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Identification of the thickets of *Heracleum sosnowskyi* using Earth remote sensing data

© 2018. E. V. Tovstik[1], T. A. Adamovich[1], V. V. Rutman[1], G. Ya. Kantor[1, 2], T. Ya. Ashikhmina[1, 2],
[1]Vyatka State University,
36 Moskovskaya St., Kirov, Russia, 610000,
[2]Institute of Biology of the Komi Scientific Centre of the Ural Branch of RAS,
28 Kommunisticheskaya St., Syktyvkar, Komi Republic, Russia, 167982,
e-mail: tovstik2006@inbox.ru

Sosnowsky's hogweed (*Heracleum sosnowskyi* Manden.) is one of the most dangerous invasive plant species, common in the European part of Russia and some European countries. Its spread threatens the biological diversity of natural ecosystems. The danger of *H. sosnowskyi* for the human health lies in its ability to cause skin burns. Large populations of *H. sosnowskyi* can be found in uncultivated fields, meadows, on the banks and in the vicinity of watercourses and reservoirs, on the outskirts of forests, and along roads. Currently in Russia, in connection with the massive spread of *H. sosnowskyi*, the question is raised about the need to create a special federal target program to control this dangerous species. The data of the Earth remote sensing can provide essential assistance in planning the measures to control the spread of *H. sosnowskyi*. Satellite imagery provide information about localization and areas of plant communities in large areas. To monitor the distribution of *H. sosnowskyi*, it is possible to use multispectral as well as monochrome satellite images of high and medium resolution. In our study we used images from the Sentinel-2 satellite with a resolution of 10 m. The detection of the foci was carried out on the territory of certain districts of the Kirov region of Russian Federation. The populations of Sosnowsky's hogweed are well recognized visually on synthesized color images using either three channels of the visible range (blue, green, red), or two visible (blue and green) and near infrared channel. Both variants give very close results, providing reliable identification of thickets of the hogweed.

Keywords: *Heracleum sosnowskyi*, invasion, remote sensing data, Sentinel 2.

Sosnowsky's hogweed (*Heracleum sosnowskyi* Manden.) is one of the most dangerous invasive plant species, common in the European part of Russia and some European countries [1–3]. Its danger is associated with the threat to the biological diversity of natural ecosystems and the ability to cause severe burns when the juice hits the human skin [4, 5].

Introduced in some regions of Russia, as well as abroad, Sosnowsky's hogweed was cultivated in the late 50th and early 60th years of the twentieth century as a silage culture. However, after revealing its inadequacy to feed livestock, the purposeful cultivation of Sosnowsky's hogweed was discontinued. The lack of control over the state of the currently abandoned crops led to the fact that *H. sosnowskyi* went beyond the boundaries of the cultivated land [6]. At the same time, the presence of pronounced allelopathic and herbicidal action, clastogenic and antigenic activity against other plants allowed him to populate significant areas [7, 8].

High seed productivity of *H. sosnowskyi*, as well as its capacity to seed dispersal with running water and floods, winds, animals, as well as by human when dispersion occurs with the air flow generated by road and rail transport, it facilitates the rapid spread of [1, 9, 10]. Most often, the Sosnowsky's hogweed is found in disturbed areas with relatively rich and well-moistened soils. Its large populations can be found on uncultivated fields, meadows, on the banks and in the vicinity of watercourses and reservoirs, on the outskirts of forests, and along roads [9, 11]. In the valleys of the large and medium rivers shores formed by rocks with a high content of solid detrital material appear as the most favorable for the growth of *H. sosnowskyi*, while wet abrasion plains and sandy shores are unfavorable for growth [3].

In connection with the mass distribution of Sosnowsky's hogweed on the territory of certain regions of the Russian Federation, the question of the need to create a federal target program to control hogweed in Russia is being raised in the State Duma. The technology of geoinformation systems (GIS) with the use of remote sensing (RS) data can provide essential assistance in planning the measures to control the spread of the Sosnowsky's hogweed from the point of view of controlling its growth zones. At present, RS data analysis is a promising method

for studying vegetation cover [12, 13], which allows obtaining information on areas occupied by plant communities, as well as their state in large areas [14–16].

Satellite images from space vehicles (RapidEye, Resourcesat, Landsat, Kompsat, Resource DK, SPOT, Sentinel) can be used to monitor foci of the distribution of Sosnowsky's hogweed [17, 18]. Reliable results can be obtained with the use of multispectral satellite images made in the spectral zones of 660–720 or 600–700 nm, which provide the greatest clarity and the best spatial resolution [19]. Good results can be obtained by synthesizing colored images for typological interpretation of Sosnowsky's hogweed snapshots.

