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Review

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**HERACLEUM SOSNOWSKYI MANDEN. –
A THREAT TO BIODIVERSITY REDUCTION
IN PHYTOCENOSES OF WESTERN UKRAINE****H. M. Korpita, I. A. Shuvar**

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The aim of the study was to assess the change in the species composition of phytocenoses under the influence of the spread of *Heracleum sosnowskyi* Manden., the projective cover of the dominant invasive species, and the change in the main biodiversity indices under the influence of its spread. The study was carried out using permanent sample plots, geobotanical records, and quantitative analysis of the phytocenotic structure during 2020–2025. A clear trend towards a decrease in the species biodiversity of phytocenoses was established: the number of species decreased from 18 in 2020 to 9 in 2025. At the same time, a stable increase in the projective cover of *Heracleum sosnowskyi* from 35 % to 72 % was observed, accompanied by a rapid decrease in the participation of associated species and the formation of monodominant groups. Analysis of biodiversity indices demonstrated a significant decrease in the Shannon-Weaver index and the Pielou evenness index, accompanied by an increase in the Simpson index, indicating a simplification of the structure of phytocenoses and a violation of species evenness. Correlation analysis confirmed the presence of strong, statistically significant relationships between the projective cover of *Heracleum sosnowskyi* and biodiversity indicators: a strong negative correlation with the Shannon-Weaver and Pielou indices, and a positive correlation with the Simpson index. The results obtained indicate a high invasive potential of *Heracleum sosnowskyi* and its determining role in the degradation of phytocenoses, which justifies the need to develop and implement scientifically based measures to control its spread.

Keywords: invasive plants, phytocenotic structure, projective cover, monodominant communities, ecological degradation, dynamics of species composition.

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***Heracleum Sosnowskyi* Manden. – загроза зниженню біорізноманіття у фітоценозах західної України**

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Метою дослідження була оцінка зміни видового складу фітоценозів під впливом поширення *Heracleum sosnowskyi* Manden., проективного покриття домінантного інвазійного виду та зміни основних показників біорізноманіття під впливом його поширення. Дослідження виконано методом постійних пробних ділянок з використанням геоботанічних записів та кількісного аналізу фітоценотичної структури впродовж 2020–2025 рр. Встановлено чітку тенденцію до зменшення видового біорізноманіття агрофітоценозів: кількість видів зменшилася з 18 у 2020 р. до 9 у 2025 р. Водночас визначено стабільне збільшення проективного покриття *Heracleum sosnowskyi* з 35 % до 72 %, що супроводжувалося швидким зменшенням участі супутніх видів та формуванням монодомінантних угруповань. Аналіз індексів біорізноманіття продемонстрував значне зниження індексу Шеннона-Вівера та індексу вирівняності Пієлу на тлі збільшення індексу Сімпсона, що свідчить про спрощення структури фітоценозів та порушення рівномірності розподілу видів. Кореляційний аналіз підтвердив наявність тісних статистично значущих зв'язків між проективним покриттям *Heracleum sosnowskyi* та показниками біорізноманіття: встановлено сильну негативну кореляцію з індексами Шеннона-Вівера та Пієлу та позитивну з індексом Сімпсона. Отримані результати свідчать про високий інвазійний потенціал *Heracleum sosnowskyi* та його визначальну роль у деградації агрофітоценозів, що обґрунтовує необхідність розробки та впровадження науково обґрунтованих заходів щодо контролю його поширення.

Ключові слова: інвазійні рослини, фітоценотична структура, проективне покриття, монодомінантні угруповання, екологічна деградація, динаміка видового складу.

Introduction. Invasive plant species are among the key factors driving biodiversity degradation in agroecosystems at both global and regional scales. Their rapid spread leads to transformations in the structure of phytocenoses, disruption of trophic relationships, reduced productivity of agricultural systems, and increased economic losses. Under conditions of global climate change, agricultural intensification, inefficient land use, and declining biological stability of agricultural landscapes, the issue of biological invasions has become particularly acute [4, 12].

