BIO Web of Conferences **126**, 01031 (2024) https://doi.org/10.1051/bioconf/202412601031
AEEA2024

Assessing landscape disturbance in Donbass using phytomonitoring data

Andrei Safonov[1*]

[1]Donetsk State University, 46/516, Shchorsa St., Donetsk, 283050, Russia

Abstract. The article presents the results of a long-term experimental monitoring (1996-2023) of the condition of indicator plants has been implemented in the territory of Central Donbass. Due to the experiment, it was proved that flowering plants have both indices of non-plasticity in the structure of vegetative and generative parts. Indicator species analyzed: *Centaurea diffusa* Lam., *Cichorium intybus* L., *Diplotaxis muralis* (L.) DC., *Echium vulgare* L., *Reseda lutea* L., *Senecio vulgaris* L. and others. Registration sites with priority pollutants and complex pollution have been established. It was found that the geostrategic pattern obtained by mapping for traits on embryotic teratogenesis and morphological heterogeneity of indicator plants coincide on 93% of the projective coverage area. It was found out that for the period 1996-2013, 32% of the total investigated area of the Central Donbass was technogenically transformed, for the period 2014-2021, this indicator was 36%, and for 2022-2023, 41%.

1 Introduction

Donbass is a large industrial centre of Europe, a highly urbanized region with a high level of transformation of the natural environment. In conditions of intensive violation of landscape integrity it becomes necessary to carry out restoration work. But this work can only be implemented with the use of high-quality diagnostics of ecosystems. Therefore, it is necessary to establish the specifics of the violation in each specific case: levels of contamination with toxic elements, the presence of supertoxicants, mechanical disturbance of soil and vegetation cover, and other causes of imbalance in ecotopes.

The monitoring system in ecologically stressed regions is necessarily based on the existing fundamental patterns of formation and development of biogeochemical processes [1-2] and the associated links between environmental components in conditions of intensive anthropotechnogenesis [3-6]. Donbass is a region with high levels of urbanization and economic industrialization: mining, metallurgical production, chemical technologies, construction of industrial centers, disposal of heavy industrial waste and other forms of impact on natural ecosystems [7]. It has been experiencing additional impacts in recent years to the already existing violations and pollution [8]. It is necessary to identify current changes in the state of ecosystems – to carry out detailed diagnostics [9-10].

[*] Corresponding author: andrey_safonov@mail.ru

The experience of studying the sites of anthropogenically altered steppe of Europe [11] shows that the use of plant and soil characteristics are reliable indicators in assessing the disturbance of landscapes under specific human influence and man-made interference in natural cycles [12–14].

The purpose of the study is to identify indicator signs of plant condition in order to obtain information in the ongoing diagnostics of local ecosystems in central Donbass.

2 Materials and Methods

The research is carried out within the framework of phytomonitoring of anthropogenic sites in Eastern Europe based on field research and geoinformation systems [15], structural indicators of higher plants [16], analytical and information control systems in the Donetsk region [17-18]. The recommendations of scientists were used as a methodology for conducting monitoring studies [19, 20].

The botanical and ecological part of the work is based on the methods of publications of scientists [21-22] with our regional amendments and taking into account the ecological valence of indicator plants [18] in difficult conditions of environmental stress [23-24].The state of the structural features of the following plant species was analyzed: *Berteroa incana* (L.) DC., *Capsella bursa-pastoris* (L.) Medik., *Centaurea diffusa* Lam., *Cichorium intybus* L., *Diplotaxis muralis* (L.) DC., *Echium vulgare* L., *Plantago lanceolata* L., *Plantago major* L., *Reseda lutea* L., *Senecio vulgaris* L., *Tanacetum vulgare* L., *Tragopogon major* Jacq., *Tripleurospermum inodorum* (L.) Sch. Bip.

To understand the spatial distribution of values throughout the study area, a cartographic model combining the values of all 113 monitoring points was built. This unique cartographic visualization technology (a project in GIS ArcView 10.4; WGS 1984 Web Mercaror, Spatial Analyst and 3-D Analyst modules) for Donbass has been presented by us in previous publications [8, 17]. The range of indices and values of plant health was divided into 5 intervals – values with equal amounts of information inside each to assess the level of ecosystem transformation.

