Original article

The problem associated with the spread of Sosnovskiyi hogweed (*Heracleum sosnovskiyi*), in the mountainous geosystems of the Ukrainian-Polish border

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ABSTRACT

The article highlights the problem of spreading of the invasive species *Heracleum sosnovskiyi* in mountainous geosystems in the border district of Turka in the Lviv region of Ukraine particularly along the border with Poland. The aim of the article was to investigate the areas covered and peculiarities of the spread of *Heracleum sosnovskiyi*. The research methodology consisted of three consecutive steps: preparation, field work, and cameral. The following general scientific methods were used: system analysis and synthesis, comparison, ranking, and the special methods of geoecological studies: field, cartographic, drone survey and photofixation. During the field studies, we sampled seven model areas, representing mountain geosystems with different types of economic use and the presence of *Heracleum sosnovskiyi*: - river valleys, uncultivated agricultural land, narrow strips along roads, abandoned territories. In one of the model areas, a drone survey was conducted, on the basis of which we charted a map presented in the article. We also analysed the stock data and the current state of distribution of the spread *Heracleum sosnovskiyi* in village councils and in the region as a whole. The main problem with the uncontrolled spread of *Heracleum sosnovskiyi* in Turka district is the lack of true data as to the extent of the environmental disaster and the absence of a systematic and planned fight control measures. The article describes the main recommendations for the effective control fight against of this invasive species using foreign experience.

KEY WORDS: *Heracleum sosnovskiyi*, Ukraine-Poland borderland, invasive species, mountain geosystems, drone survey method

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1. Introduction

The spread of *Heracleum sosnovskiyi* is an extremely urgent problem not only for Ukraine but also for other European countries (Poland, Czech Republic, Latvia, Belarus) and needs to be solved as soon as possible, since it threatens natural biodiversity, agricultural development, and people's health. In contrast to Ukraine, which only recently planned to fight against this dangerous plant, European countries have been combating this dangerous weed for decades. However, this fight is reduced to nothing in the border areas because invasive plants do not recognize political borders.

H. sosnovskiyi spreads extremely fast through the mountainous geosystems of the Ukrainian-Polish borderland, in the Turka district of Lviv region in Ukraine. According to the official data

from the Department of Ecology of the Lviv Regional Administration, the largest areas covered by the invasive *H. sosnovskiyi* in the region are concentrated in the Turka district, which is located in the south-western part of the region and in the west, it borders upon the Lublin voivodeship of Poland. Therefore, the problem of the spread of *H. sosnovskiyi* in this region has a transboundary character and must be solved by the joint efforts of both states.

The purpose of the article is to analyze the recent areas of colonization of *H. sosnovskiyi* in the boundary Turka district of Lviv region in order to develop effective measures to fight against the invasive plant, whilst taking into account the Polish experience of this species.

Ecological and geographical studies of the spread of *H. sosnovskiyi* are extremely important for the conservation of biodiversity. A lot of scientists work

on the problem of the spread and control of the weed, particularly in Ukraine (SHUVAR, 2001; VYKHOR & PROTS', 2009; KOINOVA & ROZHKO, 2015), Poland (SACHAJDAKIEWICZ ET AL., 2014), Russia (IVANOV & KOLOSOV, 2012), Latvia (KABUCE, 2010). But there are still no clear conclusions about the best methods of combating this invasive species. Thus, in order to choose effective control measures for *H. sosnovskyi*, it is important to take into account the geographical peculiarities of the territory and the environmental properties of the species. These integrated ecological and geographic studies, which are systematic and take into account the principle of regionality, make these problems more reliably solvable.

2. Research methodology

To achieve the goal, we used general scientific methods of system analysis and synthesis, comparison, ranking as well as special methods of geocological studies: field, cartography and a drone survey.