Among invasive plant species in Ukraine and Eastern Europe, *Heracleum sosnowskyi* Manden. is considered one of the most aggressive. This species is characterized by high ecological plasticity, intensive seed

reproduction, rapid formation of monodominant stands, high adaptive capacity, and effective displacement of native and cultivated plant species. Within phytocenoses, *Heracleum sosnowskyi* substantially alters species composition, reduces floristic diversity, and disrupts natural self-regulation mechanisms of agroecosystems [13, 20, 26].

The negative impact of *Heracleum sosnowskyi* is not limited to the competitive exclusion of other species. The plant forms a dense upper canopy layer that suppresses the germination and development of low-growing vegetation, modifies light and microclimatic conditions, and influences soil processes through biomass accumulation and changes in the chemical composition of organic residues. Consequently, the structural complexity of

phytocenoses is reduced, leading to a decline in their ecological stability [11, 17].

The issue of the spread of invasive plant species and their impact on biodiversity in natural and anthropogenically transformed ecosystems has been widely addressed in contemporary scientific literature. Numerous authors consider biological invasions to be one of the primary drivers of ecosystem degradation, leading to reductions in species diversity, alterations in phytocenotic structure, and disruption of ecological balance within agricultural landscapes [15, 16].

Heracleum sosnowskyi is considered one of the most dangerous invasive plant species in Europe. Initially introduced as a promising forage crop, it subsequently became widespread and uncontrolled, particularly on abandoned agricultural lands, road verges, river floodplains, and within phytocenoses. Scientific studies have demonstrated that this species exhibits high seed productivity, long-term seed viability in the soil seed bank, and a pronounced competitive advantage over native plant species. Several researchers report a significant decline in both segetal and wild-growing plant species within agroecosystems affected by *Heracleum sosnowskyi* [8, 10, 28].

The impact of *Heracleum sosnowskyi* on phytocenoses is not limited to competition for resources. Authors emphasize its ability to modify microclimatic conditions, particularly soil temperature and moisture regimes, as well as to influence soil biological processes due to the accumulation of substantial amounts of plant residues. Changes in the chemical composition of organic matter and the rate of its mineralization affect the quantity and availability of nutrients for other plant species, thereby further enhancing the invasive potential of this species [1, 3, 7].

Special attention has been given to a distinct line of research focused on assessing the ecological and socio-economic consequences of the spread of *Heracleum sosnowskyi*. Its negative impact on agricultural land productivity, complications in implementing agrotechnical practices, and risks to human health due to the plant's phototoxic properties have been well

documented. At the same time, researchers highlight the limited effectiveness of isolated control measures and emphasize the need for an integrated approach to invasion management [2, 19].

Despite the substantial number of studies available, the impact of *Heracleum sosnowskyi* on the biodiversity of phytocenoses remains insufficiently explored and poorly systematized, particularly with respect to regional land-use characteristics. Consequently, there is a clear need for further research aimed at comprehensive assessments of changes in species composition, structural organization, and ecological stability of phytocenoses under conditions of the spread of this invasive species.

Given the expanding areas affected and the complexity of controlling the spread of *Heracleum sosnowskyi*, comprehensive studies of its impact on agrophytocenoses biodiversity are highly relevant. The findings of such research are essential for developing effective invasion management strategies, biodiversity conservation measures, and the sustainable functioning of agroecosystems.

Materials and methods. The study was conducted during 2020–2025 in natural phytocenoses where *Heracleum sosnowskyi* was present. To assess the impact of this invasive species on the structure and biodiversity of plant communities, the permanent plot method was applied, which allowed the analysis of temporal dynamics in species composition.

Within areas dominated by *Heracleum sosnowskyi*, permanent sample plots of 1 m² were established under relatively homogeneous edaphic and microclimatic conditions. In total, 10 sample plots were established and maintained throughout the entire observation period (2020–2025), which made it possible to analyze temporal changes in the structure of plant communities.

Geobotanical surveys were carried out annually during the period of maximum development of herbaceous vegetation, when species composition and the spatial distribution of phytocenotic components are most clearly expressed. Within each sample plot, the complete species composition of

vascular plants was recorded, and the projective cover of each species was estimated as a percentage. The obtained values were used as a quantitative measure of species participation in the community, as this indicator most accurately reflects competitive interactions among plants in herbaceous plant communities.

