sciendo

Environmental & Socio-economic Studies

environ

DOI: 10.2478/environ-2023-0002

Environ. Socio.-econ. Stud., **2023, 11, 1: 13-32**

Original article

Vegetation changes within the Chornobyl Exclusion Zone, Ukraine

Yakiv P. Didukh[1], Nataliia Pashkevych[1], Vitaliy P. Kolomiychuk[2, 3]*, Denys Vyshnevskiy[3]

[1]M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine, 2 Tereshenkivska Str. , Kyiv, 01601 Ukraine
[2]O.V. Fomin Botanical Garden of Taras Shevchenko National University of Kyiv, 2 S. Petliury Str., Kyiv, 01032 Ukraine
[3]Chornobyl Radiation and Ecological Biosphere Reserve, 25 Preobrazhenska Str., Kyiv, 02000 Ukraine
E–mail address (corresponding author): vkolomiychuk@ukr.net;*
ORCID iD: Yakiv Didukh: http;//orcid.org/0000-0002-5661-3944; Nataliia Pashkevych http;//orcid.org/0000-0001-9345-6389; Vitaliy Kolomiychuk: https://orcid.org/0000-0001-5767-344X; Denis Vishnevskiy http://orcid.org/0000-0002-7824-5812

ABSTRACT

The article presents data from the study of vegetation dynamics in the Chornobyl Exclusion Zone 30 years after the nuclear disaster and the resettlement of its local people. The 1993 prognostic data on the further development of grass and forest community groups in this area was only partially correct. The new prognosis for demutation successions reflects deviations from the linear development with a possible horizontal "shift", depending on climatic conditions, bio-ecological features of plants, as well as the impact of fires. Based on the analysis of recent data from geobotanical studies of the vegetation, the values of ecofactors that determine the course of demutation of communities were calculated. In particular, the classic course of succession is now inherent in the former settlements of the exclusion zone where the formation of forests takes place. In the old fallow lands, the previously prevailing *Elytrigia repens* has lost its dominant position, and has been replaced by *Calamagrostis epigejos*, which we associate with a certain deficiency of nitrogen compounds in the soil. The allelopathic properties of cereals inhibit the process of replacing grass communities with forest ones, which affects the course of succession. The issues of demutation of residential areas of the Exclusion Zone are considered and the sequence of changes in different habitats is described. Post-pyrogenic changes in the forest vegetation are noted and the capacity of invasive plant species to invade natural ecosystems are characterized. It is emphasized that frequent and large-scale fires cause a significant imbalance in forest ecosystems, and result in the appearance of a largenumber of alien species.

KEY WORDS: vegetation dynamics, natural and ruderal vegetation, pyrogenic changes, invasions of plants

ARTICLE HISTORY: received 24 July 2022; received in revised form 13 March 2023; accepted 15 March 2023

1. Introduction

The Chornobyl Exclusion Zone (CEZ) was formed as a consequence of the Chornobyl nuclear accident in 1986, and is the area where the largest amount of radionuclides fell and where the impact of ionizing radiation was highest. The population was evacuated from there and traditional economic activities were stopped, and a security regime was established. Within the Exclusion Zone there were both urban (Pripyat and Chornobyl, Poliske cities) and rural (about 70 villages) settlements and artificial elements such as roads and technical structures. According to the Atlas of the Exclusion Zone (ATLAS…, 1996), about 10% of the Exclusion Zone area was composed of man-made landscapes and settlements (AZAROV, 1996). Forests covered the entire area of the CEZ by the end of the 18th century. Its active use has led to decreasing forest cover, and by the early 20th century, they covered only 11–12% of the land (BIDNA, 1999). Planned reforestation work began in the 1920s, and intensive work began in the 1950s and 1960s. A lot of the forests are monoculture pine plantations of the same age and now forested areas cover about 55% of this land (MATSALA ET AL., 2021a). In 1992, 2016 and 2020 there were large forest fires. Open landscapes such as fallow land and meadows have been formed on former agricultural lands. Today they occupy about 30% of the area of the CEZ (MATSALA ET AL., 2021b).

Information on the transformation of the anthropogenic landscapes of the CEZ into natural ones is quite limited, since in the first years after the accident, the focus of research was on changes in flora and fauna at the organism level (their loss and restoration), chronic radiation syndromes in mammals and birds, increased death of coniferous trees and soil fauna due to excessive radiation, etc. (CRISTALDI ET AL., 1991; DIDUKH ET AL., 1993; GRODZYNSKY ET AL., 1997; GAICHENKO, 2001; GERAS'KIN ET AL., 2003; FEDONYUK ET AL., 2021). Radiation damage to vegetation was observed for a short time in a limited area near the CEZ and ranged from lethal to weak. For example, "Red Forest" is a section of dead pine forest near the nuclear plant. In general, it can be stated that such changes were recorded at the organismal level, but this effect was not manifested at the population and coenotic level.

The topicality of the study of the demutation processes is important, as these processes occur in huge areas, on a regional and landscape level, and also from the standpoint of the impact of vegetation on the migration of radionuclides. These two problems are closely related, as the formation of sustainable natural ecosystems, characterized by the most closed cycle of substances, simultaneously promotes the localization of radionuclides in the rhizosphere and phytomass and minimizes their entry into the large cycle. At the same time, insufficient data have been accumulated to date, which can be used to assess the stability and duration of successive stages and characteristics of the cycle of substances at certain stages of vegetation development.

The aim of our work was to study the restoration of vegetation after the Chornobyl accident in order to predict environmental risks. The final task was to monitor and regulate these processes, to form such stable states where the outflow and migration of radionuclides would be minimal. The basis of such monitoring was phytoecological monitoring, as vegetation visually reflects changes in ecosystems in general and it is a reliable stabilizer of radioecological adverse natural processes (PLYUTA & DIDUKH, 1996). Another aspect of the importance of monitoring is that after the military invasion of the zone, natural ecosystems were damaged and for the purpose of compensation needs to take into account the time for recovery to the initial state (DIDUKH, 2022).

2. Materials and methods

2.1. Study area

We carried out the study on the area of the CEZ between 1991–2021 (Fig. 1). The territory is situated in the centre of the Polissya lowland (110–150 m above sea level) the flat relief of which was formed by Holocene glacier deposits with an average thickness of 20–30 m. Lithologically, the territory is mainly sandy with clay-sandy deposits that occur on the rocks of the Ukrainian Crystal Shield (granitoids). These zonal landforms are dissected by the river valleys of the Pripyat river basin, and are characterized by wide floodplains and low accumulative terraces with aeolian landforms and wetlands (LANDSCAPES..., 1994).

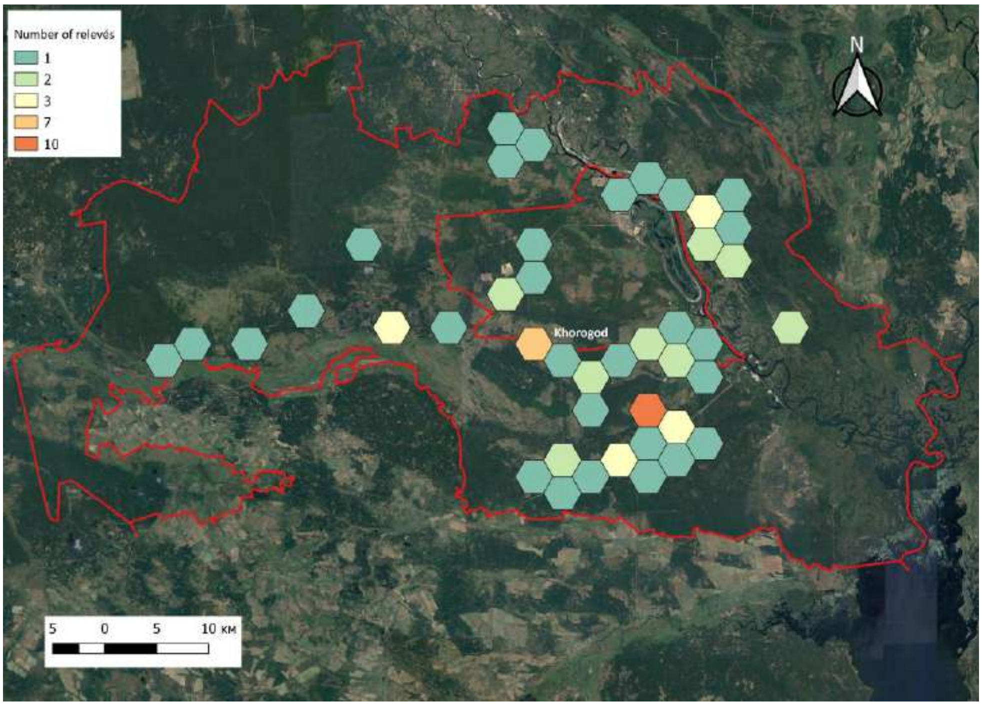

Fig. 1. Location of the study area in the Chornobyl Exclusion Zone

However, due to the specifics of the edaphic factors, pine forests prevail on poor sandy soils, less often, in richer conditions, there are areas of pine-oak forests, birch derivatives, and there are alder forests in swampy areas. Grass communities are represented by meadows and swamps. A large area is occupied by fallows (LANDSCAPES ..., 1994; DIDUKH ET AL., 1994; PLYUTA & DIDUKH, 1996; DAVYDCHUK, 1998; PETROV, 2016).

2.2. Data collection and analysis

This article is the outcome of field research of the CEZ vegetation. The vegetation was studied according to the principles of the Braun-Blanquet approach (WESTHOFF & VANDER MAAREL, 1973). 581 phytosociological relevés (380 releves 1993–1994, 201 releves – 2020–2021) were collected by the authors between 1993–2021 (Fig. 1). This dataset included phytosociological relevés of different natural and transformed types of habitats (forest, grassland, abandoned fields and settlements), stored in the phytosociological database format of the Turboveg software package (HENNEKENS & SCHAMINÉE, 2001). Data processing and classification was carried out using the JUICe software package (TICHÝ, 2002). Diagnostic species for each group of relevés were determined using the concept of fidelity (SOKAL & ROHLF, 1995; CHYTRÝ ET AL., 2002), frequency and constancy (the difference of three constancy classes) for individual taxa. The measure of species concentration in vegetation units was quantified by phi coefficient. Threshold values of phi coefficient and frequency for the species to be considered as diagnostic were set to 0.20 and 40, respectively. Fisher's exact test ($P < 0.05$) was applied to eliminate the fidelity value of species with a non-significant pattern of occurrence. The percentage constancy (frequency) was given for each species in individual clusters and they were ranked by decreasing value.

Ecological analysis of the communities included an assessment of their leading environmental factors, based on the original author's method of synphyto-indications using the ECODID database (DIDUKH, 2011, 2012). Ecological scales are characterised by the following parameters: soil humidity (Hd – 23 grades), variability of damping (fH – 11 grades), soil acidity (Rc – 15 grades), total salt regime (Sl – 19 grades), carbonate content (Ca – 13 grades), nitrogen content (Nt – 11 grades), aeration of the soil (Ae – 15 grades), thermoregime of the climate (Tm – 17 grades), humidity of the climate (Om – 23 grades), continentality of the climate (Kn – 17 grades), cryoregime of the climate (Cr – 15 grades) and lightness in the community (Lc – 9 grades). Calculation of the ecological values was made using JUICE 7.0 (TICHÝ, 2002). To visualise the multivariate floristic similarity patterns, we carried out Detrended Correspondence Analysis (DCA). In the ordination diagram, environmental factors and vegetation parameters correlated to one of the axes with $r^2 \geq 0.20$ were displayed as vectors. Syntaxonomy is in accordance with MUCINA ET AL. (2016) indicating the associations of Prodrome of the vegetation of Ukraine (DUBYNA ET AL., 2019). The plant names follow EURO+ MEDCHECKLIST (2020).

