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Original article

A phytoindicational assessment of the vegetation of afforestation belts in the Middle Dnipro Region, Ukraine

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ABSTRACT

We performed a study of the vegetation of afforestation belts in the Middle Dnipro Region of Ukraine. These were planted to protect agricultural land from adverse climatic conditions. The syntaxonomy of these afforestation belts is, so far, embedded in the synanthropic class of *Robinietea* tree plantations, but over time, these may need another syntaxonomic solution. Based on the data, a phytoindicational assessment of these communities was performed. The ecological features of the vegetation of afforestation belts have been determined by the mutual influence of ecological factors of different origin, and the extent of these impacts. In particular, the climatic conditions and edaphic factors and also the peculiarities of the environment-forming influence of different dominant tree species in the main layers and the age of these plantations, which determines at different stages of sylvestral succession processes. According to our phytoindicational assessment, use of cluster analysis of these biotopes of afforestation belts, proved their considerable similarity taking into account all ecological factors, and the distribution is mainly due to the predominant tree species. As a result of ordination analysis, it was found that the factors that most correlate with the ordinal axes are light regime, soil nitrogen and humidity. Phytocoenoses of afforestation belts are a very specific component of the forest biome in this region, because they have been artificially created.

KEY WORDS: afforestation belts, phytoindicational analysis, vegetation, Robinietea, Ukraine, cluster analysis

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1. Introduction

The afforestation belts of various species of trees were created in the Forest-Steppe and Steppe zones of Ukraine for the formation of areas of protection of adjacent agricultural lands from adverse climatic conditions. The mass ploughing of meadows and steppes of these zones on a large scale created the need to protect them from wind and water erosion of the soil, in order to retain and preserve moisture in the fields. Thus artificial afforestation belts have become an essential landscape component of the Forest-Steppe and Steppe vegetation of Ukraine.

According to State Forest accounting, the area of forest plantations that perform an agroforestry function in the plains of Ukraine is 2642.2 thousand hectares, including: 432.3 thousand hectares of forest plantations of a linear type (according to the

State Land Cadastre – 446 thousand hectares); 919.1 thousand hectares of anti-erosion forests; 289.7 thousand hectares of forest areas along river banks, around lakes, reservoirs and other water bodies; and 1001.1 thousand hectares of small forest in steppe ravines.

A survey of the state of afforestation belts in independent Ukraine wasn't conducted. Their last comprehensive assessment was made in 1967–1968 during the preparation of the General Scheme of Anti-Erosion Measures in the Ukrainian SSR for 1971–1980 and the subsequent period. There are no current data on the actual condition of afforestation belts.

The diversity of plant communities, which have formed in these artificially created plantations of afforestation belts, requires new syntaxonomic solutions due to their significant difference from natural forest communities. First, they have had a fairly long period of existence, with most of the existing afforestation belts being between 40 to 90 years old. Second, this has allowed most of the created tree plantations to go a long way towards phytocoenosis formation with the adaptation of tree species to the existing ecological conditions with the gradual formation of their floristic features. Third, the long existence of afforestation belts has led to the gradual inclusion of natural species of trees and shrubs especially with the constant presence of existing complexes of ruderal species, which can develop more extensively at the edges of fields, along the edge of the forest belt and within the vegetation adjacent to the road.

We conducted phytocoenotic studies of afforestation belts in the Middle Dnipro region (Solomakha & Shevchyk, 2020). As an element of the forest biome, they are quite specific because they are of an exclusively artificial origin. They are currently in the early stages of ecogenesis, making them an interesting object for monitoring. As quite extensive information exists on these protective forest belts, we decided to conduct a phytoindicational analysis on them mainly, to determine the environmental factors influencing their development and differentiation.

The aim of our study was to research the ecological specifics of afforestation belt communities using the method of synphytoindication. This object of our study is insufficiently studied from a syntaxonomic and ecological point of view. The advantages of using the technique of synphytoindication is that it takes into account not only the tree and dominant grass species, but also the full floristic composition (Ramensky et al., 1956; Didukh & Pliuta, 1994; Didukh, 2011). This has allowed us to detect even minor initial successional changes in the vegetation of forest belts and thus to understand more deeply the mechanisms of demutation processes that occur in them. The diverse study and development of knowledge of the processes of formation of forest phytocoenoses of an artificial origin, which currently exist in these afforestation belts, will help to identify the most functional and promising options and to develop recommendations for the reconstruction of the old, and lost, field protection properties and the creation of new protective plantations.

2. Materials and methods

Studies of the vegetation of the afforestation belts were conducted on the territory of the Middle Dnipro Region, which is part of the Forest-Steppe zone of Ukraine (Fig. 1) (Ecological Encyclopedia, 2007). There are 182 geobotanical descriptions that represent the studied vegetation. The size of the plots varied between 200–300 m^2. The projected coverage of species was recorded according to the Braun-Blanquet scale (Braun-Blanquet, 1964; Westhoff & van der Maarel, 1978). The results of the vegetation classification of the afforestation belts are given in our previous work (Solomakha & Shevchyk, 2020).