To standardize the data and enable comparison across communities with different species richness, the projective cover for each species was converted to relative values. The relative abundance of a species (p_i) was calculated as the proportion of the projective cover of the given species to the total projective cover of all species within the sample plot, using the following formula:

$$p_i = \frac{Ci}{\sum C},$$

where C_i is the projective cover of species i (%), $\sum C$ is the total projective cover of the plant community.

Biodiversity of phytocenoses was assessed using a comprehensive approach that included the analysis of species richness, dominance, and evenness of species distribution. For this purpose, the Shannon-Weaver index (H) was applied, which allows simultaneous consideration of both the number of species and the evenness of their participation within the community. The index was calculated using the following formula:

$$H = \sum_{i=1}^S p_i \ln p_i,$$

where S is the total number of species in the community, p_i is the relative abundance of species i .

To characterize the dominance level of *Heracleum sosnowskyi*, the Simpson's index (D) was applied, which is sensitive to increases in the proportion of dominant species within the community. The index was calculated using the following formula:

$$D = \sum_{i=1}^S p_i^2.$$

An increase in this index's values was interpreted as an enhancement of monodominance and a simplification of the structure of phytocenoses.

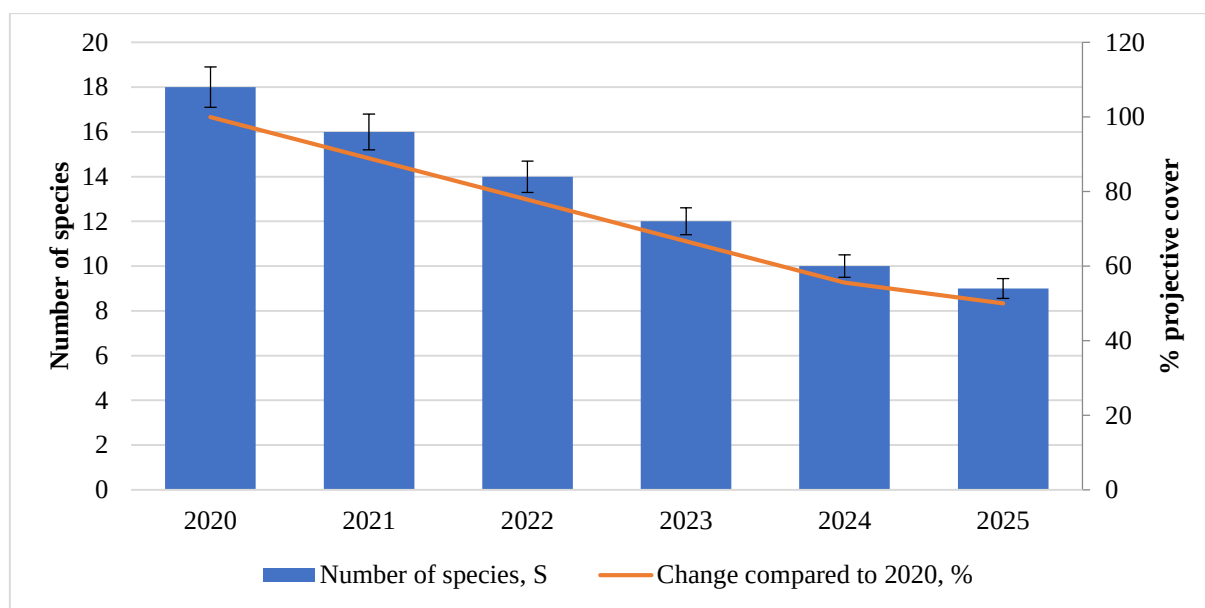
Species evenness within the community was assessed using Pielou's evenness index (J), which is derived from the Shannon-Weaver index and allows comparison of communities with different species richness. The index was calculated using the following formula:

$$J = \frac{H}{\ln S}.$$

To compare the mean values of biodiversity indices among sample plots with different densities of *Heracleum sosnowskyi*, a one-way analysis of variance (ANOVA) was applied. When statistically significant differences were detected, Tukey's post hoc test was used to determine pairwise differences between groups. Correlation relationships between the projective cover of *Heracleum sosnowskyi* and biodiversity indices were assessed using Pearson's correlation coefficient. Scatter plots and regression models were used to visualize these relationships.

