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DYNAMICS OF FORMATION OF ECOSYSTEM RELATIONSHIPS IN ROADSIDE LANDSCAPES OF THE LEFT-BANK PART OF CHERKASY REGION

Purpose. A study of the dynamics of new ecosystems forming as a result of highway construction on sites that were once natural or anthropogenically altered landscapes, with a view to restoring future biodiversity.

Methods. Field observation and photographic documentation, geochemical analysis, and instrumental monitoring.

Results. The authors focused primarily on the ecosystemic aspect of the broader issue—the anthropogenic transformation of natural landscapes. This is because ruderal vegetation, which largely forms new ecotopes resulting from human activity, plays a restorative role for degraded substrates. It actively participates in biogeochemical processes and is a key factor in the restoration of native flora following its complete destruction due to road construction. An assessment was made of the differences between roadside ecosystems on the left bank of the Cherkasy region (Kaniv–Zolotonosha–Chornobai route) and local ecosystems. The greatest prevalence of species from the Asteraceae family was observed. In addition, the spread of invasive flora was recorded in all studied areas. At the same time, ruderal and native flora families along roadways jointly contribute to the formation of ecosystem connections. Polygons were identified where abnormal deviations in the studied indicators were observed.

Conclusions. Roads function as habitats, sources, sinks, barriers and channels. As habitats, road corridors can support entire populations of plants and animals and may be important for their conservation. If they contain some of the last local or seed habitats of a species, they may be critically important. The study of individual parameters that characterize the formation of ecosystem ties in roadside landscapes of highways of the right bank of the Cherkasy region and the comparison of these parameters with the National Biotope Catalog allows us to establish certain patterns of the distribution of ruderal vegetation, which will subsequently form ecosystems resistant to external disturbances.

KEYWORDS*:* *ecosystem connection ecosystem, roadside, vegetation, group, invasive, landscape, ruderal, human activity*

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Introduction

Modern scientific methodology requires adaptation to the growing demand of society for ecosystem services [1], not only in purely natural territories, but also in anthropogenically altered landscapes. Most foreign sources emphasize the priorities of ecosystem dynamics precisely when conducting monitoring studies of roadside strips [2]. And in the most developed countries, this ap proach to monitoring is already embodied in specific practical guidelines for road services [3].

According to the authors, natural landscapes, the stability of which is supported by the appropriate ecosystem dynamics, should become the standard with which any human interference and impact on the environment should be compared. Thanks to the presence of the phenomenon of life, the biosphere can "fight" with such influences in different ways - eliminate, tolerate, adapt, and nullify. Actually, this phenomenon is in the subject field of modern ecology as a science of the relationship between the body and the environment.

Therefore, with any human intervention in the ecosystem dynamics in the process of forming anthropogenic landscapes (including road ones), it is necessary to expect an adequate response of natural ecosystems in the form of the formation of adaptation mechanisms. In other language, on the site of the former natural ecosystem as a result of road construction, ecosystems adapted to new conditions are formed, which one of the authors calls «noospheric» [4]. In fact, ecosystems adapted to anthropogenic intervention are formed with phenomenal speed in roadside landscapes, the completeness of the formation of which was studied by us earlier [5]. Previous studies conducted using this methodological approach covered the right-bank part of the Cherkasy region [6]. Therefore, in order to logically complete the complete study of the region's territory, we continued to implement this approach to the rest of the region's territory, namely, to the left-bank part of it. Actually, this publication is dedicated to the results of such research.

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On domestic territory, the priorities of ecosystem dynamics when conducting monitoring studies of road landscapes are indicated only in a few works [5; 7; 8; 9].

In particular, in geographical works it is proposed to define the basic geosystem as a genetic ecological and geospatial model of the landscape, the central (controlled) component of which is ground cover. Ground cover combines phenomena of biotic and social origin, which are fundamental to the definition of ecosystem services [10]. From a theoretical point of view, this approach brings scientific methodology closer to biosphere (ecosystem) dynamics through the symbiosis of Earth sciences (geography, landscape science) with life sciences (ecology, ecosystemology).