3. Results

3.1. Vegetation

As a result of the analysis of vegetation, we selected 20 clusters representing 15 alliances of three classes of ruderal vegetation and eight classes of natural vegetation (Table 1). We present here the characteristics of the selected syntaxons and the current distribution of vegetation within the Exclusion Zone has the following features (Table 2).

Acidophilic pine-oak forests of the boreal zone of Eastern Europe *Quercetea robori-petraeae* are represented by *Querco robori-Pinetum* forests, which grow on fresh sod-podzolic soils of dry pine forest and *Serratulo-Pinetum*, are confined to fresh sod soils. Deciduous forests of *Carpino-Fagetea sylvaticae* are represented by oak-hornbeam communities of *Tilio cordatae-Carpinetum* on rich podzolic fresh poorly drained soils. Birch forests (*Molinio-Betuletea pubescentis, Betulion pubescentis*) occur in the lowlands of the terrain, and in the terraced part of the floodplains of the River Pripyat and small tributaries, conenoses of black alder forest bogs on silty-peat soils (*Ribo nigri-Alnetum*) are sporadically distributed. *Salix daphnoides* subsp. *acutifolia* (Wild.) Ahlf. communities are common on sandy sediments. Often, especially along the banks of the rivers, there are thickets of shrubs (*Franguletea, Salicion cinereae*).

Artificial forests of the class *Robinietea* Jurko ex Hadač et Sofron 1980 spontaneously expand their areas along the roads of abandoned settlements. *Chelidonio majoris-Robinion pseudoacaciae* with the dominance of *Robinia pseudoacacia* grows here on poor soils, and *Chelidonio-Acerion negundi* with *Acer negundo* dominates on more nutritious soils. Sometimes in more formed thickets, the coenotic role of ash and maple species (*Acer platanoides* L., *A. pseudoplatanus* L., *A. tataricum* L.) increases.

Table 1. Classification scheme of Chornobyl Exclusion Zone vegetation (20 clusters)

Claster	Class	Alliance	Association (Derivate)	Profil
1	Molinio-Betuletea pubescentis Passarge 1968	Betulion pubescentis Lohmeyer et Tx. ex Oberd. 1957	Menyantho trifoliatae-Betuletum pubescentis Grygora, Vorobyov et Solomakha 2005	-
2	Vaccinio-Piceetea Br.-Bl. in Br.-Bl. et al. 1939	Dicrano-Pinion sylvestris (Libbert 1933) Matuszkiewicz 1962	Vaccinio uliginosi-Pinetum Kleist 1929	1, 4
3			Dicrano-Pinetum Preising et Knapp ex Oberd. 1957	-
4	Quercetea robori-Petraeae Br.-Bl. et Tx. ex Oberd. 1957	Pino-Quercion Medwecka-Kornaš et al. in Szafer 1959	Querco robori-Pinetum Matuszkiewicz 1981	-
5			Serratulo-Pinetum (Matuszkiewicz 1981) J. Matuszkiewicz 1988	-
6	Carpino-Fagetea sylvaticae Jakucs ex Passarge 1968	Carpinion betuli Issler 1931	Tilio cordatae-Carpinetum Traczyk 1962	-
7	Alnetea glutinosae Br.-Bl. et Tx. ex Westhoff et al. 1946	Alnion glutinosae Malcuit 1929	Ribo nigri-Alnetum Solińska-Górnicka (1975) 1987	-
8			Ribo nigri-Alnetum var. Populus tremula (forest burners of Pinus sylvestris)	-
9	Phragmito-Magnocaricetea Klika in Klika et Novák 1941	Magnocaricion gracilis Géhu 1961	derivate	-
10	Molinieto-Arrhenatheretea Tx. 1937	Deschampsion cespitosae Horvatić 1930	Deschampsietum cespitosae Horvatić 1930	9 - var. Carex praecox 11 – var. Carex hirta
11			Poo palustris-Alopecuretum pratensis Shelyag-Sosonko et al. in Shelyag-Sosonko et al. 1987	-
12		Arrhenatherion elatioris Luquet 1926	Poëtum pratensis Ravarut et al. 1956 (fallow)	-
13		Agrostion vinealis Sipaylova et al. 1985	Agrostio vinealis-Calamagrostietum epigei Shelyag-Sosonko et al. ex Shelyag-Sosonko et al. 1985	5, 12 – var. Car. hirta
14	Koelerio-Corynephoretea Klika in Klika et Novák 1941.	Coriophorion canescentisKlika 1931	Corniculario aculeatae-Corynephoretum canescentis Steffen 1931	3, 8
15		Coriophorion canescentis	fallow	7
16	Polygono arenastri-Poëtea annuae Rivas-Martínez 1975 corr. Rivas-Martínez et al. 1991	Polygono-Coronopodion Sissingh 1969	Deriv. Polygonum aviculare	-
17	Robinietea Jurko ex Hadač et Sofron 1980	Chelidonio majoris-Robinion pseudoacaciae Hadač et Sofron 1980	Elytrigio repentis-Robinietum pseudoacaciae Smetana 2002	14
18		Chelidonio-Acerion negundi Ishbirdina L. et Ishbirdin A.1989	Chelidonio-Aceretum negundi Ishbirdina L. et Ishbirdin A. 1991	15
19	Artemisietea vulgaris Lohmeyer et al. in Tx. ex vonRochow 1951	Convolvulo arvensis-Agropyrion repentis Görs 1967	Agropyretum repentis Felföldy 1943	2, 13 6 – var. Urtica dioica
20	Molinieto-Arrhenatheretea Tx. 1937	-	derivate	10 - var. Carex praecox+Urtica dioica

Table 2. Synoptic table of the Chornobyl Exclusion Zone vegetation. The full data matrix computed contained 581 relevés and 638 species.
All species with a percentage lower than 10% in columns were excluded

Syntaxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Number of relevés	**3**	**25**	**27**	**20**	**17**	**19**	**11**	**15**	**22**	**70**	**14**	**102**	**70**	**27**	**19**	**6**	**49**	**26**	**15**	**24**
Number of species	**21**	**56**	**100**	**68**	**113**	**96**	**85**	**121**	**78**	**151**	**80**	**241**	**255**	**165**	**90**	**28**	**149**	**128**	**96**	**97**
***Molinio-Betuletea pubescentis* Passarge 1968, *Betulion pubescentis* Lohmeyer et Tx. ex Oberd. 1957, *Menyantho trifoliatae-Betuletum pubescentis* Grygora, Vorobyov et Solomakha 2005**																				
Carex nigra	**33**	16	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus effusus	**33**	12	11	-	-	-	-	-	5	3	7	9	3	4	-	-	-	12	-	8
Nardus stricta	**33**	24	7	10	-	-	-	-	-	7	-	-	-	7	-	-	-	-	-	-
Salix cinerea	**33**	4	-	-	-	-	-	-	18	1	-	5	3	7	-	-	-	-	-	4
Andromeda polifolia	**33**	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Molinia caerulea	**100**	60	41	5	12	-	-	-	-	6	-	1	-	-	-	-	-	-	-	-
Vaccinium uliginosum	**100**	44	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium vitis-idaea	**100**	64	33	45	53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium myrtillus	**100**	88	78	55	47	21	9	-	-	-	-	-	-	4	-	-	-	-	-	-
Betula pendula	**100**	52	89	65	35	21	18	27	-	3	-	5	11	11	5	-	18	15	7	-
Sorbus aucuparia	**33**	12	41	-	12	11	18	27	-	-	-	-	1	-	-	-	4	-	-	-
***Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939, *Dicrano-Pinion sylvestris* (Libbert 1933) Matuszkiewicz 1962, *Vaccinio uliginosi-Pinetum* Kleist 1929**																				
Calluna vulgaris	67	**68**	22	65	6	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-
Pteridium aquilinum	-	**12**	81	45	82	42	27	7	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla erecta	-	**12**	37	-	12	5	9	-	-	6	-	1	1	-	-	-	-	-	-	-
Trientalis europaea	33	**16**	48	15	24	26	-	7	-	-	-	-	-	-	-	-	-	-	-	-
Melampyrum pratense	-	**20**	19	35	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
***Dicrano-Pinetum* Preising et Knapp ex Oberd. 1957**																				
Maianthemum bifolium	-	8	**89**	30	71	89	-	-	-	-	-	-	-	-	-	-	4	-	-	-
Convallaria majalis	-	-	**33**	20	41	47	18	20	-	-	-	-	-	-	-	-	4	-	-	-
Ajuga reptans	-	-	**30**	5	82	58	9	27	-	-	-	-	-	-	-	-	-	-	-	-
Polygonatum odoratum	-	4	**7**	60	65	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Luzula pilosa	33	28	**70**	25	59	37	-	-	-	-	-	-	-	4	-	-	-	-	-	-
Pinus sylvestris	-	92	**81**	100	82	42	27	47	-	1	-	1	7	15	26	-	4	-	13	-
***Quercetea robori-Petraeae* Br.-Bl. et Tx. ex Oberd. 1957, *Pino-Quercion* Medwecka-Kornaš et al. in Szafer 1959, *Querco robori-Pinetum* Matuszkiewicz 1981**																				
Quercus robur	33	52	81	**30**	71	84	36	47	-	-	-	-	3	4	-	-	10	8	-	-
Solidago virgaurea	-	4	33	**85**	41	16	-	53	5	-	-	1	6	41	11	-	-	-	13	-
Genista tinctoria	-	4	22	**40**	59	11	-	7	-	-	-	3	10	11	-	-	-	-	-	-
Veronica officinalis	-	-	15	**40**	65	21	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Peucedanum oreoselinum	-	-	11	**65**	59	-	-	20	-	-	-	-	1	-	-	-	-	4	-	-
Antennaria dioica	-	-	4	**55**	47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex praecox	-	4	4	**65**	24	-	-	-	-	23	7	4	20	-	-	-	2	8	-	4
Thymus serpyllum	-	-	4	**40**	24	-	-	-	-	-	-	-	1	4	-	-	-	-	-	-

Syntaxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Arctostaphylos uva-ursi	-	-	-	**40**	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthericum ramosum	-	-	-	**25**	6	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Centaurea scabiosa	-	-	-	**25**	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
***Serratulo-Pinetum* (Matuszkiewicz 1981) J. Matuszkiewicz 1988**																				
Fragaria vesca	-	-	19	40	**88**	16	-	-	-	-	-	-	1	-	-	-	4	8	-	-
Cytisus ruthenicus	-	8	19	65	**76**	5	-	-	5	-	-	1	1	15	-	-	-	-	-	-
Veronica chamaedrys	-	-	26	-	**65**	37	-	-	-	11	7	2	-	-	-		4	-	-	-
Campanula persicifolia	-	-	11	10	**59**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stachys officinalis	-	-	22	5	**59**	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthilia secunda	-	-	7	-	**53**	5	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Hylotelephium telephium	-	-	4	10	**53**	11	-	-	-	-	-	-	-	4	-	-	-	-	-	-
0Trifolium montanum	33	-	4	5	**53**	5	-	-	-	19	-	2	-	-	-	-	-	-	-	-
Geranium sanguineum	-	-	4	20	**47**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clinopodium vulgare	-	-	4	-	**41**	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Melica nutans	-	-	22	5	**76**	53	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex digitata	-	-	15	-	**53**	42	-	7	-	-	-	-	-	-	-	-	-	-	-	-
Rubus saxatilis	-	4	7	5	**47**	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla alba	-	-	-	-	**41**	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euonymus verrucosa	-	-	-	-	**35**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cruciata glabra	-	4	4	-	**41**	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pulsatilla patens	-	-	-	25	**24**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
***Carpino-Fagetea sylvaticae* Jakucs ex Passarge 1968, *Carpinion betuli* Issler 1931, *Tilio cordatae-Carpinetum* Traczyk 1962**																				
Carpinus betulus	-	-	15	5	35	**79**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corydalis solida	-	-	11	-	41	**58**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galium odoratum	-	-	7	-	12	**74**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria holostea	-	-	-	-	18	**63**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asarum europaeum	-	-	4	-	18	**58**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex pillosa	-	-	4	10	6	**53**	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Anemone nemorosa	-	-	30	-	6	**53**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Digitalis grandiflora	-	-	7	-	29	**11**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aegopodium podagraria	-	-	7	-	-	**42**	-	-	-	-	-	1	1	-	-	-	-	-	-	-
Pulmonaria obscura	-	-	4	-	12	**42**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lamium galeobdolon	-	-	-	-	-	**26**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
***Alnetea glutinosae* Br.-Bl. et Tx. ex Westhoff et al. 1946, *Alnion glutinosae* Malcuit 1929, *Ribo nigri-Alnetum* Solińska-Górnicka (1975) 1987**																				
Rubus caesius	-	-	-	-	-	-	**91**	33	-	-	-	1	4	-	-	-	12	4	-	-
Alnus glutinosa	-	-	15	-	-	-	**73**	-	14	-	-	1	1	-	-	-	-	-	-	-
Frangula alnus	67	36	26	-	18	11	**73**	47	-	-	-	-	-	4	-	-	10	-	-	-
Humulus lupulus	-	-	-	-	-	-	**73**	7	-	-	-	1	-	-	-	-	12	4	7	-
Calamagrostis canescens	-	4	-	-	-	-	**55**	-	-	1	-	1	-	4	-	-	-	-	-	-
Galeopsis ladanum	-	-	-	-	-	-	**45**	20	-	-	-	2	6	-	-	-	2	15	13	-
Carex spicata	-	-	-	-	-	16	**36**	7	-	-	-	2	1	-	-	-	14	-	-	-
Galium mollugo	-	-	-	-	-	-	**27**	7	-	-	-	-	3	-	-	-	-	-	7	-

Syntaxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Fallopia convolvulus	-	-	-	-	-	-	**27**	7	-	-	-	4	3	-	5	-	-	-	-	-
Bidens frondosa	-	-	-	-	-	-	**27**	-	-	-	-	-	1	-	-	-	-	-	-	-
Myosoton aquaticum	-	-	-	-	-	-	**27**	-	-	-	-	-	-	-	-	-	2	-	-	-
Solanum dulcamara	-	-	-	-	-	-	**27**	-	-	-	-	-	-	-	-	-	-	-	-	-
Ribo nigri-Alnetum **var.** ***Populus tremula*** **(forest burners of** ***Pinus sylvestris*****)**																				
Populus tremula	-	8	26	5	12	26	45	**73**	-	-	-	4	9	7	-	-	10	4	-	-
Senecio viscosus	-	-	-	-	-	-	-	**40**	-	-	-	-	-	4	-	-	-	-	-	-
Lactuca serriola	-	-	-	-	-	-	18	**40**	-	-	-	1	4	-	-	-	4	4	7	8
Viola tricolor	-	-	-	-	-	-	-	**53**	-	-	-	5	20	11	11	-	-	23	67	-
Spergula arvensis	-	-	-	5	-	-	-	**40**	-	-	-	-	1	26	5	-	-	-	-	8
Epilobium angustifolium	-	-	-	-	-	-	9	**33**	-	-	-	9	4	11	5	-	2	12	-	-
Hypochaeris radicata	-	-	-	-	12	-	9	**27**	-	-	-	2	1	19	16	-	-	-	7	-
Phragmito-Magnocaricetea **Klika in Klika et Novák 1941,** ***Magnocaricion gracilis*** **Géhu 1961**																				
Carex acuta	-	-	-	-	-	-	9	-	**86**	1	-	-	-	-	-	-	-	-	-	-
Glyceria maxima	-	-	-	-	-	-	-	-	**64**	-	-	1	-	-	-	-	-	-	-	-
Carex vesicaria	-	-	-	-	-	-	-	-	**50**	3	-	-	-	-	-	-	-	-	-	-
Caltha palustris	-	-	-	-	-	-	-	-	**45**	3	7	-	-	-	-	-	-	-	-	-
Phalaroides arundinacea	-	-	-	-	-	-	-	-	**41**	3	21	5	1	-	-	-	-	4	-	-
Galium palustre	-	-	-	-	-	-	9	-	**36**	17	7	1	1	-	-	-	-	-	-	-
Glyceria fluitans	-	-	-	-	-	-	9	-	**32**	-	7	-	-	-	-	-	-	-	-	-
Molinieto-Arrhenatheretea **Tx. 1937,** ***Deschampsion cespitosae*** **Horvatić 1930,** ***Deschampsietum cespitosae*** **Horvatić 1930**																				
Schedonorus pratensis	-	-	-	-	-	-	-	-	14	**80**	93	22	3	4	5	-	4	19	7	58
Potentilla anserina	-	-	-	-	-	-	-	-	41	**71**	93	10	6	7	-	-	-	-	-	17
Deschampsia caespitosa	-	-	4	-	-	-	-	-	18	**61**	14	19	1	-	5	17	2	8	-	4
Trifolium prantense	-	-	-	-	-	-	-	-	-	**54**	86	9	3	-	-	-	-	4	-	38
Ranunculus acris	-	-	7	-	24	-	9	-	14	**53**	57	13	1	4	-	-	-	-	-	38
Medicago lupulina	-	-	-	-	-	-	-	-	-	**43**	43	5	4	4	-	17	-	-	-	58
Polygala vulgaris	-	-	-	-	-	-	-	-	-	**46**	-	-	-	-	-	-	-	-	-	-
Cerastium fontanum	-	-	-	-	-	-	-	-	-	**44**	14	-	1	-	-	-	-	-	-	-
Phleum pratense	-	-	-	-	-	-	-	-	-	**40**	7	21	20	7	11	-	-	4	13	8
Carex panicea	-	-	-	-	-	-	-	-	-	**37**	7	-	-	-	-	-	-	-	-	-
Stellaria graminea	-	-	-	-	-	-	-	-	-	**33**	14	9	1	4	-	-	-	4	7	4
Dianthus deltoides	-	-	-	-	-	-	-	-	-	**31**	-	2	1	-	-	-	-	-	-	0
Anthoxanthum odoratum	-	-	4	15	-	-	9	-	-	**31**	-	2	1	7	11	-	-	-	-	4
Equisetum pratense	-	-	-	-	-	-	-	-	-	**31**	-	4	4	-	-	-	-	4	-	-
Dianthus borbasii	-	-	-	-	-	-	-	-	-	**30**	-	-	7	11	5	-	-	-	-	-
Carex nigra	-	-	-	-	-	-	-	-	23	**30**	7	4	-	4	-	-	-	-	-	4
Rhinanthus minor	-	-	-	-	-	-	-	-	-	**30**	7	-	-	-	-	-	-	-	-	-
Agrostis vinealis	-	-	-	-	-	-	-	-	-	**23**	-	-	-	-	-	-	-	-	-	13
Carex leporina	-	-	22	-	-	5	9	7	5	**29**	-	11	1	4	-	-	6	8	7	4
Poo palustris-Alopecuretum pratensis **Shelyag-Sosonko et al. in Shelyag-Sosonko et al. 1987**																				
Alopecurus pratensis	-	-	-	-	-	-	-	-	9	27	**100**	30	7	4	-	-	2	15	7	4

Syntaxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Ranunculus repens	-	-	-	-	-	-	-	-	55	53	**100**	2	3	-	-	-	-	-	-	8
Poa palustris	-	4	-	-	-	-	-	-	18	7	**71**	-	-	0	-	-	-	-	-	-
Lathyrus pratensis	-	-	-	-	-	-	-	-	-	6	**79**	4	1	0	-	-	-	4	-	-
Inula britannica	-	-	-	-	-	-	-	-	-	3	**71**	-	-	0	-	-	-	-	-	4
Lathyrus palustris	-	-	-	-	-	-	-	-	-	1	**64**	-	-	0	-	-	-	-	-	-
Veronica longifolia	-	-	-	-	6	-	-	-	-	-	**57**	8	1	0	-	-	-	8	-	-
Agrostis canina	-	-	-	-	-	-	-	7	-	4	**57**	4	4	4	-	-	18	8	-	-
Stellaria palustris	-	-	-	-	-	-	-	-	18	3	**57**	-	-	-	-	-	-	-	-	-
Thalictrum minus	-	-	-	-	-	-	-	-	-	-	**50**	-	-	-	-	-	-	-	-	-
Galium boreale	-	-	-	-	-	-	9	-	-	1	**50**	1	-	-	-	-	-	-	-	-
Thalictrum lucidum	-	-	-	-	-	-	-	-	-	9	**50**	1	-	-	-	-	-	-	-	-
Lythrum virgatum	-	-	-	-	-	-	-	-	-	3	**43**	2	-	-	-	-	-	-	-	-
Bidens tripartita	-	-	-	-	-	-	9	-	-	-	**36**	-	-	-	-	-	2	-	-	-
Geranium pratense	-	-	-	-	-	-	9	-	-	3	**36**	-	-	-	-	-	-	-	-	-
Scutellaria hastifolia	-	-	-	-	-	-	-	-	-	-	**36**	-	-	-	-	-	-	-	-	-
Alopecurus geniculatus	-	-	-	-	-	-	-	-	14	6	**29**	1	-	-	-	-	-	-	-	-
Arrhenatherion elatioris **Luquet 1926,** ***Poëtum pratensis*** **Ravarut et al. 1956 (fallow)**																				
Cirsium arvense	-	-	-	-	-	-	18	-	-	9	-	**45**	14	4	5	-	-	27	13	21
Agrostion vinealis **Sipaylova et al. 1985,** ***Agrostio vinealis-Calamagrostietum epigei*** **Shelyag-Sosonko et al. ex Shelyag-Sosonko et al. 1985**																				
Poa angustifolia	-	-	-	-	-	-	9	-	-	19	7	1	**49**	7	5	-	6	23	53	-
Tanacetum vulgare	-	-	-	-	-	-	-	-	5	-	-	12	**30**	15	11	-	2	8	13	4
Koelerio-Corynephoretea **Klika in Klika et Novák 1941,** ***Coriophorion canescentis*** **Klika 1931,** ***Corniculario aculeatae-Corynephoretum canescentis*** **Steffen 1931**																				
Coryneforus canescens	-	8	7	15	-	-	-	13	5	-	-	-	4	**81**	32	-	-	-	7	8
Jasione montana	-	-	-	15	-	-	-	40	-	-	-	-	7	**44**	32	-	-	-	-	-
Helichrysum arenarium	-	-	-	10	-	-	-	-	-	-	-	-	3	**41**	16	-	-	-	-	13
Sedum acre	-	-	-	-	-	-	-	-	-	7	-	-	6	**30**	-	-	-	-	-	-
Pilosella officinarum	-	4	4	30	18	-	-	13	-	21	-	-	3	**33**	21	-	-	-	20	13
Coriophorion canescentis **(fallow)**																				
Artemisia campestris	-	-	-	-	-	-	-	-	-	-	-	1	4	19	**42**	-	-	-	-	-
Erodium cicutarium	-	-	-	-	6	5	-	-	-	-	-	1	3	4	**26**	-	-	4	7	-
Trifolium arvense	-	-	-	-	-	-	-	-	-	11	-	3	13	7	16	-	-	-	-	13
Polygono arenastri-Poëtea annuae **Rivas-Martínez 1975 corr. Rivas-Martínez et al. 1991,** ***Polygono-Coronopodion*** **Sissingh 1969, Deriv.** ***Polygonum aviculare***																				
Ochlopoa annua	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	**100**	-	-	-	-
Lolium perenne	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	**100**	-	4	-	33
Geum urbanum	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	**100**	31	8	-	-
Avena sativa	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	**100**	-	-	-	42
Polygonum aviculare aggr.	-	-	-	-	-	-	-	7	-	7	-	-	3	7	-	**50**	4	-	-	17
Plantago major	-	-	-	-	-	-	-	-	-	19	-	3	3	4	-	**50**	2	4	-	13
Robinietea **Jurko ex Hadač et Sofron 1980,** ***Chelidonio majoris-Robinion pseudoacaciae*** **Hadač et Sofron 1980,** ***Elytrigio repentis-Robinietum pseudoacaciae*** **Smetana 2002**																				
Chelidonium majus	-	-	-	-	-	-	27	20	-	-	-	4	1	-	11	83	**76**	15	-	-
Ballota nigra	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	**59**	4	-	-

Syntaxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Galium aparine	-	-	-	-	-	-	-	-	9	4	-	10	6	-	-	-	**53**	58	-	-
Robinia pseudoacacia	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	**47**	-	-	-
Fraxinus excelsior	-	-	-	-	-	11	-	7	-	-	-	-	-	-	-	-	**29**	-	-	-
Impatiens parviflora	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	**29**	-	-	-
Fallopia dumetorum	-	-	-	-	-	-	9	7	-	-	-	1	3	-	-	-	**27**	8	-	-
Chelidonio-Acerion negundi **Ishbirdina L. et Ishbirdin A.1989,** ***Chelidonio-Aceretum negundi*** **Ishbirdina L. et Ishbirdin A. 1991**																				
Acer negundo	-	-	-	-	-	-	18	-	-	-	-	5	10	4	11	-	69	**50**	7	-
Anthriscus sylvestris	-	-	4	-	-	-	9	-	-	-	-	1	-	-	-	-	24	**27**	7	-
Bromopsis inermis	-	-	-	-	-	-	-	-	-	3	-	3	6	-	-	-	-	**12**	7	13
Artemisietea vulgaris **Lohmeyer et al. in Tx. ex von Rochow 1951,** ***Convolvulo arvensis-Agropyrion*** **repentis Görs 1967,** ***Agropyretum repentis*** **Felföldy 1943**																				
Apera spica-venti	-	-	-	-	-	-	-	7	-	-	-	9	6	7	11	-	-	15	**87**	17
Verbascum lychnitis	-	-	-	-	-	-	-	7	5	-	-	3	19	26	-	-	-	-	**53**	4
Holcus lanatus	-	-	-	-	-	-	9	7	-	-	-	5	7	0	5	-	-	4	**47**	-
Pyrus communis	-	-	-	-	-	-	-	7	-	-	-	-	9	4	0	-	20	12	**40**	-
Daucus carota	-	-	-	-	-	-	-	-	-	6	14	6	7	0	0	-	2	8	**40**	4
Molinieto-Arrhenatheretea **Tx. 1937 (derivate)**																				
Setaria viridis	-	-	-	-	-	-	-	-	-	-	-	5	4	11	5	-	-	-	-	**50**
Capsella bursa-pastoris	-	-	-	-	-	-	-	-	-	24	м	7	-	-	-	-	-	-	7	**50**
Bromus hordeaceus	-	-	-	-	-	-	-	-	-	11	-	1	1	-	-	-	-	-	-	**42**
Echinochloa crus-galli	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	**25**
Bromus arvensis	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	**21**
Centaurea cyanus	-	-	-	-	-	-	-	-	-	-	-	8	1	-	11	-	-	4	7	**17**
Pulicaria vulgaris	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	**17**
Bromus commutatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**17**
Other species:																				
Festuca rubra	67	4	56	80	71	16	9	7	5	64	21	4	16	26	-	-	24	12	-	17
Carex hirta	-	-	4	5	18	5	9	27	9	51	50	6	29	7	-	-	10	23	7	4
Euphorbia cyparissias	-	12	15	35	24	-	-	20	-	-	-	1	10	11	11	-	4	4	7	-
Lysimachia vulgaris	-	12	30	-	6	21	64	13	27	-	14	5	1	-	5	-	-	-	7	4
Calamagrostis epigejos	33	12	-	75	24	5	9	67	5	6	14	19	56	26	5	-	6	42	27	8
Hypericum perforatum	-	-	7	10	47	-	-	60	-	-	-	18	24	37	37	-	4	12	67	-
Galium verum	-	-	7	-	29	5	-	7	-	34	43	11	40	4	5	-	4	12	80	-
Achillea millefolium	-	-	-	15	35	-	9	27	-	1	-	28	40	26	5	-	8	27	47	63
Rumex acetosella	-	4	-	15	-	-	-	73	-	60	7	5	10	44	32	-	-	4	20	46
Rumex acetosa	-	-	-	-	-	-	-	60	-	47	21	8	37	19	16	-	2	8	60	29
Agrostis capillaris	-	-	4	-	18	11	-	40	-	47	-	14	16	33	5	-	-	19	27	67
Chenopodium album	-	-	-	-	-	-	-	7	-	-	-	4	9	4	16	33	-	8	-	8
Campanula patula	-	-	-	-	-	-	-	-	-	19	-	5	11	4	0	-	-	4	40	-
Viola arvensis	-	-	-	-	-	-	-	7	-	3	-	4	20	7	5	-	2	8	33	-
Anchusa officinalis	-	-	-	-	-	-	-	-	-	-	-	-	13	4	5	-	-	-	27	-
Agrostis stolonifera	-	-	-	-	-	-	-	-	55	3	36	-	4	-	-	-	-	4	-	-

Syntaxon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Plantago lanceolata	-	-	-	-	-	-	-	-	-	79	86	13	4	22	16	-	-	-	7	21
Silene flos-cuculi	-	-	-	-	-	-	18	-	14	73	50	2	-	-	-	-	-	4	-	-
Trifolium hybridum	-	-	-	-	-	-	-	-	-	33	36	7	-	-	-	-	-	4	-	-
Centaurea jacea	-	-	-	-	-	-	-	-	-	31	50	-	-	7	-	-	-	4	-	-
Taraxacum sect. Taraxacum	-	-	-	-	-	-	-	-	-	30	79	22	3	-	16	-	-	8	7	4
Rumex confertus	-	-	-	-	-	-	-	-	5	10	43	14	3	-	-	-	-	8	-	33
Artemisia vulgaris	-	-	-	-	-	-	-	7	-	-	-	28	11	7	11	-	12	27	13	-
Prunella vulgaris	-	-	-	-	29	16	-	-	-	61	64	4	1	4	-	-	-	-	-	13
Artemisia absinthium	-	-	-	-	-	-	-	-	-	1	-	14	46	22	37	17	2	19	80	8
Artemisia campestris	-	-	-	-	-	-	-	-	-	-	-	1-	30	41	-	-	-	-	27	-
Crepis tectorum	-	-	-	-	-	-	-	40	-	26	-	3	11	4	5	-	-	-	53	25
Trifolium repens	-	-	-	-	-	-	-	27	-	70	100	15	3	-	-	17	6	4	-	38
Equisetum arvense	-	-	-	-	-	-	-	-	-	29	-	27	16	11	21	-	4	15	40	29
Vicia cracca	-	-	-	-	-	-	18	13	-	23	86	33	16	7	11	-		15	47	46
Berteroa incana	-	-	-	-	-	-	-	-	-	20	-	12	29	22	42	-	6	12	40	25
Potentilla argentea	-	-	-	-	-	-	-	-	-	21	-	1	26	26	21	-	-	-	27	29
Silene latifolia	-	-	-	-	-	-	-	-7	-	-	-	38	56	7	32	-	20	46	73	-
Oenothera biennis	-	-	-	-	-	-	-	20	5	1	-	23	26	63	84	-	2	4	40	50
Convolvulus arvensis	-	-	-	-	-	-	-	7	-	-	-	37	41	19	37	-	2	35	33	38
Erigeron canadensis	-	-	-	-	-	-	36	80	-	-	-	18	34	44	84	-	20	31	33	63
Cichorium intybus	-	-	-	-	-	-	-	-	-	1	-	7	7	11	-	-	2	4	-	17
Echium vulgare	-	-	-	-	-	-	-	-	-	-	-	2	10	15	-	-	-	-	7	17
Urtica dioica	-	-	-	-	-	-	45	7	-	-	-	29	19	-	11	100	71	88	20	4
Dactylis glomerata	-	-	-	-	-	-	-	-	-	4	14	55	9	4	21	100	29	42	-	54
Poa pratensis	-	-	-	-	-	-	-	7	-	74	57	49	17	26	-	100	14	54	27	21
Elytrigia repens	-	-	-	-	-	-	18	20	5	11	36	61	49	15	63	83	59	85	73	96
Agrostis gigantea	-	-	-	-	-	-	9	-	5	29	79	38	16	15	42	67	18	12	13	71
Euphorbia esula	-	-	-	-	-	-	-	7	-	17	-	-	9	4	-	-	-	4	7	17
Lamium album	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	83	-	4	-	4
Leonurus cardiaca	-	-	-	-	-	-	-	-	-	-	-	1	-	4	-	83	12	-	-	-
Mentha arvensis	-	-	-	-	-	-	-	-	5	-	-	3	3	-	-	83	-	-	-	-
Saponaria officinalis	-	-	-	-	-	-	-	-	-	-	-	1	6	-	-	83	6	4		21
Amaranthus retroflexus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67	-	-	-	-
Rubus idaeus	-	-	-	-	-	-	9	13	-	-	-	1	-	-	-	50	12	8	-	-
Sonchus arvensis	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	50	-	4	-	4
Erysimum cheiranthoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
Triticum aestivum	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	13

Meadow vegetation (*Molinieto-Arrhenatheretea*) is characteristic of the floodplain and occupies a large area. The vegetation of wet meadows of low and flat areas of river floodplains on meadow sandy soils of the *Deschampsion cespitosae* union are represented by the syntaxons of *Deschampsietum cespitosae* and *Poo palustris-Alopecuretum pratensis*. These communities are formed in the inter-strip depressions of the central and near-river parts of the river floodplain and in areas of its narrow depressions. The most common types of mesic coenosis *Poëtum pratensis* (*Arrhenatherion elatioris*) are formed in the upper parts of river floodplains, in the place of abandoned sown hayfields, in areas with sod, sod-meadow and meadow sandy soils.

Psammophyte vegetation within the CEZ is represented by syntaxons of two classes: *Molinieto-Arrhenatheretea* and *Koelerio-Corynephoretea*. The vegetation of meadows on sands (*Agrostio vinealis-Calamagrostietum epigei*) is formed in the middle and upper parts of the slopes of ridges and low elevations of the floodplain and on variously turfed, levelled areas on loose sandy soils. Psammophyte communities with the participation of *Corynephorus canescens* and lichens (*Cladonia* sp.) are formed on the elevations of river terraces, on acidic mobile sands of fluvioglacial deposits. Their formation has been facilitated by habitat disturbances, in particular under the influence of grazing, recreation, etc.. Communities that growth on sandy soils in similar conditions in the place of abandoned fields in terms of their floristic composition have both characteristic species (*Corynephorus canescens, Calamagrostis epigejos, Jasione montana* L., *Rumex acetosella* L., *Helichrisum arenarium* (L.) Moench) and alien species (*Oenothera biennis* L., *Erigeron canadensis* L.). In some areas, pine trees grow singly.

