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Analysis of the floristic composition of the afforestation belts of the Left-Bank Middle-Dnipro region of Ukraine

The paper is dedicated to the memory of V. A. Solomakha, an outstanding Ukrainian scientist, a well-known specialist in the field of phytosociology and phytosozology, Doctor of Biological Sciences, Professor, laureate of M. G. Kholodny Prize of the National Academy of Sciences of Ukraine.

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Abstract: The species composition and the floristic structure of afforestation belt vegetation of the Left-Bank Middle-Dnipro region of Ukraine were studied. The data was obtained during geobotanical studies of forest belts conducted in 2019–2021. A quantitative analysis of the taxonomic, biomorphological structure and diagnostic species proportions of vegetation classes is presented with a detailed analysis of the anthropophyte fraction. The studied vegetation has transitional features between anthropogenic forests and natural broad-leaved forests. On the one hand, we noted the predominance of native species in tree and shrub layers with a differentiated layer structure and the predominance of a competitive type of strategy. On the other hand, we have established a relatively poor or even monotypic species composition with a significant participation of indigenous synanthropic as well as alien species in the herbaceous layer. The studied forest belts represent a distinctive and quasi-stable type of forest vegetation that requires further syntaxonomic study.

Keywords: afforestation belts, floristic structure, alien and invasive species, Forest-Steppe zone.

Introduction

Forest belts play an important role in the Forest-Steppe landscape of Ukraine, where natural vegetation on watersheds is destroyed and replaced by agricultural land. They perform an environment-forming and landscape-stabilizing function and serve as a habitat for other organisms, including birds. The combination of all these factors contributes to the active research and preservation of protective afforestation belts in many countries and it is relevant today.

Data about the creation, research and reproduction of afforestation belts has a long history. Afforestation belts were actively created in the USA, China, Canada, and Europe, and anti-erosion forest belts were created in Denmark and Germany (Lyubenova 2019). The first anti-erosion belts in Romania were in the 19th century, and in the middle of the 20th century the length of the afforestation belts in Dobrudja, Romania, reached 4500 km (Bucur 2016; Popov et al. 2017). Active government policies and subsidies for the creation of afforestation belts are currently being implemented in China, Australia and Canada (Dobrev & Peshev 1957; Peev 1990; Stancheva et al. 2004; The Global Forest Goals Report 2021). Already in the 1930s, several countries (e.g. Romania, Bulgaria, Moldova and former Yugoslavia) created and continued projects to create protective afforestation belts (Dobrev & Peshev 1957; Bucur 2016; Haensel & Spitoc 2016; Lyubenova 2019; State aid 2022).

Artificial shelterbelts effectively perform anti-erosion and water-regulating functions and are a characteristic landscape component of the Forest-Steppe and Steppe zones of Ukraine. The creation of new and regenerating shelterbelts in many European countries is considered a way to improve the overall environmental condition (Weber 2000). The issue of preservation and restoration of afforestation belts is also important for many regions of Ukraine (Dubyna et al. 2023; Goroshko et al. 2023). On average, forest belts in the country are 1.3%, and in the Forest-Steppe zone – 1.0% (Vysotska et al. 2019).

Although in relative terms the area of forest belts is insignificant, this type of vegetation is of great interest from the point of view of studying the processes of demutation of forest vegetation. The vegetation of the afforestation belts of Ukraine is insufficiently studied, and there are only fragmentary data available now (Marcenuyk 2013; Strelchyuk & Boiko 2015; Solomakha & Shevchyk 2020; Goncharenko et al. 2022).

Insufficient knowledge of this type of vegetation in general (Godovanyuk 2013; Listopadsky 2015), the possibility of studying the restoration and succession processes of forest vegetation in specific zonal and climatic conditions, and the active spread of alien species along the “channels” of forest belts prompted us to conduct a comprehensive study of forest belts.

The purpose of the study is to analyze the floristic composition and structure, including the distribution of invasive species in the vegetation of forest belts in the Forest-Steppe zone of Ukraine.

Material and Methods

The study region is located in the central part of Ukraine, namely, within the Left-Bank Forest-Steppe. The studied territory is located within the zone of broad-leaved and mixed forests of the East European Province (Popov et al. 1968). It is located in the valley of the Dnipro River and stretches in a wide almost 300-kilometer strip from southwest to northeast (Khilchevskyi et al. 2014). In administrative terms, the territory of the studied region covers Kyiv and Cherkasy regions (Fig. 1).

