring sites as follows: *Gleditsia triacanthos*: *1* – under the age of 30, *2* – under the age of 40, *3* – aged more than 50 years; *Quercus robur*: *4* – under the age of 30, *5* – under the age of 40, *6* – aged more than 50 years; *7* – *Robinia pseudoacacia* aged more than 50 years; *8* – *Pinus pallasiana* under the age of 30; *9* – *Pinus pallasiana* and *P. sylvestris* aged more than 50 years; *10* – *Quercus robur* with undergrowth of *Caragana arborescens* under the age of 40; *11* – *Quercus robur* with undergrowth of *Caragana arborescens* and *Euonymus europaea* under the age of 40; *12* – 'Urochyshche Stepok', *13* – 'Balka Zelena', *14* – 'Urochyshche Prygirya', *15* – 'Balka Komarova; the same numbers of the sites are shown in the Figures 3–6

Each species of any flora is characterized by an uneven distribution both within its natural and historical ranges, and beyond. Therefore, tracing of modern geographical patterns in species distribution areas is important for identification of specific origin of certain flora elements. Geographic elements of the flora of forest plantations belong to 9 habitat types. The core of the geographic structure of vegetation is composed by species with a Palaearctic type of range (from 30.3% to 54.5%). The group of transitional range is the second largest in number (3.6–23.3%). The percentage of Holarctic species within the forest communities is stable (10.0–17.2%), except for plantations of *Q. robur* under the age of 40, where this group makes 7.0%. The geographic structure of the steppe phytocenoses is based on species that also belong to 9 habitat types, but with predominance of the Black Sea type of range (15.6–24.0%). 'Urochychshe Stepok' is the only exception with the domination of representatives of the Palaearctic type of species range (30.5%). Percentages of the Palaearctic group of species are close for three steppe plots (22.0–22.7%), except for the protected area ('Urochyshche Stepok') and the group of transitional habitats (18.8–21.7%). The species with Central-Eurasian type of range are in the fourth place (9.6–14.1%).

As far as environmental confinement of the species is concerned, aeropedophytes prevail both in the forest (80.9–100%) and in the steppe communities (91.6–97.6%). Lithophytes (5.6–7.2%) except for 'Urochyshche Stepok' are present in all steppe sites due to the rocky substrate and limestone. A small proportion of psammophytes in all steppe phytocoenoses is found in the slopes in small sandy soil localities.

The moisture regime is the determining environmental factor in the fescue-feather grass steppe. The hygro-spectra of forest communities have significant differences from those inherent to the steppes (Fig. 3). Xeromesophytes prevail in planted forests (33.3–100%). A natural decrease in the participation of xeromesophytes and the growth of eumesophyte and mesoxerophyte quantities is observed in plantation of *G. triacanthos*, *Q. robur* and *R. pseudoacacia* in the course of ageing. The prevalence of mesoxerophytes and xeromesophytes is characteristic for pine plantations. The proportion of eumesophytes (18.9%) increases and the share of euxerophytes (12.2%) decreases with ageing in these plantations.

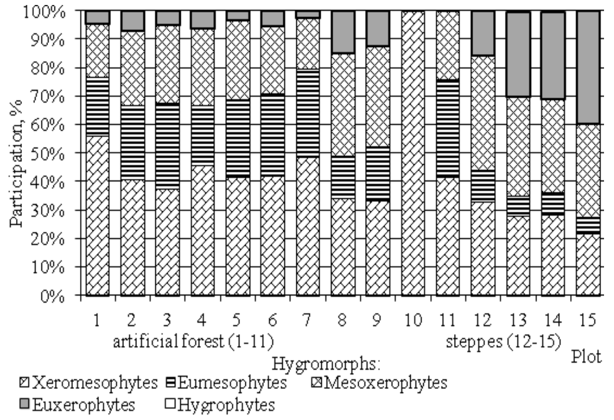

Fig. 3. The hygro-spectra of forest and steppe communities in the south of Kryvyi Rih region

In the spectra of hygromorphs of all steppe communities, almost the same percentages of mesoxerophytes (32.9–40.6%) are observed. Our investigation revealed significant differences in the distribution of hygromorphs in 'Urochyshche Stepok' from other hygro-spectra: the participation of euxerophytes is reduced 2–3-fold compared to other steppe areas due to protection-related mesophytisation. The accumulation of steppe litter layer in the reserve site causes an increase in the proportion of eumesophytes (10.9%) (Fig. 3).

