

## STUDY OF SYNANTHROPIC PLANTS OF THE SOUTH URAL

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**ABSTRACT:** The present study aimed to assess the long-term dynamics of the synanthropic vegetation of the road and path network of the Ilmen State Reserve. The analysis of the synanthropic species spread among coenofloras of the elements of the road and path network revealed an increasing synanthropization index in the gradient of the stress factor for all forest types. Pine forest is the most resistant to the introduction of synanthropic species. The paper considers the element composition in the period before seed formation. 10 weeds most common in the central regions of Russia were analyzed. The studied weeds can accumulate metals in their green mass. Some wild plants are potentially resistant to metals, as they can grow on heavily dirty substrates. The analysis of the vegetational metals shows that most of the species do not translocate metals into their overground part, so they act as excluders. Due to the human-made impact on the natural landscape, synanthropic species of plants are taking a significant place in the structure of biodiversity.

*Keywords: Reserve, Synanthropic Plants, Anthropophytes, Apophytes, Metal Concentration*

### 1. INTRODUCTION

There has always been increased interest in ruderal plants. The structure and composition of vegetative cover is irreversibly affected by human activity. Weeds strangle cultivated plants, absorbing large amounts of water and nutrients from the soil, discharging harmful substances from the roots, and blocking light. But the problem has not been studied comprehensively. Natural reserves are not the solution, as phytocoenosis can't but be affected by human activity even in a conservation area [1]. In economic and scientific activities, the main line used for preventing fires is connected with the process of invasion. The Ilmen State Reserve, which serves as a reserve for the gene and coenobank of South Ural region vegetation and a standard of common vegetation communities that, as part of environmental monitoring, may be compared with other territories' phytocoenosis under various human impact, is not an exception [1], [2].

The vegetation composition and structure on paths and roads are different. Species diversity and weed abundance are directly connected to their usage. Roads and paths are the place where "alien" species (or anthropophytes) invade the natural vegetation. As a result, separate species of native flora (apophytes), adapting to human-made impact, alter their coenotic positions. According to some researchers, these plants become dominant in new communities and oust common species [2]. Along with these transformations, synanthropization of the Reserve's vegetative cover occurs. The flora is degrading, derived communities are replacing the native, and phytocoenosis stability is declining.

Since many synanthropic plants were reported to accumulate heavy metals, the nature of soil is changing [3]. The problem of heavy metal accumulation by synanthropic plants is of current interest. Researchers all over the world have come to study heavy metal concentration in weeds. Some wild plants are potentially resistant to metals, as they can grow on heavily polluted substrates [4]. Both climate diversity and increasing human-made impact on natural ecosystems explain the high adaptability of synanthropic plants [5].

The growing interest of scientists in Russia and former Soviet republics in studying synanthropic flora is connected, first of all, to the increased role of synanthropic species of plants in the regional floras, secondly, to the influence of floristic schools of Central and Northern Europe that have achieved much in the sphere. Adventitious and synanthropic plants are well-studied in Primorsky Krai and some other regions [6]. There are some open questions concerning synanthropic species in phytogeography, ecology and phytocoenology.

The efficiency of monitoring the vegetative cover and tracking the natural (by anthropophytes) and cultivated (introduction) enrichment of local flora depends on working out the theory of synanthropization of the vegetative cover. Investigating these issues in the South Ural region seems to be important, as the territory is a complex structure of climatic, ecological, and phytocoenotic factors with a focus on the high ecological flexibility of species. This paper is aimed at studying heavy metal accumulation by the synanthropic vegetation in the road and path network of the Ilmen State Reserve and finding out

the instances of the growth of their ecological and phytocoenotic positions.

The study of adaptability given human-made transformation of the vegetative cover is crucial for defining ecological and phytocoenotic positions of synanthropic species. It is important to identify the chemical and biological features of ruderal plants in a natural geographic habitat and in the newly developed territories of the road and path network of the Ilmen State Reserve.

## **2. METHODS**

### **2.1 Study Area**

The Ilmen State Reserve is located on the eastern South Ural macroslope between the latitude of 54° 58' – 55° 20' north and longitude of 60° 07' – 60° 21' east. It's a part of the South Ural physiographic region of the Ural highlands. The Reserve is a refuge for many endemic and extinct plants and for rare and protected species.

The complex history of the evolution of the South Ural fauna in the Quaternary Period and the Ilmen mountains unique borderline location between mountain (forest) and piedmont (forest-steppe) parts of the region allow the invertebrate animals, diverse in species and complex in composition, to evolve. In that context, the phenomenon of "rich local invertebrate fauna of the Ilmen mountains" is worth mentioning.

