

Diversity, dynamics and ecological analysis of flora of reclaimed soil

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Abstract

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The flora of vegetation cover of sod-lithogenic soil on loess loams was studied at a reclaimed site in the Nikopol manganese-ore basin. The control site is located on the black soil of the steppe area. The species composition of plants was studied in both sites annually for three years. Ecological analysis of the flora was carried out according to Raunkiaer's system of life-forms and Belgard's system of ecomorphs. It has been established that the floristic composition on the reclaimed site is significantly poorer than that of the steppe site. The reclaimed site was found to have fewer species and a smaller number of families. The comparative inconstancy and dynamism of floristic composition on reclaimed soil is shown. The reclaimed ecosystem is distinguished by a significant share of the participation of annual and biennial plant forms. This indicates the anthropogenic transformation of the vegetation cover of the reclaimed soil. Also, a distinctive feature of the reclaimed soil flora is the smaller number of ecological groups of species. Such groups are united according to the ecological optimum to one of the environmental parameters.

Key words

Nikopol manganese-ore basin, phytoindication, reclamation, Ukraine

Introduction

The process of ecosystem destruction is an integral part of open pit mining (SHEORAN et al., 2010). When mineral resources are exploited in a quarry, the black soil of Ukraine is completely deprived of vegetation cover, wildlife and its humus horizon. Rocks are carried from different depths to the surface. They do not have a living phase and differ sharply in their properties from zonal soils (ZHUKOV and ZADOROZHNYA, 2016). The settling of living organisms in the substrate begins upon contact with the atmosphere, soil

formation processes occur, and the formation of ecosystems begins (ZHUKOV et al., 2012). Of great importance are questions of possible economic use of territories with reclaimed soils and their diagnostics (VORON, 2010). The study of the processes accompanying the reclamation provides the basis for a comprehensive assessment of the state of the environment (ANDRUSEVYCH and SHTIRTS, 2014).

Data on plant cover diversity are integral to a wide variety of soil quality indicators. Flora characteristics are used as an indicator of habitat environment assessment (DIDUKH, 2011, 2012; MATVEEV, 2011). The activ-

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ity of organisms (both transformative (VERNADSKIY, 1978; LOVELOCK, 2000; KORZH, 2013a) and niche-forming (ODLING-SMEE et al., 2003)), indicates the mutual influence of organisms and their habitat (KORZH, 2013a). The combination of conditions in which a species exists is the result of existing effects. This result is related to the concept of environmental capacity (KORZH et al., 2016). Evaluation of the relative contribution of each factor in maintaining this capacity is extremely difficult (KORZH et al., 2016). The habitat capacity can be used as an indicator of the “security” of a species. It can also be used as a limit to the implementation of its adaptive properties (KORZH, 2013b). A complex generalized characteristic of environmental conditions can be obtained using the ecological characteristics of species of flora (DIDUH, 2011; ANDRUSEVICH and SHIRTIS 2014). The course of ecosystem and soil formation is generally reflected in the dynamic rearrangement of the plant community (ZADOROZHNA, 2018; ZADOROZHNA et al., 2018.). Studies on this theme have great prospects for use because they are practical and relatively simple to carry out.

The aim of this paper is assess of the dynamics of ecosystems on reclaimed soil by indicators of diversity, dynamics and data of ecological analysis of flora.

Materials and methods

The research was carried out at a reclaimed site of the Nikopol manganese ore basin for three years (2012–2014). The experimental site is located on sod-lithogenic soil on loess-like loams (YETEREVSKA et al., 2008). According to IUSS Working Group WRB (2015) the soil is called Hyperskeletal Technosol (Calcaric, Supramollic, Vertic). Mining activity ceased 40 years ago, after which soil was added to make the site suitable for agriculture. At the time of the study, the land of the reclamation site had not used as an agricultural land for about 20 years.

The control site is located in a steppe area adjacent to the south-eastern slope of the Kamenistaya Gully (southern outskirts of Dnipro, Ukraine). On the north side of the steppe site there is a forest belt and an agricultural field. The soil of the control site is represented by black soil. According to IUSS Working Group WRB (2015) the soil is called Vermic Protovertic Chernozem (Katoloamic, Humic, Protocalcic). The control site is located on loess loam as it is the source rock for black soil. Meteorological data

was taken at the meteorological stations of Nikopol and Dnipro (Table 1).

Species composition taken into consideration in the analysis of plant community. The names of species of plants and their systematic position is given according to the TARASOV (2012).

Ecological analysis of flora was carried out according to the classification of Raunkiaer’s life-forms (RAUNKIÆR, 1937; Tarasov, 2012) and the ecological characteristic of species according to BELGARD (1971).

Plant life forms are represented by annual, biennial and perennial forms (ANDRUSEVICH and SHIRTIS, 2014). The share of perennial form in this paper was calculated as the sum of shares of perennial grasses, subshrubs, shrubs and trees.

Raunkiaer’s life-forms (or climamorphs) are groups of plants separated by the position and method of protection of the regenerative buds during adverse periods (cold or dry). According to this classification, there are:

Class I: Phanerophytes (Ph) – They are any tall plants visible all year round, which can afford to carry their perennial buds well above the ground, at least 25 cm up. This would include all trees, lianas, and virtually all shrubs in the structural classification.

Class II: Chamaephytes (Ch) – They are low growing plants that are visible all the year-round, which carry their perennial buds up to 25 cm above the ground. They are more capable of handling rougher environments than phanerophytes because of their low stature (they are less exposed to the wind and receive some ground warming).

Class III: Hemicryptophytes (H) – They die back, to buds at ground surface during the unfavourable seasons. Their perennial buds lie close to the ground surface (above or below) and are often hidden by litter during unfavourable season, which protects them. So they are “half-hidden” plants.