Phytoindicational calculations for vegetation descriptions were carried out at ecological scales according to the traditional methodology of weighted average scale estimates of species (Ramensky et al., 1956; Didukh & Pliuta, 1994; Didukh, 2011). We took into account 14 environmental indicators, including: 7 edaphic, 4 climatic and also light regimes, which are given in accordance with phytoindicational scales according to Didukh (Didukh, 2011) and 2 indicators that assess the degree of anthropogenic transformation of the species composition of these groups – hemerobility (Frank & Klotz, 1990) and naturalness index (Borhidi, 1995). All ecological scales were reduced to a 100-point scale, in order to compare the values of phytoindicational indicators between syntaxa and the different factors (Goncharenko, 2017).

We used the array developed from the obtained phytoindicational indicators as input data and conducted an assessment using the method of cluster analysis to assess the degree of similarity of biotopes of the syntaxa of afforestation belts. The degree of similarity of syntaxon habitats in phytoindicational indicators was assessed using the Bray-Curtis distance (Bray & Curtis, 1957) and the flexible beta grouping algorithm (Dufrêne & Legender, 1997) at beta = -0.25.

According to the method of correspondence analysis of the removed trend (DCA ordination) an ordination analysis of syntaxa of afforestation belts was carried out (Hill & Gauch, 1980; Legendre & Legendre, 2012). The calculations were performed using the statistical environment R ver. 3.5.3 (https://cran.r-project.org/bin/windows/base/old/3.5.3/). An assessment of the relationship of the environmental factors with the axes of ordination was performed using the "envit" function from the Vegan package (Oksanen et al., 2018). To interpret the ordination axes, the degree of correlation between the ecofactor values was calculated using the phytoindicational method and the ordination coordinates of the descriptions was evaluated using the Pearson correlation coefficient. The total contribution of ecofactors in the variation of the floristic composition of the vegetation was carried out on the basis of the coefficient of determination r^2, and took into account the first and second DCA axes.

According to the phytoindicational assessment of the afforestation belt communities, an analysis of the correlations between environmental factors was performed. The method of constructing a choreogram, using the corrplot package, was used to visually display the matrix of correlations between environmental factors (Wei & Wei, 2016). The values of the correlation matrix between the phytoindicational indicators were also used in the analysis of the main components (using PCA analysis), which was performed using the package FactoMineR (Lê et al., 2008).

Fig. 1. Map scheme of the study area

3. Results and discussion

3.1. General phytocoenotic characteristics of the vegetation of afforestation belts

First of all, we need to take into account the specifics of the vegetation being studied. Thus, the artificial plantings of the afforestation belts up to 20–30 years of age have in their composition, in addition to trees, and depending on the configuration of the afforestation belts, of shrubs, a mixture of segetal and ruderal species and sometimes species accidentally included in these communities from adjacent ravine-beam systems, which were distributed in meadows or meadow steppes. After planting, the growth of trees and the closure of their crowns caused the appearance, under their canopy, of various forest weeds, which were more or less present in the 80–90 years of existence of these plantations. Only in the plantations of afforestation belts over 60 years old have the processes of silvatization begun due to the introduction of different forest species. These processes in the plantations of older age are more intense, but their distribution is still chaotic and not sufficient for the formation of diagnostic blocks of associations, nor the higher syntaxonomic units.

The syntaxonomy of the afforestation belts is still part of the synanthropic class of *Robinietea* Jurko ex Hadač et Sofron 1980, but over time these belts may need a different syntaxonomic solution. From our point of view, it is not expedient to continue the development of syntaxonomy on the maximum simplification of the scheme due to the attribution of selected phytocoenoses to derive communities.

3.2. Phytoindicational assessment of the vegetation of afforestation belts syntaxa

The average scores of phytoindicational indicators calculated for the descriptions of syntaxa of the studied afforestation belts are given in Table 1 (Solomakha & Shevchyk, 2020). Four aggregate indicators: the minimum and maximum value of the ecofactor, the average value taking into account all syntaxa and the range of values are given at the bottom of the table. All scales are unified and reduced to a single 100-point scale.

Given that the range of the scale of each indicator is unified and has a 100-point format, it is permissible to compare eco-factors with each other in terms of averages. The maximum value (mean = 66.18) is observed for the factor of soil richness in nitrogen, which indicates nitrified soils, which are characteristic of anthropogenic communities. The minimum value (mean = 34.01) is observed for the soil aeration factor, which indicates compacted soils, as a result of which their aeration rates are lower. As for the amplitude of the values, the greatest length of the gradient (range = 17.00) is for the soil nitrogen factor, that is, the differences in syntaxon optimums for this indicator are quite significant.