The territory of the Left-Bank Forest-Steppe belongs to the temperate climate zone (Khilchevskyi et al. 2014). The study area belongs to three geostructural regions: the Ukrainian Crystalline Shield, the Dnipro-Donetsk Basin and the southwestern slopes of the Voronezh Crystalline Massif (Marynych & Shyshchenko 2005). Typical chernozems are widespread, occupying the ancient terraces of the Dnipro and all the watersheds of its tributaries to the spurs of the Central Russian Upland (Balaiev et al. 2005; Pankiv 2017).

The vegetation is dominated by oak-maple-linden and oak forests, meadow and marsh vegetation in the river valleys, meadow steppes and salted meadows (Barbarych 1977; Konyakin & Chemeris 2013; Martyn et al. 2015).

Forest belts are represented by linear protective forest plantings. The most common are blown, openwork and openwork-blown, having from three to six rows with a width of 7.5 to 15 meters (Furdychko & Stadnyk 2012). Most forest belts are located along field boundaries in flat conditions (Fig. 2).

Fig. 1 Schematic map of the study region.

We worked with afforestation belts with a predominance of ages from 40 to 60 years. *Quercus robur* is the main tree species used in the creation of forest belt plantations, as well as *Robinia pseudoacacia*, *Acer platanoides*, *Tilia cordata*, *Fraxinus excelsior*, *Ulmus laevis*. Plantations dominated by *Pinus sylvestris*, *Fraxinus pennsylvanica* and *Ulmus minor* were also found.

The data were obtained during the geobotanical surveys conducted in 2019–2021. The material represents the total floristic composition of 285 geobotanical sites (relevés) with an area of 100–400 m^2. The projected coverage of species was recorded according to the Braun-Blanquet scale (Braun-Blanquet 1964). The results of the vegetation classification of afforestation belts were given in our previous papers (Solomakha & Shevchyk 2020; Goncharenko et al. 2022).

The general list of species and the alien fraction of vascular plants were analyzed separately. The taxonomic structure was described by the ratio of the number of species from different families, which is traditional for floristics (Tolmachev 1941, 1986). Using Raunkiaer's system, an analysis of the biomorphological structure of the flora of forest belts was carried out (Raunkiaer 1937). The proportion of plant-based strategies was analyzed using the Grime's system (Grime 1977). The ratio of stress-tolerant species to ruderal strategies was estimated as an indicator of successional stages using the formula: ISR = (S – R) / (S + R); S – number of stress-tolerants, R – number of ruderals (Goncharenko 2017).

The EuroVegChecklist was used as a basis for classifying species between vegetation classes (Mucina et al. 2016). The ratio of diagnostic species from different vegetation classes reflects the directions of successional processes in the transitional vegetation (Goncharenko et al. 2013).

Fig. 2 Typical location and appearance of afforestation belt in the landscape of the Forest-Steppe zone.

In the alien fraction, analysis by time of invasion according to the Kornaś classification was used (Kornaś 1968). We distinguish two groups: archaeophytes and kenophytes.

According to the degree of naturalization of alien plant species, we follow the Schroeder system (Schroeder 1969), modified by Protopopova & Shevera (2005). We distinguish the following groups: agriophytes (naturalized in semi-natural and natural communities); epecophytes (completely naturalized on anthropogenic ecotopes); colonophytes (with more or less stable local colonies on anthropogenic ecotopes); ephemerophytes (with a weak degree of naturalization, sometimes locally appear in different areas) and ergasiophygophytes (introduced species that have been deliberately attracted into the local flora).

The classification of alien species follows Richardson et al. (2000), which reflects a biological phenomenon associated with the species' overcoming certain barriers in the process of naturalization (geographical, reproductive and coenotic barriers).

The nomenclature of vascular plant species was unified according to POWO (https://powo.science.kew.org/), authors of the taxa are cited in the Appendix. The names of syntaxa correspond to the EuroVegChecklist (Mucina et al. 2016).

Results and Discussion

Taxonomic structure

In afforestation belts, we recorded a total of 267 species of vascular plants belonging to 183 genera, 57 plant families. This indicator is lower than for natural forests in similar climatic conditions. For example, 294 species of vascular plants are noted for the forest coenoflora of the Cherkasko-Chyhyrynsky geobotanical district (Gaiova 2005). 349 species are recorded in the classes *Carpino-Fagetea* and *Robinietea* for the Kaniv Nature Reserve (Shevchyk et al. 1996). Smolyar (2000) indicates 206 species for the *Asaro-Quercophytum* forest coenoflora. The forest flora of Romny-Poltava geobotanical district has 680 species (Davydov 2013).