On the basis of the analysis of literary sources (SHUVAR, 2013), scientific publications (KOINOVA, 2013; KOINOVA & ROZHKO, 2015; KOINOVA & SHTOIKO, 2015), internet resources (VYKHOR & PROTS', 2012), stock materials from the Department of Ecology and Natural Resources of Lviv Regional State Administration (CONDUCTING MEASURES FOR THE PROTECTION, 2013) and Turka district state administration (COLLECTED DATA OF TOWN, 2016), we collected the available information about *H. sosnovskyi*, the peculiarities of its development and adaptation, the areas of its spread, the threat to geosystems, economy and people.

The field studies covered seven model sections in the boundary Turka district, which represented mountain geosystems with different types of economic use and the presence of *H. sosnovskyi*. The main methods of studying the spread of *H. sosnovskyi* were route and expeditionary studies and drone survey. Such studies do not allow us to reliably estimate the real areas of *H. sosnovskyi* and to fix the various phases of weed development, as it releases toxic substances that lead to burns on the human skin. Therefore, we used an additional method of drone survey in one of the experimental areas.

The genus of a *Heracleum* includes up to 70 species, five of which grow naturally in the territory of Ukraine. The most common (almost throughout Ukraine – in meadows, on river banks, along the roads) is *Heracleum sibiricum*. In the Carpathians, *Heracleum carpaticum*, *Heracleum spotilium*, and occasionally *Heracleum palmatum*

are present. *Heracleum steveni* grows in Crimea (SHUVAR, 2013).

Heracleum sosnovskyi grows all over Ukraine but unlike the naturally occurring species it poses a great threat to biodiversity, since it is an alien and has no natural enemies or rivals. *H. sosnovskyi* belongs to the group of invasive species, these are allochthonic species with a significant capacity for expansion, which spread naturally or artificially with the help of people and constitute a significant threat to certain geosystems, competing with autochthonal species for ecological niches, causing the death of local species, and rendering it impossible to restore them. *H. sosnovskyi* comes originally from mountain forests and subalpine meadows of Central and Eastern Caucasus, Transcaucasia and Turkey.

In the former USSR, *H. sosnovskyi* was cultivated in the 1940s specially for introduction into agricultural production as a promising silage culture. *H. sosnovskyi* was selected out of several species, since it was the most productive. In 1947, due to J. Stalin's order, *H. sosnovskyi* was included into the list of Soviet crops. Despite the objections of scientists, the plant was actively cultivated as a silage culture in the former USSR and the countries of the "socialist camp". Thus, *H. sosnovskyi* was cultivated in Latvia, Estonia, Lithuania, Belarus, Ukraine and the former GDR, since 1958 – in Poland. In Ukraine, *H. sosnovskyi* was introduced in 1949 from the Kabardino-Balkar Autonomous Soviet Socialist Republic and sowed in the Central Botanical Garden of the Academy of Sciences of the USSR. Since 1962, *H. sosnovskyi* was profoundly studied in Ukraine as a new forage plant and promising bee forage plant (Kyiv Livestock Station – Terezine village of Bila Tserkva district, Pozhyzhevskaya valley on the ridge of Chornohora, Ivano-Frankivsk region, Panfily research station – Yahotyn district of Kyiv region, Zhytomyr bee breeder, etc.). However, as it turned out later, after eating silage from *H. sosnovskyi*, cows began to produce milk with a bitter taste that was unsuitable for consumption (MOSHKIVSKA, 2016). Therefore, the plant ceased to be cultivated and controlled. But the large seed bank that remained in the soil for years from *H. sosnovskyi* cultivation provoked its significant proliferation. It has become an environmental problem in the places of its former cultivation. If the sap of *H. sosnovskyi* gets on human skin, it causes severe burns (KOINOVA & ROZHKO, 2015). The morphological peculiarities of *H. sosnovskyi* contribute to its effective adaptation to different conditions and rapid reproduction. The plant is waterloving, but it does not withstand waterlogging, it is frost-hardy, and capable of producing 15-100 thousand seeds per year (SHTOIKO, 2017).