Class IV: Cryptophytes (Cr) – The surviving buds or shoot apices in this group of plants are buried in the ground (or under water).

Class V: Therophytes (Th) – They get through adverse periods (seasonal or even years long) as seeds or spores. They go through their entire life cycle, from seed/spore to seed/spore, within one growing season, which can be amazingly short.

Ecological forms according to BELGARD (1971) include:

1. Trophomorphs are groups of species united by

Table 1. Meteorological data of test sites

Year	Reclamation site		Test site	
	Precipitation (mm)	Average temperature (°C)	Precipitation (mm)	Average temperature (°C)
2012	312.9	18.3	322.70	17.6
2013	205.4	17.3	184.70	16.7
2014	235.8	17.5	387.30	16.7

their ecological optimum in relation to the trophicity (fertility) of the soil. Different trophomorphs prefer soils with different levels of mineralization of the soil solution. They are divided into oligotrophs (OgTr) (a group of plants that live on depleted soils), mesotrophs (MsTr) (a group of plants of medium-rich soils) megatrophs (MgTr) (plants of rich habitats).

2. Hygromorphs are groups of plant species that differ in the required moisture regime. Hygromorphs are divided into seven subgroups according to the degree of humidification: xerophytes (Ks) (plants of dry biotopes), mesoxerophytes (MsKs) (plants of dryish biotopes), xeromesophytes (KsMs) (plants of fresh, slightly moist biotopes), mesophytes (Ms) (plants of moist biotopes), hygromesophytes (HgMs) (plants of wet biotopes).

3. Heliomorphs are groups of species that need certain light conditions. They are divided into heliophytes (He) (an ecological group of plants whose ecological optimum corresponds to the light regime of open spaces), scioheliophytes (ScHe) (the ecological optimum corresponds to the light regime of partly shaded forests with a latticed light structure), heliosciophytes (HeSc) (the ecological optimum corresponds to the light regime of semi-dense plantations of the penumbral structure).

4. Coenomorphs are ecological groups of plants that are tied to the environment of the community as a whole. They are divided into pratants (Pr) (meadow species), psammophytes (Ps) (plants of sandy habitats), ruderals (Ru) (weedy species), silvants (Sil) (forest species), steppants (St) (steppe species).

Methods of descriptive statistics are used in statistical calculations. As a measure of similarity used the Jaccard index, also known as Intersection over Union and the Jaccard similarity coefficient (Jaccard, 1901):

$$K_j = c / (a + b - c)$$

where a is the number of species of the first test site, absent at the second test site, b is the number of species unique to the second test site, and c is the number of species common to both test sites.

Results

46 vascular plant species were identified in the vegetation cover of the reclaimed site, sod-lithogenic soil on loess loams, during the study period (Table 2). The composition of the flora of the experimental site changed significantly during the study period. So, 17 plant species were recorded in every year of the study period. They constitute 36.95% of the total number of registered species. The remaining components of the flora were not recorded every year. 15 species (32.60%) were recorded for two years. 14 species (30.43%) were registered in only one of the three years of research. The Jaccard index as a measure of similarity between the floristic composition of the test site in 2012 and 2014 amounted to 0.67.

73 species of higher vascular plants were found in the flora of the steppe slope of the gully (Table 3). The composition of the flora of the control area also changed during the study period. On the black soil site, 49 plant species were identified in 2012, 63 species were identified in 2013, 60 species were identified in 2014. 42 plant species were recorded annually. This accounted for 57.53% of the total number of species. The remaining components of the flora were not recorded every year. 16 species (21.91%) were present for 2 years. 15 species (20.54%) were found once in three years of study. The Jaccard index between the data of the floristic composition of 2012 and 2014 at the control site is 0.75. The Jaccard index averaged 0.28 when assessing the similarities between the species diversity of the reclamation and steppe sites.

An ecological analysis of the flora was carried out with the aim of making an integrated assessment of the conditions of the studied sites. Namely, moisture regimes, lighting, soil fertility conditions (trophicity) as a combination of existing environmental conditions.

The study found that approximately half of the plant species in the reclamation site were perennials. Their share in the list of flora varies from 45.45 to 55.17%. The other half consisted of biennial plants (10.34–18.18%) and annuals (33.33–36.36%) (Fig. 1).

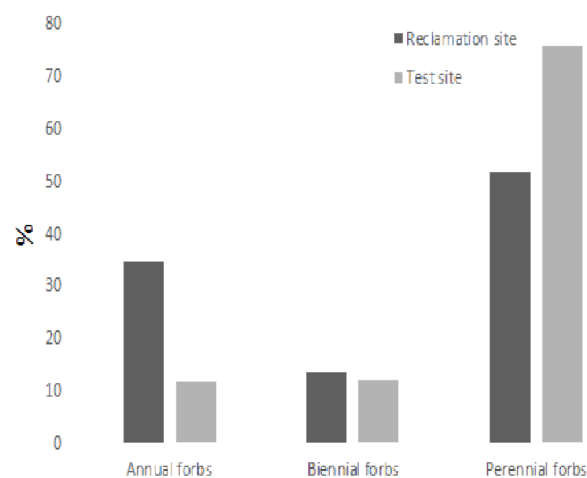


Fig. 1. The average values of the share of participation of plant life forms of the reclamation and the control sites.

The overwhelming majority of the flora species in the control area were representatives of perennial forms (71.43–81.63%). The subordinate position was occupied by biennial (11.11–13.33%) and annual plants (6.12–17.46%) (Fig. 1).