The first three families include 79 species, which is 29.6% % of the total number of species. The leading role of Asteraceae and Poaceae is characteristic of the Holarctic flora (Tolmachev 1974; Schmidt 1980; Didukh 1992). Considering that forest belts of small width have blowing character and are located on open ground, also explains the large number of species of Asteraceae, most of which are anemochores. In addition, there is evidence that a high content of Rosaceae species is characteristic of forest-type coenoflora (Didukh & Plyuta 1994). The 10 leading genera include 46 species, which is 17.2% of the total species list. The highest numbers of species are concentrated in *Prunus* (9 species), *Acer* (6 species), *Viola*, *Silene*, *Carex*, *Sonchus*, *Ribes*, *Campanula* and *Poa* (4 species in each). The predominance of the *Prunus* is a characteristic feature of the afforestation belt vegetation. In general, the majority are nemoral and boreal-nemoral elements of a wide geographical area of distribution.

The first ten families count 156 species, or 58.3% of the total species list (Tab. 1).

Tab. 1 Taxonomic structure of the floristic composition of the afforestation belt vegetation.

№	Family	Number of species	% of the total number of species	% of the first 10 families	Genus	Number of species	% of the total number of species	% from the first 10 genera
1	*Asteraceae*	35	13.1	22.4	*Prunus*	9	3.4	19.6
2	*Rosaceae*	23	8.6	14.7	*Acer*	6	2.2	13.0
3	*Poaceae*	21	7.9	13.5	*Viola*	4	1.5	8.7
4	*Apiaceae*	16	6.0	10.3	*Silene*	4	1.5	8.7
5	*Brassicaceae*	14	5.2	9.0	*Carex*	4	1.5	8.7
6	*Lamiaceae*	12	4.5	7.7	*Sonchus*	4	1.5	8.7
7	*Fabaceae*	12	4.5	7.7	*Ribes*	4	1.5	8.7
8	*Caryophyllaceae*	11	4.1	7.1	*Campanula*	4	1.5	8.7
9	*Boraginaceae*	6	2.2	3.8	*Poa*	4	1.5	8.7
10	*Sapindaceae*	6	2.2	3.8	*Geranium*	3	1.1	6.5
	Total	156	58.3	100	Total	46	17.2	100

Frequency distribution, layer structure, and dominant species

The distribution curves of the first 10 most constant species in each stratum are shown in Fig. 3. Table 2 shows the 10 species with the highest occurrence in each layer.

The curves for the tree and shrub layers have an initial segment that drops off sharply. This indicates a more pronounced dominance of several species and correlates with intense competitive relationships in these layers.

Despite the artificial origin of the afforestation belts, natural species predominate in the tree and shrub layer, while the herb layer is formed mainly of synanthropic species.

Thus, *Quercus robur*, *Fraxinus excelsior*, *Ulmus laevis*, *Acer platanoides* dominate in the tree layer and *Acer tataricum*, *Crataegus rhipidophylla*, *Euonymus europaeus*, *Cornus sanguinea* predominate in the shrub layer. In general, the predominance of these species is also characteristic of the afforestation belts of the Middle-Dnipro

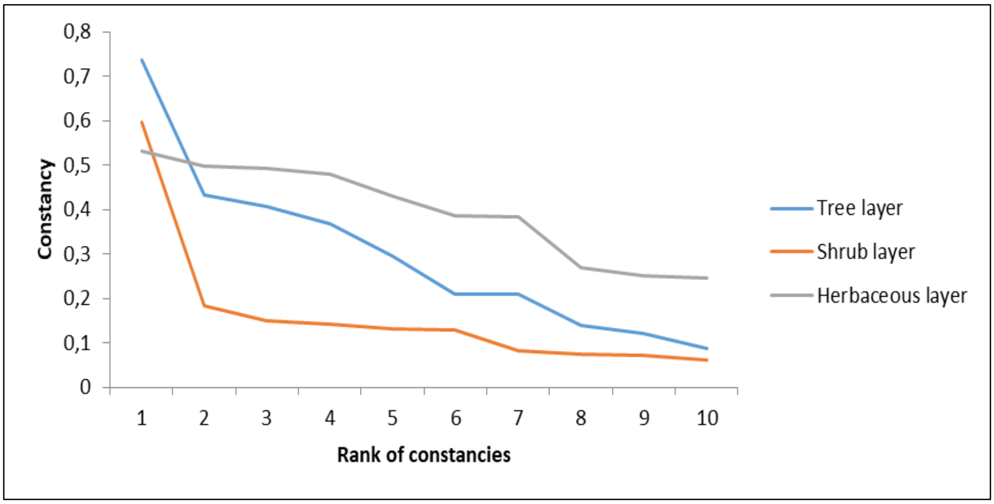

Fig. 3 Distribution curve of the most constant species in each layer of the afforestation belt vegetation.