3. The results of the study

In the territory of Turka district, there were favorable natural conditions for the spread of *H. sosnovskyi*: a dense river network, sufficient moisture, and a favourable temperature regime, typical for the mountainous climate. In addition, a significant decline of agriculture, a great number of untreated lands, deforestation and inactivity of local authorities contribute to the increase in the range of this invasive species.

The results of the study on the spread of *H. sosnovskyi* in the mountainous regions of Lviv (KOINOVA & SHTOIKO, 2015) and Transcarpathian

(VYKHOR & PROTS', 2013) regions made it possible to reveal the characteristic locations of this dangerous plant – floodplains of rivers and water reservoirs, the roadsides of motorways and railways, canals, ravines, gullies, abandoned agricultural lands, heaths, landfill sites, edges of forests, parks, and gardens.

The spatial spread of the populations of *H. sosnovskyi* territory is heterogeneous. Fig. 1 shows that the largest areas under *H. sosnovskyi* are concentrated in Yavora village council (90.95 hectares), and the smallest – in Syanky village council (0.01 hectares).

Fig. 1. Areas occupied by *H. sosnovskyi* in Turka district (Conducting measures for the protection..., 2016)

Due to the sizes of the areas, occupied by *H. sosnovskyi*, we can single out the following groups of village or town/city councils:

- up to 1 hectare: (Syanky, Kryvka, Yasenytsya)
- 1-5 hectares (Komarnyky, Rosluch, Verkhnye)
- 5-10 hectares (Isayi, Verkhnye Vysotske, Lastivka)
- 20 hectares (Zavadiivka, Ilnyk Turka, Borynya)
- more than 20 hectares (Nyzhnye Vysotske, Mokhnate, Yavora).

The mean value of the areas occupied by *H. sosnovskyi* in the district is 13.7 hectares. The size of the weed areas depends on natural and anthropogenic factors. The significant forest cover of the territory makes the growth of *H. sosnovskyi* impossible, on the contrary, the large area of grasslands or pastures, not being used now, contributes to the increase of its covered area.

Particularly dangerous to the border territories are the large areas of *H. sosnovskyi* in Borynya and Nizhnye Vysotske village councils. Because of its proximity to the border with the Lublin voivodeship and unsystematic measures of fight control against the weed from the Ukrainian side, there is a great threat of the extension of these areas of *H. sosnovskyi* and its "crossing" across the border. In the boundary territory of Syanky and Verkhnye village councils, the areas occupied by *H. sosnovskyi* are not large due to the large forest lands and unfavourable conditions for its distribution. In addition to boundary regions, the development and implementation of effective means to fight against the spread of this invasive species is required by the village councils with a higher average cover value of *H. sosnovskyi* areas in the Turka district – Borynya, Mokhnate, Yavora, Nizhnye Vysotske.

The dynamics of the indicators show that the areas of *H. sosnovskyi* are constantly expanding: by 36 hectares during a two year period. The dynamics of the spread of *H. sosnovskyi* in the territory of Turka district is presented in more detail in Table 1 and Fig. 2.

In general, the areas occupied by *H. sosnovskyi* in the district, increased by 1.2 times (by 19.9%) and amounted to 218.8 hectares in the 2016. In the territories of Mokhnate village and Turka town councils, the areas covered by *H. sosnovskyi* have increased 6 times. The favourable conditions and absence of any measures of weed control have contributed to the rapid spread of this plant.

The positive tendency of reducing the area under *H. sosnovskyi* was observed only in the territory of Borynya village council. This is due to the one-time mowing and extirpating of *H. sosnovskyi* along the Turka-Borynya road. In the territories of Nizhnye Vysotske, Verkhnye Vysotske, Lastivka, Yavora village councils, there is an extremely negative tendency of increasing areas of the weed (from 0.5 to 3 hectares). Obviously, no measures were taken there fight against to control this dangerous weed. The field studies of seven model plots during 2014-2016 confirm that the areas covered by *H. sosnovskyi* tend to extend over time.