3 Results

Due to the experiment, it was proved that plants are indicators of the degree of disturbance of ecotopes. Flowering plants have both indices of non-plasticity in the structure of vegetative and generative parts (the architectonics of the upper parts of the plant shoot, the structure of the root system, along the lower end motor, the venation of the corolla limb, the marginal zone on the leaf blade, the symmetry of cells around the stomata, the thickness of the parenchyma tissue and the thickness of the cuticle on the plant stem) and indices of plasticity (indicators of teratogenesis of seeds and fruits, morphology of leaf blades, trichomes on the lower side of the leaf, structure of conformational tissues of the embryo, hyaline membrane, polymorphism of leaves of the lower formation, rosette of leaves near the root) in structure, which often changes depending on environmental conditions, for example, mechanical disturbances of the soil cover, the level of man-made load in terms of contamination with particular toxic elements (cadmium - plant structures associated with respiration *Centaurea diffusa*, lead and zinc - integumentary structures of leaves and fruits of indicator plants *Capsella bursa-pastoris* and *Tanacetum vulgare*, mercury - symmetry of root meristems *Plantago lanceolata* and other characteristics).

Of all the botanical criteria in the structure of plants, the IETp (index of embryonic teratogenesis by frequency of terate plant embryos) and IMHp (index of morphological heterogeneity - as the total sum of abnormalities in the structure of a leaf, shoot) indices have the greatest positive correlation, primarily with the pollutogenic groups Sc-U-Ss and Ce-La–Sm and inflorescences for all indicator species on the same accounting platform), as shown in Figures 1 and 2 – cartographic material of the ecological scale and diagrams of the flower structure of indicator plants for the ecological scale.

Registration sites with priority pollutants (no more than three) and complex pollution (association of pollutants) have been established.

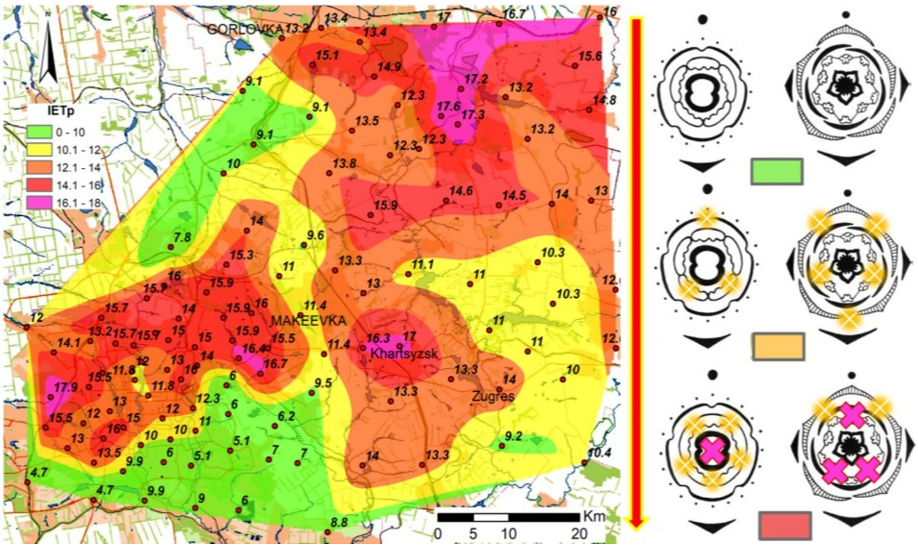

Fig. 1. Map of the ecological scale for the indicator of embryonic teratogenesis in plants IETp (index of embryonic teratogenesis of plants) in the territory of Central Donbass.