Tab. 2 Most constant species in each layer in the afforestation belt vegetation (Freq. – relative frequency).

Tree layer	Freq.	Shrub layer	Freq.	Herbaceous layer	Freq.
Quercus robur	0.74	*Sambucus nigra*	0.60	*Ballota nigra*	0.53
Fraxinus excelsior	0.43	*Acer tataricum*	0.18	*Chelidonium majus*	0.50
Acer negundo	0.41	*Crataegus rhipidophylla*	0.15	*Elymus repens*	0.49
Ulmus laevis	0.37	*Euonymus europaeus*	0.14	*Geum urbanum*	0.48
Acer platanoides	0.29	*Cornus sanguinea*	0.13	*Urtica dioica*	0.43
Morus alba	0.21	*Prunus spinosa*	0.13	*Galium aparine*	0.39
Pyrus communis	0.21	*Rhamnus cathartica*	0.08	*Lactuca serriola*	0.38
Robinia pseudoacacia	0.14	*Sorbus aucuparia*	0.07	*Anthriscus sylvestris*	0.27
Tilia cordata	0.12	*Ptelea trifoliata*	0.07	*Artemisia vulgaris*	0.25
Prunus avium	0.09	*Rubus caesius*	0.06	*Poa nemoralis*	0.24

region (Solomakha & Shevchyk 2020). Although they were planted, the predominance of natural nemoral species in the vegetation of the studied forest plantation indicates favourable conditions for their successional restoration in the forest-steppe zone. A distinctive feature of the southern afforestation belts is the significant role of *Fraxinus excelsior*, which is quite demanding on soil fertility. Several dominant tree species, particularly *Acer negundo* and *Robinia pseudoacacia* are not native to the region. *Acer negundo* is self-seeded and planted in places with pronounced soil erosion. It is actively spreading in the studied vegetation, especially in places of windbreaks, along the forest edges and human-destroyed communities.

The most frequent dominants in the shrub layer are *Sambucus nigra*, *Acer tataricum*, *Crataegus rhipidophylla*, *Euonymus europaeus*, etc. (Tab. 2). All these species are native to the region, but their origin in forest belts is secondary, here they appeared through spontaneous introduction.

The situation is quite different in the herb layer, where nemoral species are absent. *Ballota nigra*, *Chelidonium majus*, *Elymus repens*, *Geum urbanum*, *Urtica dioica* and others are dominated here. They are nitrophilous and the growth of these species in forest belts is facilitated by fertile soils in the region.

Proportion of plants of different life forms

The dominant biomorph is hemicryptophytes (34%), which is explained by a greater diversity of herbaceous species (Fig. 4).

The share of phanerophytes is quite significant (22%) and they are in the second position. The share of therophytes is 12%, which is explained by the artificial origin of forest belts and constant anthropogenic load in the zone of contact with agrophytocenoses. But they are inferior to perennial plants. This is a consequence of the late successional stages of the studied afforestation belts. Most of the therophytes are concentrated on forest edges, on the border with arable lands.

Proportions of species of different plant strategies

The dominant plant strategy is C-type, which indicates a significant tension of competitive relations in the studied vegetation with a formed layered structure (Fig. 5).

Ruderals are not abundant and are displaced by the more competitive species. There are also few quotas for a stress-tolerant strategy. A ratio of stress-tolerant to ruderal strategies, ISR = (S–R) / (S+R) = (0.29 − 0.27) / (0.29 + 0.27) = 0.04. A near-zero value is characteristic of the vegetation in the intermediate demutation stages.

Proportions of diagnostic species of different classes of vegetation

The distribution of species that are diagnostic for different classes of vegetation is shown in Fig. 6.