Wetlands are mainly lowland and dominated by tall marsh grasses (*Magnocaricetalia*), with some small areas of transitional sphagnum bogs. In the floodplains of rivers, on the shores of lakes and reclamation canals, communities of marsh meadows and grass bogs *Phragmito-Magnocaricetea* growth, sometimes with the participation of willows.

Areas left fallow are overgrown mainly with ruderal vegetation of the class *Artemisietea vulgaris*. In places of excessive recreation, along roads and paths with a compacted surface, in abandoned settlements, trampled communities are created with the dominance of *Polygonum aviculare*.

3.2. Ecological and coenotic analysis

Using the synphytoindication method, we calculated the values of environmental factors of the studied transformed communities, which are illustrated by the example of the ecological and coenotic transect laid near the village of Korogod, as well as the DCA-ordination matrix. To assess trends in vegetation change, we relaid the transect (Fig. 2) near Korogod, with a length of about 2 km. The coenoses typical for the Zone are presented (Table 1), and the distribution of point indicators on the graphs reflects the amplitude of their fluctuations, dependence on ecological and coenotic conditions, and the nature of the correlation. In 1993, plots **1** and **4** were occupied by a pine forest, and plots **14** and **15** were at the site of a village settlement. Other territories were under fields and yards.

On the profile, a linear relationship between moisture (**Hd**), nitrogen content (**Nt**), acidity (**Rc**), salt regime (**Sl**) and aeration (**Ae**) of the soil is clearly visible on the one hand, on the other there is a weak correlation between more global climatic factors and the thermoregime (**Tm**) and cryoregime of the climate (**Cr**) (Fig. 2).

The nature of correlations between ecofactors, as well as their influence on the distribution of a representative sample of plant communities of all types of vegetation of the CEZ based on DCA-ordination, are much more clearly traced (Fig. 3). DCA results for all vegetation units, including 581 descriptions, are shown. The figure shows that all differentiating factors are close to the main axis of DCA1. Accordingly, DCA1 follows the nitrogen gradient (**Nt**) with vegetation types from *Robinietea* anthropogenic forest to *Koelerio-Corynephoretea* psammophytic vegetation communities. Humidity (**Hd**), acidity (**Rc**), and carbonate content (**Ca**) of the soil, are also differentiating factors close to the main axis of DCA1, but they are characterized by shorter vectors, i.e. smaller amplitude indices. Brightness of the community (**Lc**) and variability of damping (**fH**) have the reverse direction. On the DCA2, on the right are the forests of *Betulion pubescentis, Dicrano-Pinion sylvestris, Vaccinio uliginosi-Pinion sylvestris, Pino-Quercion Carpinion betuli*, and *Alnion glutinosae*. In the opposite position are herbal meadow and marsh communities *Phragmition, Magnocaricion, Deschampsion cespitosae*. The central position is occupied by terrestrial meadows (*Arrhenatherion elatioris*) characteristic of the subtropical conditions of this region. At the same time, meadow and psammophyte-cereal vegetation form an ecological continuum.

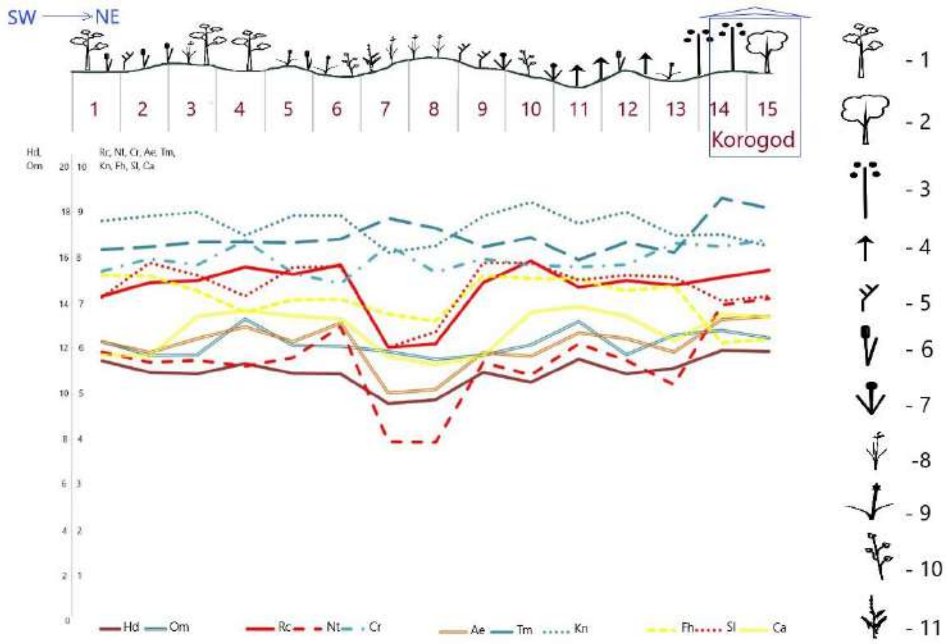

Fig. 2. Ecological and coenotic profile of vegetation reflecting patterns of differentiation of the vegetation cover near Khorogod village

Ecological factors: Hd – soil humidity; Fh – damping variability; Ae – soil aeration; Nt – nitrogen content in soil; Rc – soil acidity; Sl – salt regime; Ca – carbonate content in soil; Tm – thermal climate; Om – climate humidity (ombroregime); Kn – climate continentality; Cr – cryoclimate; Lc – light; Dominants and characteristic species (see Tabl. 1) : 1 – *Pinus sylvestris*, 2 – *Acer negundo*, 3 – *Robinia pseudoacacia*, 4 – *Carex hirta*, 5 – *Apera spica-venti*, 6 – *Calamagrostis epigejos*, 7 – *Carex praecox*, 8 - *Corynephorus canescens*, 9 – *Elytrigia repens*, 10 – *Urtica dioica*, 11 – *Rumex acetosella*

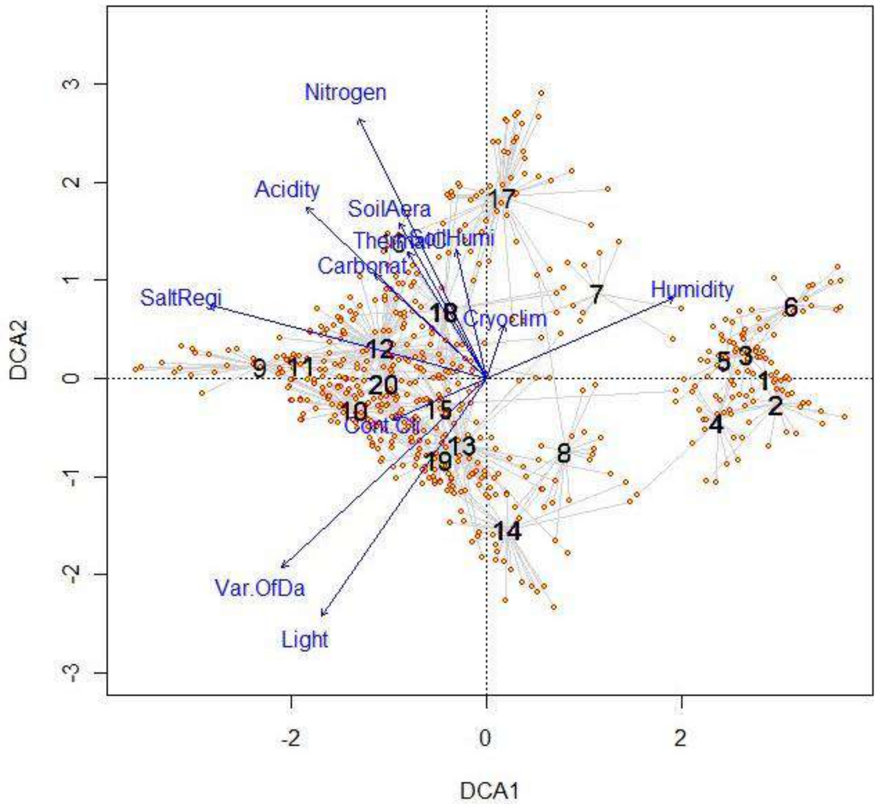

Fig. 3. DCA analysis (distribution) of 20 clusters (for Table 1) of the vegetation according to environmental factors

Interestingly, burned areas on the site of a pine forest were ecologically close to pioneer psammophyte communities of the *Koelerio-Corynephoretea* class and abandoned fields on uplands (19). Ecologically close is a group of mesophytic herbaceous vegetation on fallows (12 and 20) with nitrophilous tree-shrub communities (18). This indicates the possible direction of the succession to the growth of lignogenic forms of fallow under conditions of sufficient moisture.

3.3. Demutation of vegetation cover

Geobotanical studies that were conducted in 1992 (DIDUKH ET AL., 1994) showed that abandoned fields (fallow lands) were overgrown mainly with *Elytrigia repens* (L.) Nevski, the thickness of the litter of which reached 7–15 cm. Tree species *Betula pendula* Roth, *Populus tremula* L., and *Pinus sylvestris* L. were inhabiting such fields singly. *Acer negundo* and *Robinia pseudoacacia* were actively growing in the abandoned settlements, shading and displacing trees cultivated in the gardens. Based on such studies, given the position of this area in the forest zone, it was logical to think that in 20-30 years time there will be dense natural forest stands. According to the classical notions of succession, appropriate forecasts were developed which took into account the existing ecological conditions (Fig. 4). But much more time passed, and during visits to the same settlements in 2021 and repeated geobotanical descriptions on the profiles, it was found that, despite the actual absence of people, grazing, haying and other economic activities, open territories occupying a significant area, and after even bigger fires, there was no change of grass vegetation to woody vegetationThe site survey in 2021 showed that *Elytrigia repens* lost its dominant position, and its place was taken by *Calamagrostis epigejos* even in those areas where the conditions for wheatgrass were optimal. On the other hand, the floristic composition of these communities has not changed significantly.