Results were considered statistically significant at $p < 0.05$. Data are presented as mean $\pm$ standard deviation ($M \pm SD$) or as median with interquartile range (IQR), depending on the distribution.

Results and discussion. During 2020–2025, a clear trend of declining overall species biodiversity was observed in phytocenoses with *Heracleum sosnowskyi* present. At the initial stage of the study (2020), the communities were characterized by relatively high floristic richness. However, as the projective cover of the invasive species increased, less competitive plant species were gradually displaced. Specifically, in 2021, 16 species were recorded (88.9 % of the initial 2020 level), in 2022 – 14 species (77.8 %), in 2023 – 12 species (66.7 %), in 2024 – 10 species (55.6 %), and by 2025, the number of species had decreased to 9 (50 % of the 2020 level). Figure 1 illustrates the dynamics of species composition, clearly showing a gradual reduction in species numbers over time.



Note: values represent the total number of species recorded in the study plots; n = 3 sampling plots.

Fig. 1. Dynamics of overall species biodiversity in phytocenoses with the presence of *Heracleum sosnowskyi* (mean values for 2020–2025)

Over the six-year study period, the total number of species in the investigated communities decreased by half, indicating the gradual displacement of less competitive species due to the dominance of *Heracleum sosnowskyi*.

One of the key factors driving the transformation of phytocenoses during the study period was the gradual increase in the projective cover of *Heracleum sosnowskyi*. In

2020, *Heracleum sosnowskyi* occupied approximately 35 % of the total projective cover, while the combined cover of other species accounted for 65 %. Over the following years, the proportion of *Heracleum sosnowskyi* steadily increased: 42 % in 2021, 50 % in 2022, 58 % in 2023, 65 % in 2024, and 72 % in 2025. At the same time, the projective cover of all other species decreased correspondingly from 65 to 28 % (Figure 2).

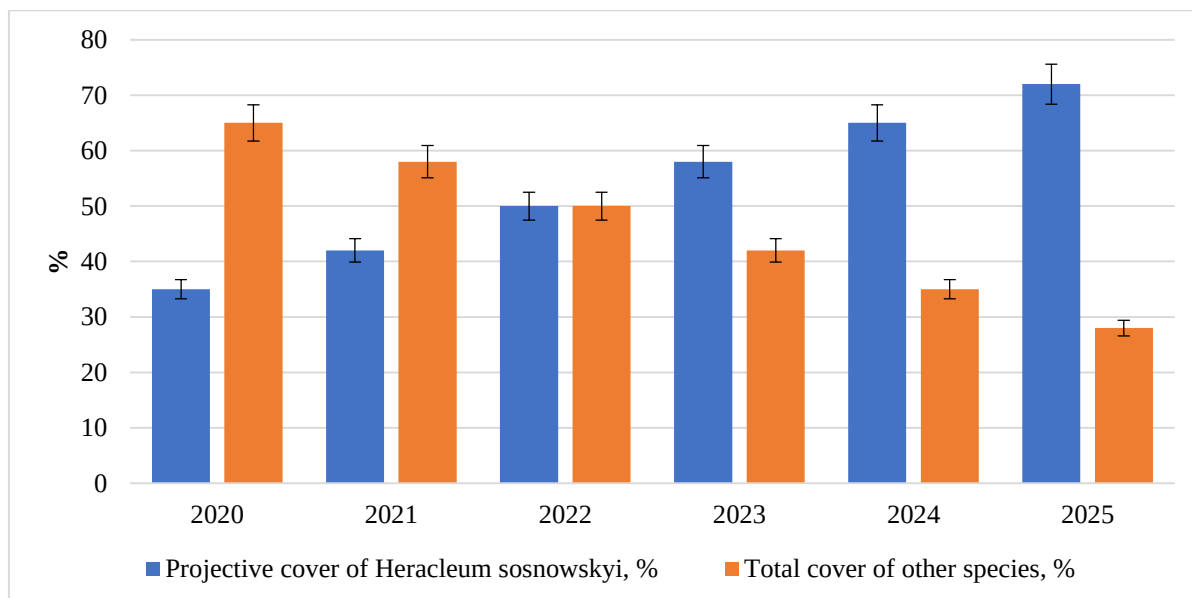


Fig. 2. Dynamics of the projective cover of *Heracleum sosnowskyi* compared to other species in the agrophytocenoses