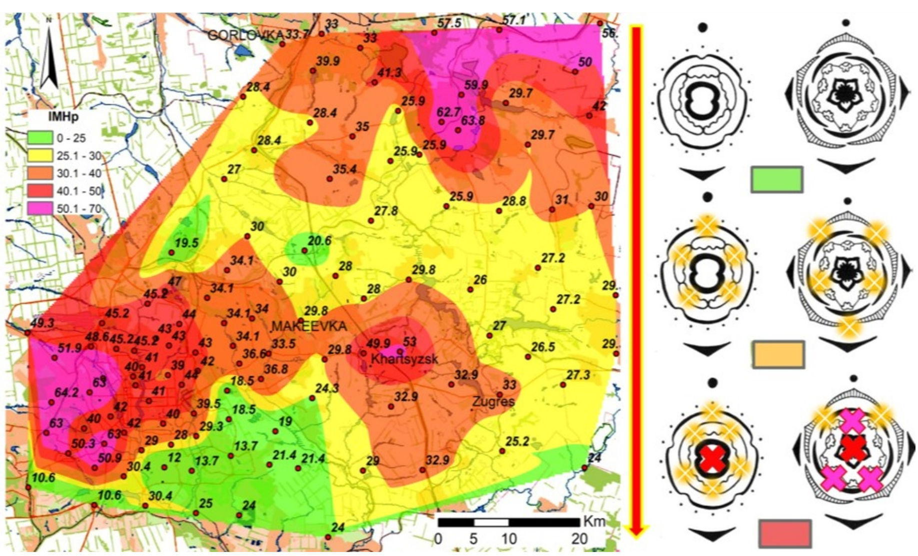

Fig. 2. Map of the ecological scale for the index of morphological heterogeneity of plants IMHp (index of morphological heterogeneity of plants) in the territory of Donbass.

This specificity is explained by the greater physiological activity of protein structures in the embryonic apparatus of the plant and the meristems of shoots and inflorescences of

 https://doi.org/10.1051/bioconf/202412601031

indicator plants for all studied species with different weight coefficients: *Berteroa incana* (6-10), *Capsella bursa-pastoris* (11-12), *Centaurea diffusa* (5-16), *Cichorium intybus* (12-15), *Diplotaxis muralis* (7-18), *Echium vulgare* (12-19), *Plantago lanceolata* (4-14), *Plantago major* (8-19), *Reseda lutea* (5-18), *Senecio vulgaris* (3-14), *Tanacetum vulgare* (7-16), *Tragopogon major* (4-12), *Tripleurospermum inodorum* (6-18).

The assessment of the degree of disturbance of ecotopes is based on the level of structural plasticity of plants (index of embryonic teratogenesis, index of morphological heterogeneity) and the results of ingredient analytical control in the indicator tissues of plant organisms.

Data on the state of plant organisms (Figures 1 and 2) are considered macromarkers in ecological diagnostics. That is, these data can be obtained in the conditions of a route expedition, which are express methods of analysis in field conditions. It was found that the geostrategic pattern obtained by mapping for traits on embryotic teratogenesis (IETp, Figure 1) and general morphological heterogeneity (IMHp) of indicator plants (Figure 2) coincide on 93% of the projective coverage area. This level of correlation was obtained by combining the overlapping areas of the terrain for intervals III-V of the considered trait values (Figures 1 and 2). However, the index of morphological heterogeneity is more accurate for disturbed habitats, which were determined by mechanical disturbance of vegetation and soil cover on the territory of the Central Donbass. Also, IMHp on the characteristics of floral structure is more associated with the factors of ecosystem transformations as a result of socio-political conflict in the studied area. According to the results of researches of 2022 and 2023, this process of disturbance of ecosystems is identified on the maps.

4 Discussion

In most cases, pollution is complex – in places of increased industrial load, several causes of integrity violations are observed. The more diverse the forms and methods of human influence on natural systems are, the more contrasting are the geochemical and geophysical characteristics, for example, in an urban environment with a large source of harmful emissions. Geochemical contrast is the result when emissions from different pollution sources are mixed. Then the toxicity indicators in air, soil, water and plants can vary greatly at small distances from each other.

The results of monitoring toxic substances by the dynamics of the mobility of pollutants conform with the work of the authors [2, 4, 25-26] in the field of environmental assessment of pollutants [9, 21, 27-28] and drawing conclusions about the state of local ecosystems [15, 29-31].