For the correlogram, or matrix graph, of the correlation analysis, the values of environmental indicators are shown in Figure 2. In the upper part of the diagram, the magnitude and direction of correlations of each pair of indicators are indicated by ellipses, and in the lower part – the corresponding values of correlation coefficients between ecofactors.

The correlation structure of the matrix of phytoindicational assessment data in the space of the main components is shown by the PCA analysis diagram in Figure 3.

Table 1. Average values of phytoindicational indicators calculated for syntaxa of the afforestation belts

Cluster	Hd	Rc	Sl	Nt	Lc	Nv	Hm	fH	Ae	Ca	Tm	Kn	Om	Cr
1	42.98	58.29	36.52	73.00	55.50	30.98	48.89	51.32	31.89	46.62	62.35	40.41	51.94	57.24
2	47.31	59.52	35.16	73.19	55.47	33.53	43.87	46.29	36.50	45.12	62.54	42.04	53.59	57.48
3	41.21	56.54	37.45	56.19	61.90	40.54	49.19	51.83	30.86	51.00	58.82	43.66	54.27	51.37
4	46.13	57.76	33.09	63.33	53.14	42.16	43.61	45.53	35.17	46.04	59.82	40.48	53.99	54.13
5	45.53	56.03	33.13	62.77	53.86	42.52	44.05	46.88	34.53	46.02	59.53	40.32	55.72	53.90
6	44.52	59.64	35.02	65.98	54.57	38.36	46.48	47.25	34.14	46.64	60.64	39.84	52.57	55.97
7	45.68	59.50	35.63	68.34	53.92	39.57	46.11	46.59	35.26	45.31	63.02	40.67	50.76	56.92
8	45.32	57.45	35.79	66.74	56.35	36.85	42.72	46.69	33.12	48.42	60.95	39.88	52.76	57.00
9	44.20	58.19	35.89	65.24	57.01	39.93	44.70	47.83	33.84	48.13	60.81	41.20	53.23	55.26
10	45.79	57.91	34.95	67.05	56.39	39.51	44.74	46.71	34.75	47.53	60.03	40.85	53.90	55.91
Min	41.21	56.03	33.09	56.19	53.14	30.98	42.72	45.53	30.86	45.12	58.82	39.84	50.76	51.37
Max	47.31	59.64	37.45	73.19	61.90	42.52	49.19	51.83	36.50	51.00	63.02	43.66	55.72	57.48
Mean	44.87	58.08	35.26	66.18	55.81	38.40	45.44	47.69	34.01	47.08	60.85	40.94	53.27	55.52
Range	6.10	3.61	4.36	17.00	8.76	11.54	6.47	6.30	5.64	5.88	4.20	3.82	4.96	6.11

Numbers of syntaxa: 1 – *Chelidonio-Robinietum* Jurko 1963; 2 – *Chelidonio-Aceretum negundi* L. Ishbirdina et A. Ishbirdin 1991; 3 – *Chelidonio-Pinetum sylvestris* (Gorelov 1997) Davydov 2019; 4 – Elytrigio repentis-Aceretum platanoidis Vorobyov et I. Solomakha in I. Solomakha et al. 2015; 5 – *Poo nemoralis-Tilietum cordatae* I. Solomakha et Shevchyk 2020 prov.; 6 – *Geo urbano-Fraxinetum* I. Solomakha et Shevchyk 2020 prov.; 7 – *Balloto nigrae-Ulmetum* I. Solomakha et Shevchyk 2020 prov.; 8 – *Alliario petiolatae-Ptelietum trifoliatae* I. Solomakha et Shevchyk 2020; 9 – *Elytrigio repentis-Quercetum roboris* I. Solomakha et Shevchyk 2020; 10 – *Sambuco nigrae-Quercetum roboris* I. Solomakha et Shevchyk 2020

Ecological factors: Hd – soil humidity, fH – variability of soil moisture regime, Ae – soil aeration, Sl – total salt regime of the soil, Rc – soil acidity, Nt – the content of mineral nitrogen in the soil, Ca – carbonate content in the soil, Tm – thermal regime, Kn – continental regime, Cr – coldness (cryoregime), Om – humidity of the climate (ombroregime), Lc – lighting regime, Hm – hemerobility, Nv – index of naturalness

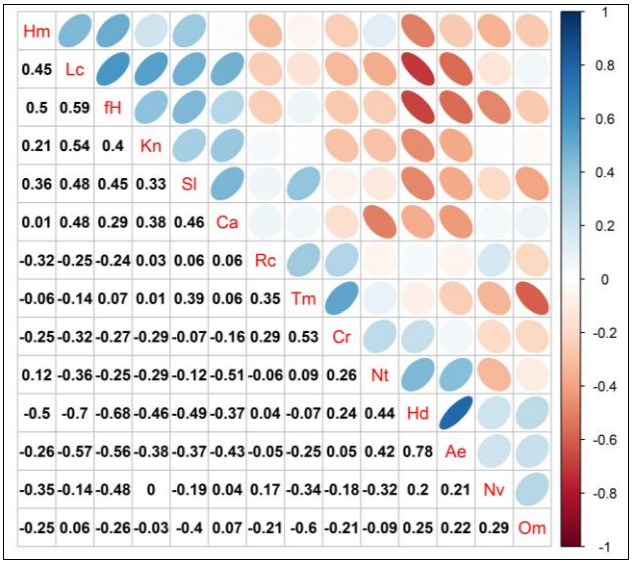

Fig. 2. Correlogram of environmental factors (according to phytoindicational assessment of the vegetation of afforestation belts syntaxa)