Most environmental studies of roads usually focus on their harmful effects, and these biases prevent a full assessment of the environmental functions of roads. The characteristic features of the roads are their narrow continuous shape with a fairly large area of roadsides (compared to the core), which support ecosystems other than nearby lands. The impact of the roadside is stronger because roads have a much higher density of terrain, are impenetrable, always carry people and vehicles that themselves create some noise, light, pollution and physical obstacles [2].

The effects of the edge of the road are intensified, as many of them are permanent. According to the Wildlife crossing structure handbook design and evaluation in North America [3], the overall impact of roads and transport infrastructure on biodiversity is three-way:

• Many types of impact on certain sections of the road are cumulative - accumulation of pollutants from vehicles, maintenance of roadside agricultural land, support of surface water by road embankments.

• The impact of several roads is cumulative at the level of a particular landscape, as new roads are being built and old ones are not eliminated. This increases the impact on the «untouched» particles of natural ecosystems, which contributes to their fragmentation.

• Some negative effects have a delayed effect, such as fragmentation effects that prevent the re-colonization of residual habitats by the fauna and the increase in the number of ruderal and invasive flora.

The work Effects of road age and distance on plant biodiversity: A case study in the Yellow River Delta of China [11] investigated the impact of distance from the side of the road and the road on the richness, diversity and composition of plant species in 17 sites. The results showed that there were more species near the side of the road than further from the side of the road (>200 m). Species richness and plant diversity increased with the age of the road at most measured distances, while species richness on the side of the road increased significantly with the age of the road and peaked at the age of the road 20 years after the richness of the species stabilized.

Monitoring studies of the Kyiv-Odesa highway as a landscape engineering system but along its entire length were carried out in 2021 by R.V. Didura. According to the author, road landscape engineering systems (DLIS) are zonal-azonal structures of technogenic origin and their knowledge is possible at the geotechnical level, covering knowledge of natural geography, landscape science, technology, economics, ecology, etc. [9].

Geochemical studies are devoted to the accumulation of micro-elements (Cu, Pb, Zn, Cd) by the phytomass of plants of technogenically transformed ecotopes (on the example of m. Cherkasy) was carried out by N.M. Kornelyuk and S.M. Konyakin [12].

Our main focus was on the environmental, more precisely the ecosystem aspect of the identified problem. It is important that the communication routes we have selected within the Cherkasy region are almost completely "covered" by the Galicia-Slobozhan ecological corridor, which is a significant part of the national ecological network [13].

When analyzing the above works, it is important to pay attention to the following quantitative and qualitative parameters of roadside landscapes, which can affect their ecosystem dynamics:

– The species composition of plant groups, which can be an indicator of individual road impacts, for example, the presence of halophytic plants indicates the fight against glaciation with salt [14], or the soil washing regime is insufficient; the presence of invasive plants - the intensity of their seed transfer by vehicles or birds; the presence of hydrophytic plants, which may indicate insufficient drainage of the roadway (aquifers), etc.

– External signs of animal life in roadside areas (anthills, burrows, excrement, predator hunting, animal remains, etc.) to assess the completeness of ecosystem relationships in roadside ecosystems.

– Signs of disruption of ecosystem dynamics on the road (fragmentation of ecotopes, death of animals as a result of traffic, etc.).

A certain synthesis of these theoretical approaches is the concept of noospheric ecosystems. It investigates the evolution of the noospheric development of mankind, the main spatial consequence of which is the formation of three groups of elements of territorial structure. These three groups form a modified ecological niche of our species. In particular, there are three types of noospheric ecosystems – agroeco-systems (planar, areal), urboecosystems (cell, nodal) and infraecosystems (linear, network), which have all the features of the ecosystem and are in complex interdependent relationships with each other [4]. Thus, considering infraecosystems as part of the ecological niche of Homo Sapiens, we preserve the ecosystem essence of all road landscapes, since for the most part their artificial nature depends entirely on man, who regulates their species diversity, being, however, limited by general physical and geographical conditions.