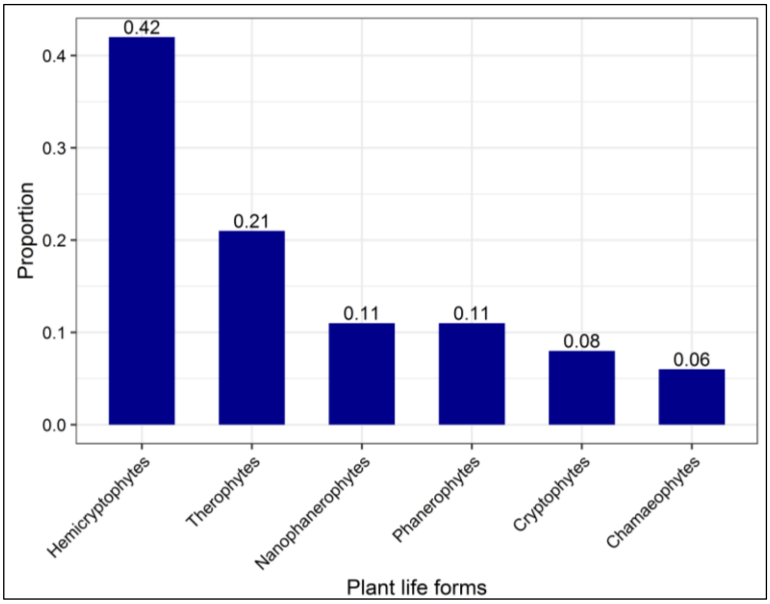

Fig. 4 Proportions of species of different biological types.

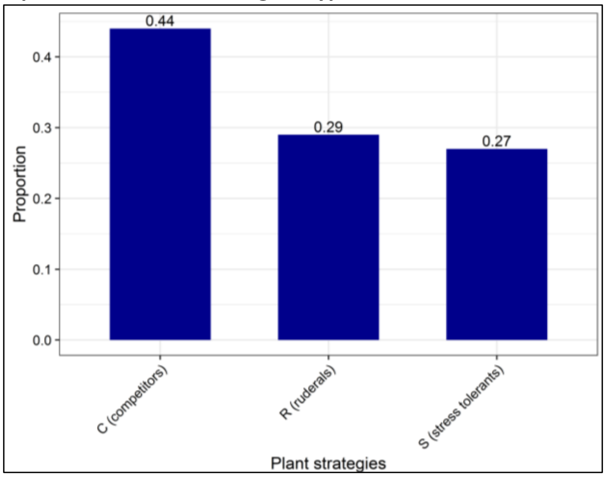

Fig. 5 The ratio of species of different plant strategies.

The share of the ten leading classes of vegetation is 0.96, or 96%. Thus, the first ten classes sufficiently characterize the phytosociological structure of the vegetation of the afforestation belts. Class *Carpino-Fagetea sylvaticae* is on the first position and marks the main direction of succession of the studied vegetation towards a nemoral class that is zonal in the region. The species of *Molinio-Arrhenatheretea* class is on the second position (0.12, Fig. 6). A significant proportion of meadow species is explained by favourable light conditions in open plantings. The significant influence of the light regime is also confirmed by the *Crataego-Prunetea* class, which took third place. Quite a high position of the *Robinietea* class (10%) is explained by the artificial origin of afforestation belt vegetation and permanent anthropogenic impact (Solomakha 2015; Dubyna et al. 2023). Its representatives have a high occurrence, significant projective coverage and are present in all layers. The share of other synanthropic classes (*Epilobietea angustifolii*, *Artemisietea vulgaris*, *Sisymbrietea*) depends on a degree and is an indicator of the level of anthropogenic impact.

Alien fraction of the floristic composition of the afforestation belts

The alien fraction is represented by 59 species, which is 25% of the total number of species. Kenophytes prevail (36 species) and archaeophytes number 23 species. The predominance of kenophytes is related to both historical factors and internal (biocoenotic) reasons, which makes them open to active invasions.

Given the considerable overall length of the forest belts, the presence of alien species should be considered a threat to the native flora of the region due to the possibility of rapid migration of alien species through such long "channels" and the role of forest belts as potential rooting centres for new alien species.