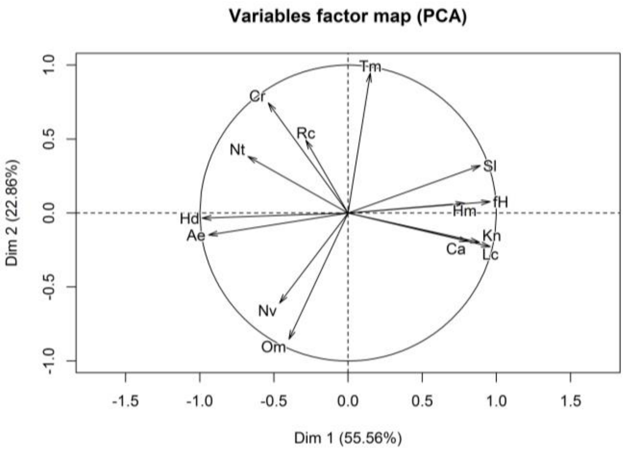

Fig. 3. Analysis of the main components (PCA) of correlations between environmental factors (according to a phytoindicational assessment of the vegetation of afforestation belts syntaxa)

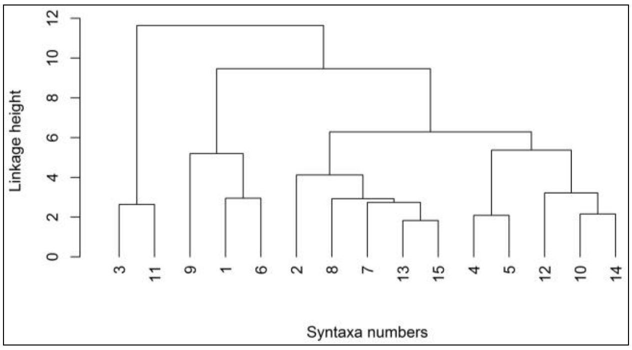

Fig. 4. Assessment of the degree of similarity of biotope conditions for the syntaxa formation of the vegetation of afforestation belts (according to their phytoindicational analysis)

The first component explains 55.56% of the correlations between ecofactors. The predominance of medium and significant correlations between ecological factors is associated with a fairly high contribution rate of the first component (Fig. 2). The second component explains 22.86%, which is about half that of the first component. The largest positive value of the correlation coefficient is observed between the factors of humidity (Hd) and aeration (Ae) (0.78), and the highest negative is the correlation between the factors of humidity (Hd) and the variability of humidity (fH) (-0.68) (Fig. 2). There is a significant correlation between the light regime (Lc) and the hemerabicity (Hm) of communities (0.45), which indicates that the share of synanthropic species is higher in sparse stands of tree. On the contrary, a closed tree layer promotes successional processes associated with an increase in the share of forest species. A fairly significant correlation between the light regime (Lc) and the variability of humidity (fH) (0.59) indicates that tree stands of higher closure and maturity contribute to the stabilization of soil moisture, protecting against excessive evaporation in the dry summer.

We conducted a cluster analysis to assess the degree of similarity using phytoindicational indicators of syntaxa as indicator parameters for the assessment of habitats of syntaxon communities of afforestation belts. The dendrogram of similarity of biotopes of the syntaxa of afforestation belts according to their phytoindicational assessment is shown in Figure 4.

As can be seen from Figure 4, the most distinctive, by taking into account our phytoindicational indicators, are the habitat of the association *Chelidonio-Pinetum sylvestris*, which forms a separate group on the dendrogram and doesnt unite with other syntaxa.

The habitats of the associations *Elytrigio repentis-Aceretum platanoidis* and *Poo nemoralis-Tilietum cordatae* are quite close in terms of ecological indicators, and *Elytrigio repentis-Quercetum roboris* and *Sambuco nigrae-Quercetum roboris*, and *Geo urbano-Fraxinetum* and *Balloto nigrae-Ulmetum*. These syntaxa are also close in floristic composition, as evidenced by their position in the syntaxonomic scheme of floristic classification and belong to the same unions. The associations *Chelidonio-Robinietum* and *Chelidonio-Aceretum negundi* joined the group of syntaxa 6–10 in the dendrogram according to the ecological indicators of their habitats and don't form a separate cluster. In general, the similarity of ecological conditions of all syntaxa, except the *Chelidonio-Pinetum sylvestris* association (№ 3), is quite significant. This is due to their formation in similar climatic conditions within the Middle Dnipro Region, and similar edaphic conditions of mainly fertile soils, in particular chernozems and grey forest soils on loess-like loams.