Therefore, road landscapes (according to the current classification [15], we will consider as infraecosystems (from the term «infrastructure») according to the concept of noospheric ecosystems [4].

Our research focused on determining the dynamics and directions of development of roadside ecosystems that are formed on the left bank of the Cherkasy region. The main questions that needed to be answered were:

1. How significantly are the roadside ecosystems of the left-bank Cherkasy region (directions Kaniv - Zolotonosha - Chornobay) different from the natural ecosystems of this area. In particular, the assessment of all (or some types of influences). Soil composition, hydrological regime, phyto- and zoo-varienation, dustiness, noise pollution, radiation background, etc. That is, determining the current state of roadside ecosystem data using a number of indicators.

2. How these ecosystems have adapted to the conditions of anthropogenic influence (changes in the species composition of plants and animals, the formation of new trophic relationships, etc.).

3. What should be done to reduce the negative impact of transport activities on a new ecosystem adapted to environmental conditions.

Monitoring studies were carried out by route by car along the following roads: Zgar village – Pishchane village – Sofiivka village – Nova Dmytrivka village – Kropyvna village – Irkliiv – the border of Cherkasy and Poltava regions on the Kremenchuk reservoir – Novy Kovray village – Chekhiv pumping station). In total, 9 stops were made for measurements and appropriate sampling. Stops were made at the branches of the side roads adjacent to the main one in order to move sideways (right or left) for a distance of up to 50 m to determine the degree of change in ecosystem interconnections depending on the distance from the main route [16].

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Research methodology

In total, 5 stops were made on the first route and 5 stops on the second route for appropriate measurements and sampling.

The following types of measurements and observations were performed at each of the polygons (sampling points):

- Fixation of geographical coordinates;
- Measurement of the radiation background with a TERRA-P dosimeter;
- Photographing the plant and animal world directly near the roadway and 25-30 meters from it (10 photos each) (Nikon 5000 camera);
- Taking soil samples directly near the roadway and 25 meters from it (1 kg per bag) with subsequent chemical analysis;
- Noise level measurements (Benetech GM1351);
- Fixing the number of vehicles;
- Dust measurements with data entry into the appropriate log (PM2.5 Walcom SR-516A log dust meter);

Fig. 1 – Polygon №2. Marshal gas station near the village of Pishchane

- Air quality measurements with an Air quality detector.

The results of measurements and fixation are shown in Fig. 1.

The main methods that were applied: polygon method, comparative, cartographic, visual observation and photofixation.

Results

Approaches to the formation of ecotopes in anthropogenic landscapes are important from a methodological point of view. We adhere to the methodological scheme of R.I.Burda. According to the author, the nature and degree of anthropogenic transformation of locations, habitats, as well as biotopes, determines the formation of specific features of an anthropogenic dwelling as a habitat in which at least one of the abiotic or biotic components has undergone changes as a result of direct or indirect anthropogenic impact [17].

The prerequisites for creating a motivated, fast, open, understandable, acces-sible and simple classification of anthropogenic habitats are to take into account a number of their characteristics. The most important of them are.

1. Location of environments relative to the relief.

2. Place of growth (biological cycle).

3. The absence of a single dominant vegetation cover is the mandatory participation of determinants reflecting anthropogenic changes in the biotope and physiotype.

4. Variety of types of nature use.

We tend to identify road embankments as eluvial habitats located on elevated relief elements, because each road has an elevated embankment.

In general, ruderal phytocenoses in urbanized and man-made conditions can become ecological niches for many species of fauna and contribute to ecosystem regeneration [18]. At the same time, ruderal groups are the main centers of distribution of alien species, especially those with high invasion potential and transformer species, which pose a real threat to the biodiversity of natural ecosystems [19].