The purpose of this work was the approbation of the method for detecting the foci of the distribution of Sosnowsky's hogweed in the territory of the Kirov region using the available satellite images.

Objects and methods

With regard to the study of foci of the spread of plant populations, including Sosnowsky's hogweed, several of the most important tasks can be identified, in which satellite images can be used.

First of all, this is a qualitative and quantitative assessment, which includes the identification of different types of phytocenoses, areas of their distribution, the state of vegetation on the basis of spectral indices [17]. An important task, along with a qualitative and quantitative assessment, is the inventory of the vegetation cover, which includes the primary information on its composition and structure. It includes mapping based on remote sensing data; obtaining information on the distribution of vegetation cover units of different scale from formations to individual species.

Spatial analysis of Earth remote sensing data in combination with field research data opens up the possibility of statistical analysis of patterns of distribution and occurrence of plant communities (including Sosnowsky's hogweed).

One of the important tasks of studying the dynamics of plant populations is modeling and forecasting the distribution of plant communities, changing their boundaries over time, identifying corridors suitable for habitats of the studied plant communities [16].

The detection of the foci of the distribution of Sosnowsky's hogweed was carried out in Falensky, Slobodskoy and Belokholunitsky dirstricts.

A multispectral space image obtained from the Sentinel-2A spacecraft on August 23, 2017, was used to test the method for detecting hotspot distribution. This device is equipped with an optoelectronic multispectral sensor for surveys with a resolution of 10 to 60 m in the visible, near infrared (VNIR) and short-wave infrared (SWIR) spectral zones, which include 13 spectral channels, which ensures the display of differences in the vegetation state, including temporary changes, and also minimizes the impact of the atmosphere on the survey quality. The increased width of the survey strip, along with the high repeatability of surveys, makes it possible to track rapidly changing processes, including changes in the nature of the vegetation during the vegetation period, which makes it possible to identify hogweeds in different seasons of the year.

Results and discussion

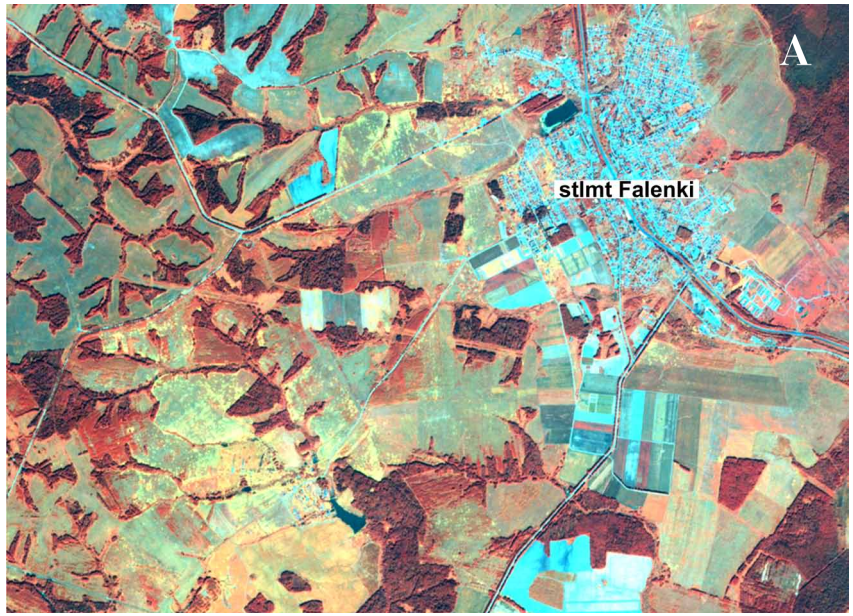
The processing of multispectral images was carried out using the ENVI 5.2 program. Four spectral channels with a spatial resolution of 10 m were used to search for the foci of growth of the Sosnowsky's hogweed: blue B2 (447.6–545.6 nm), green B3 (537.5–582.5 nm), red B4 (645.5–683.5 nm) and near infrared B8 (762.6–907.6 nm). The standard way of visualization in the ENVI environment involves using only three spectral channels to form a color image on the screen. In this case, the best visuall results are given by the combination of RGB = B4 + B3 + B2 (in accordance with [19, 20]) and RGB = B8 + B3 + B2. In the first case, thickets of hogweed are highlighted in bright green (Fig. 1, see color insert), and in the second case – bright yellow (Fig. 2, see color insert).