In the terrain analysis of Chelyabinsk region, the Ilmen State Reserve is a part of the erosion and denudation landscape of eastern foothills of South Ural that evolved on the eruptive rocks. The South forest division is located in the south terminal ridge of the Ilmen mountains, which is a mild terrace slope with a steep on the Ilmenskoye lake. The abundant flora and phytocoenosis diversity of the site is caused by the borderline location between steppe and forest-steppe zones, challenging landscape, various rock formations. The site's landscape is longitudinal-ridge-steep-sloping (400–300 m above sea level). According to the phytogeographical analysis, the South forest division is located in mixed forests of the preforest-steppe pine and birch forests subzone of the south taiga forests zone. On the west, the subzone borders on dark coniferous forests of dividing ridges, on the east – on forest-steppe of trans-Ural peneplain [7]. The variegated vegetative cover was formed under the challenging climate and landscape.

The data were gathered in 9 biotopes [7].

### **2.2 Characteristic Features of Vegetation**

The Ilmen State Reserve is 90 % covered by forests, which can be classified as South Ural preforest-steppe pine and leafed-pine forests. The main forest-forming species are pine and birch, covering 56 % and 40 % of the territory of the Reserve, respectively. The territory of road and path vegetation is 6.4 % of all the Reserve's area [1].

Scotch pine (55 %) and European white birch (40 %) mainly constitute forests. Herb-grass, green moss, green moss-vaccinium (close to the original) and steppified biotopes are presented in the forests. Peat-bog and bog-moss pine forests are seen in the wetlands. European white birch and European aspen make young growth with herbs and grass at logging sites. Grass-pine and sedge-reed-sphagnum biotopes are seen in valleys, lakesides, and bogs. Such meadow herbs as various grasses (bluegrass, bentgrass, cocksfoot grass), many legume species, buttercups, globeflowers, meadow cranesbills, syndows, etc. are found at the outskirts of the forest.

Being diverse and numerous, bogs don't cover large territories. Almost all of them appear at the sides of "aged" lakes or former bays thereof. Some of them occupied by reed-sedgy formations still have the character of floating bogs. More developed bogs are characterized by the presence of sphagnum moss, bog low shrubs, and herbs specific for taiga bogs such as bog rosemary, swamp ledum, bog cranberry, moorberry, *Scheuchzeria palustris*, roundleaf sundew, mud sedge, whortleberry willow, white beak sedge, English sundew, cloudberry, and blueberry. Sometimes trees (birch, suppressed pine) are seen. Water and coastal water vegetation is rich and diverse. There are about 70 species of water macrophytes [1], [2]. Macrophyte vegetation is developing in shallow water in bays of the littoral zone of open shores.

### **2.3 Research Methods**

The research was conducted in 2015–2016. Standard methods were used to collect data. Sampling points were selected based on the landscape features, vegetation spread and human-made impact. Expedition trips were planned based on natural zone analysis, remote sensing of the earth (Landsat/ETM+ satellite images) with a landscape diversity assessment.

Road and path network with complexes of vegetation communities was chosen for analysis. 6 permanent sampling sites in glague-herb-gramineous birch forests and pleurocarpous moss herb-gramineous pine forests and 3 types of roads (unsurfaced road, forest road, and foot path) were

described. The routes cover 10 km in total. Geo-referenced data integration and correlation were completed with a geographic information system (GIS). A total of about 100 plant samples were described. The area of the studied stations was more than 25m<sup>2</sup>.

The number of species, projective cover (%), species abundance (according to Drude), and share of synanthropic species were determined for every 10 m<sup>2</sup> structural unit of the road. The level of phytocoenosis synanthropization was assessed based on the synanthropic species share (synanthropization index). An assessment scale of the synanthropization of vegetation communities [8] was used: I – human-made impact is low, synanthropic species up to 15 %; II – human-made impact is considerable, 16 % to 60 % synanthropic species; III – human-made impact is long-term and high, synanthropic species are dominant - 61 % to 100 %. Species grouped by coenotic and ecological similarity of ecotopes [9] and forming communities on separate parts of paths and roads are meant as coenoflora.