In addition to the listed indicators and characteristics, quantitative assessments of the degree of biodiversity were also used [20].

At this stage of research, the main attention was paid to the identification of individual species of plants and plant groups. The authors will receive the rest of the results after conducting laboratory studies of soil samples, plant samples and analysis of biodiversity. The data of expeditionary monitoring studies were entered in the relevant table (Table 1.).

In the future, to increase the clarity in the comparative analysis, the method of petal diagrams was used (Fig. 2), using the indicators reflected in Table. 1.

The vegetation is represented by the families: Amaranthaceae Juss. (Amaranth); Apocynaceae Juss. (Swalloom); Asteraceae Bercht. & J.Presl (Asters); Boraginaceae Juss. (Roarse); Brassicaceae Burnett (Cabbage or Cruciferous); Caryophyllaceae Juss. (Cloves); Fabaceae Lindl. (Legumes); Euphorbiaceae Juss. (Eauth or milkweed); Hypericaceae Juss. (St. John's Wort); Lamiaceae Martinov (Deaf nettle or lipflowered); Papaveraceae Juss. (Popies); Poaceae Barnhart (Thin-legged); Polygonaceae Juss. (Buck); Portulacaceae Juss. (Portulace); Ranunculaceae Juss. (Zhovtetsev); Rosaceae Juss. (Roses or Pink); Rubiaceae Juss. (Maren); Sapindaceae Juss. Equisetaceae Michx. ex DC. (Horseytails); Apiaceae Lindl. (Circular or umbrella); Convolvulaceae Juss. (Birch); Geraniaceae Juss. (Crane, geranium); Scrophulariaceae Juss. Urticaceae Juss. (Nettles); Balsaminaceae A. Rich. (Balsamins); Malvaceae Juss. (Malva); Plantaginaceae Juss. (Podant); Violaceae Batsch. (Violet); Cannabaceae Martinov. (Hemp); Cyperaceae Gen. Pl. (Osoceae); Onagraceae Juss. (Onagrovi); Solanaceae Juss. (Solanaceae); Sapindaceae Juss. (Sapind); Aristolochiaceae Juss. Salicaceae Mirb. (Willow); Ulmaceae Mirb. (Elm). The most common are plants of the aster family.

The spread of invasive plants such as: Asclepias syriaca L. (Syrian Vatochnik), Ambrosia artemisiifolia L. (Ambrosia polynolist), Erigeron annuus (L.) Desf. (One-year-old), Euphrosyne xanthiifolia (Nutt.) A.Gray, Robinia pseudoacacia L. (Robinia common), Erigeron canadensis L. (Canadian Zlinka), Acer negundo L. (Ash-leaved maple), Ulmus pumila L. (Elm low, dwarf), Solidago canadensis L. (Canadian gold).

Analyzing Table 2 by the number of recorded species, polygons 1 (Zgar village) and 5 (Kropyvna village), 36 and 44, respectively, draw attention. They also have the largest number of plants that are characteristic of the corresponding biotopes from the national catalog, respectively 13 and 14.

The visual relationship between the overall air quality and the number of recorded plant species (as, for example, at polygons 1,2,3,8) requires the use of correlation analysis, to which the authors will devote their future research. The same applies to the relationship between the noise level and the total number of plants. For the 1st and 5th polygons, such a visual dependence should be confirmed by the results of correlation analysis.

The remaining indicators given in the table can play with new colors if they are supplemented with future results of plant repeatability, as well as in the case of their comparison using the method of petal diagrams, which the authors will certainly do upon completion of the processing of these expeditionary studies.

Conclusions

Roads perform various ecological functions that affect wildlife.

Roads function as habitats, sources, sinks, barriers and channels. Depending on the road, its location and the number of vehicles that move it, some of these features can be of important environmental importance.