This dynamic indicates a gradual increase in the dominance of *Heracleum sosnowskyi* and the strengthening of monodominance in phytocenoses. The observed balance between *Heracleum sosnowskyi* and other species in 2022, when their shares reached approximately 50 %, can be considered a critical threshold, after which less competitive species are actively displaced, and floristic diversity declines rapidly.

The illustration of the increasing projective cover of *Heracleum sosnowskyi* compared to other species visually highlights its tendency to dominate and transform community structure. Analysis of the presence of individual species within the phytocenoses allows for a more detailed assessment of

structural changes under the dominance of *Heracleum sosnowskyi*.

In the 2020 experiment, *Heracleum sosnowskyi* accounted for approximately 35 % of the total species cover, while traditional accompanying species such as *Elytrigia repens*, *Taraxacum officinale*, and *Plantago major* accounted for 10–20 %. By 2022, the share of *Heracleum sosnowskyi* increased to 50 %, while the cover of accompanying species decreased as follows: *Elytrigia repens* – 14 %, *Taraxacum officinale* – 12 %, *Plantago major* – 9 %, and other species – 15 %. By 2025, the dominance of the *Heracleum sosnowskyi* population reached 72 %, whereas the proportion of accompanying species had critically declined (Table 1).

1. Relative abundance of main plant species within the agrophytocenoses

Plant species in the agrophytocenoses	Year					
	2020	2021	2022	2023	2024	2025
<i>Heracleum sosnowskyi</i> Manden.	0.35 ± 0.02	0.42 ± 0.03	0.50 ± 0.03	0.58 ± 0.04	0.65 ± 0.04	0.72 ± 0.05
<i>Elytrigia repens</i> (L.) Nevski	0.20 ± 0.02	0.17 ± 0.02	0.14 ± 0.02	0.11 ± 0.02	0.09 ± 0.01	0.08 ± 0.01
<i>Taraxacum officinale</i> F.H. Wigg	0.15 ± 0.02	0.13 ± 0.02	0.12 ± 0.01	0.09 ± 0.01	0.08 ± 0.01	0.06 ± 0.01
<i>Plantago major</i> L.	0.10 ± 0.01	0.09 ± 0.01	0.09 ± 0.01	0.07 ± 0.01	0.06 ± 0.01	0.05 ± 0.01
<i>Trifolium repens</i> L.	0.05 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.03 ± 0.01
<i>Achillea millefolium</i> L.	0.05 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01
Other species	0.10 ± 0.02	0.10 ± 0.02	0.08 ± 0.02	0.08 ± 0.02	0.07 ± 0.02	0.04 ± 0.01

Note. Values are presented as relative species abundances (pi), reflecting the proportion of each species in the total projective cover of the community. Values are presented as mean ± standard deviation (M ± SD) calculated from permanent sampling plots (n = 10).

To quantitatively assess the transformation of phytocenoses under the influence of *Heracleum sosnowskyi* dominance, changes in key biodiversity indices were analyzed: the Shannon-Weaver index (H), Simpson's index (D), and Pielou's evenness index (J). These indicators allow simultaneous consideration of species diversity, dominance, and the evenness of species distribution within the community.

It was found that over the period 2020–2025, the Shannon-Weaver index decreased from 2.21 to 1.23, i.e., to 55.7 % of

its initial value (Figure 3). This trend indicates a gradual loss of species diversity and equilibrium among species within the communities. In the early stages of the study (2020–2021), the decrease in the H index was moderate (down to 91.9 % of the initial level). However, after surpassing the "critical threshold" of *Heracleum sosnowskyi* dominance in 2022, when its share in total cover exceeded 50 %, a rapid decline in the index was observed, reflecting the active displacement of less competitive species.