In the period 1996-2013, high levels of technogenic pollution were observed as a result of the development of metallurgical, mining and chemical industries, as well as in conditions of high concentration of urbanized systems. Then, since 2014, the levels of toxic impact on natural landscapes in Donbass began to acquire completely new characteristics in connection with specific locations (geolocalites).

The level of teratogenesis for wild plant species of natural flora is a reliable indicator of ecosystem disturbance. 22 geochemically contrasting (anomalous) monitoring sites were identified, where specific plant neoplasms were described in connection with dominant pollution by specific elements or a group of priority pollutants of a narrow-local territory, on an area of no more than 500 m^2. The frequency of occurrence of abnormal morphological features is related to the type of pollution by toxic concentrations of elements (with indication of the correlation coefficient – R).

From the data on joint pollution, zones of ecological contrast were identified for the following elements, indicating the most informative types of indicators: Ti-Sb –

https://doi.org/10.1051/bioconf/202412601031

teratological syncotyly, folding of the leaf blade, proliferation of flowers (R – +0.89); Fe-Cs – hypergenesis of leaves and hypogenesis of shoots (R – +0.82); Co-Eu – teratological schizocotyly; matrix heterospermia, a change in the characteristic shape of the leaf blade (R – +0.81); Cu-Sr-W – choriza of flower organs and disturbance of the nature of shoot branching, fasciation of gametophyte axes (R – +0.80); Hg-Sb-Cd – proliferation of flowers and inflorescences, proliferation of inflorescences (R – +0.79); Dy-Yb-Cd – dystopia of gametophyte elements in the general architectonics of growth, choriza of various parts of the flower, fasciation of the inflorescence axes (R – +0.77); Ni – teratological syncotyly, false branching of inflorescences, habitual terates (R – +0.77); Fe-Hf – oligomerization of leaf blade; flower proliferation (R – +0.76).

When conducting a paired correlation analysis, plant species with reliable values according to the characteristics of "structure – index – chemical element" were identified: Cu-Yb – fasciation of leaf blades, gametophyte dystopia (R – +0.92); Hg-Sc-Zr – dystopia of leaf arrangement, shoot hypogenesis (R – +0.90).

The central criterion of the potential genotoxicity of the territories is determined by the characteristics of the pollen and seed apparatus of indicator plants.

The characteristics of structural polymorphism of plants are presented in a cartographic equivalent for visual analysis in the distribution of data throughout the territory of Donbass. This method helps to visually assess and compare the situation throughout the territory. But at the same time, it is important to choose the ranges of variation of the index and the scale so that the map is informative and understandable when used.

5 Conclusions

The dynamics of the results, especially between 2010 and 2023, indicates the mobility of the "fields of technogenesis" geographically for the northern and southern parts and along the western line of the extreme sampling sites (monitoring spots) of the entire monitoring network of Central Donbass (2022 and 2023). Such results and conclusions are important in carrying out measures to restore disturbed ecotopes as a result of intensive anthropogenic interference and destruction.

In the list of further measures for planning economic activities in Donbass, it is important to take into consideration the natural geochemical cycles of all elements available for study, as well as the locations of geochemical and geophysical anomalies. This is important in order to avoid mistakes in the construction of new infrastructure facilities for the life and development of industry in the study area.

The assessment of disturbance of open systems (landscapes) was carried out taking into account their mechanical transformation and toxic load by the state of plastic structures of plant organisms. Since plants lead an attached lifestyle, they are the primary link for obtaining functional information about the loss of indigenous structural and functional properties of natural landscapes. It was found out that for the period 1996-2013, 32% of the total investigated area of the Central Donbass was technogenically transformed, for the period 2014-2021, this indicator was 36%, and for 2022-2023, 41%.

Acknowledgement

Completed within the framework of the work of the Azov-Black Sea Mathematical Center (Agreement No. 075-02-2024-1446 dated February 29, 2024).