The spectrum of Raunkiaer's life-forms of the plant species composition of the sod-lithogenic soils on loess loams was represented by 3 forms. Hemicryptophytes (with shares (51.52–5.17%) dominated, therophytes (31.03–33.33%) and cryptophytes (12.12–15.15%) were in a subordinate position (Fig. 2).

Table 2. List of plant species of the reclamation site for three years of research, their life forms and ectomorphs

	Species of plants	Year			Life-forms	Raunkiaer's life-forms	Trophomorphs	Hygromorphs	Heliomorphs	Coenomorphs
		2012	2013	2014						
1	<i>Achillea millefolium</i> L.	+	+	+	PF	H	MgTr	KsMs	He	Pr
2	<i>Aegilops cylindrica</i> Host	-	-	+	AF	Th	OgMsTr	MsKs	He	Ptr
3	<i>Agropyron pectinatum</i> (M. Bieb.) P. Beauv.	-	+	+	PF	H	MsTr	Ks	He	St
4	<i>Alyssum desertorum</i> Stapf.	-	+	-	AF	Th	MsTr	MsKs	He	St
5	<i>Ambrosia artemisifolia</i> L.	+	-	+	AF	Th	OgMsTr	MsKs	ScHe	Ru
6	<i>Anisantha tectorum</i> (L.) Nevski	+	+	+	AF	Th	MgTr	KsMs	ScHe	St
7	<i>Anthemis arvensis</i> L.	-	+	-	AF	Th	MsTr	MsKs	He	St
8	<i>Artemisia absinthium</i> L.	+	+	+	PF	H	MsTr	KsMs	He	St
9	<i>Bromus squarrosus</i> L.	+	+	+	AF	Th	MgTr	MsKs	ScHe	St
10	<i>Centaurea diffusa</i> Lam.	+	+	+	BF	H	MsTr	Ks	He	St
11	<i>Consolida regalis</i> Gray	+	+	+	AF	Th	MsTr	MsKs	ScHe	St
12	<i>Convolvulus arvensis</i> L.	+	+	+	PF	Cr	MsTr	MsKs	ScHe	St
13	<i>Crepis tectorum</i> L.	+	-	-	AF	Th	MsTr	MsKs	He	St
14	<i>Elytrigia repens</i> (L.) Nevski	+	+	+	PF	Cr	MsTr	KsMs	ScHe	Pr
15	<i>Erigeron acris</i> L.	-	-	+	AF	Th	MsTr	MsKs	He	St
16	<i>Erysimum diffusum</i> Ehrh.	-	+	+	BF	H	MsTr	Ks	He	St
17	<i>Euphorbia stepposa</i> Zoz. ex Prokh.	-	+	-	PF	H	MgTr	Ks	He	St
18	<i>Falcaria vulgaris</i> Bernh	+	-	+	PF	H	MgTr	Ks	He	St
19	<i>Festuca valesiaca</i> Goud. s.l.	+	-	-	PF	H	MgTr	MsKs	He	St
20	<i>Lactuca serriola</i> L.	+	-	+	AF	Th	MsTr	KsMs	He	St
21	<i>Lactuca tatarica</i> (L.) C.A.Mey	-	+	+	PF	Cr	MsTr	KsMs	He	St
22	<i>Lepidium perfoliatum</i> L.	+	+	-	AF	Th	MsTr	MsKs	He	St
23	<i>Linaria genistifolia</i> L.	-	-	+	PF	H	Og-MsTr	Ks	He	St
24	<i>Lotus ucrainicus</i> Klkov	+	+	-	PF	H	MsTr	KsMs	He	Pr
25	<i>Medicago lupulina</i> L.	+	-	-	AF	H	MsTr	KsMs	He	Pr
26	<i>Medicago romanica</i> Prod.	+	-	+	PF	H	MgTr	KsMs	He	Pr
27	<i>Medicago sativa</i> L.	+	+	+	PF	H	MgTr	KsMs	He	Pr
28	<i>Melica transsilvanica</i> Schur	+	+	+	PF	H	MsTr	KsMs	ScHe	St
29	<i>Melilotus albus</i> Medik.	-	-	+	BF	H	MsTr	HgMs	He	Pr
30	<i>Melilotus officinalis</i> (L.) Pall.	-	+	+	BF	H	MsTr	KsMs	He	Pr
31	<i>Onobrychis vicifolia</i> Scop.	+	+	+	PF	H	MsTr	KsMs	He	St
32	<i>Poa pratensis</i> L.	-	+		PF	Cr	MsTr	Ms	He	Pr
33	<i>Reseda lutea</i> L.	+	+	+	AF	Th	MgTr	KsMs	He	St
34	<i>Rosa canina</i> L.	+	+	+	AF	Th	MgTr	KsMs	He	St
35	<i>Rumex confertus</i> Willd.	-	-	+	PF	H	MsTr	KsMs	ScHe	St
36	<i>Securigera varia</i> (L.) Lassen	+	+	+	PF	Cr	MgTr	KsMs	ScHe	Pr
37	<i>Senecio jacobaea</i> L.	+	+	-	PF	H	MsTr	KsMs	He	Pr
38	<i>Seseli campestre</i> Besser	+	+	+	PF	H	MgTr	MsKs	He	St
39	<i>Silene dichotoma</i> Ehrh		+	+	AF	Th	MsTr	KsMs	ScHe	St
40	<i>Sonchus arvensis</i> L.	+	-	-	PF	Cr	MgTr	KsMs	He	St
41	<i>Stellaria holostea</i> L.	-	+	-	PF	H	MsTr	HgMs	HeSc	Sil
42	<i>Taraxacum officinale</i> Wigg.	+	+	-	PF	H	MsTr	KsMs	ScHe	St
43	<i>Tragopogon major</i> Jacq.	+	+	+	BF	H	MsTr	MsKs	ScHe	St
44	<i>Vicia cracca</i> L.	+	+	+	PF	H	MsTr	HgMs	He	Pr
45	<i>Xanthium strumarium</i> L.	-	+	+	AF	Th	MsTr	KsMs	He	St
46	<i>Xeranthemum annuum</i> L..	-	+	+	AF	Th	MsTr	Ks	He	St
	Total	29	33	33						