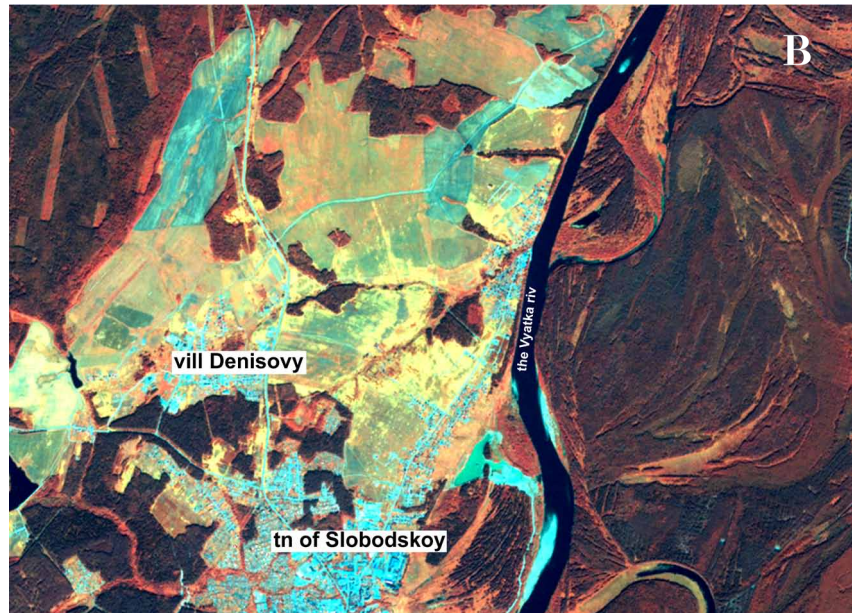
Conclusion

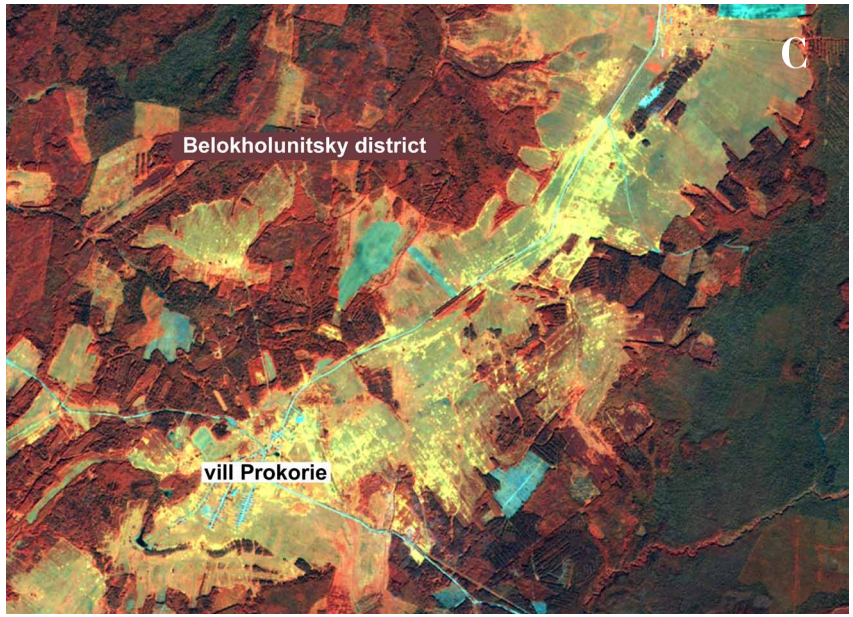
Thus, the method of visual interpretation of satellite imagery obtained from the Sentinel-2 satellites series of the European Space Agency and provided by the agency to the public via the Internet network can be effectively used to identify the sources of the spread of the dangerous invasive plant Sosnowsky's hogweed. Available software allows to determine the coordinates of the hotspot distribution areas, which is the basic information for operative monitoring of natural environments and planning of measures to control the spread of dangerous invasive plant species.

– populations of *Heracleum sosnowskyi* (light green)

Fig. 1. The foci of the distribution of the Sosnovski's hogweed during flowering on satellite images with the use of Sentinel-2 red, green and blue spectral channels for visualization:
A) stlmt Falenki Falensky District;
B) vill Denisovy Slobodskoy District;
C) vill Prokorie Belokholunitsky District







– populations of *Heracleum sosnowskyi* (light yellow)

Fig. 2. The foci of the distribution of the Sosnovski's hogweed during flowering on satellite images with the use of Sentinel-2 near infrared, green and blue spectral channels for visualization:
A) stlmt Falenki Falensky District;
B) vill Denisovy Slobodskoy District;
C) vill Prokorie Belokholunitsky District

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