3.3. Ordination analysis of the vegetation of syntaxa of afforestation belts and assessment of the relationship of ordination axes with ecofactors

The ordination diagram syntaxa of afforestation belts obtained using the DCA ordination method (see Methodology) is shown in Figure 5. The vectors of ecological indicators designed in the plane of the first two axes of ordination, were obtained by the method of phytoindication, as described above.

According to the floristic composition of the ordination field, the associations *Chelidonio-Pinetum sylvestris*, *Sambuco nigrae-Quercetum roboris*, *Elytrigio repentis-Aceretum platanoidis*, *Elytrigio repentis-Quercetum roboris* and *Poo nemoral* are located far from the main central group of syntaxa. The biotopes of the first association *Chelidonio-Pinetum sylvestris* differed significantly from the rest also in terms of ecological indicators, as shown in Figure 3. The differences of other associations are due to the different floral composition and features of the layered structure of the tree layer. Although most of the dominant species of the tree layer of the afforestation belts of the Middle Dnipro Region are deciduous species, the lighting conditions in tree stands with a predominance of different species (*Quercus robur*, *Acer platanoides*, *Tilia cordata* etc.) differ significantly; this may explain the floristic differences that cause the different positions of syntaxa on ordination diagrams. The leading role of the light regime, in particular, in relation to its influence on the floristic composition of the afforestation belts syntaxa, is also evidenced by the considerable length and direction of location along the first axis of the vector Lc. As for other factors that were evaluated in phytoindications, their correlation with the axes of ordination is shown in Table 2. In this table, the factors are ranked by r^2 (coefficient of determination), which reflects the degree of correlation with the first and second axes, which account for the maximum variability of the floristic composition of syntaxa.

Table 2 shows that all factors by the level of significance (p-value) are significantly correlated with the loads on the ordination axes, but their contribution is significantly different, as evidenced by the values of r^2. In particular, light regime, humidity and content of nitrogen compounds in soils (which is also an indicator of soil fertility) were included in the list of the first three that most influence the variability of the floristic composition syntaxa of afforestation belts. But, as already noted in the analysis of correlations between ecological factors (Figures 2, 3) and as can be seen from the ordination diagram (Fig. 5) in relation to the relative position of ecofactor vectors, most factors are correlated. The opposite direction of the vectors of light regime, humidity and nitrogen content in Figure 4, indicates a negative correlation between them: drier and poorer soils in the afforestation belts with light tree stands and, conversely, in shady habitats.