“+” – identified; “-” – not identified; life-forms: AF – annual forbs, BF – biennial forbs, PF – perennial forbs; Raunkiaer's life-forms: Ph. – phanerophytes, Ch. – chamaephytes, H – hemicryptophytes, Cr – cryptophytes, Th – therophytes; trophomorphs: OgTr – oligotrophs, MsTr – mesotrophs, MgTr – megatrophs; hygromorphs: Ks – xerophytes, MsKs – mesoxerophytes, KsMs – xeromesophytes, Ms – mesophytes, HgMs – hygromesophytes; heliomorphs: He – heliophytes, ScHe – scioheliophytes, HeSc – heliosciophytes; coenomorphs: Pr – meadow species, Ps – plants of sandy habitats, Ru – weedy species, Sil – forest species, St – steppe species.

Table 3. List of plant species of the steppe site for three years of research, their life forms and ecomorphs

	Species of plants	Year			Life-forms	Raunkiaer's life-forms	Tropho-morphs	Hygro-morphs	Helio-morphs	Coeno-morphs
		2012	2013	2014						
1	<i>Acer tataricum</i> L.	+	-	-	PF	Ph	MsTr	KsMs	He	Sil
2	<i>Achillea millefolium</i> L.	+	+	+	PF	H	MgTr	KsMs	He	Pr
3	<i>Agrimonia eupatoria</i> L.	+	+	-	PF	H	MgTr	KsMs	ScHe	St
4	<i>Agropyron pectinatum</i> (M. Bieb.) P. Beauv.	-	+	-	PF	H	MsTr	Ks	He	St
5	<i>Ajuga genevensis</i> L.	+	+	+	PF	Cr	MsTr	MsKs	ScHe	Pr
6	<i>Allium paniculatum</i> L.	-	-	+	PF	Cr	MsTr	MsKs	He	Pr
7	<i>Allium waldsteinii</i> G. Don fil.	-	-	+	PF	Cr	MsTr	Ms	He	Pr
8	<i>Armeniaca vulgaris</i> Lam.	+	+	+	PF	Ph	MsTr	MsKs	He	Sil
9	<i>Artemisia absinthium</i> L.		+	+	PF	H	MsTr	KsMs	He	St
10	<i>Artemisia austriaca</i> Jacq.	+	+	+	PF	H	MsTr	Ks	He	St
11	<i>Asparagus officinalis</i> L.	+	+	+	PF	H	MgTr	MsKs	ScHe	St
12	<i>Bromus squarrosus</i> L.	-	+	+	AF	Th	MgTr	MsKs	ScHe	St
13	<i>Calamagrostis epigeios</i> (L.) Roth	-	+	+	PF	Cr	OgTr	Ms	ScHe	Pr
14	<i>Campanula patula</i> L.	+	+	+	BF	H	MsTr	Ms	ScHe	Sil
15	<i>Carduus acanthoides</i> L.	+	+	+	AF	Th	MsTr	KsMs	ScHe	Sil
16	<i>Centaurea scabiosa</i> L.	+	+	+	PF	H	MgTr	MsKs	ScHe	St
17	<i>Chamaecytisus ruthenicus</i> (Fisch. Ex Wox.) Klasova	+	+	+	PF	nPh	MsTr	KsMs	ScHe	St
18	<i>Chondrilla juncea</i> L.	+	+	+	BF	H	OgTr	MsKs	He	Ps
19	<i>Consolida regalis</i> Gray		+	+	AF	Th	MsTr	MsKs	ScHe	St
20	<i>Convolvulus arvensis</i> L.	+	+	+	PF	Cr	MsTr	MsKs	ScHe	St
21	<i>Crepis tectorum</i> L.	-	+	-	AF	Th	MsTr	MsKs	He	St
22	<i>Descurainia sophia</i> L.		+	-	AF	Th	MsTr	KsMs	He	St
23	<i>Dianthus fischeri</i> Spreng.	-	-	+	PF	H	OgTr	MsKs	ScHe	Ps
24	<i>Elytrigia repens</i> (L.) Nevski	+	+	+	PF	Cr	MsTr	KsMs	ScHe	Pr
25	<i>Eryngium campestre</i> L.	+	+	+	PF	Cr	MsTr	Ks	He	St
26	<i>Erysimum diffusum</i> Ehrh.	+	+	+	BF	H	MsTr	Ks	He	St
27	<i>Euphorbia stepposa</i> Zoz. ex Prokh.	+	+	+	PF	H	MgTr	Ks	He	St
28	<i>Euphorbia virgata</i> Waldst. & Kit	+	+	+	PF	H	MsTr	MsKs	ScHe	Pr
29	<i>Falcaria vulgaris</i> Bernh.	+	+	+	BF	H	MgTr	KsMs	He	St
30	<i>Festuca rubra</i> L.		+	+	PF	HK	MgTr	Ms	ScHe	Pr
31	<i>Festuca valesiaca</i> Goud. s.l.	+	+		PF	H	MgTr	MsKs	He	St
32	<i>Galatella villosa</i> (L.) Rech.f.	+	+	+	PF	Cr	MsTr	Ks	He	St
33	<i>Galium hupanicum</i>	+	-	+	PF	H	MgTr	MsKs	He	St
34	<i>Gleditsia triacanthos</i> L.	+	+	+	PF	Ph	MsTr	MsKs	He	St
35	<i>Helichrysum arenarium</i> (L.) Moench	+	+	+	PF	HK	OgMsTr	MsKs	He	St
36	<i>Herniaria polygama</i> J. Gay	+	+	+	AF	Th	OgMsTr	MsKs	ScHe	St
37	<i>Hieracium umbellatum</i> L.		+	+	PF	H	OgMsTr	KsMs	ScHe	Pr
38	<i>Hieracium virosum</i>	+	-	-	PF	H	MsTr	MsKs	ScHe	St
39	<i>Hypericum elegans</i> Stephan ex Willd.	-	+	+	PF	H	MsTr	MsKs	He	St
40	<i>Koeleria cristata</i> (L.) Pers.	+	+	+	PF	H	MgTr	Ks	He	St
41	<i>Lactuca serriola</i> L.		+	+	AF	Th	MsTr	KsMs	He	St
42	<i>Lepidium perfoliatum</i> L.	-	+	-	AF	Th	MsTr	MsKs	He	St
43	<i>Limonium sareptanum</i> (A. Becker) Gams	+	+	+	PF	H	MgTr	Ks	He	St
44	<i>Linaria genistifolia</i> L.	-	+	+	PF	H	Og-MsTr	Ks	He	St
45	<i>Medicago romanica</i> Prod.	+	+	+	PF	H	MgTr	KsMs	He	Pr
46	<i>Medicago sativa</i> (L.) Mill.	+	+	+	PF	H	MgTr	KsMs	He	Pr
47	<i>Melica transsilvanica</i> Schur	-	+	+	PF	H	MsTr	KsMs	ScHe	St
48	<i>Melilotus officinalis</i> (L.) Pall.	-	+	+	BF	H	MsTr	KsMs	He	Pr
49	<i>Morus alba</i> L.	+	+	+	PF	Ph	MsTr	MsKs	ScHe	Sil
50	<i>Nonea pulla</i> DC.	+	+	+	PF	H	MsTr	MsKs	He	St
51	<i>Orites wolgensis</i> (Hornem.) Grossh.	+	+	+	BF	H	MgTr	MsKs	He	St
52	<i>Phalacrolooma annuum</i> (L.) Dumort	-	-	+	AF	Th	MsTr	MsKs	ScHe	Ru