Table 1. Dynamics of the areas occupied by *Heracleum sosnovskyi* in Turka district of the Lviv region (Conducting measures for the protection..., 2016)

Name of village, town council	2014 [ha]	2015 [ha]	2016 [ha]	Dynamics [ha]
Nyzhnye Vysotske	20.00	20.10	20.10	+0.10
Verkhnye	3.65	3.65	3.65	0
Ilnyk	11.00	11.00	11.00	0
Borynya	20.00	19.50	19.50	-0.50
Verkhnye Vysotske	6.00	6.50	6.50	+0.50
Lastivka	6.66	8.00	8.00	+1.34
Kryvka	0.50	0.50	0.50	0
Yavora	88.00	90.95	90.95	+2.95
Turka	2.40	12.40	12.40	+10.00
Isayi	5.00	5.00	5.00	0
Komarnyky	1.20	1.20	1.20	0
Rozluch	2.50	2.50	2.50	0
Syanky	0.001	0.001	0.001	0
Yasenytsya	0.50	0.50	0.50	0
Zavadiivka	11.00	11.00	11.00	0
Mokhnate	4.00	26.00	26.00	+22.00
Total	182.41	218.80	218.80	+36.39

A rather large area of *H. sosnovskyi* was occupied along the shores of the River Stryi, near the Javora Hydroelectric Power Station. Here the plant dominates the geosystems of the valleys of the main rivers with fragments of lower terraces with soddy, brown soil, sandy and loam soils on mountain alluvium (MUKHA, 2003). The dense thickets of *H. sosnovskyi* stretched along the river bed at a width of 3-4 m on the flat left bank of the river and occupied 60% of the area under study. The plants in this area were up to 3 m high, with inflorescences of about 50 cm in diameter and thick trunks of about 15 cm. One plant occupied an area of at least 1 m². There were no other plants growing under *H. sosnovskyi*. Its presence has forced out the following floodplain species from the natural

plant cover: *Petasites hybridus*, *Equisetum fluviatile*, *Trifolium arvense*, *Inula helenium*. The reason for this is the morphological features of the weed. It is a moisture-loving species that grows well on floodplains. *H. sosnovskyi* is the first among other plants to sprout in the spring and its big leaves shade large areas and make it impossible for natural vegetation to grow (SHTOIKO, 2017).

The largest areas of *H. sosnovskyi* during the field studies are located near Yavora village in abandoned pastures. Here the geosystems of low-mountain wide interscale declines prevail with fragments of ancient drains in longitudinal valleys with soddy and brown soils on the deluvium of flysch and ancient alluvial sediments under agricultural land (MUKHA, 2003). We chose this

section for detailed studies using the drone-survey method. The use of a pilotless aerial vehicle enabled us to cover large areas of land occupied by *H. sosnovskiyi*. A drone can cover large areas occupied by *H. sosnovskiyi*, and outline the areas and distinguish different stages of plant development.

During the study, about 15 photographs were taken from different angles on the basis of which a comprehensive picture of the territory was created Fig. 3, which became the basis of the map shown in Fig. 4.

Fig. 2. Dynamics of the areas occupied by *Heracleum sosnovskiyi* in Turka district of the Lviv region (Conducting measures for the protection..., 2016)

Fig. 3. Comprehensive picture of the territory occupied by *Heracleum sosnovskiyi* in Turka district of the Lviv region (July 2016) (Shtoiko, 2017)

Fig. 4. The spread of *H. sosnovskyi* near Yavora village (July 2016) (Shtoiko, 2017)

The studies covered an area of 3.24 hectares, 1.75 hectares (54%) of which were occupied by *H. sosnovskyi*. Across the whole area, large plants grow which are 3-4 m high, with trunks of 10-12 cm in diameter and massive inflorescences of about 50-60 cm in diameter.

H. sosnovskyi grows practically throughout the whole area under study, it is confined only by wetlands, shrubs and understorey as well as small plots where agricultural activities are carried out. These are the factors that are unfavourable and limit the spread of this weed.