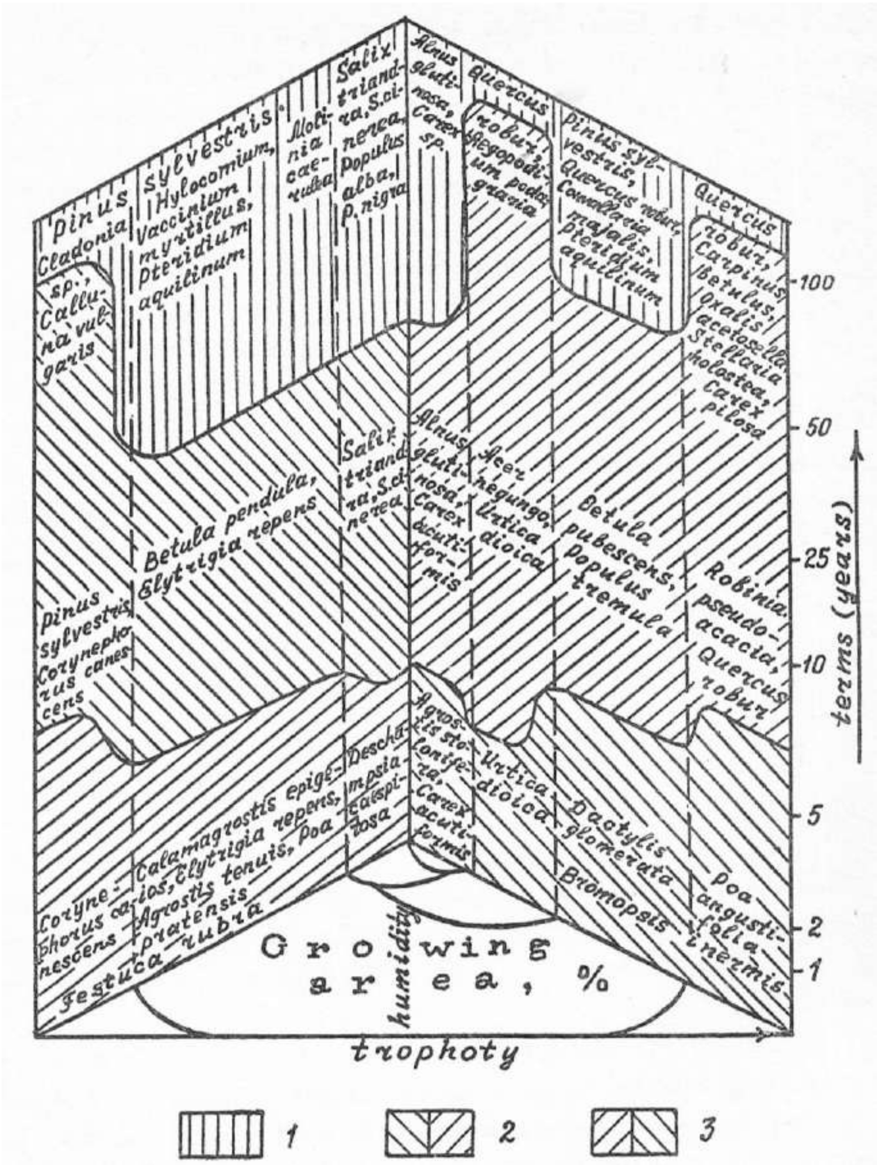

Fig. 4. Scheme of vegetation development in the Chernobyl Exclusion Zone (Didukh et al., 1993), phases of development: 1 – ligneous subclimax, 2 – gramineous-ligneous, 3 – herbaceous-pioneer

Analysis of the spontaneous vegetation growth of abandoned villages and cities of the Exclusion Zone showed that the processes of vegetation demutation on the territory of numerous abandoned settlements take place in different ways (Fig. 5). The main variant of successional development is the overgrowth of yards and streets by anthropogenic groups of *Robinietea*, primarily the nitrophiles *Robinia pseudoacacia* L. and *Acer negundo* due to the formation of a sparse shrub layer of *Syringa vulgaris* L, *Pyrus communis* L., *Sambucus nigra* L., with the participation of *Humulus lupulus* L. In conditions of strong shading, ruderal nitrophilic species are formed in gardens with the predominance in the species composition of *Elytrigia repens, Chelidonium majus* L., *Galium aparine* L., *Urtica dioica* L., and *Balota nigra* L.

Natural apophyte species occur with high constancy in these groups: *Carex caryophyllea* Latourr., *Heracleum sphondylium* L., *Schedonorus giganteus*. The share of alien species of annual plants (*Anisantha tectorum* (L.) Nevski, *Erigeron canadensis* L., *Impatiens parviflora* DC.) is insignificant, and is not more than 2–15%. Gardens in river valleys and meadows have been restored, as evidenced by the elements of steppe meadows present in the species composition, in addition to the dominant *Elytrigia repens* are: *Carex caryophyllea, Poa angustifolia* L., *Euphorbia cyparisias* L. An inspection of the vegetation of the city of Pripyat revealed an abnormal formation of a large population of the hellebore *Epipactis helleborine* (L.) Crantz, which is listed in the "Red Data Book of Ukraine". The population is localized in the city centre and the stadium, under a sparse canopy of aspen and birch trees. It is numerous, mostly generative individuals have been recorded, which reach significant sizes – up to 50–70 cm in height.

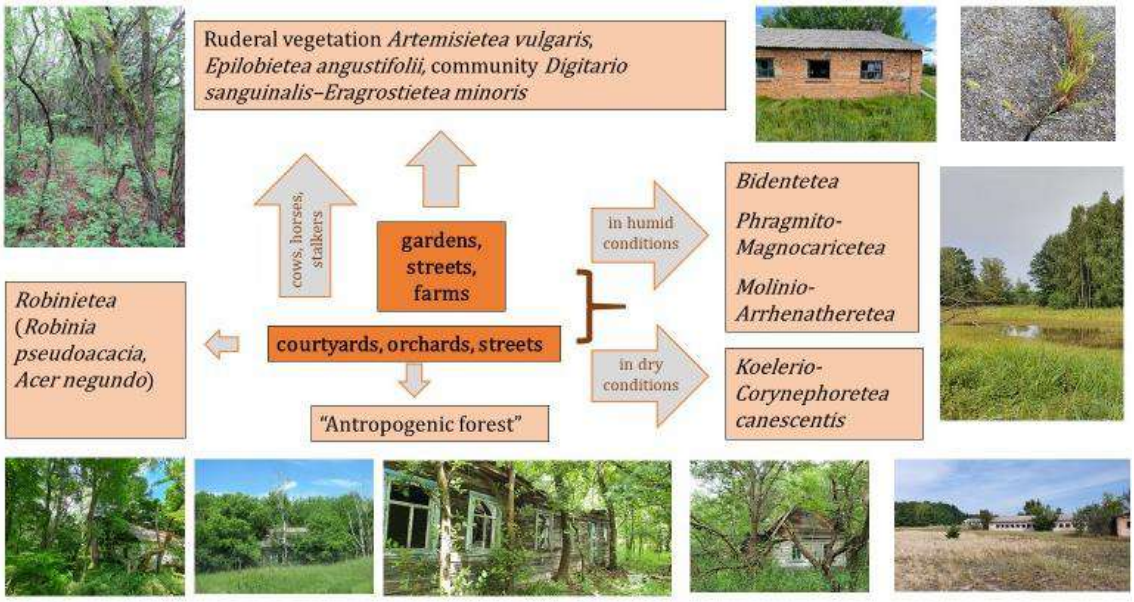

Fig. 5. Direction of development of plant communities of abandoned settlements

The vegetation is developing in another way in settlements located on elevated elements of the landscape. A two-three-tiered stand is formed here, with the closure of 50–90% often from the natural tree species: *Acer platanoides, Fraxinus excelsior* L., *Betula pendula, Populus tremula, Pyrus communis, Tilia platyphyllos* Scop., *T. cordata* Mill., *Malus pumila* Mill., *Morus nigra* L. The species composition of the grass cover is sparse (up to 50%), formed by species of ruderal vegetation *Artemisietea vulgaris* Lohmeyer et al. in Tx. ex von Rochow 1951. It occurs in isolated remains of cultivated orchards of apple, pear, bitter chestnut, and wild populations of herbaceous plants: *Vinca minor* L., *Hemerocallis lílioasphodelus* L., *Rudbeckia laciniata* L., *Symphyotrichum novi-belgii (L.) G. L. Nesom* and liana *Parthenocissus* sp. The peculiarity of the demutation of gardens and farms in the absence of trees, and their overgrowth is attended by single shrubs (*Syringa vulgaris, Corylus avellana* L., *Rubus caesius* L., *R. idaeus* L., *Ribes nigrum* L.), with nitrophilic species (*Urtica dioica, Galium aparine*, *Convolvulus arvensis* L.) on the site of farm animals, or a psammophytic grass layer on the site of gardens (*Calamagrostis epigejos, Elytrigia repens*).

Another trend in the formation of vegetation on open areas of the Chornobyl Exclusion Zone is the fluctuating succession of vegetation under the influence of trampling by wild cows and horses. At the same time, one- and two-story canopies made of robinia, ash maple and natural tree species are formed. However, the grassy, fairly dense layer is dominated by cereals (*Schedonorus pratensis* (Huds.) P. Beauv., *Drymochloa sylvatica* (Pollich) Holub, *Festuca valesiaca* Gaudin, *Elytrigia repens, Poa angustifolia, P. pratensis*) and ruderal thermophilic perennials, which are a response to trampling and grazing by animals.

Another feature of the exclusion zone is the fairly clear differentiation of the vegetation of streets and yards. At the same time, the streets are not overgrown with lignosed forms, but mainly with grassy psammophytic and xerophytic vegetation of the class *Koelerio-Corynephoretea* Klika in Klika et Novák 1941, and a locus of nitrophilic and thermophilic ruderal vegetation are formed in the depressions. It should be noted that the grouping of the vegetation of ruderal juveniles of the class *Stellarietea mediae* Tüxen et al. ex von Rochow 1951 are not formed here, they are growing only alongside the roads used.

3.4. Fires and plant invasions

The fires that periodically occur here significantly affect the conditions and structure of the forest vegetation in the zone. In 1992, 2005, 2016 and 2020, large-scale fires occurred in the forests of the Exclusion Zone, so post-pyrogenic successions of vegetation were found in these areas (Fig. 6). All these materials are a basis for assessing the dynamics of the vegetation of the Chornobyl Exclusion Zone.

Fig. 6. Fire in the spring of 2020 (A) and the restoration during the summer of 2021 (B) near village Kryva Gora

We studied the first stages of post-pyrogenic demutation, as well as the burns of 1992 and 2005, which allowed us to assess the course of these processes in all types of forests from dry lichen pine to wet alder. Such a wide range of burns indicates that the litter is drying even in swampy forests due to climate change (Flannigan et al., 2009; Borsuk, 2011; National report ..., 2014). Although the stands of all types of forests have not recovered, due to the vulnerability of crown fires, the grass cover responds quickly to these changes and is a sensitive indicator of these processes (Fig. 7).

In more optimal, but poorer soils, tall-stemmed closed (50–70%) plantations (II-III bonity: is an indicator that indicates the formation of high-native forest under optimal conditions with abiotic factors) were formed on levelled areas of the terrain, and such forests belong to ass. *Dicrano-Pinetum*. These forests are mainly of artificial origin, and in such conditions, after fires, pine recovers well naturally and its coenoses occupy the largest areas. Such forests turned out to be the most vulnerable, and the destructive effect of fires was reflected in all components of the coenosis, from the tree layer to the grass-moss layer. In the second year after the fire, the ground cover has the appearance of a charred solid layer, where plants grow as individuals or curtains. Their species composition is depleted and the basis is formed not by typical post-pyrogenic species, such as *Epilobium angustifolium* L., but by alien species or apophytes (*Crepis foetida* L., *Chenopodium album* L., *Erigeron canadensis*, *Lactuca serriola* L., *Oenothera biennis* L., *Senecio viscosus* L.).