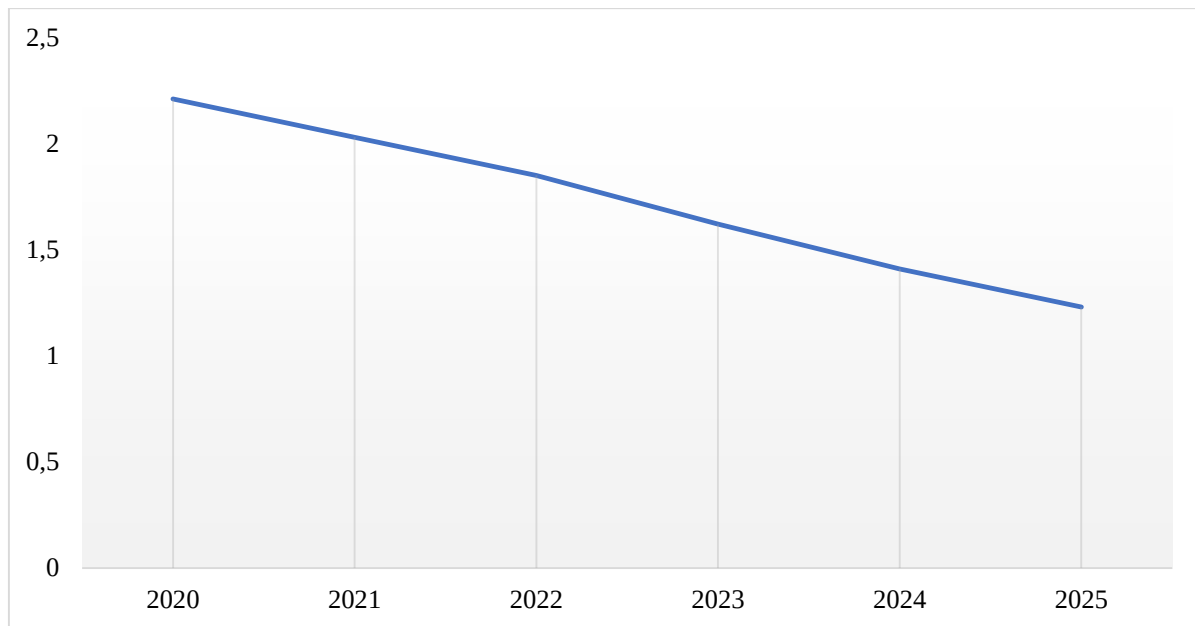


Fig. 3. Dynamics of changes in the Shannon-Weaver index for 2020–2025

At the same time, Simpson's index (D) increased from 0.21 to 0.55 over this period (Figure 4). The rise in D reflects the strengthening monodominance of *Heracleum sosnowskyi* within the communities and, consequently, the simplification of the

agrophytocenoses structure. Simultaneously, Pielou's evenness index (J) decreased from 0.77 to 0.56, indicating a disruption in the evenness of species distribution and the dominance of a single species.