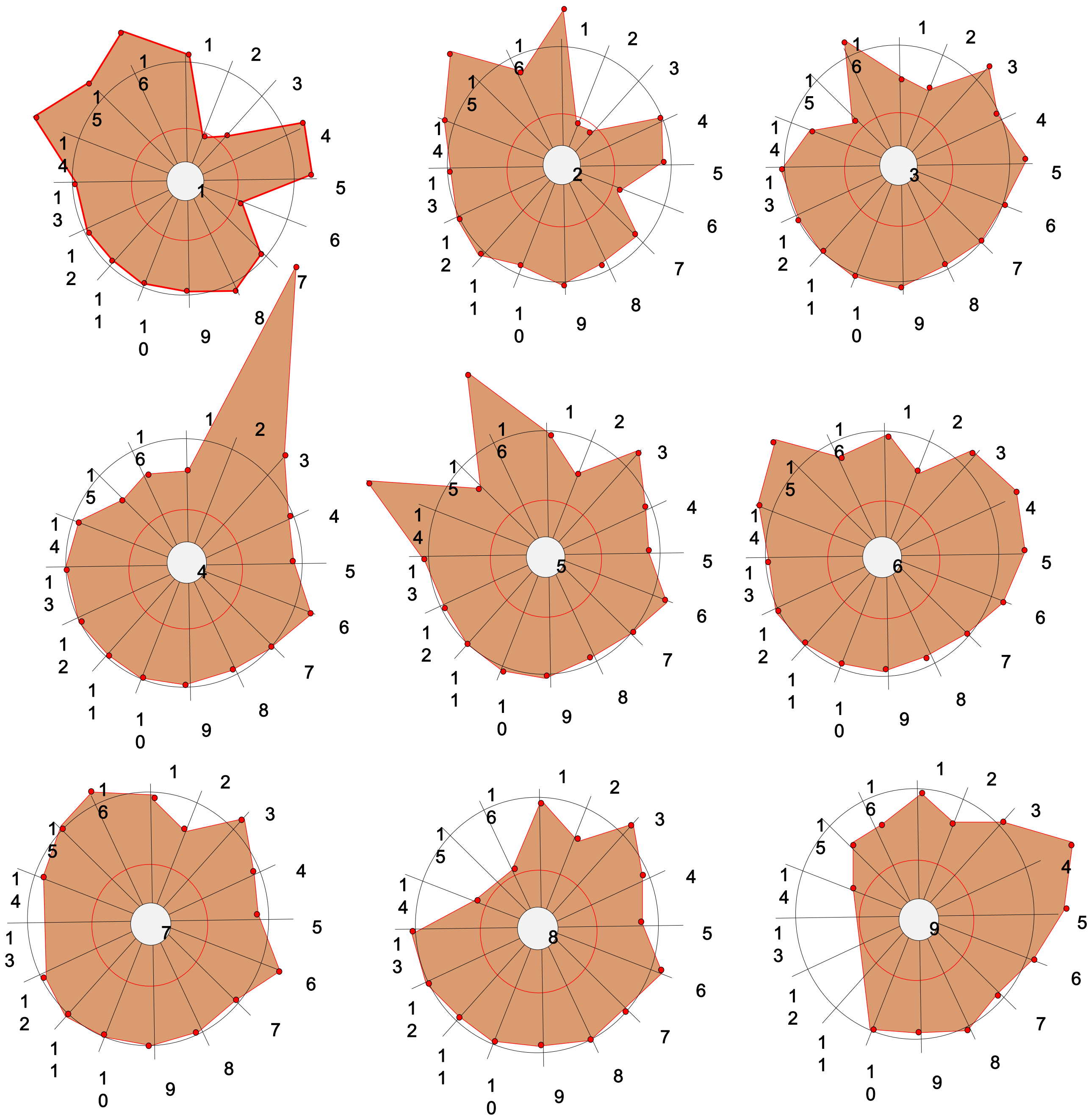
As habitats, road corridors can contain entire populations of plants and animals and may be important for their preservation. If they contain some of the species' recent local or seed habitats, they may be critical

The study of individual parameters that characterize the formation of ecosystem connections in the roadside landscapes of the right bank of the Cherkasy region and the comparison of these parameters with the National Catalog of Biotopes allows us to establish certain patterns of distribution of ruderal vegetation, which will subsequently form ecosystems resistant to external disturbances.