The distribution of trophomorphs in forest and steppe communities is characterized by absolute predominance of mesotrophs (57.1–98.4% and 47.0–52.1% respectively) (Fig. 4). The share of mesotrophs decreases significantly in multiple-aged pine plantations, while the participation of oligomesotrophs (10.8% and 15.2% respectively) and megatrophs (4.3% and 11.6% respectively) increases. This is associated with poor nutrition in the sandy terraces these pine plantations were planted on. The accumulation of litter and the soil enrichment with humus causes an increase in the proportion of megatrophs and oligomegatrophs in the 'Urochyshche Stepok' (25.0% and 6.3% respectively).

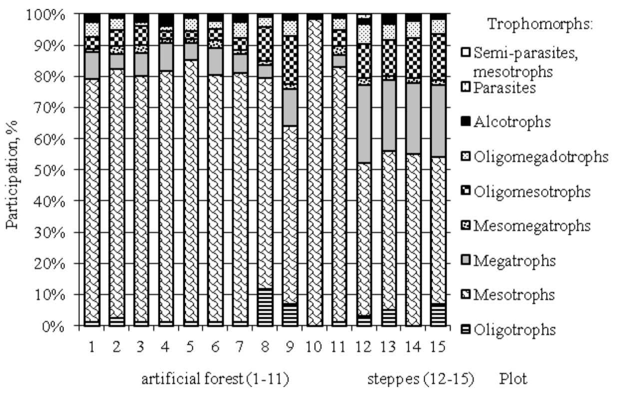

Fig. 4. Tropho-spectra of forest and steppe communities in the south of Kryvyi Rih region

Heliophytes absolutely dominate in helio-spectra of both forest and steppe communitites (62.3–97.1% and 50.8–67.5% respectively). The share of scioheliophytes ranges from 2.9% to 37.7% in forest communities and is 31.4–49.2% in steppe ones. In the steppe slopes, the proportion of heliophytes and scioheliophytes is approximately 2 : 1, and only in the floristic composition of 'Urochishche Stepok' is the participation of these plant groups almost equal (50.8% and 49.2%).

The biomorphological structure of the flora of a certain territory depends on the soil, climatic, ecological and cenotic conditions of the environment. According to the detailed life-forms system of Serebrjakov (1964), depending on the species composition, age and type of light structure, forest communities are dominated by monocarpics (27.3–59.6%), grassy polycarpics (25.6–48.5%) and tree plants (6.4–41.8%), whereas in steppe communities grassy polycarpics (54.5–67.2%) and monocarpics (21.1–31.7%) (Table 3) predominate. The share of monocarpic plants, to a certain extent indicative of the ecosystem disturbance, increased by 1.5 times in the protected area of 'Urochyshche Stepok' and almost twice in the 'Balka Komarova'. The participation of shrub species is the largest in plant communities of 'Balka Zelena' and 'Urochyshche Prygirya' (8.4% and 9.3% respectively). This is due to the development of lateral ravines, which are suitable habitats for shrub and woody vegetation.

As far as the types of aboveground shoots are concerned, within the structure of forest plots, rosetteless and semi-rosette species are distributed in equal portions (see Table 3). The minimum number of rosette species (43.6%) occurs in young plantings of *P. pallasiana* and their maximum number (60.5%) is found in young stands of *G. triacanthos*. Within the structure of species distribution by aboveground shoot type, semi-rosette species prevail in steppe communities with a stable proportion of 47.4–49.1%. According to the type of root system, the number of taproot species in the forest communities is approximately twice as high as fibrous root species. The predominance of taproot species is also observed in steppe sites (61.7–71.9%). Participation of species with a fibrous root system is somewhat greater in the 'Urochyshche Stepok' reserve (36.7%). In terms of underground shoots structure, species without special underground formations (33.3–65.1%) and caudex species (18.6–36.4%) are the most numerous, that is a manifestation of xerophytic conditions of growth. Short-root species are abundant in forest plantations, and their share grows with age.