Decoding of the drone images allowed us to identify the various stages of plant development, which makes it possible to choose more effective measures of fight to control the spread of this species. The developmental cycle of *H. sosnovskyi* is from 2 to 7 years or more. The culture belongs to the monocarpic type, each plant blossoms only once in its life: in the second, fifth, or seventh year (SHUVA, 2013). In 2016, in the area under study, the plants that blossomed were distributed unevenly and occupied 50% of the area occupied by *H. sosnovskyi*. Therefore, in 2016, measures to combat the dangerous weed in this area were not taken.

As evidenced by some small plots with low plant density, the growth, development and spread of *H. sosnovskyi* are affected by the structure and mechanical composition of the soil.

The drone survey made it possible to contour in detail the contemporary areas of *H. sosnovskyi*

spread, to determine the phase of its development and differences in the locality, which matters when choosing the methods to combat the spread of this species. One can also build models to show the expanding territories of its growth in the absence of effective fight control.

In geosystems, the spread and current state of this invasive species depends more on the type of economic use of the land and methods to control it. Along the highways and railways, the areas of *H. sosnovskyi* are linear, on agricultural land or on landfill, the cover area depends on general planning or cutting of fields.

The studies of *H. sosnovskyi* along the Turka-Borynya highway showed that the weed areas are large: continuous strips longer than 100 m and 5-7 m wide on both sides of the road. Here the plants are depressed and smaller in size. Some of them were not more than 2 m high, with inflorescences 20-30 cm in diameter, the diameter of the stems was 4-5 cm. Owing to its smaller size, the density of plants is greater than in flood geosystems or abandoned pastures. Here dominating are the geosystems of low-mountain flat and slanting slopes, divided by the cavities lower plots of interflues, formed in the soft flisch (MUKHA, 2003). For two years, the weed areas have not increased significantly, but the size of the plants has decreased. This can be explained by the fact that in July 2015, mowing was conducted of plants in bloom. The time for mowing was chosen wrong because when

plant seeds fall off, they contribute to the further spread of the *H. sosnovskyi* (KOINOVA & ROZHKO, 2015). Thus, the wrong measures of control against *H. sosnovskyi* not only did not reduce its areas, but on the contrary, contributed to its spread and expansion.

The only plot under study, where, we observed the decrease of the areas with *H. sosnovskyi*, during the two surveys was located on agricultural land within the town of Turka. In 2014, *H. sosnovskyi* was up to three metres tall and occupied private plots in the southeastern part of the town, which were divided into vegetable gardens and most of these were abandoned and not cultivated. The neighboring plots were planted with agricultural crops (potatoes, beets, carrots, etc.). The control measures which were taken over two years changed the situation for the better. *H. sosnovskyi* was periodically mowed and extirpated, and the gardens started to be cultivated. As a result, in 2016, the areas of the invasive species decreased by half, the plants were suppressed, they were up to 1.5 m tall, only a few of them bloomed, the diameter of the inflorescence was up to 25 cm. However, the density was still high and the spread was even. *H. sosnovskyi* totally disappeared on the plots, which started to be cultivated and planted with cultivated species.

The most suppressed and smallest plants among all the areas under study grew near the landfill 2 km south-east of the village of Borynya. Their average height was 1 m, rarely 1.5 m, the inflorescences were small (up to 25 cm), the stems were thin, the plants were solitary, distributed unevenly along the perimeter of the landfill on leeward slopes.

The results of a three-year study of the spread of *H. sosnovskyi* in the mountainous geosystems of Turka district in Lviv region confirmed the data about typical locations of this dangerous plant – floodplains of reservoirs, sides of highways and railways, uncultivated agricultural land, barren areas, landfill sites, ravines, gullies. Unfavourable conditions for *H. sosnovskyi* are in wetlands or forest geosystems on poor soils. The processes of silviculture supplant this invasive hogweed, and the return of the land to economic use is an effective method of exterminating the weed.