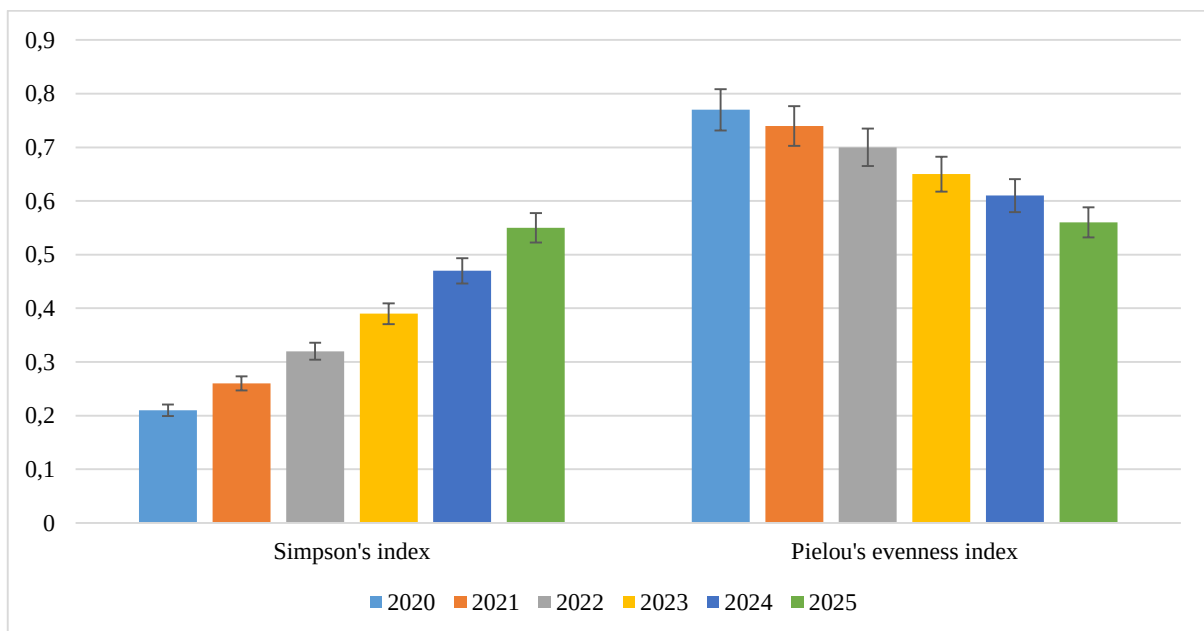


Fig. 4. Dynamics of Simpson's index and Pielou's evenness index for 2020–2025

A generalized analysis of the results convincingly demonstrated that the transformation of phytocenoses occurred directly under the influence of the increasing projective cover of *Heracleum sosnowskyi*.

Gradual growth in its dominance was accompanied by a simultaneous depletion of species diversity and a weakening of species evenness, as evidenced by the dynamics of the

Shannon-Weaver, Simpson, and Pielou indices.

To quantitatively confirm the observed patterns, a correlation analysis was performed, allowing us to assess the strength and direction of the relationship between the projective cover of *Heracleum sosnowskyi* and the main biodiversity indices of phytocenoses (Table 2). The correlation analysis revealed very strong

statistically significant relationships between the projective cover of *Heracleum sosnowskyi* and biodiversity indicators of the phytocenoses. An inverse relationship was found between the cover of *Heracleum sosnowskyi* and the Shannon-Weaver index ($r = -0.998$; $p < 0.001$), indicating a rapid decline in species diversity with increasing dominance of the invasive species.

2. Correlation between the projective cover of *Heracleum sosnowskyi* and biodiversity indices

Biodiversity index	Pearson r	p-value
Shannon-Weaver index	-0,998	< 0,001
Simpson index	0,988	< 0,001
Pielou's evenness index	-0,996	< 0,001

Note. Correlation analysis was performed using Pearson's coefficient ($n = 6$). Values of $p < 0.05$ indicate statistically significant relationships.

Similarly, Pielou's evenness index showed a strong negative correlation ($r = -0.996$; $p < 0.001$), indicating disruption of species evenness within the communities.

At the same time, Simpson's index showed a strong positive correlation with the projective cover of *Heracleum sosnowskyi* ($r = 0.988$; $p < 0.001$), confirming that monodominance intensified and community structure simplified as *Heracleum sosnowskyi* activity increased.

The obtained results indicate that the transformation of phytocenoses under the influence of *Heracleum sosnowskyi* is associated not only with an increase in its projective cover but also with a complex set of ecological mechanisms affecting the structure of plant communities. One of the key factors is strong light competition. *Heracleum sosnowskyi* forms tall and dense stands with a large leaf surface area, which leads to significant shading of the ground vegetation layer. Under such conditions, light-demanding species, particularly many representatives of forbs, are gradually displaced, while more shade-tolerant species may persist only during the early stages of invasion.

In addition, the large biomass and high density of *Heracleum sosnowskyi* stems contribute to changes in the microclimatic conditions within the phytocenosis, including increased humidity and reduced temperature

fluctuations in the near-ground layer. Such changes may negatively affect seed germination and the development of many herbaceous plant species. Another important factor is the accumulation of a large amount of plant litter after the dieback of aboveground biomass, which leads to the formation of a dense litter layer and limits the germination and establishment of other species.