The task has been completed within the framework of the youth laboratory "Diagnostics and mechanisms of adaptation of natural and anthropogenically transformed ecosystems of Donbass" (No. 1023110700153-4-1.6.19;1.6.11;1.6.12).

https://doi.org/10.1051/bioconf/202412601031

References

1. V.V. Ermakov, S.F. Tyutikov, Geochemistry International **58**, 3 (2020)
2. M.-C. Lafrenière, J.-F. Lapierre, D.E. Ponton, F. Guillemette, M. Amyot, Geochimica et Cosmochimica Acta **353** (2023)
3. S. Yeprintsev, S. Kurolap, O. Klepikov, P. Vinogradov, E3S Web of Conferences **389**, 03030 (2023)
4. S.V. Shekoyan, S.A. Yeprintsev, P.M. Vinogradov, L.A. Lepeshkina, A.A Voronin, IOP Conference Series: Earth and Environmental Science **543** (1), 012025 (2020)
5. T.V. Avraimova, Scientific and Technical Libraries **14**, 3 (2023)
6. S.I. Kolesnikov, N.A. Vernigorova, A.A. Kuzina, K.Sh. Kazeev, Journal of Experimental Biology and Agricultural Sciences **5**, 5 (2017)
7. I. Zinicovscaia, K. Vergel, A.I. Safonov, Ecosystem Transformation **6**, 3 (2023)
8. A.I. Safonov, A.S. Alemasova, I. Zinicovscaia, K.N. Vergel, N.S. Yushin, A.V. Kravtsova, O. Chaligava, Geochemistry International **61**, 10 (2023)
9. S. Yeprintsev, S. Kurolap, O. Klepikov, S. Shekoyan, E3S Web of Conferences **215**, 03009 (2020)
10. N.N. Kharchenko, V.N. Kalaev, V.O. Kornienko, IOP Conference Series: Earth and Environmental Science **875**, **1**, 012049 (2021)
11. A. Safonov, A. Glukhov, BIO Web of Conferences **31** (2021)
12. E. I. Mirnenko, Ecosystem Transformation **5**, 2 (2022)
13. S. Yeprintsev, S. Kurolap, O. Klepikov, S. Shekoyan, AIP Conference Proceedings **2647**, 070030 (2022)
14. V.O. Korniyenko, V.N. Kalaev, Contemporary Problems of Ecology **15**, 7 (2022)
15. I. Zinicovscaia, C. Hramco, O. Chaligava, N. Yushin, K. Vergel, Plants **10**, 3 (2021)
16. A. Safonov, E3S Web of Conferences **431**, 01031 (2023)
17. I. Zinicovscaia, A. Safonov, A. Kravtsova, O. Chaligava, E. Germonova, Physics of Particles and Nuclei Letters **21**, 2 (2024)
18. A. Safonov, BIO Web of Conferences **43**, 03002 (2022)
19. Y.A. Semenishchenkov, Russian Journal of Biological Invasions **8**, 3 (2017)
20. T.I. Kutyavina, T.Ya. Ashikhmina, Theoretical and Applied Ecology **2** (2022)
21. P. Swisłowski, K. Vergel, I. Zinicovscaia, Ecological Indicators **138** (2022)
22. M.A. Outram, M. Figueroa, Current Opinion in Plant Biology **67** (2022)
23. O. Frunze, E3S Web of Conferences **462**, 02004 (2023)
24. V.V. Ermakov, Geochemistry International **53**, 3 (2015)
25. Y. Hautier, D. Tilman, F. Isbell, E.W. Seabloom, Science **348**, 6232 (2015)
26. S. Zheng, C. Xu, G. Lv, H. Shuai, Q. Zhang, Environmental Pollution **333** (2023)
27. J. Kattge, G. Bonisch, S. Diaz, S. Lavorel, Global Change Biol. **26**, 1 (2020)
28. X. Luo, Ch. Wu, Y. Lin, W. Li, Journal of Environmental Sciences **125** (2023)
29. T.K. Parmar, D. Rawtani, Y.K. Agrawal, Frontiers in Life Science **9**, 2 (2016)
30. J. Wan, Q. Li, N. Li, J. Si, Z. Zhang, Global Ecology and Conservation **14** (2018)
31. I. T. Bayouli, H. T. Bayouli, A. Dell'Oca, Ecological Indicators **125**, 107508 (2021)