#### 2.4 Sampling and Determination of Metal Concentration

Sampling occurred in July 2016, when plants stopped in growth. To analyze the chemical content of ruderal plants and to minimize their individual distinctions, 5 samples of each plant species were gathered and air-dried. The air-dry samples of 5 plants were united into one mixed sample, they were then ashed at 550 °C for 5 hours. The ashed samples were ground in a mortar. The finely ground rock powder, mixed with a small amount of polyvinyl alcohol dissolved in water, was compressed using a hydraulic press into a pellet.

In the pellets, Cu, Zn, Mn, and Fe were measured using X-ray fluorescence (XRF) analysis. XRF patterns were registered in the lab of Education and Research Center for Nanotechnology at South Ural State University. A Rigaku SuperMini XRF Spectrometer was used for XRF analysis. The relative standard results deviation was not more than 5 %.

### 3. RESULTS AND DISCUSSION

The problem of synanthropic species is becoming more important not only for developed areas but also for reserves. Synanthropization significantly influences the flora of conservation areas. Synanthropic flora is heterogeneous. According to E.V. Dorogostayskaya [10], anthropophilic flora consists of some local species (apophytes) and species brought by man (anthropochores). The main factor for the growth

of synanthropic plants is soil microclimate change made by man both deliberately and indeliberately or spontaneously. Anthropogenic plants are classified into native and adventive (anthropochores). Native species are divided into sedentary, indifferent, and apophytes. Apophytes fall into erosiophilous (in freshly exposed substrates) and nitrophilous-halophilous apophytes (in the dirty anthropogenic habitat). Adventive species (anthropochores) are classified into unnaturalized (accidental, permanently brought) and naturalized (growing only in the anthropogenic habitat; moving to the natural habitat). According to common classification [11], synanthropic plants are divided into local (or apophytes) and alien (or anthropophytes). Among synanthropic flora, S.G. Kudrin [12] distinguishes the following ecological-phytocoenotic groups: forest group (ruderal-forest element), meadow group (ruderal-meadow element), ruderal group (ruderal element with wide environment, brought or adventive element), and the cultivated group (food element, decorative element, introduced element).

The modern synanthropic flora of the Ilmen State reserve has increased by 45 species since 1986 [13], both apophytes (28 species) and anthropophytes (17 species). The synanthropization index has grown by 1.6 % (Table 1).

Table 1 Dynamics of synanthropization of the Ilmen State Reserve flora according to the references

Plants groups	References	
	Gorchakovsky and et al., 2005 [1]	Gorchakovsky and Kozlova, 1998 [13]
Plants totally	953	841
Synanthropic species totally	265	220
Including apophytes	144	116
Including anthropophytes	121	104
Synanthropization index %	27.8	26.2
Apophytization index %	54.3	40.0

Our research revealed 51 species of synanthropic flora on the road and path network of the Reserve, 37 of which are apophytes and 14 - anthropophytes. It has been established that the number of synanthropic species has insignificantly increased in comparison with 2014 [14].

In the birch forests, the number of synanthropic species is larger (42–32) than in the pine forests (25–19), which may be explained by more

favourable conditions for the growth of the herbal and suffruticose layer in the birch forests. A large number of published studies do not establish any differences in the parameters of the ecotopes of pine and birch forests, therefore the increasing number of species in the synanthropic vegetation of the road and path network of the Reserve may be attributed to the anthropogenic factor. The study shows that with the increase of stress load, microclimate is slightly changing; humidity, trophicity, acidity, and nitrogen grow; and luminance in the pine and birch forests in all types of the main line is increasing [14].

The quality of soil on the unsurfaced roads is lower than on the forest roads. Test planting is characterized by more xerophytic conditions, which may be explained by the drainage properties of the vegetative cover transpiring water surplus from organic-mineral substrate. Integrity disturbance of the herbal and suffruticose layer results in stagnation in tracks and the space between them, bogging, and acidification; increased nitrate is caused by polluting [14].

Analysis of synanthropic species distribution in the coenoflora of the elements of the road and path network revealed an increasing synanthropization index in the gradient of stress factor for all the forests. According to the assessment scale of synanthropization level, the heaviest and most lasting impact is identified in the coenoflora of birch forests that belong to all the types of forest roads. In the pine forests, only unsurfaced and forest roads are affected.

The most coeno-stable populations were chosen to study heavy metal concentration in the ruderal plants of the Ilmen State Reserve species formation. Such metals as Zn, Mn, Fe, Cu, and Sr were found in the plants (Table 2).