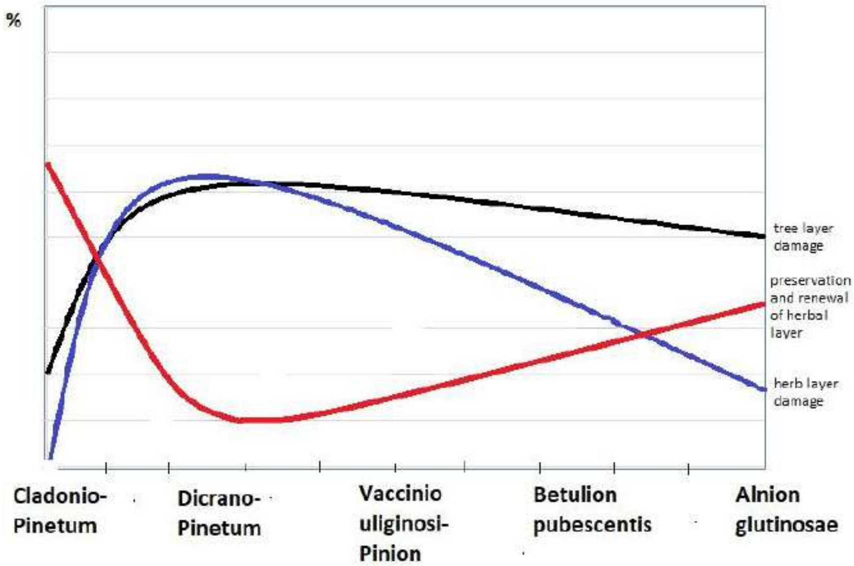

Fig. 7. Impact of fires on the condition and restoration of tree and grass tiers of different types of forest communities

The most resistant of the natural species were *Agrostis capillaris, Rumex acetosa* L., *R. acetosella, Calamagrostis epigejos, Jasione montana, Hypericum perforatum* L. The moss cover is formed of *Ceratodon purpurascens* (Hedw.) Jenn. and *Polytrichum commune* Hedwig. A similar pattern is characteristic of the richer forests of *Querco-Pinetum*. *Robinia pseudoacacia*, *Betula pendula* and *Populus tremula* are the most common in low young growth.

In the driest forests (*Cladonia-Pinetum*), the grass cover did not change, instead there was damage to the stands. The wetter forests of *Molinio-Pinetum*, partly *Vaccinio uliginosae-Pinetum* with high, closed pine stands have undergone significant changes, but in conditions of increasing concentration of nitrogen and carbon compounds in sufficiently moist soil there is intensive growth of tall plants, especially *Rubus caesius, R. idaeus*, *Pteridium aquilinum* (L.) Kuhn, and *Humulus lupulus*, which form impassable thickets.

The rapid and intensive formation of such coenoses indicates that the fires did not affect the lower, sufficiently moist, soil horizons, where the underground organs of these species are concentrated. Birch forests *Molinio-Betuletea* (*Betulion pubescentis*), close in moisture to the previous ones, occur in relatively small localities in low relief forms. As a result of fires in such communities the coenotic role of *Populus tremula* increases.

The influence of alien invasive species on the processes of vegetation transformation in the Exclusion Zone should be noted separately. Before the accident, nitrogen-fixing leguminous species were planted and sown in artificial pine forests: *Amorpha fruticosa* L., *Cytisus scoparius* (L.) Link, *Lupinus polyphyllus* Lindl., *Robinia pseudoacacia*. All of them are successfully kept in coenoses and settle in new ones. *Fraxinus pennsylvanica* Marshall, *Phellodendron amurense* Rupr., *Physocarpus opulifolius* (L.) Maxim., *Pinus banksiana* Lamb., *Ptelea trifoliata* L., and *Quercus rubra* L. were also cultivated. Now these species bear fruit and are maintained in forest coenoses without human help. *Fraxinus pennsylvanica* from the Chornobyl plantations fell into the floodplain of the River Pripyat and now it is actively propagated by seeds and settles on the islands of the Pripyat branch of the Kyiv Reservoir.

The most common alien species for the study area are *Robinia pseudoacacia, Acer negundo, Asclepias syriaca* L., *Erigeron canadensis, E. annuus* (L.) Desf., and *Erechtites hieraciifolius* (L.) DC. Due to the "closed" nature of this area, the range of invasive species in the exclusion zone differs significantly from neighbouring regions. The main sources of their spreading are from abandoned settlements, forest nurseries and a small number of visitors.

4. Discussion

The restoration of the vegetation after the accident at the Chornobyl nuclear power plant is the result of various processes: demutation, post-pyrogenic changes and phytoinvasion. The processes that take place in ecosystems should be interpreted on the basis of thermodynamic, synergistic positions, which are based on the assessment of energy reserves and transformations, which are determined by the reserves of carbon and nitrogen compounds. Successions were considered and predicted by us as a linear, climactic process from annual to perennial herbaceous plants, the introduction of forest species of trees and shrubs and the formation of appropriate type forest coenoses with their inherent grass cover.

As our research has shown, the vegetation on abandoned arable fields was characterized by a decrease in the value of annual plants, by communities of perennial species, both synanthropic and natural, with a significant share of trees (*Pinus sylvestris, Betuls pendula, Robinia pseudoacacia, Acer negundo*). The appearance of species considered to be in danger of extinction according to the Red Lists was noted (Prévosto et al., 2011) in the territory of settlements (*Iris sibirica, Epipactis heleborine*), in abandoned cities, in yards, and at the stadium in the city of Prypiat. This classic course of succession is quite clearly manifested in the settlements, where individuals of *Acer negundo* appeared in the ruderal nitrified groups of *Onopordion acanthiiin* gardens, and in the grass layer there was a spread of nitrophils, which led to the appearance of *Chelidonio-Acerion negundo* (Shestopalov et al., 2001; Petrov, 2016).

A completely different situation was observed in the grass vegetation of the reserve. In order to study the successional processes, repeated profiles were established with reference to the previous ones and detailed descriptions of vegetation in standard test plots were performed. In the example of the study of repeated profiles near the settlement of Korogod it was found that such processes are much more complex, take longer and deviate from the linear demutation progress. Vegetation research showed that on the tops of sandy hills in dry poor conditions develop communities of *Corynephorion canescentisi* dominated by *Corynephorus canescens*, and in slightly wetter, or richer, conditions *Artemisietea vulgaris* and (union *Convolvulo arvensis-Agropyrion repentis*) dominated by *Elytrigia repens, Agrostis capillaris* L. and *Apera spica-venti* (L.) P. Beauv. In our opinion, this is due to several reasons. The most optimal conditions were occupied by wheatgrass, among which single specimens of *Betula pendula* grew. We believe that although a thick layer of wheatgrass litter does not allow the formation of birch forests, but mechanical violation, including digging rodents, ungulates and other ways, will contribute to the growth of birches as the initial stage of coniferous forests (Didukh et al., 1993).

Apparently, wheatgrass and other cereal coenoses inhibit the growth of forest species. This phenomenon of allelopathy, which Grodzinsky (1973) wrote about, is underestimated by geobotanists, and it significantly inhibits, or alters, successive vectors. The dominance of *Elytrigia repens* on fallow lands has been associated with the organic fertilization of gardens in the past, but over time the content of nitrogen compounds in the soil has been depleted and the role of *Elytrigia repens* has decreased. On poor sandy soils, the long-rooted *Calamagrostis epigejos* played a dominant role. Restored herbaceous vegetation in river valleys on abandoned agricultural land is resilient, as dominant herbaceous species can persist for up to 50 years (Joyce, 2014), limiting tree invasion, although the coenoses are sparse. These are mainly herbaceous species that dominate abandoned meadows, tall perennial grasses and sedges (Szirmai et al., 2022). However, a longer period may threaten the impoverishment of the species composition (Fülöp et al., 2021).

In general, it can be stated that after 35 years, the pioneering, syngenetic stage is over and cereals play a dominant role everywhere. It will be a long time before the soil accumulates a critical mass of available nutrients, and energy that the ecosystem will try to convert into more stable forms, stored in the biomass of woody vegetation, and then fully-fledged forest communities will be formed. The direction and speed of succession depends on the conditions (habitats) and ecological features of plants, as well as the influence of external zoogenic components and fires, which contribute to the alienation of energy. As a result of the interrelationship of these factors, the processes will occur gradually and in stages with a possible horizontal "shift" in development, which leads to a deviation from linear development and is interpreted as a non-linear process. The task is to control and optimize the restoration of various plant communities on abandoned agricultural lands through local species with biomass accumulation, carbon stocks, to complete the formation of sustainable stages with minimal biomass and radionuclide removal.

Another factor affecting the state of the forest vegetation is fires that periodically spread across the exclusion zone (MATSALA ET AL., 2021b.). Due to climate change, the length and frequency, and therefore the scale, of adverse events such as fires are increasing (FLANNINGEN ET AL., 2009; LANDMANN ET AL., 2015; ZIBTSEV, 2015). In the 70s and 80s of the 20th century their significant negative consequences have been recorded for the south of Ukraine (Crimea), in recent years they have been manifested throughout Ukraine, including the Chornobyl Exclusion Zone (KASHPAROV ET AL., 2017; AGER ET AL., 2019; EVANGELIOU & ECKHARDT, 2020; SOROKINA & PETROV, 2020; NEWMAN-THACKER & TURNBULL, 2021). The natural recovery of pine and other tree species after fire is unsatisfactory, which raises the question of the formation of forest coenoses of more stable structures with mixed stands (TYSHCHENKO & LANDIN, 2020; DOMBROVSKI ET AL., 2022). Therefore, a scheme for reforestation after a fire was developed, with a shift in emphasis from the creation of monodominant pine plantations to mixed stands, since deciduous forests are the most resistant. It is proposed to remove and, in the case of high radionuclide content, store trees in areas with high humidity, which will help speed up the destruction of wood and minimize the migration of radionuclides.

The main habitats of invasive species are abandoned settlements, cemeteries, roadsides and areas affected by fire. *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Heracleum pubescens* (Hoffm.) M. Bieb., and *Solidago canadensis* L., which are a huge problem in the Polissya region, are almost non-existent in the area (PASHKEVYCH & BURDA, 2017; KOLOMIYCHUK ET AL., 2019; PROTOPOPOVA & SHEVERA, 2019). It should be noted that the first post-pyrogenic stage of dry pine forests is attended by alien species and differs significantly from the classical scheme.

5. Conclusions

The study of the vegetation showed that it is represented by vegetation classes typical for the forest region *Molinio-Betuletea pubescentis*, *Vaccinio-Piceetea, Quercetea robori-petraeae, Carpino-Fagetea sylvaticae, Alnetea glutinosae*, meadow *Molinieto-Arrhenatheretea*, swamp *Phragmito-Magnocaricetea*, and psamophytic *Koelerio-Corynephoretea* natural vegetation, and on abandoned fields and settlements the vegetation is dominated by perennial herbaceous and woody ruderal vegetation of the classes *Artemisietea vulgaris, Polygono arenastri-Poëtea annuae, Robinietea*. However, almost all types of vegetation have features caused by the shutdown of the CEZ. Vegetation succession in the exclusion zone actually occurs much more slowly than is possible. In addition to the "vertical" changes that are characteristic of forest vegetation and which can be predicted, grasslands are experiencing "horizontal shifts" with processes that are difficult to predict, so the vector of successions may shift significantly.

Frequent and large-scale fires cause significant imbalances in forest ecosystems, resulting in the disruption of relationships, leading to the emergence of large numbers of alien species in the early stages, including species with a high invasive capacity. The structure of *Cladonio-Pinetum* communities is the best preserved, and *Dicrano-Pinetum* is the worst. In the direction from wet/ damp (*Molinio-Pinetum, Vacciniouliginosi-Pinetum, Molinio-Betuletea*) to wet forests (*Alnion glutinosae*) there is an intensive recovery and formation of a dense tall grass layer. However, in the study of changes in the structure of the Earth's landscape by deciphering satellite images from different times (SOROKINA & PETROV, 2020), the vegetation most resistant to fires and other natural factors were pine forests (*Dicrano-Pinetum*), as well as floodplain forests, which are natural forest groups for these areas.