In the steppe communities, the proportion of caudex plants adapted to arid conditions is the greatest in 'Balka Komarova' (47.9%) and the lowest in the 'Urochyshche Stepok' (39.1%). Under the strict protection regime in the 'Urochyshche Stepok' the participation of long-rooted species increases (13.3%). This is due to a significant area of meadow-steppe communities, characterized by predominance of grasses with such type of underground shoots.

According to the biological types' classification of Raunkiær's (1934), hemicryptophytes dominate in the spectra of all forest communities (25.6–42.4%), with a high participation of phanerophytes (6.4–39.5%) (Fig. 5). The largest proportion of the therophytes was observed in the plantation of *P. pallasiana* under 30 years of age (42.6%), *R. pseudoacacia* (30.8%) and *G. triacanthos* under 40 years old (31.0%). In multiple-age pine plantations, the participation of phanerophytes (6.4–8.9%, respectively) is low and hamephytes are present (6.4–3.3%, respectively).

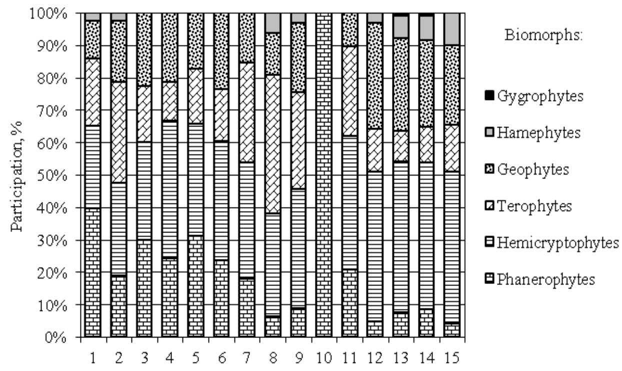

Fig. 5. Biomorphological structure of vegetation of forest and steppe communities in the south of Kryvyi Rih region (according to C. Raunkiaer)

Hemicryptophytes also form the basis of steppe communities sensu C. Raunkiaer, the proportion of them being stable (45.8–47.0%). The percentage of hamephytes is practically the same in the three steppe slope areas (6.8–10.2%) and decreases only in the 'Urochyshche Stepok' (3.1%), as this life-form of plants is largely associated with rocky carbonate soils.

Table 3
Biomorphic structure of forest and steppe communities in the south of Kryvyi Rih region (participation, %)