Table3. List of plant species of the steppe site for three years of research, their life forms and ecomorphs – continued.

Species of plants	Year			Life-forms	Raunkiaer's life-forms	Tropho-morphs	Hygro-morphs	Helio-morphs	Coeno-morphs
	2012	2013	2014						
53 <i>Poa pratensis</i> L.	+	+	+	PF	Cr	MsTr	Ms	He	Pr
54 <i>Potentilla argentea</i> L.	+	+	+	PF	H	OgMsTr	KsMs	ScHe	Pr
55 <i>Potentilla erecta</i> L.	-	+	+	PF	Cr	MsTr	HgMs	ScHe	Pr
56 <i>Potentilla obscura</i> Willd.	+	-		PF	H	MgTr	KsMs	He	Pr
57 <i>Reseda lutea</i> L.	+	+	+	AF	Th	MgTr	KsMs	He	St
58 <i>Salvia nemorosa</i> L. (Klokov et Pobed.) Soó	+	+	+	PF	H	MsTr	Ms	ScHe	Sil
59 <i>Securigera varia</i> (L.) Lassen)	+	+	+	PF	Cr	MgTr	KsMs	ScHe	Pr
60 <i>Senecio jacobaea</i> L.	+	+	+	PF	H	MsTr	KsMs	He	Pr
61 <i>Senecio vernalis</i> Waldst. Et Kit	-	+	-	AF	H	Og-MsTr	KsMs	ScHe	Pr
62 <i>Seseli campestre</i> Besser	+	+	+	PF	H	MgTr	MsKs	He	St
63 <i>Silene dichotoma</i> Ehrh.		+		AF	Th	MsTr	KsMs	ScHe	St
64 <i>Stachys transsilvanica</i> Schur	+	+	+	PF	H	OgMsTr	MsKs	He	St
65 <i>Stellaria holostea</i> L.		+		PF	H	MsTr	HgMs	HeSc	Sil
66 <i>Stipa capillata</i> L.	+	+	+	PF	H	MgMsTr	Ks	He	St
67 <i>Teucrium polium</i> L.	+	+	+	PF	Ch	MsTr	Ks	He	St
68 <i>Thymus marschallianus</i> Willd.	+	+	+	PF	Ch	MsTr	Ks	He	St
69 <i>Tragopogon major</i> Jacq.	+	+	+	BF	H	MsTr	MsKs	ScHe	St
70 <i>Verbascum phoeniceum</i> L.	+	+		PF	H	MsTr	MsKs	ScHe	St
71 <i>Verbascum thapsus</i> L.			+	BF	H	OgTr	KsMs	ScHe	Pr
72 <i>Veronica steppacea</i> Kotov	+	+	+	PF	H	MsTr	Ks	He	St
73 <i>Viola ambigua</i> Waldst. & Kit.	+	-	+	PF	H	MgTr	MsKs	ScHe	St
Total	49	63	60						

For key to abbreviations see Table 2.