The demutation processes of residential areas in the exclusion zone are influenced by several factors: landscape and ecological conditions of the studied villages determine the nature of the secondary regenerative succession, which occurs after the removal of the impact of anthropogenic factors. Another factor that forms certain differences that affect the type of overgrowth is the species composition of trees and shrubs and also proximity or remoteness of a particular village to the ways of entering diasporas (roads, waterways), accidental external influences (fires, animal influences) that can cause changes in the directions and rates of succession. These studies of the structure and dynamics of plant communities are important for the forecasts of their changes and the likely measures needed to restore sustainable ecosystems with minimal outflow of radionuclides. However, after the invasion of the Russian Federation into the territory of Ukraine and the uncontrolled presence of its troops in the exclusion zone, other impacts are possible (fires, infiltration of diasporas of alien species with military vehicles, damage to soils and plants), the impact of which we can trace later.

References

Ager A.A., Lasko R., Myroniuk V., Zibtsev S., Day M.A., Usenia V., Bogomolov V., Kovalets I., Evers C.R. 2019. The wildfire problem in areas contaminated by the Chernobyl disaster. *Science of the Total Environment*, 696.

Atlas of the Chornobyl exclusion zone [Maps]. 1996. V.M. Shestopalova (Ed.) Ministry of Ukraine for protection of the population from the Consequences of the Chornobyl Accident. Kyiv. Cartography.

Azarov S.I. 1996. Landscapes of the Chernobyl zone and estimation on their fire risk condition. *Problems of Chernobyl Exclusion Zone*. 3: 204–208 [in Russian].

Bidna S.M. 1999. Autogenic successions of forest vegetation under conditions of reducing antropogenic impact. *Sci. Bulletin of Foresty Research in Ukraine*, 9, 10: 20–25 [in Ukrainian].

Borsuk O.A. 2011. Natural fire danger of pine forests of the Exclusion Zone and the Zone of unconditional (compulsory) resettlement of the Chernobyl NPP. *Scientific Bulletin of the National University of Life and Environmental Sciences of Ukraine*, 164: 105–111 [in Ukrainian].

Chytry M., Tichý L., Holt J., Botta-Dukat Z. 2002. Determination of diagnostic species with statistical fidelity measures. *Journal of Vegetation Science*. 13: 79–90.

Cristaldi M., Ieradi L.A., Mascanzoni D., Mattei T. 1991. Environmental impact of the Chernobyl accident: mutagenesis in bank vole from Sweeden. *Journal of Radiation Biology,* 59, 1: 31–40.

Davydchuk V.S. 1998. Excessively wetlands of the Chornobyl exclusion zone under the influence of reclamation systems. *Bulletin of the Ecological Condition of the Exclusion Zone and Unconditional (Compulsory) Resettlement*, 11: 22–29.

Didukh Ya., Andrienko T.L., Plyuta P., Pryadko O., Sypaylova L. 1993. Vegetation formation in the Chornobyl exclusion zone. *Oikymena*, 2: 13–22 [in Ukrainian].

Didukh Ya., Kordyum E., Andrienko T., Priadko O., Sidorenko P., Sytnik K. 1994. *Phytocoenotic and cytogenetic monitoring of vegetation in continuous irradiation conditions caused by accident at the Chornobyl nuclear power station*. Preprint. Kiev.

Didukh Ya.P. 2011. *The ecological scales for the species of Ukrainian flora and their use in synphytoindication*. Kyiv: Phytosociocentre.

Didukh Ya.P. 2012. *Fundamentals of bioindication*. Naukova dumka, Kyiv [in Ukrainian].

Dombrovski V., Zhurauliou D., Ashton-Butt A. 2022. Long-term Effects of Rewilding on Species Composition: 22-years of Raptor Monitoring in the Chernobyl Exclusion Zone. *Restoration Ecology*, 30(8), e13633.

Dubyna D.V., Dzyuba T.P., Yemelyanova S.M., Bagrikova N.O., Borisova O.V., Borsukevych L.M., Vinokurov D.S., Gapon S.V., Gapon Yu.V., Davydov D.A., Dvoretsky T.V., Didukh Ya.P., Zhmut O.I., Kozyr M.S., Konishchuk V.V., Kuzemko A.A., Pashkevych N.A., Ryff L.E., Solomakha V.A., Felbaba-Klushyna L.M., Fitsailo T.V., Chorna G.A., Chorney I.I., Shelyag-Sosonko Y.R., Yakushenko D.M. 2019. *Prodromus of vegetation of Ukraine*. (Ed. D.V. Dubina, T.P. Dziuba). Naukova dumka, Kyiv [in Ukrainian].

Euro+Med (2006-): Euro+Med PlantBase - the information resource for Euro-Mediterranean plant diversity. Available at https://europlusmed.org/ [accessed 20.02.2023].

Evangeliou N., Eckhardt S. 2020. Uncovering transport, deposition and impact of radionuclides released after the early spring 2020 wildfires in the Chernobyl Exclusion Zone. Scientific Reports 10: 10655.

Fedoniuk T., Borsuk O., Melnychuk T., Zymaroieva A., Pazych V. 2021. Assessment of the consequences of forest fires in 2020 on the territory of the Chornobyl radiation and ecological biosphere reserve. *Scientific Horizons,* 24, 8: 26–36.

Flannigan M., Krawchuk M., Wotton M., Johnston L. 2009. Implications of changing climate for global Wildland fire. *International Journal of Wildland Fire*, 18: 483–507.

Fülöp B., Pacsai B., Bódis J. 2021. Minor Treatments Can Play a Significant Role in Preserving Natural Habitats and Protected Species on the Shore of a Central European Lake. *Agronomy*, 11: 1540.

Gaichenko V.A. 2001. *Features of the existence of animals in conditions of radioactive contamination biocenosis*. In Chernobyl Catastrophe – fifteen years. Naukova dumka, Kyiv [in Ukrainian].

Geras'kin S., Zimina L.M., Dikarev V.G., Dikareva N.S., Zimin V.L., Vasiliyev D., Udalova A., Blinova L.D., Alexakhin R.M. 2003. Bioindication of the anthropogenic effects on micropopulations of *Pinus sylvestris* L. in the vicinity of a plant for the storage and processing of radioactive waste and in the Chernobyl NPP zone. *Journal of Environmental Radioactivity*, 66: 171–180.

Grodzinsky A.M. 1973. *Fundamental of chemical interaction of plants*. Naukova dumka, Kyiv [in Ukrainian].

Grodzinsky D.M., Bulakh A.A., Gudkov I.N. 1997. *Radiobiological effects in plants. Chernobyl Catastrophe* (pp. 314-328). Edit. House of Ann. Issue «Export of Ukraine», Kyiv [in Ukrainian].

Hennekens S., Schaminée J. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. *Journal of Vegetation Science*, 12: 589–591.

Joyce Ch. 2014. Ecological consequences and restoration potential of abandoned wet grasslands. *Ecological Engineering*, 66: 91–102.

Kashparov V.A., Myroniuk V.V., Zhurba M.A., Zibtsev S.V., Glukhovskiy A.S., Zhukova O.M. 2017. *Radiological Consequences of the Fire in the Chernobyl Exclusion Zone in April 2015*.

Kolomiychuk V., Shevera M., Vorobyov E., Orlov O., Pryadko O. 2019 *Erechtites hieracifolia* (L.) Raf. ex DC. (*Asteraceae* Bercht., J. Presl) – new for the Kyiv Polissia alien species. *Visnyk Taras Shevchenko National University of Kyiv*, Ser. Biologia, 3, 79: 37–43 [in Ukrainian].

Landmann G., Held A., Schuck A., Van Brusselen, Jo. 2015. *European Forests at Risk. A scoping study in support of the development of a European Forest Risk Facility*. European Forest Institute, Freiburg.

Landscapes of the Chornobyl zone and their assessment of radionuclide migration conditions. 1994. Ed. A.M. Marynich. Naukova dumka, Kyiv [in Ukrainian].

Matsala M., Bilous A., Myroniuk V., Diachuk P., Burianchuk M., Zadorozhniuk R. 2021a. Natural forest regeneration in Chornobyl Exclusion Zone: predictive mapping and model diagnostics. *Scandinavian Journal of Forest Research*, 36, 2–3: 164–176.

Matsala M., Bilous A., Myroniuk V., Holiaka D., Schepaschenko D., See L., Kraxner F. 2021b. The Return of Nature to the Chernobyl Exclusion Zone: Increases in Forest Cover of 1.5 Times since the 1986 Disaster. *Forests*, 12: 1024.

Mucina L., Bültmann H., Dierßen K., Theurillat J.-P., Raus T., Čarni A., Šumberová K., Willner W., Dengler J. (…), Tichý L. 2016. Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. *Applied Vegetation Science*, 19: 3–264.

National report on the state of man-made and natural security in Ukraine in 2014. State Service of Ukraine for Emergencies. *Ukrainian Research Institute of Civil Defense*. Available at https://undicz.dsns.gov.ua/ua/nacionalna-dopovidpro-stan-tehnogennoyi-ta-prirodnoyi-bezpeki-v-ukrayini.html [in Ukrainian].

Newman-Thacker F., Turnbull L. 2021. Investigating the drivers of the unprecedented Chernobyl Power Plant Wildfire in April 2020 and its effects on Cs dispersal. *Natural Hazards*m, 109: 1–21.

Pashkevych N.A., Burda R.I. 2017. Spread of alien plant species in the habitats of the ukrainian forest steppe. *Ekologia (Bratislava)*, 36, 2: 121–129.

Petrov M.F. 2016. Botanical and geographical studies of the Chornobyl Zone. *Problems of the Chornobyl Exclusion Zone*, 15–16: 52–263 [in Ukrainian].

Plyuta P.G., Didukh Ya.P. 1996. Phytoecological research in the Chornobyl exclusion zone nuclear power plant. *Problems of the Chornobyl Exclusion Zone*, 3: 39–48 [in Ukrainian].

Prévosto B., Kuiters L., Bernhardt-Römermann M. et al. 2011. Impacts of land abandonment on vegetation: successional pathways in european habitats. *Folia Geobotanica*, 46: 303–325.

Protopopova V.V., Shevera M.V. 2019. Invasive species in the flora of Ukraine. I. The group of highly active species. *GEO&BIO*, 17: 116–135 [in Ukrainian].

Shestopalov V.M., Frantsevich L.I., Balashov L.S. et al. 2001. *Autorehabilitation processes in the ecosystems of the Chornobyl exclusion zone*. Resp. ed. Yu.O. Ivanov, V.V. Dolin [in Ukrainian].

Sokal R.R., Rohlf F.J. 1995. *Biometry: The Principles and Practice of Statistics in Biological Research*. 3rd Edition, W.H. Freeman and Co., New York.

Sorokina L.Yu., Petrov M.F. 2020. Changes in the structure of the land cover and fire safety of the Chernobyl exclusion zone landscapes: assessment methods using satellites. *Ukrainian Geographical Journal*, 2, 110: 45–56 [in Ukrainian].

Szirmai O., Saláta D., Benedek, L.K., Czóbel, S. 2022. Investigation of the secondary succession of abandoned areas from different cultivation in the Pannonian biogeographic region. *Agronomy*, 12, 4: 773.

Tichy L. 2002. *JUICE, software for vegetation classification. Journal of Vegetation Science*, 3: 451–453.

Tyshchenko O., Landin V. 2020. Changes in the underlying surface and vegetation in the Chornobyl Exclusion Zone during 1986–2017. *Nuclear Power and the Environment*, 19: 75–84 [in Ukrainian].

Westhoff V., E. van der Maarel. 1973. *The Braun-Blanquet approach*. In Handbook of Vegetation Science (Ed. R. Tüxen) Part V. Ordination and Classification of Communities (ed. R. H. Whittaker). Junk, The Hague: 617–726.

Zibtsev S., Goldammer J.G., Robinson S., Borsuk, O.A. 2015. Fires in Nuclear Forests: Silent Threats to the Environment and Human Security. *Unasylva*, 66: 40–51.