Life-form traits	Plantation of *Gleditsia triacanthos*			Plantation of *Quercus robur*			Plantation of *Robinia pseudo-acacia*	Pine plantation		Plantation of *Quercus robur* with undergrowth of		Urochyshche Stepok	Balka Zelena	Urochyshche Prygirya	Balka Komarova
	aged under 30	aged under 40	aged over 50	aged under 30	aged under 40	aged over 50	aged over 50	*Pinus pallasiana* aged under 30	*Pinus pallasiana* i *P. sylvestris* aged over 50	*Caragana arborescens* aged under 40	*C. arbo-rescens* and *Euonymus europaea* aged under 40				
By general habit and life cycle															
Arboreal plants:	41.8	22.0	30.0	24.2	31.0	23.7	17.9	6.4	8.9	100.0	20.6	4.7	8.4	9.3	5.4
trees	20.9	12.2	15.0	12.1	13.8	13.2	12.8	6.4	6.7	50.0	17.2	0.8	1.2	1.3	1.8
shrubs	20.9	9.8	15.0	12.1	17.2	10.5	5.1	–	2.2	50.0	3.4	3.9	6.8	8.0	3.0
subshrubs	–	–	–	–	–	–	–	–	–	–	–	–	0.4	–	0.6
Semi-arboreal plants:	–	–	–	–	–	–	–	6.4	2.2	–	–	2.3	5.2	5.5	8.4
semi-shrubs	–	–	–	–	–	–	–	2.1	–	–	–	–	–	0.4	–
semi-subshrubs	–	–	–	–	–	–	–	4.3	2.2	–	–	2.3	5.2	5.1	8.4
Grassy polycarpics	25.6	39.0	42.5	48.5	31.0	47.3	30.8	27.6	43.3	–	34.6	67.2	65.3	63.1	54.5
Monocarpics:	32.6	39.0	27.5	27.3	38.0	29.0	51.3	59.6	45.6	–	44.8	25.8	21.1	22.1	31.7
biennial	11.7	9.7	10.0	18.2	20.7	15.8	20.5	17.0	14.4	–	13.8	13.3	12.3	11.9	19.7
annual	20.9	29.3	17.5	9.1	17.3	13.2	30.8	42.6	31.1	–	31.0	12.5	8.8	10.2	12.0
By aboveground shoot structure															
Rosetteless	60.5	46.3	50.0	51.5	48.3	55.3	43.6	38.3	40.0	100.0	41.4	44.5	46.2	47.0	44.9
Semi-rosette	37.2	46.3	42.5	42.4	48.3	42.1	48.7	55.3	56.7	–	51.7	47.7	47.4	47.5	49.1
Rosette	2.3	7.4	7.5	51.5	48.3	55.3	7.7	6.4	3.3	–	6.9	7.8	6.4	5.5	6.0
By root system type															
Taproot	81.4	75.6	75.0	78.8	79.3	65.8	82.1	76.6	73.3	100.0	86.2	61.7	66.1	66.9	71.9
Fibrous root	18.6	24.4	25.0	21.2	20.7	34.2	17.9	23.4	26.7	–	13.8	36.7	33.9	32.7	28.1
Rootless	–	–	–	–	–	–	–	–	–	–	–	1.6	–	0.4	–
By underground shoot structure															
Caudex	18.6	22.0	25.0	36.4	31.0	28.9	28.2	31.9	32.2	–	34.6	39.1	43.4	44.2	47.9
Short-root	14.0	12.2	15.0	6.1	10.4	18.4	10.3	8.5	15.6	–	10.3	23.4	24.3	22.0	19.8
Long-root	2.3	4.9	5.0	21.2	6.9	10.5	5.1	8.5	10.0	–	3.4	13.3	7.6	7.2	7.8
Bulbo-rhizomatous	–	2.4	2.5	–	–	–	2.6	–	1.1	–	–	2.3	1.6	2.1	–
Special formations absent	65.1	53.7	47.5	33.3	51.7	39.5	51.2	51.1	41.1	100.0	51.7	18.8	20.3	22.0	22.1
Bulbous	–	4.8	5.0	–	–	–	2.6	–	–	–	–	2.3	1.6	1.7	2.4
Bulbo-tuberiferous	–	–	–	3.0	–	2.7	–	–	–	–	–	0.8	0.8	0.4	–

An analysis of vegetation cenomorphs is of great importance for the disclosure of relationships and the nature of adaptation of a plant organism to the environment (Belgard, 1950). Ecological-coenotic spectra of forest communities are characterized by the dominance of synanthropophants (36.3–58.6%). There is a widespread development of forest weed and steppe weed annuals and perennials capable of rapid invasion into territory under conditions of the absence of competition on the part of rhizomatous perennials and sod grasses. The communities dominated by nemorants have extremely few species (Fig. 6). The percentages of stepants range from 6.9% to 23.4% in all monitoring plots, that is indicative of a powerful environment transforming impact of the forest on the steppe. Halophants present in all sites (1.1–3.0%) are random species, which in these conditions are in ecological pessimum.

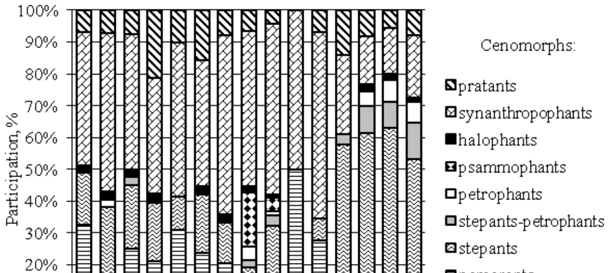

Fig. 6. Ecological and cenotic structure of forest and steppe communities from the south of Kryvyi Rih region

The cenomorphological composition of the vegetation of the steppe communities is rather homogenous, the stepants are dominant in the spectra of all steppe plots: from 51.8% in the 'Urochyshche Prygirya' to 55.0% in the 'Balka Zelena'. The share of ruderants and culturants is the greatest in the absolutely protected area ('Urochyshche Stepok') – 25.0%, whereas in the steppe slopes it is only 14.4–19.8%. Rugged terrain and closeness of limestone outcrops cause a significant increase in the participation of petrophants (4.8–6.8%) (Fig. 6).