Table 1

Some parameters of the dynamics of the formation of roadside ecosystems along the roads of the left-bank part of the Cherkasy region

№	Sampling points	Geographical co-ordinates	Total air quality (points)	Phenols (mg/m3)	Organ. compounds	Dust particles PM 2.5(ug/m3)	Dust particles PM 10(ug/m3)	CO (ppm)	CO_2 (ppm)	Temperature (°C)	Humidity (%)	Radiation back-ground (mSv/h)	Noise level of trucks (db)	Noise level of car (db)	Noise level of pas-senger cars (db)	Number of plant spe-cies (unit)	Number of invasive species (units)	Number of plant spe-cies from the national biotope catalog (un.)
1	Zgar vil.	49º39’23,1” N 32º06’34,8” E	4	0,008	0,09	025	032	003	0443	31,2	52	0,13	83,4	78,5	80,2	36	4	13
2	Pishchane vil.	49º44’00,9” N 31º52’33,0” E	5	0,008	0,009	017	022	003	0437	23,3	56	0,13	90,9	85,5	82,5	26	5	6
3	Sofiivka vil.	49º52’10,0” N 31º44’00,0” E	2	0,053	0,604	017	032	012	0531	22,3	61	0,16	88,8	82,3	87,3	18	1	8
4	N. Dmytrivka vil.	49º42’05,9” N 31º58’42,5” E	2	0,555	0,613	016	020	013	0501	23,7	55	0,14	87,4	84,0	89,0	21	2	5
5	Kropyvna vil.	49º38’10,6” N 32º10’56,6” E	3	0,053	0,598	016	020	013	0502	22,5	56	0,16	87,5	82,4	86,3	44	2	14
6	Irkliiv city	49º30’53,9” N 32º23’02,3” E	3	0,052	0,579	025	032	013	0480	23,5	50	0,13	87,3	88,6	83,9	29	5	6
7	Border of region	49º28’38,2” N 32º39’50,0” E	3	0,052	0,565	016	020	013	0502	27,4	49	0,15	88,1	81,15	-	21	3	9
8	Novy Kovray vil	49º28’38,2” N 32º39’50,0” E	3	0,052	0,566	016	020	012	0537	25,7	50	0,15	89,18	84,9	88,2	6	-	1
9	Chekhovka pumping station	49º30’14,4” N 32º13’17,2” E	3	0,050	0,540	029	038	012	0476	26,0	49	0,13	-	-	-	9	2	5



Symbols: - numbers of polygons (observation points), respectively, respectively, 1 – Zgar village; 2 – Pishchane village; 3 – Sofiivka village; 4 – Dmytrivka village; 5 – Kropyvna village; 6 – Irkliiv city; 7 – border of Cherkasy and Poltava regions; 8 – Novy Kovray village; 9 – Chekhovka pumping station. Indicators: 1 – Total air quality (points); 2 – Phenols (mg/m3); 3 – Organ. compounds (mg/m3); 4 – Dust particles PM 2.5(ug/m3); 5 – Dust particles PM 10(ug/m3); 6 – CO (ppm); 7 – CO2 (ppm); 8 – Temperature (oC); 9 – Humidity (%);10 – Radiation background (µSv/h); 11 – Noise level of trucks (db); 12 – Noise level of passenger vehicles (db); 13 – Noise level of passenger vehicles (db); 14 – Number of plant species (units) ; 15 – Number of invasive species (unit) ; 16 – Number of plant species from the national biotope catalog (dis.)Plant groups at individual points of study are formed by almost all families of ruderal and aboriginal flora.