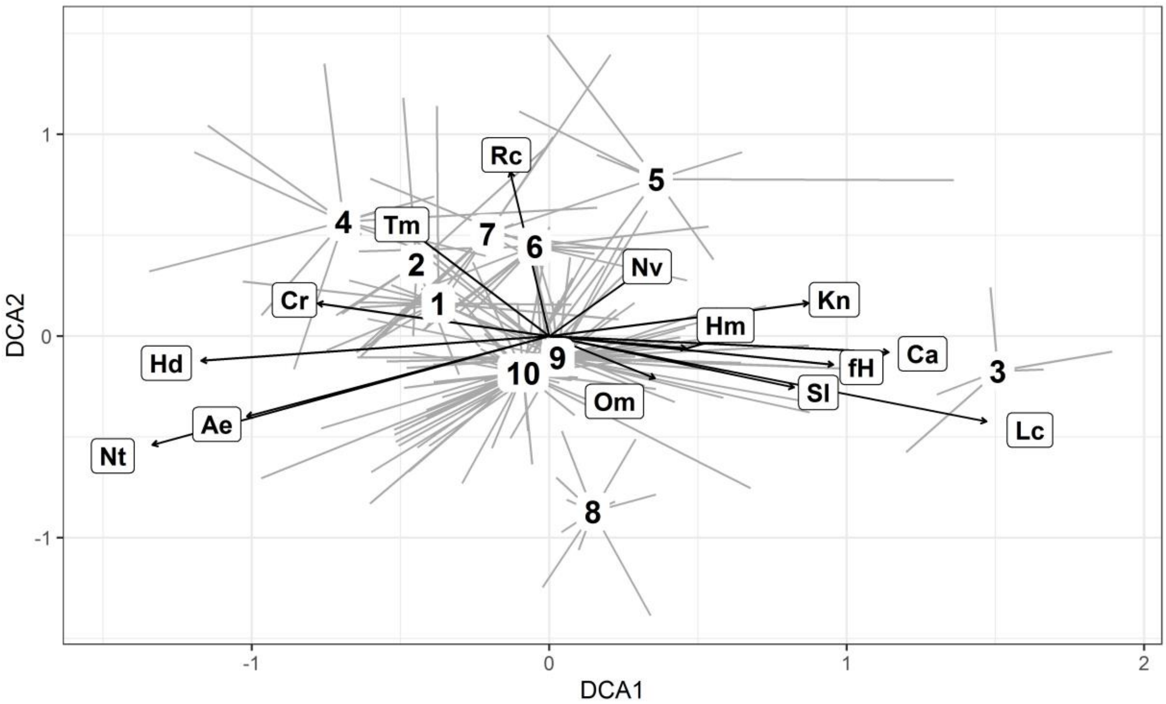

Fig. 5. Ordination analysis (DCA ordination) of the vegetation of afforestation belts syntaxa and projection of axes of ecological factors into the ordinance plane of the first two axes of ordination. Syntaxa numbers and designations of ecological factors are the same as in Table. 1

Table 2. Assessment of the correlation between ordination axes and ecological factors

Ecological factors	cor.dca1	cor.dca2	r2	r.rank	p-value
Lc	0.73	-0.21	0.58	1	1.00E-04
Nt	-0.67	-0.27	0.52	2	1.00E-04
Hd	-0.59	-0.06	0.35	3	1.00E-04
Ca	0.57	-0.04	0.33	4	1.00E-04
Ae	-0.51	-0.20	0.30	5	1.00E-04
fH	0.48	-0.07	0.23	6	1.00E-04
Kn	0.44	0.08	0.20	7	1.00E-04
Sl	0.41	-0.13	0.19	8	1.00E-04
Rc	-0.07	0.41	0.17	9	1.00E-04
Cr	-0.39	0.08	0.16	10	1.00E-04
Tm	-0.23	0.25	0.11	11	2.00E-04
Hm	0.23	-0.03	0.05	12	7.60E-03
Nv	0.15	0.16	0.05	13	1.75E-02
Om	0.18	-0.10	0.04	14	2.41E-02

Legend: cor.dca1, cor.dca2 – correlation of ecological indicators with the first and second ordinance axes, respectively, r^2 – coefficient of determination, r.rank – ranks of ecological indicators in accordance with the values of r^2 and their contribution to the ordination model, p-value – the level of significance of the correlation of the ecological indicator with the ordinate axes

3.4. Ecological features of certain types of communities (syntaxa)

All syntaxa previously identified by us according to the results of vegetation classification were assigned to the class of anthropogenic forest vegetation *Robinietea* (Solomakha & Shevchyk, 2020). It unites groups of artificial tree plantations, tree communities and urban spontaneous tree vegetation, as well as communities of afforestation belts of the plain of Ukraine.

The phytocoenotic characteristics and ecological features of syntaxa, which were established based on the results of phytoindicational assessment, are given below:

The association *Chelidonio-Robinietum*. Phytocoenoses of the association in the Middle Dnipro Region most often occur in 3–5-row interfield and roadside afforestation belts, 8–15 m wide, with a thickened shrub layer formed on grey forest and chernozem soils. The height of the tree layer is from 15 to 30 m, age is 40–90 years, diameter of trunks is 15–90 cm. *Robinia pseudoacacia* dominates in the upper layer, and *Sambucus nigra* in the understory. Due to the relatively late development of the leaves of *Robinia*, these tree stands are quite light. The layer of grasses is dominated by synanthropic annuals and few-year-old species, in particular, *Galium aparine*, *Alliaria petiolata*, *Anisantha tectorum*, *Chelidonium majus*. In ecological terms, these communities have the lowest indicators for the naturalness of the species composition, Nv (30.98, Table 1), and the largest share of synanthropic species, and demutation processes occur most slowly in them. Due to the nitrogen-fixing properties of the main dominant *Robinia pseudoacacia*, these communities have high soil nitrogen (73.00, Table 1).

Fig. 6. *Chelidonio-Aceretum negundi*

The association *Chelidonio-Aceretum negundi* (Fig. 6). These communities are distributed in 1–5-row interfield blown afforestation belts with a width of 6–15 m, on grey forest and chernozem soils. The general condition of the afforestation belts is different, in some trees the tops dry up, with very dense thickets of *Acer negundo*, their height is from 15 to 30 m, age is 40–90 years, diameter of trunks is 20–120 cm. This type of afforestation belt is characterized as being quite shady, the wettest, slightly acidic, quite rich in mobile forms of nitrogen and well-aerated soils (Table 1). Due to high shading in the subordinate layers, regenerative processes in the populations of most tree and shrub species is only weakly expressed. In this regard, such phytocoenoses should be considered one of the worst variants of afforestation belts.

The dominance and regeneration process in populations of trees of non-native origin is determined by the low level of natural phytocoenoses of these associations of *Chelidonio-Robinietum* and *Chelidonio-Aceretum negundi* (Table 1).