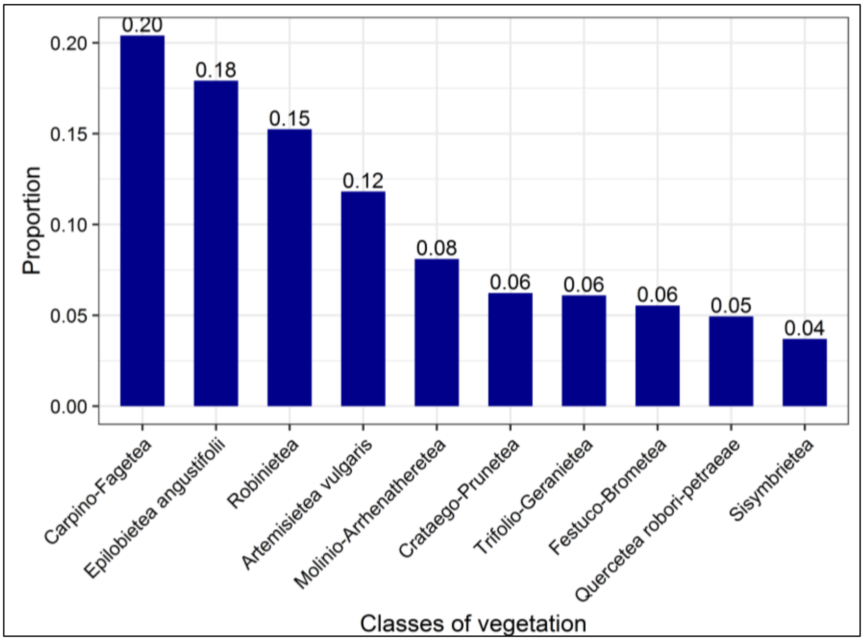

Fig. 6 Distribution of diagnostic species of different classes of vegetation.

The alien fraction is dominated by the epoecophytes – 36 species (61%), ergasiophygophytes – 11 species (19%) with less numerous agriophytes and ephemerophytes – 4 species each (7%), agrioepoecophytes – 3 (5%) and colonophytes – 1 (2%).

Agrio-epoecophytes are mainly kenophytes – *Acer negundo* (North American origin), *Impatiens parviflora* (Central Asian origin), and *Saponaria officinalis* (Mediterranean origin). Agriophytes are only 4 species (7%), all of them are kenophytes, two of which are of North American origin – *Stenactis annua* and *Quercus rubra*. It is worth noting that not all species, despite the high degree of naturalization in the studied territory, are active in spreading. The total share of epoecophyte, agriophytes, agrioepoecophytes, and colonophytes makes up the majority of the entire species composition of the alien fraction of the flora of the forest shelterbelts (75%), which is a stable component. The unstable component of the alien fraction consists of ephemerophytes and egasiophigophythes (15 species, or 25%).

The problem of active intruders deserves special attention (Protopopova & Shevera 2019). In the studied forest belts, the most active transformative role was demonstrated by such species as *Acer negundo*, *Quercus rubra*, *Ambrosia artemisiifolia*, *Amorpha fruticosa*, *Parthenocissus quinquefolia*. Most of the mentioned invasive species (*Acer negundo*, *Ambrosia artemisiifolia*, *Asclepias syriaca*, *Parthenocissus quinquefolia*) exhibit the same aggressive and transformative tendency in the Romny-Poltava geobotanical district as a whole (Dvirna 2015). Most invasive species recorded in forest belts have a wide ecological amplitude and high ecological plasticity, which allows them to successfully naturalize and spread in heterogeneous conditions.

Conclusion

We have studied the structure and species composition of forest belts in the Left Bank of the Middle-Dnipro region of Ukraine, as well as their alien fraction. The predominant direction of succession of forest belts in the studied zonal-climatic conditions is directed towards broad-leaved forests, which are zonal in this part of the region. This is clearly visible only for old-growth forest belts and under the condition of a closed tree layer with a predominance of planted nemoral species. The taxonomic, biomorphological and phytosociological structure of the flora of the predominant majority of the studied forest belts characterizes this vegetation as a transitional type of communities, combining features of anthropogenic and natural forests.

On the one hand, we noted a significant proportion of alien species, predominance of non-forest, meadow or synanthropic species in the herbaceous layer, and relative impoverishment of the species composition. All these features bring forest belts closer to anthropogenic forests, to which they are also close in syntaxonomic terms. On the other hand, features characteristic of forests of natural origin are observed a differentiated canopy structure, a significant proportion of phanerophytes and nanophanerophytes and a relatively small number of therophytes in closed forest belts. The main factors that determine the variation in species composition in forest belts are: the age of the plantings, the dominant species of planted trees, the width (row) of the forest belt, which affects the light regime, distance and nature of agrophytocenoses.

Despite the relative duration of the formation of forest belts, we noted that alien species retain and strengthen their positions in them. Considering the significant total length of forest belts and the absence of native vegetation on watersheds, the latter pose a potential threat as possible migrants, including species that can cause outbreaks or transform communities.

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