The similarity of the floristic composition of vegetation was calculated using Czekanowski-Sörensen's coefficient (only the presence or absence of a species was taken into account). Based on the of the coefficient values, a tree diagram was constructed. According to this dendrogram, five clusters are distinguished at the 80–50% level of similarity (Fig. 7). The first cluster combines four steppe communities at the similarity level of 65.5%. 'Urochyshche Stepok' has a relatively weak correlation with the group of three other steppe sites. One of the reasons for the rather low similarity of the floristic composition is the drastic transformation of the whole ecosystem and a decrease in species diversity due to protection. The second cluster quite expectedly unites pine plantations under 30 years old and over 50 years old, the level of similarity being 38.5%. The third cluster is characterized by a high level of similarity (64.7%) grouping plantations of *R. pseudoacacia* over 50 years old and 40-year-old stands of *Q. robur* with understory of *C. arborescens* and *E. europaea.* The fourth cluster consists of multiple-aged plantations of *G. triacanthos*. A high similarity level of floristic composition is observed between the trees of *G. triacanthos* under the age of 40 and older than 50 years (similarity level of 62.5%). In conjunction with them is the plantation with *G. triacanthos* under the age of 30 (similarity level of 56.2%). The fifth cluster combines multiple-aged trees of *Q. robur*. As in the case of *G. triacanthos*, the largest similarity of the floristic composition (66.7%) is observed between *Q. robur* aged under 40 and over 50. At the level of similarity of 56.6% *Q. robur* under 30 years of age joins them.

The similarity of the floristic composition between the forest and steppe communities is small. The highest coefficient between coniferous stands and steppe sites is 31.5%, the smallest similarity between tree stands of *Q. robur* with undergrowth of *C. arborescens* and *E. europaea* under the age of 40 is only 12.1%. The largest similarity in the floristic composition was detected among the total of forest sites and 'Urochysche Stepok'(24.8%). The similarity of the species composition in three multiple-aged plantations of *G. triacanthos* and *Q. robur* is 58.3% and 60.0%, respectively, and only 19.3% in coniferous stands. The smallest coefficient of similarity of the floristic composition is 20%, namely, between pine plantations and all other hardwood species.

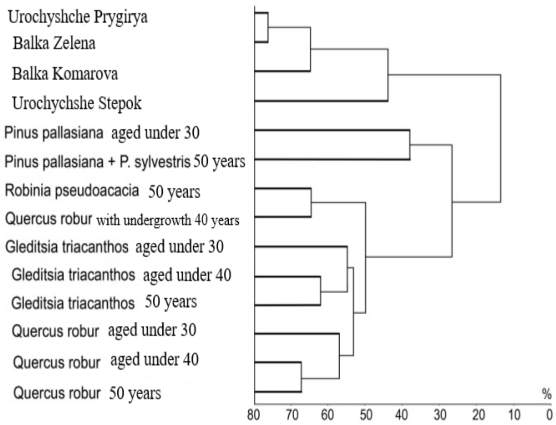

Fig. 7. Dendrogram of similarity-differences of species composition of vegetation in steppe communities and forest plantations of south Kryvyi Rih region

Thus, even in the 50-year-old plantations of *G. triacanthos*, *Q. robur*, *R. pseudoacacia*, *P. pallasiana* and *P. sylvestris*, the species composition of the grass cover is 14.0–31.5% of the floristic composition of the natural steppe phytocenoses. All this indicates that planted forests in the steppe are a powerful factor in the transformation of natural vegetation and changes in O. L. Belgard's biotic cycle.