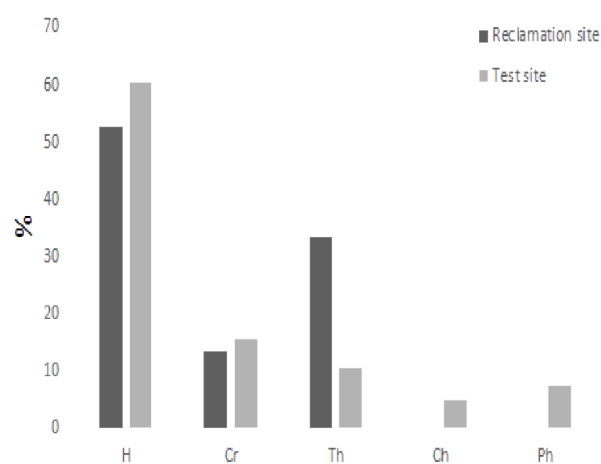


Fig. 2. The average values of the share of participation of Raunkiaer's life-forms of the reclamation and the control sites. H is hemicryptophytes, Cr is cryptophytes, Th is therophytes, Ch is chamaephytes, Ph is phanerophytes

Raunkiaer's life-forms of the plant species composition of the black soil site were represented by 5 forms. Hemicryptophytes occupied a dominant position (58.33–63.27%). Cryptophytes (14.29–18.33%), therophytes (6.12–14.30%), phanerophytes (6.35–10.20%) and chamaephytes (4.76–6.12%) were in the subordinate position (Fig. 2).

The trophomorphs of the plant species composition of the reclaimed soil were represented by megatrophs (a group of species that prefer soils with a high concentration of soil solution) and mesotrophs (a group of species that prefer soils with a moderate concentration of soil solution). The share of mesotrophs was somewhat higher (58.62–72.73%) than megatrophs (27.27–41.38%). Trophomorphs of the control site were represented by mesotrophs (57.14–68.25%), megatrophs (26.98–40.82%) and oligotrophs (2.04–6.67%) (Fig. 3).

In the spectrum of hygromorphs, the species composition of plants in the experimental area was dominated by xeromesophytes (51.52–58.62%) and mesoxerophytes (24.24–34.48%). The share of xerophytes was slightly less (3.45–15.15%). Hygromesophytes were recorded with a participation share of 3.45–5.19% (Fig. 4).

Hygromorphs in the species composition of plants on the chernozem were very diverse: mesoxerophytes (36.51–42.86%), xeromesophytes (28.33–31.75%), xerophytes (20.00–22.45%), mesophytes (6.12–10.00%) and hygromesophytes (1.67–3.17%). In 2012 hygromesophytes were not recorded (Fig. 4).

Among the heliomorphs, three forms were found on the both test sites. Heliophytes were also dominant at the reclamation site (65.52–66.67%) and in the control site (57.14–61.22%). Sciopheliophytes occupied a subordinate position. Their representation was on average 9%

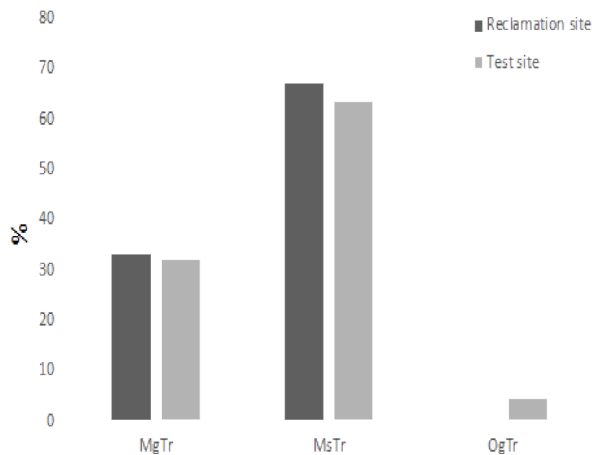


Fig. 3. The average values of the share of participation of trophomorphs of the reclamation and the control sites. MgTr is megatrophs; MsTr is mesotrophs; OgTr is oligotrophs.

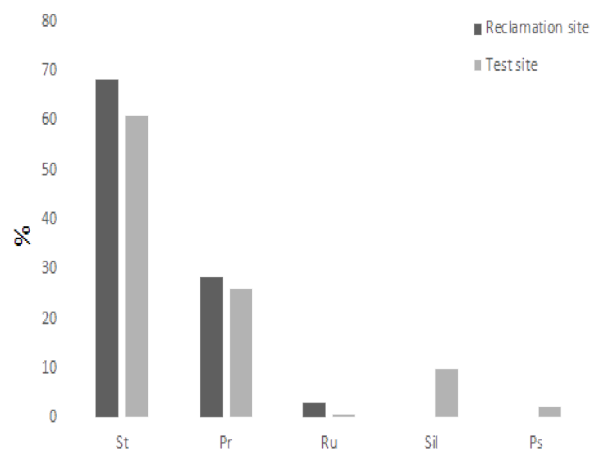


Fig. 6. The average values of the share of participation of coenomorphs of the reclamation and the control sites. St is steppe species; Pr is meadow species; Ru is weedy species; Sil is forest species; Ps is plants of sandy habitats.

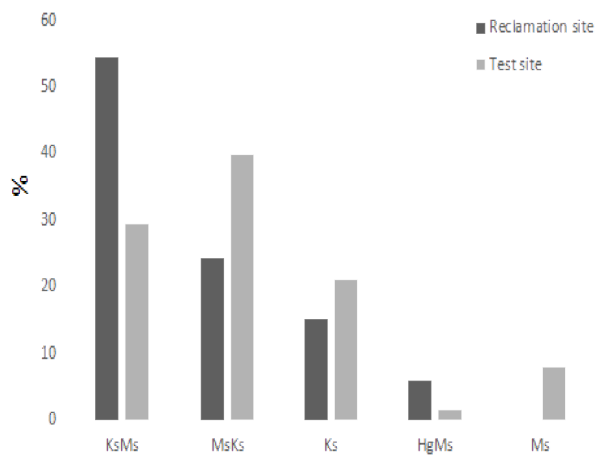


Fig. 4. The average values of the share of participation of hygromorphs of the reclamation and the control sites. KsMs is xeromesophytes; MsKs is mesoxerophytes; Ks is xerophytes; HgMs is hygromesophytes; Ms is mesophytes.