The association *Chelidonio-Pinetum sylvestris*. This syntax is represented by vegetation on the territory of the Left Bank Forest-Steppe. It is distributed in 3–5-row inter-field blown afforestation belts, 8–12 m wide, on grey forest soils. The general condition of the afforestation belts is satisfactory, the trees in it are twisted, sparse, often with fall out, their height is from 20 to 27 m, age is 70–80 years, trunk diameter is 20–80 cm. It can be argued that there are no optimal conditions for these tree stands based on the conditions of the plantations. According to a combination of ecological factors, this type of plantation is characterized as the lightest, highly hemerobic with the driest, quite rich in calcium ions and poor in nitrogen soils (Table 1). In the conditions of relatively rich soil nutrition of such forest belts *Pinus sylvestris*, being at the age of 70–80 years, shows signs of ageing, therefore the processes of drying of separate trees are characteristic everywhere. In most areas of these afforestation belts there is recovery in populations of deciduous trees and shrubs, in particular: *Sambucus nigra*, *Pyrus communis*, *Ulmus laevis*, *Morus nigra*. In some places, *Pinus sylvestris* is being restored in areas without competitive deciduous species. Populations of meadow-steppe and meadow coenology species are dominant in the grass layers.

The association *Elytrigio repentis-Aceretum platanoidis*. This community is distributed throughout the study region. It was found in 3–6-row roadside and interfield afforestation belts, mostly overgrown with an undergrowth of trees and shrubs, 7–20 m wide, on grey forest soils and chernozems. The general condition of the afforestation belt varies from satisfactory to excellent, their height is from 22 to 30 m, age is 40–90 years, trunk diameter is 15–80 cm. The activity of the reproductive process in the population of the native dominant species determines the high naturalness of these phytocoenoses. At the same time, intensive immobilization of the main nutrients from the soil causes low values of soil richness for these elements, which is indicated by the types of subordinate layers. The strong aedificatory effect of *Acer platanoides* determines the specifics of the microclimate, namely low variability of humidity and lack of light (Table 1).

The association *Poo nemoralis-Tilietum cordatae*. This community is distributed throughout the study region. It was found in 3–5-row roadside, interfield and riverine blown afforestation belts, 5–10 m wide, on grey forest soils and chernozems. The general condition of the afforestation belt is good, some trees have been cut down, their height is from 20 to 30 m, age is 40–70 years, trunk diameter is 15–70 cm. A characteristic feature of these phytocoenoses is the relatively good recovery of the main tree species in the subordinate tiers, which probably explains the increased degree of naturalness of these phytocoenoses against the background of other afforestation belts (Table 1). The lower layer is characterized by an alternation of large areas of shaded dead cover areas and lit ones, where annual grasses grow with a projected cover of up to 30%.

The association *Geo urbano-Fraxinetum*. Phytocoenoses of this association are widely distributed in the Middle Dnipro Region. It's found in 2–6-row roadside and inter-field blown afforestation belts, which are very overgrown with an undergrowth of trees and shrubs, 4–20 m wide, on grey forest soils and chernozems. The general condition of the forest strip varies from satisfactory to excellent, with some branches and trees dried up, their height is from 20 to 30 m, age is 30–80 years, trunk diameter is 15–90 cm. The restoration of native trees is quite good. According to the main ecological factors, these phytocoenoses occupy a central place in the ordination scheme (Fig. 4). Probably, relatively high levels of acidity and calcium poverty in soils are determined by the specific impact on soils of the main dominant soil species (Table 1). They are characterized by a high level of light at the beginning of the growing season and insufficient light during the second half of summer due to the late leafing and finesse of the crowns of dominant trees. This determines the high constancy and coverage of early spring vegetation with light-demanding perennial plants and winter annual grasses and light-demanding trees and shrubs of the subordinate layer. In the second half of the growing season, the layer of grasses is almost absent. In the phytoindicational tables, this is reflected in the high rate of variability of the humidification regime.

The association *Balloto nigrae-Ulmetum*. This is quite well distributed in the study area. It was found in 3–6-row interfield blown afforestation belts on grey forest and chernozem soils. The general condition of the afforestation belts is different, from satisfactory to excellent, many branches and trees dry up, their height is from 20 to 30 m, age is 50–70 years, trunk diameter is 20–70 cm. Phytocoenoses are represented by artificial, mostly dead-cover communities. They have formed on the slopes at the junction of forest and sand terraces with deteriorating rainfall conditions and sharp changes in winter and summer temperatures, which determined high acidity, good aeration and appropriate cryoregime of soils (Table 1).