Fig. 2 – Images of parameters that reflect the dynamics of roadside ecosystems using the petal diagram method

Conflict of interest

The authors certify that, although one of the authors of the article is a member of the editorial board of this journal, the peer review, publication decision, and editorial processes were conducted independently, without their participation or influence. Any potential conflicts of interest were fully mitigated through external oversight of the process.

In addition, the authors fully complied with ethical standards, including plagiarism, data falsification, and double publication.

Authors Contribution: all authors have contributed equally to this work.

AI Statement

In this study, generative artificial intelligence was not used.

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ДИНАМІКА ФОРМУВАННЯ ЕКОСИСТЕМНИХ ВІДНОСИН У ПРИДОРОЖНІХ ЛАНДШАФТАХ ЛІВОБЕРЕЖНОЇ ЧАСТИНИ ЧЕРКАСЬКОЇ ОБЛАСТІ

Мета. Дослідження динаміки формування нових екосистем, що формуються в результаті будівництва автомобільних доріг на місці колись природних або атропогенно змінених ландшафтів для відновлення майбутнього біорізноманіття.

Методи. Польові спостереження та фотофіксації, геохімічний, інструментально-моніторинговий.

Результати. Приділено пріоритетну увагу екосистемному аспекту антропогенізації природних ландшафтів. Оскільки рудеральна рослинність, яка здебільшого формує нові екотопи, що виникають в результаті антропогенної діяльності, відіграє відновлювальну роль для деградованих субстратів;а бере активну участь у біогеохімічних процесах та є важливою умовою для відновлення аборигенної флори після її повного знищення в результаті дорожньо-будівельних робіт. Екосистемні зв'язки у придорожніх ландшафтах досліджувались шляхом вивчення видового складу рослинних угруповань, зовнішніх ознак життя тварин у придорожніх зонах, ознак порушення динаміки екосистем дорогою (фрагментація екотопів, загибель тварин внаслідок наїзду транспортних засобів тощо). Динаміка придорожніх екосистем досліджувались шляхом реєстрації та подальшого порівняння рослинності з її відповідним списком у Національному каталозі біотопів. Зроблена оцінка відмінності придорожніх екосистем лівобережжя Черкаської області (напрямки Канів - Золотоноша - Чорнобай) від місцевих екосистем. Встановлено найбільше поширення представників родини Айстрових (Asteraceae). Крім того, на всіх досліджуваних ділянках зафіксовано поширення інвазійної флори. Водночас родини рудеральної та аборигенної флори вздовж дорожніх смуг разом беруть участь у формуванні екосистемних зв'язків. Визначено полігони, на яких спостерігаються аномальні відхилення досліджуваних показників.

Висновки. Дороги функціонують як середовища існування, джерела, поглиначі, бар'єри та канали. Як середовища існування, дорожні коридори можуть утримувати цілі популяції рослин і тварин і можуть мати значення для їх збереження. Якщо вони містять деякі з останніх місцевих або насіннєвих середовищ існування виду, вони можуть бути критично важливими. Дослідження окремих параметрів, які характеризують формування екосистемних зав'язків у придорожніх ландшафтах автошляхів правобережжя Черкаської області і порівняння цих параметрів з Національним каталогом біотопів дозволяє встановити певні закономірності розповсюдження рудеральної рослинності, яка згодом сформує стійкі до зовнішніх збурень екосистеми.

КЛЮЧОВІ СЛОВА: *екосистемний зв'язок, придорожній, рослинність, угруповання, інвазійний, ландшафт, екосистема, рудеральна, антропогенна діяльність*

Конфлікт інтересів

Автори засвідчують, що, незважаючи на те, що один із авторів статті є членом редакційної колегії цього журналу, процес рецензування, прийняття рішення щодо публікації та редагування проводилися незалежно, без його участі чи впливу. Будь-які потенційні конфлікти інтересів були повністю усунені шляхом зовнішнього контролю процесу.

Крім того, автори повністю дотримувались етичних норм, включаючи плагіат, фальсифікацію даних та подвійну публікацію.

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