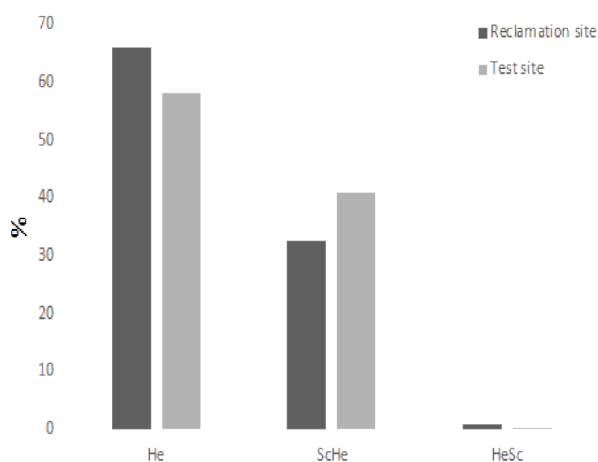


Fig. 5. The average values of the share of participation of heliomorphs of the reclamation and the control sites. He is heliophytes; ScHe is scioheliophytes; HeSc is heliosciophytes.

higher at the control steppe site. In 2013, one plant species belonging to heliosciophytes was recorded at both sites (Fig. 5).

Steppe species had the highest share at both sites (65.52–69.70% – on the reclamation site, 56.67–63.49% – on the control site), but on the reclaimed soil the share was several percent higher. The remaining plant species of the experimental site were meadow species (27.27–31.03%). One weed was recorded in this site during the study period. In addition to steppe species, meadow (22.45–30.00%) and forest species (8.33–12.24%) were observed in the flora of the control steppe site. One weed plant and two psammophytes species (plant of sandy habitats) were recorded in the control area during the study period (Fig. 6).

The presence of the invasive and quarantine species *Ambrosia artemisifolia* in both areas should be noted. Also, invasive species *Phalacrolooma annuum* and *Gleditsia triacanthos* were found in the control site, and species *Centaurea diffusa* and *Xanthium strumarium* were found in the reclaimed site. Invasive species are listed according to ZAVIALOVA (2017), quarantine according to the Instructions for the identification, localization and elimination of source of quarantine weeds, approved by order of the Ministry of Agrarian Policy of Ukraine (27.01.2005 N 40).

Discussion

The results of the study showed that the flora of the reclamation site was significantly poorer than the flora on the black soil in the virgin steppe. The number of plant species in the control area was 1.48 times greater than in the experimental one. The excess of the number of steppe flora families was even more significant, by 1.69 times. This situation was observed throughout the three years of research. At the same time, the share of the dominant plant species at the reclamation site was almost twice the

share at the steppe site. This suggests comparative poverty and homogeneity of the vegetation cover of the reclamation soil. Almost half of the species of virgin steppe flora (48.05%) were recorded annually. This figure does not reach even one third of the whole list of plants on the reclamation soil (28.84%). This indicates the comparatively inconstant and dynamic floristic composition of an artificial ecosystem. This is confirmed by the calculation of the measure of similarity. The value of the Jaccard index of flora diversity of the reclamation site is significantly lower than the values of the Jaccard index of flora of the control site (0.75 and 0.68, respectively).

A characteristic feature of the flora of the both studied ecosystems is the dominance in the species composition of a small number of families. This phenomenon is characteristic of both artificial and natural ecosystems. According to TOKHTAR (2013), this indicates the presence of anthropogenic influence on both sites. However, the lifetime of the studied ecosystems varies significantly. When creating a site for reclamation, such components of the ecosystem as the relief and natural soil cover are completely transformed, the vegetation cover is formed a new on a new substrate. The control steppe site on the slope of a steppe gully is also subject to anthropogenic impact. This is expressed in sporadic weeding out of vegetation due to grazing. It is also likely to be subject to washout of pesticides from adjacent agricultural land, which is located higher than the control site. The share of the permanent components of the flora at the experimental and control sites differ by more than 1.6 times. This indicates different degrees of anthropogenic influences. Accordingly, the findings suggest the more unstable state of the artificial ecosystem flora, which confirms our previous conclusions.

The life forms of plants as a complex of habitual features emerging in the course of adaptive evolution reflect the complex relationship between plant species and environmental conditions in an integral form (SEMENOVA-TYAN-SHANSKAYA, 1954; SLUGINOVA, 2009). As is well known, annual and biennial species are practically absent in stable formed plant communities (IPATOV et al., 1996). An increase in their number is usually associated with the anthropogenic transformation of the vegetation cover (ILYINA, 2003). The prevalence of perennial plants in the community in the spectrum of flora life forms of the control site indicates a high degree of formation and stability of the community. Analysis of the ratio of flora life forms at the reclamation site showed a sufficiently large proportion of perennial plants. This indicates the process of naturalization of the plant community. However, the larger percentage of annual and biennial plant forms ($x = 23.98\%$) at the experimental site compared to the control site indicates the relatively young age of the ecosystem. The experimental site was founded in 1970–1971. Until the beginning of the 2000s, it was cultivated as agricultural land.

Climamorphs or Raunkiaer's life-forms are formed historically as a result of the adaptation of plants to the climatic conditions of the environment (RAUNKIÆR, 1937; STEPANOVSKIĖ, 2001; ANDRUSEVICH and SHTIRTS, 2014).