The association *Alliario petiolatae-Ptelietum trifoliatae*. This has a wide distribution in the Middle Dnipro Region. It was found in 3–5-row interfield afforestation belts, which are very overgrown with shrubs, 6–12 m wide, on grey forest and chernozem soils. The general condition of the afforestation belt is good or excellent, some have branches and trees dried up. Their height is from 22 to 27 m, age is 50–90 years, trunk diameter is 15–90 cm. Phytocoenoses of this association are formed in areas with sharply changing moisture supply in different seasons (sufficient moisture in spring and a fairly high deficit of moisture in summer). It represents artificial *Quercus robur* plantations on levelled areas with a dense layer of undergrowth, formed mainly by *Ptelea trifoliata* and *Sambucus nigra* with an admixture of other shrubs. The layer of grasses dominated only by shade-tolerant nitrophilic hemicryptophytes and geophytes, as well as low-growing undergrowth of shrubs and trees. The absence of many heliophilic species is due to strong shading of shrubs. The small number and insignificant role in these phytocoenoses of ever-growing species during the summer indicates a low level of continental microclimate (Table 1).

The association *Elytrigio repentis-Quercetum roboris*. This is quite widely distributed in this area and is found in 3–5-row interfield blown afforestation belts, 8–20 m wide, on grey forest or chernozem soils. The general condition of the afforestation belt is good (trees grow sparsely) or excellent, their height is from 12 to 27 m, age is 40–90 years, trunk diameter is 15–90 cm. As a rule, phytocoenoses of the association is confined to sloping areas. Their floristic similarity is explained by the highest level of light supply during the growing season, which is confirmed by the position of these phytocoenons in the plane of ordination by various factors. The dominant role in the grass layer belongs to such optional heliophiles as *Elytrigia repens*, *Anisantha tectorum*, *Taraxacum officinale*, *Poa pratensis*, *Artemisia absinthium.* Also, these phytocoenoses are characterized by a relatively rich representation of the obligate heliophytes group. In general, this block of phytocoenoses are characterized as fairly dry and light communities on slightly depleted if mobile nitrogen soils with a high richness of other nutrients, including calcium (Fig. 4). They are also characterized by a fairly high indicator of the continentality of the microclimate and high variability of the humidity regime at low rates of soil aeration (Table 1).

The association *Sambuco nigrae-Quercetum roboris* (Fig. 7). This syntax is the most well distributed and is represented in the Middle Dnipro Region. It is found in 2–6-row interfield and roadside afforestation belts, which are very overgrown with an undergrowth of trees and shrubs, 6–20 m wide, on grey forest and chernozem soils. The general condition of the afforestation belt is from satisfactory to excellent, trees grow infrequent, they dry up or have been cut down, their height is from 15 to 30 m, age is 40–90 years, trunk diameter is 15–90 cm. This type of community is formed in areas sufficiently rich in mineral nutrition soils and sufficient moisture in the first half of the growing season. An important and determining factor in their structure and functioning is the high level of light provided by shrubs and grasses due to the dominance of trees in the upper layer with late leaf onset. These communities are most grouped on gradients of different ecological factors (Fig. 5). They aren't characterized by extremes of most ecological factors, except for soil aeration (Table 1).

Fig. 7. *Sambuco nigrae-Quercetum roboris*

4. Conclusions

We conducted a phytoindicational assessment of afforestation belt vegetation communities. Ecologically, they differ from young artificial plantations because they are more mature in age and more differentiated in the layered structure of the forest, and from natural forests because they have not reached equilibrium succession and sylvestral processes have not reached the level of natural forests.

The ecological features of the vegetation communities of afforestation belts were determined by the mutual influence of ecological factors of different origin and the scale of their impact.

Among all the studied types of communities, the most ecologically different conditions were found in the community of the association *Chelidonio-Pinetum sylvestris*. This is characterized by the most extreme (minimum or maximum) values of phytoindicational indicators, including humidity, nitrogen regime (minimum indicators), light regime and the variability of humidity (maximum indicators).

Regarding the average (background) values of ecofactors, taking into account all studied syntaxa, the communities of afforestation belts are characterized by high levels of soil nitrogen, which is typical for anthropogenic communities, and minimal soil aeration. In terms of correlations between environmental factors, they are quite significant in general for most indicators, in particular in the absolute value of correlations between soil moisture and aeration and humidity and moisture variability. According to phyto-indicational assessment, cluster analysis of habitats of afforestation belts proved to be quite similar, taking into account all ecological factors, on the one hand. On the other hand, the distribution is mainly due to the predominant timber species, such as deciduous trees, light stands of robinia and pine, and ash-maple afforestation belt, which are ecologically closer to afforestation belts with a predominance of deciduous species than robinia stands.

According to the ordination analysis, it was found that the three factors that most closely correlate with the ordination axes are light regime, soil nitrogen and humidity. These factors can be considered the main factors influencing the floristic composition of communities, especially the grass layer. Thus, the phytocoenoses of the afforestation belts of the Dnipro Forest-Steppe are currently a very specific component of the forest biome of this region. Since they are artificially created, they are now quite young and poorly differentiated in terms of ecological differentiation. Conversely, due to the significant time since their formation, they have acquired the features of natural forests, in particular the presence of some forest species and a clear layer structure with distinct shrub and grass layers.

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