Effective control and the safest methods in mountain geosystems will be the following: agrotechnical, harrow, mowing, undermining at the roots, before flowering of the plant. In flooded areas, forest and shrub species should be planted, which will gradually supersede *H. sosnovskyi*.

Such a complicated situation and the positive dynamics of the areas covered by the invasive weed is due to the fact that by 2014, there was

no active control against *H. sosnovskyi* in the Turka district and its spread was out of control. The measures for combating *H. sosnovskyi* were conducted only partially in private households. According to the polls, the residents themselves fought the spread of the dangerous plant by mowing and extirpating roots. The lack of information on the toxic effects of *H. sosnovskyi* often led to severe burns and stopped further fight with the plant. As a result, a large part of unused agricultural land has turned into dense thickets of the hogweed.

In 2014-2015, a program of financial support for the destruction of *H. sosnovskyi* was developed for the Turka district, determined the measures to destroy *H. sosnovskyi* in this district. In 2015, the Fund for the Protection of the Environment in the Lviv region allocated 99 thousand UAH to fight against *H. sosnovskyi*. However, they were used inefficiently because a single mowing of *H. sosnovskyi* was carried out in late July, when *H. sosnovskyi* was in the blooming stage and it was categorically impossible to mow it. All mowings in subsequent years did not give the expected result due to unsuccessfully selected terms and the use of a single method – mowing.

4. Conclusions

The main problem is the annual increase in the area occupied by *H. sosnovskyi* in different geosystems as well as the fact that the plant is still included in the lists of valuable forage crops in Ukraine. Therefore, it is impossible to organize effective fight control measures against this dangerous weed. The inclusion of *H. sosnovskyi* into the list of quarantine species, will make it possible to establish state control and allocate funds for integrated effective measures.

Inaction or ineffective and unsystematic fight control against *Heracleum sosnovskyi* is the cause of its annual increase in cover area. The uncontrolled spread of *H. sosnovskyi* in the boundary mountain geosystems of Turka district in the Lviv region poses a threat to the neighboring mountain territories and geosystems of Poland. The favorable natural conditions, the decline of agricultural land use, the vulnerability of mountain geosystems over the past three years has contributed to the increase in area covered by this invasive hogweed by 20%.

The problem is the modern decline of agriculture in Turka district and the dispersion of responsibility and control over the use of land mines between different departments in Ukraine. Modern use is under the control of water management, the state agency of motor roads in Ukraine (Ukravtodor)

and local authorities. Control fight will only be successful if all the land users join together.

A great problem is the lack of monitoring, and hence reliable data on the real areas of spread of this invasive plant. In order to solve it, it is necessary to use the experience of Poland, where an electronic database of *H. sosnovskyi* areas has been created for each administrative territory. This data bank is interactive, it can be filled by inhabitants themselves. Having identified the areas of *H. sosnovskyi*, they need to photograph them, set GPS coordinates and send them to the general database. Owing to an effective information policy in Poland and the activity of local citizens, supplemented by scientific studies and public financing, over several years, the spread of *H. sosnovskyi* is under control and a map of its distribution was created. A systematic, scientifically grounded control fight with the use of various complementary methods yielded good results in reducing the areas covered by this dangerous weed.

An important problem is the ineffective "formal" programs of fighting control against this dangerous weeds, which were developed without scientific justification. To successfully overcome the danger of uncontrolled spread of *H. sosnovskyi* in the boundary mountain geosystems, it is necessary to develop an effective control strategy. This should include information on the scope of the disaster, in particular active eco-education, cooperation with local residents and managers at different levels, supplemented by scientific studies and recommendations, and public financing. This will make it possible to determine the real scope of the spread of *H. sosnovskyi* and create a map of its distribution. The next step should be a consistent, well-planned, regular control against the weed. It is necessary to take into account the natural conditions of the Turka district and use a system of various methods, depending on the specific conditions of each area.

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