Discussion

More than 2 billion hectares of woodland degrades worldwide (Stanturf et al., 2014), and therefore studying population genetic diversity is relevant (Korshikov & Pirko, 2002). The afforestation of arid steppe in southern Ukraine dates back to two centuries ago. This problem is also urgent for other states, such as in Turkey, where the Forest Service has laid down 2.3 million hectares of artificial forests in semi-arid landscapes (Boydak, 1997; Boydak & Saliskan 2015; Salıskan & Boydak, 2017). Our study has shown that artificial woodland in the arid steppe zone of Ukraine, which occupies 40% of country's area, significantly changes natural steppe phytocenoses. It is clear that in the investigated plantations the floristic richness of regional natural steppe phytocoenoses is significantly reduced, especially in the stands of *Q. robur* trees with understory and shade type of light structure. Obviously, the light structure of the tree stand is a decisive factor for vegetation development under the canopy and in clearings, the floristic diversity and changes in dominant species in the process of development of plantation of one or different species. The similarity and difference of the flora of plantations is quite clearly visualized in the dendrogram. The development of grass cover in multiple-aged plantations without understory but with illuminated type of light structure leads to the formation of phytocoenoses with different floristic composition, including dominant species. A total of 15 tree and shrub species and 31 species of herbaceous plants are found in plantations and absent from steppe communities. In relation to tree stand age, 21 herbaceous species were found in 30-year-old plantations, 7 species grow in 40-year-old stands and 24 species occur in 50-year-old plantations. In general, our studies have shown that in steppe plantations of different age and tree species there are complex structural dynamic processes of phytocenoses formation, which differ significantly from the indigenous steppes. This viewpoint agrees with other investigations (Erdösa et al., 2017). Due to the significant changes in the species composition of plantations, the structure of these phytocenoses in terms of the ecological and biological characteristics of plants differs significantly from steppe native communities. The heterogeneity of the floristic composition of plants in multiple-aged plantations of one species or different species can also be associated with the location of plantations in steppe phytocoenoses of varied origin, formation and degree of disturbance (Erdösa et al., 2017). It is obvious that the aboveground vegetation in the steppe forests is an additional factor for their adaptation to adverse natural and climatic conditions. In addition, forests can be a habitat for rare and endangered species (Erdösa et al., 2015, 2017). The World Resources Institute (WRI) sets a strategic goal for 2020 to recover 150 million hectares of deforested and degraded land worldwide (Reinecke & Blum, 2018). However, as shown by the recent Hungarian experience with the use of *Robinia pseudoacacia* in afforestation of pastures, it entails the loss of grassland species and their replacement by nitrophils (Matus et al., 2003). The widespread model of the late 19th – early 20th century, oriented at creation of pure stands of economically valuable species, mainly softwood, has led to decline in biodiversity. Therefore, it is proposed to create polydominant forest ecosystems that would be close to natural ones that can increase their resistance to fungal diseases and pests (Korotkov, 2017).

Conclusions

Thus, the specific floristic composition of the planted forests in the south of Kryvyi Rih region are formed due to differences in their composition, age, type of light structure, ecological and edaphic conditions, and other factors. All forest plantations investigated in this region are characterized by low species richness (2–90 species in comparison with 167–251 species from local natural phytocoenoses). The largest floristic representation was characteristic of pine plantations (over 50 years old) on sandy terraces (90 species), due to the formation of a specific environment and differentiation on different quality parcels. The similarity of the floristic compositions of the forest and steppe communities varies from 6.8% to 39.4%, and the largest one is found for 'Urochyshche Stepok'(19.4–39.4%), while dominant and subdominant species of these phytocoenoses, as a rule, are quite different. The floral similarity among the forest sites is within the range of 15.6–66.7%, although, it is variable in multiple-aged plantations of the same species. The ecological and biomorphological composition of forest plant communities depends on the species and age, which determine the type of light structure and edaphic conditions. In essence, true silvants (nemorants) represent a small amount of woodland species introduced artificially. Herbaceous species form the basis for species diversity in all monitoring sites. This is the reason for the significant proportion of synanthropopants (weed-forest and weed-steppe annuals and perennials) in the ecological-cenotic spectra of the forest communities. The core of the geographical structure of the forest communities is formed by Palearctic species, and in the steppe communities it is the species from the Black Sea range type.

The terrain, differences in soil cover and the pasture load affect the species richness, ecological, biomorphic and cenotic structure of steppe phytocoenoses. As a result of a protection regime, ruderants are invading the steppe communitites, and a significant ruggedness of terrain and limestone outcrops cause a significant increase in the participation of petrophants.

The conducted analysis is indicative of significant differences in the structure of the floristic composition in the forest and steppe communities agreeable with the conceptions of O. L. Belhard on the environment transforming function of artificial steppe forests, which change the biotic cycle, inherent in the steppes.

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