Ecological phytomonitoring in Donbass using geoinformational analysis

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Abstract. The results of the phytoindication monitoring carried out in the central industrial units of Donbass during 1996 – 2021 have summarized. Botanical indication is considered as a way to carry out a reliable ecological expertise when zoning ecological crisis areas in an industrial region. Geographic information analysis of botanical and ecological indices (occurrence frequency of teratogenic deviations of plants, structure and concentration of pollen grains, level of taxonomic diversity of bryophytes) allows to visualize indicators of the state of local geosystems in an anthropogenically transformed region.

1 Introduction

The range of knowledge about plants in an industrial region is constantly expanding due to emergence of new technical and instrumental capabilities [1 – 3]. Industrial botany is a topical scientific and applied area of biological research in Donbass. For example, geostrategic information is needed for planning and environmental zoning. For the Donetsk economic region, reliable information on the degree of disturbance of individual ecosystems is extremely important. It is also being studied at the level of toxic effects on landscapes [4 – 6].

Geodata are widely used to study and comprehensively control situations in technologically disturbed and urbanized areas [7, 8].

The target program for geoinformation analysis of phytomonitoring data is a set of interactive cartographic visualizations and plane models, which allows ranking territories according to the specifics and depth of their anthropogenic transformations [9, 10]. Ecological phytomonitoring in the context of studying a technogenically altered environment is a method for assessing local landscape systems by the state of phytocomponents [11 – 13].

2 Materials and Methods

Scientific developments in the study of plants in order to implement monitoring technologies in Donbass are organized within the existing two-level network of localization of registration sites. The accounting zones cover the territory of the Donetsk-Makeyevka

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agglomeration, the Gorlovka-Yenakievo industrial hub, individual cities (Shakhtersk, Khartsyzsk, Yasinovataya, Zugres, Snezhnoye) and all adjacent territories of the central part of Donbass [14].

For 154 species of flowering plants and 23 species of bryophytes of Donbass, a database of features of diagnostic significance has been formed. The identification of informative features in the status of life-supporting strategies for the species of natural flora of an industrially developed region forms a methodological approach to practical assessment of the state of ecotopes [5, 9].

A long-term experiment (1996 – 2021) in the nodes of localization of the Donbass monitoring network (more than 120 registration stations with different levels of anthropogenic load on natural environments) was verified by the procedures of 1) compiling ecological scales of phytoindication characteristics, 2) mono- and polyfactorial correlation calculations in systems "indicator – function", 3) cartographic visualization in the analysis of the planar distribution of values and 4) the formation of blocks of conjugate response to unfavourable factors of transformation of the environment [6, 15].

The final products of the current phytoindication monitoring provide for the compulsory compilation of an annotated list of signs and characteristics that have a reliable value under the tested experimental conditions. A mandatory visualization program involves the collection and preparation of an illustrated atlas of territorial environmental stresses in the region based on detailed and complex indicators of disturbance or balance in natural systems [9, 12, 13].

3 Results

It has been found that with a density of the monitoring network of 3-4 km distance from the sampling localization nodes, such an array of plant material data allows for a reliable sampling of field collections for cartographic visualization on one plane - the use of ArcGIS 10.4 in proximity analysis and interpolation with built-in geographic information system tools (GIS).

Examples of the importance of the GIS analysis performed:

1. It has been established that the zones of toxic crisis include 12% of the territory in 1996, 14% in 2002, 16% in 2007, 19% in 2013, 18% in 2016 and 14% in 2021, which is largely associated with the level and dynamics of industrial load on the ecotopes of the Donetsk economic region. This result is based on the data of the general index of registered teratogenic deviations (abnormalities at the morphological level) in the embryonic apparatus of the species *Echium vulgare* L., *Atriplex patula* L., *Berteroa incana* (L.) DC., *Cichorium intybus* L., *Tripleurospermum inodorum* (L.) Sch. Bip., *Reseda lutea* L., *Capsella bursa-pastoris* (L.) Medik., *Tragopogon major* Jacq., Diplotaxis muralis (L.) DC., *Tanacetum vulgare* L. and *Plantago major* L.

2. If we use intermediate scales, it is possible not only to identify the zones of specific ingredient pollution of the atmospheric surface layer, but also to outline the particular boundaries of pollutants impact, to compare data for different years and decades. For example, the use of the deformation index (defectiveness) of pollen grains *Cichorium intybus* L., *Tragopogon major* Jacq., *Berteroa incana* (L.) DC., *Tripleurospermum inodorum* (L.) Sch. Bip., *Reseda lutea* L., Echium vulgare L., *Plantago major* L. and *Tanacetum vulgare* L. can be decomposed into 10, 5 or 3 intervals. Particularly toxic environments form pollen heterogeneity up to 35-45%, which requires mandatory consideration in determining the functional status of plants and potential reproductive capacity.

3. Over the observation period, for example, from 2014 to 2020, two sites were established to increase the functional criterion for the quality of pollen material of wild-growing indicator species: southern regions of Khartsyzsk, eastern regions of Shakhtersk and adjacent zones. This indicates an increase in toxic load, which in the total balance corresponds to 5.5% of the entire monitoring network. In the central and eastern regions of Donetsk, the indicator of the number of defective pollen grains was reduced by 10–15 impact indices, which indicates a significant improvement in the environment in terms of ecological and toxic characteristics in the last 6 years. This conclusion is associated with a significant decrease in industrial load on the environment in the Donetsk economic region in recent years.

4. In the strategic planning of the territory, we consider the formed ecological corridor as a justification for functional zoning and the inclusion of objects into the natural reserve fund of Donbass. Thanks to the cartographic analysis, an ecological corridor was determined according to the criterion of the bryophyte species richness: it is located in a single elongated line, connecting the northwestern to southeastern regions. These are the registration sites of the villages Mikhailovka, Monakhovo, Verkhnyaya Krynka, Nizhnyaya Krynka, Lipovoye, Olkhovka, Zuevka, Zarechye. The district is the place of registration of the largest number of bryophyte species (up to 18-22 species on one registration site).

Based on the data obtained on the morphological plasticity of plant species in an anthropogenically transformed environment, the criteria for phytoindication monitoring in Donbass have been determined (Table 1).

Table 1. Criteria for assessing the toxic load on ecotopes in an industrial region

Index	Environment parameter	Correlation coefficient	Reliability level
The number of abnormalities in the structure of the embryonic apparatus	industrial dust air pollution	+ 0.78	$P \leq 0.05$
Level of pollen grains defectiveness	high mutagenic organic pollutant background	+ 0.86	$P \leq 0.01$
Structural heterogeneity of the leaf anastomosis mesh	soil contamination with heavy metals (threshold limit value exceeding)	+ 0.77	$P \leq 0.05$
Specificity of covering trichomes of the leaf surface		+ 0.90	$P \leq 0.01$

4 Conclusions

If you use GIS technologies in an industrial region for environmental monitoring, then by changing the parameters of the formulated tasks you can get a result that was not previously detected during field work and cameral research. With the help of the implemented geostrategic mapping, the function of a prompt response to a new combination of information request for processing data of phytoindication content and environmental diagnostic use is carried out, which is important for modern environmental programs in Donbass. Such a strategy is important in the tasks of adequate territorial analysis.

The main conclusion to the work is that during periods of contradictory data on the level of toxic load in the region, plant organisms are the most reliable markers in the diagnosis of anthropogenically transformed ecotopes.

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