During the invasion process, changes in the ecological structure of the plant community are also observed. The proportion of grasses and legumes gradually decreases, while the dominance of *Heracleum sosnowskyi* leads to a simplification of the community structure and the formation of monodominant stands. The participation of perennial meadow species, which are important components of stable herbaceous ecosystems, also declines.

Furthermore, according to previous studies, *Heracleum sosnowskyi* may exhibit allelopathic properties by releasing biologically active compounds that inhibit the germination and growth of neighboring plants. In combination with light competition, microclimatic changes, and litter accumulation, these processes create a complex mechanism of displacement of accompanying species and contribute to the gradual decline of biodiversity within affected phytocenoses.

Thus, *Heracleum sosnowskyi* appears to influence the structure and functional stability of phytocenoses. During the study period, the phytocenoses showed a noticeable decline in biodiversity, reflected in reduced species richness, increased monodominance, and lower ecological evenness. The increasing projective cover of *H. sosnowskyi* was identified as a potential contributor to these changes, highlighting the need for informed management and monitoring measures to address its spread.

The results of this study, demonstrating the significant impact of *Heracleum sosnowskyi* on the composition and structural stability of phytocenoses, are consistent with numerous contemporary studies that highlight the invasive potential of this species and its ecological consequences. Indeed, the study revealed that a systematic increase in the share of *Heracleum sosnowskyi* in the overall structure of plant communities was accompanied by a corresponding decrease in the participation of companion species, which directly affected the floristic structure and increased the dominance of invasive species. These data indicate a rapid decrease in the dominance of companion species and the loss of structural multicomponent diversity in communities, which confirms the high competitive ability of *Heracleum sosnowskyi* and its ability to transform the composition of phytocenoses.

In particular, most authors note the extensive distribution of *Heracleum sosnowskyi* in Ukrainian plant communities and emphasize its ability to form distinct phytocoenotic groups that strongly affect local plant assemblages. These data confirm the high invasive potential of *Heracleum sosnowskyi* and its close association with transformations of plant cover in natural and semi-natural environments [9, 21].

These findings also align with studies that consider *Heracleum sosnowskyi* an invasive species with a negative impact on biodiversity and the ability to displace native species due to its ecological plasticity and adaptive traits [10, 14, 25]. Furthermore, results from local field studies confirm that

Heracleum sosnowskyi possesses a high spread potential in certain landscapes, demonstrating stable range expansion and considerable phytocoenotic pressure on the floristic structure of local communities [24, 27].

International publications also emphasize that *Heracleum sosnowskyi* is one of the key invasive species threatening biodiversity, alongside Canadian goldenrod (*Solidago canadensis*) and common ragweed (*Ambrosia artemisiifolia*), underscoring its relevance to national strategies for invasive species management [6, 22].

Scientific research further indicates that species of the genus *Heracleum*, including *Heracleum sosnowskyi*, not only displace native species but can also cause long-term changes in ecosystem functions, manifested in suppressed species diversity and disruption of natural processes in herbaceous communities [5, 18, 19, 23].

Thus, the results of the present study over 2020–2025, demonstrating increased monodominance, decreased biodiversity indices, and changes in plant community structure, align with a broad body of scientific research on the negative impact of *Heracleum sosnowskyi* on local ecosystems. The species can suppress less competitive plants and contribute to biodiversity degradation at both global and regional scales.

Conclusions. The study demonstrated that *Heracleum sosnowskyi* significantly alters the structure and stability of phytocenoses. Its increasing dominance leads to the displacement of less competitive species, reduced species diversity, and the formation of monodominant communities. These changes indicate a disruption of community evenness and simplification of phytocoenotic structure.

The findings highlight the high invasive potential of *Heracleum sosnowskyi* and underscore the need for timely and scientifically informed management measures. Monitoring species composition, projective cover, and biodiversity indices can help identify critical thresholds for intervention and support effective planning of control and restoration strategies. Implementing such measures will contribute to the conservation of

biodiversity and the maintenance of ecosystem stability in affected agricultural landscapes. It is recommended to regularly monitor the proportion of *Heracleum sosnowskyi* in

communities and take measures to limit its dominance in order to maintain species diversity and even distribution of species.

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