Cuprum is an essential element playing a key role in a range of physiological processes such as photosynthesis, respiration, carbohydrate distribution, reducing nitrogen decline and fixation, protein metabolism, and cell wall metabolism. Many plants have cuprum. It also influences water

permeability, and thus, governs water relationships. The most significant practical consequences of cuprum function for plants are attributed to its deficit and toxicity. Cuprum is a part of the disease resistance mechanism. Plant resistance to mycosis may be explained by an adequate cuprum supply. There is the evidence that plants with a rich cuprum concentration are more susceptible to some diseases.

Zinc is an essential microelement playing a key role as a specific activator of some ferments, such as carbonic anhydrase catalyzing the breakage of carbonic acid into water and carbon dioxide. It is easily absorbed as hydrated ion  $Zn^{2+}$ . Zn concentration in plants depends on the age and state of vegetation. A high concentration of Zn is usually seen in young plants, and it reduces with the age as a result of dilution. In general, plants can in large amounts of Zn without showing any instances of rejection with Zn concentration in soil being less than 500 mg/kg.

Iron is of great importance for the enzyme system and necessary for chlorophyll synthesis. It is part of the redox processes in plants, it can convert from oxidated form into protoxydic and vice versa.

Manganese is a significant element used in the reduced form of  $Mn^{2+}$ . Like cuprum, manganese, being the part of ferments that enable these processes, plays an important role in the redox reaction in plants.

The most influential factor in the absorption of strontium by plants is Ca concentration in soil. Other factors are pH and organic matter concentration.

Accumulation of strontium by different organisms depends not only on their species but also on the interrelations of strontium, calcium and phosphorus in the environment. The total strontium concentration in soil is 0.035 % (in mass).

Strontium in adequate concentrations is favourable for plant metabolism [15].

Table 2 Heavy Metal Concentration in ash residue of ruderal plants, %

Plant	Zn	Mn	Fe	Cu	Sr
<i>Carduus crispus L.</i>	0.62	1.12	1.53	0.22	0.11
<i>Tanacetum vulgare L.</i>	0.45	1.42	1.65	0.24	0.12
<i>Trifolium montanum L.</i>	1.64	1.17	1.58	0.25	0.11
<i>Euphorbia esula L.</i>	0.49	2.04	2.10	0.26	0.11
<i>Leonurus quinquelobatus GILIB.</i>	1.12	2.52	2.13	0.21	0.10
<i>Linaria vulgaris MILL.</i>	0.65	1.54	1.79	0.25	0.12
<i>Artemisia vulgaris L.</i>	1.98	1.32	1.74	0.26	0.11
<i>Artemisia absinthium L.</i>	0.65	2.56	2.03	0.21	0.11
<i>Barbarea vulgaris W.T.AITON</i>	0.56	1.69	1.91	0.28	0.12
<i>Galeopsis ladanum L.</i>	0.48	1.23	1.65	0.22	0.10
<i>Capsella bursa-pastoris (L.) MEDIK.</i>	0.42	1.51	1.78	0.26	0.12

Plant chemical composition reflects soil element composition. But this is affected by many factors. Therefore, heavy metal concentration in plants is very changeable and widely varies. This study found that motherwort and wormwood accumulate a high amount of manganese and may be used for drawing it out from soil in the process of phytoremediation. Phytoremediation is known as a relatively inexpensive method of soil reclamation [16, 17]. Clover and thistle accumulate more zinc and may be used for drawing it out from soil. Other plants accumulate iron ions and may be used for drawing out iron from soil.

#### 4. CONCLUSION

The study has identified 51 species of synanthropic plants on the road and path network of some parts of the Ilmen State Reserve. The plants cover ditches, quarries, embankments, wastelands, and the side of the roads. Rapidly growing annuals and perennials are dominant in such coenofloras, as they are not demanding of soil and grow well in sites lacking a humous soil horizon.

The paper analyzes the chemical composition of the metals Zn, Mn, Fe, Cu, and Sr for the most coeno-stable species. These elements are essential in low concentrations for plant metabolism and may be used for the phytoremediation of soil.

The obtained results indicate declining efficiency in the use of the current mainlines of the Reserve. But the road and path network of the birch forests is more frequently used than that of the pine forests, which are more resistant to the invasion of synanthropic species.

Climate and a growing human-made impact on the natural ecosystems explain the high adaptability of synanthropic plants. This study revealed the nonequivalence of different environmental factors for forming the adaptability of synanthropic species. Such parameters of the ecoarea as moisture variability, drainage, light, and anthropotolerance are gaining particular importance for increasing the ability to settle on various habitats.

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