They characterize the adaptability of various plant species to the effect of unfavourable climatic and weather conditions during the winter period (MATVEEV, 2011). Such spectra are used to analyze the vegetation of different communities of the same climatic zone (BELGARD, 1971). It is considered by some that climamorph types are too extensive and heterogeneous to serve as climate indicators (STEPANOVSKIĖ, 2001). We present the flora data of two test sites of the same climatic zone as a relative indicator of the ecological capacity of biotopes. According to ABDULOVA and SOLOMAKHĖ (2011), the more complex the organization of the community and the higher the ecological capacity of the habitat, the more diverse is the spectrum of the climamorph (life forms according to Raunkiaer). According to our data, the representation of climamorph types of reclaimed soil is somewhat less than in the virgin steppe site. The limiting factor may be the variability and a certain degree of extremes of the ecological regimes of the environment. Extremity is due to the low content of organic matter in reclaimed soil, severe shrinkage, wide variations in the temperature of the anthropogenic soil, and a high content of lumpy fractions in the aggregate composition (ANDRUSEVICH and LAGUNINA, 2013; ANDRUSEVICH and LYADSKA 2014; ZHUKOV and ZADOROZHNAJA, 2015, 2017).

The ecomorphic analysis proposed by BELGARD (1971), is an apparatus for studying ecosystems, built on the use of information about the requirements of the ecosystem populations for environmental parameters (temperature, light, nutrients, humidity) (CHERNYSHENKO and LYSENKO, 2008; ZHUKOV, 2009). All types of plant communities are coordinated by a series of gradients – spatial, temporal, chemical, physical, etc. The variety of ecological forms allows different species to coexist and effectively distribute among themselves resources in time and space according to their needs (ABDULOVA and SOLOMAKHĖ, 2011). A distinctive feature of the reclaimed soil flora is the smaller number of ecomorphs – groups of species combined by ecological optimum to one of the environmental parameters.

According to the results of an ecomorphic (ecological) analysis of the spectrum of the trophophs of both polygons, mesotrophs dominate, which indicates that the soils of the studied sites are medium rich (medium fertile). However, the representation of megatrophs is also significant – 32.99% and 32.04% for reclaimed soil and black soil, respectively. This indicates a local presence of places with a higher content of mineral substances in the soil solution. The number of the trophomorphs at the control site is larger; it includes oligotrophic species (mean = 4.49%).

In the spectrum of the hygromorphs of the flora of the test site, xeromesophytes, that is, plants of fresh biotopes, prevail. In the control site mesoxerophytes dominated – plants of rather dry habitats. However, the number of ecological groups of plants that require different moisture regimes was greater on the black soil in two out of the three years of research.

The heliomorph spectra of both the studied sites are identical. They are dominated by heliophytes, an ecological group of plants, the ecological optimum of which corresponds to the light regime of open spaces.

The number of environmental groups associated with different habitats was also smaller at the experimental site. Steppe, meadow and weed species were recorded on the reclaimed soil site. The flora of the control site also included forest and sandy habitats.

It can be argued the ecological capacity of the environment of an artificial ecosystem is substantially less. The possibility of the existence of a certain number of organisms in the existing conditions of the reclamation site is significantly lower. The relatively low capacity of the medium exerts a kind of pressure on the corresponding group of organisms. This pressure can in a certain way limit various vital manifestations – distribution, number, reproduction, etc. (KORZH et al, 2016; KIRILOV and BANOV, 2017; BUTA et al., 2019).

As mentioned earlier, the formation of the structure of the plant group is directly dependent on the influence of the environment (MONTAGU et al., 2001; VANAGS et al., 2004; GODEFROID and KOEDAM, 2003). Changes of the soil properties as a component of the environment for plants are of paramount importance (CHESSON, 2000). The intraspecific and interspecific relationships of plants of the virgin steppe have long been formed. The transformation of the environment here is relatively slow, the habitat capacity is higher. In anthropogenic soil, soil formation processes proceed at an increased rate (GERASIMOVA et al., 2003; ZADOROZHNA, 2018). This is confirmed by accelerated changes in the species composition of the plant cover. At the same time, anthropogenic soil is considered as a simpler system with low buffering capacity (GHOSE, 2001; ANAND et al., 2002; SERAFIM et al, 2008). The comparative poverty of the composition and ecological forms of the flora is explained by the small variety of ecological conditions of the artificial ecosystem, the relatively low level of its environmental capacity (ULLAH and WOLKENHAUER, 2011). The reason for this is the comparative youth of the anthropogenic ecosystem. About 42–45 years have passed from the beginning of the technical reclamation stage. The rapid change in species composition over this time indicates the variability of environmental regimes for vegetation of anthropogenic soil.

Conclusions

During the three years of research, it was found that the number of plant species at the reclamation site was 1.48 times less than at the steppe site. Changes in the flora composition of the reclamation site proceeded at a faster rate: out of the total number of plant species, 28.84% were recorded annually. This indicator in the control area was almost twice as high (48.05%).

According to the floral ecological analysis of the life forms system, a greater number of annual and biennial

plant forms grow on the reclamation site. This indicates the presence of anthropogenic load.

Analysis of the ratio of flora life forms at the reclamation site showed a sufficiently large proportion of perennial plants. This indicates the process of naturalization of the plant community. However, the larger percentage of annual and biennial plant forms (23.98%) at the experimental site compared to the control site indicates the relatively young age of the ecosystem.

A distinctive feature of the reclamation site flora is the smaller number of ecological groups of species. These groups are united according to the ecological optimum to one of the environmental parameters. The flora of the reclamation site demonstrates a smaller variety of ecological plant forms according to position and way of protecting restoration buds during unfavourable periods, according to the ecological optimum in relation to soil fertility, moisture regime, lighting conditions, and also in relation to the plant community environment as a whole.

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