PREDICTIVE MODELING OF *HERACLEUM SOSNOWSKYI* MANDEN. DISTRIBUTION IN THE VOLGA-KAMA REGION IN A CHANGING CLIMATE

V. E. Prokhorov
Kazan Federal University, 18 Kremlevskaya Str., 420008, Kazan, Russia
(*vadim.prokhorov@kpfu.ru*)

Introduction. Currently, the secondary range of caucasian *Heracleum sosnowskyi* covers the forest zone of European Russia, Ukraine, Belarus, the Baltic States, Finland, Denmark, Germany, Poland, the Czech Republic, Slovakia, Hungary and Romania. The species continues to expand its range in the east and southwest directions. Since 2005, the species has been actively settling in Altai, since 2007 in Tomsk, and since 2010 in Novosibirsk regions. In 2016 it was recorded in Serbia, in 2017 in Bulgaria.

To control Sosnovsky's hogweed, an urgent problem is to identify the places of its growth and predict its distribution in the future. Due to global climate change, the areas of many organisms will change their outlines; therefore, the long-term dynamics of the distribution of *H. sosnowskyi* is also of interest. The aim of the research is to identify the distribution of the *H. sosnowskyi* in the Volga-Kama region and to predict its dispersal taking into account climate change.

A number of studies have shown that the northern boundary of the distribution of this species is determined by the isotherm of the sum of active temperatures (SAT) equal to 800 to 1,000°C (Chadin et al., 2017). The southern boundary of the secondary range corresponds to the isoline of the hydrothermal coefficient equal to 1.25 (Afonin et al., 2017).

The development of spatial models for the purpose of predicting the distribution of this invasive species and identifying its dependence on climate was undertaken by a number of researchers for the Ukrainian Carpathians, the Komi Republic and southern European Russia.

The study area covers the Volga-Kama region – a territory located in the east of the Russian Plain approximately between the meridians of Nizhny Novgorod and Ufa and the parallels of Kirov and Orenburg. The southern border of the secondary range of Sosnovsky hogweed runs along the territory of the region.

Materials and methods. The materials for this work were our own observations, data from the "Flora of Russia" project on the iNaturalist platform (Seregin et al., 2020) and records from the "Flora" database (Prokhorov, Rogova & Kozhevnikova, 2017) – a total of 4,114 identified locations.

The Maxent method was used to model potential habitats (Phillips, Anderson & Schapire, 2006).

WorldClim climatic variables, SoilGrids soil data and TerraNorte landcover were used as a model predictors. For predictive models, averaged data from 9 different climatic models was used (BCC-CSM1-1, CCSM4, GISS-E2-R, HadGEM2-AO, HadGEM2-ES, MIROC5, MIROC-ESM, MIROC-ESM-CHEM, NorESM1-M) for two climate change scenarios (RCP2.6 and RCP8.5) and two time periods (2050 and 2070).

After carrying out the correlation analysis, 17 predictors were selected for creating a model. To reduce the sampling bias, the observations were spatially filtered, as a result of which the number of observations was reduced by almost 10 times to 420.

Results. Most of the observations of *H. sosnowskyi* in the Volga-Kama region are recorded in the forest zone (taiga and mixed forests); in the forest-steppe zone hogweed is found scattered, reaching in its distribution the northern border of the steppes.

Pre-simulation with MaxEnt showed good results (AUCtest = 0.824). The landcover (38 %), maximum July temperature (18 %) and altitude (12 %) have the largest contribution to the model. Together, these three factors explain more than two thirds (68 %) in the distribution of hogweed. When analyzing the response curves of the model, it turned out that Sosnovsky's hogweed prefers urbanized areas, meadows and swamps, maximum July temperatures in the range of +20 ... + 21 °C, and altitudes of about 100 m above sea level.

As a result of the final data processing, a spatial model of the potential habitats of the *H. sosnowskyi* was built. In the northern part of the Volga-Kama region, a high probability of occurrence is associated with both river valleys and watersheds, while in the central and southern parts, the hogweed selects habitats with increased moisture exclusively along river valleys.

Conclusion. The area of the potential range of *H. sosnowskyi* in the Volga-Kama region is currently estimated at 141,000 sq. km, which is 23.3 % of the entire territory. According to the climate change scenario RCP 2.6, by 2050 its area will be 31,000 sq. km (5.2 %), and by 2070 it will reach 50,000 sq. km (8.3 %). If the RCP 8.5 maximum warming scenario is realized by 2050, the potential range of hogweed will occupy 27,000 sq. km (4.4 %), and by 2070 there will be no suitable habitats for this species.

Thus, according to our model, as a result of climate change, the area of habitats suitable for Sosnovsky hogweed in the Volga-Kama region will significantly decrease (almost five times by 2050). In the event of the development of the most unfavorable scenario of climatic changes (RCP 8.5), Sosnovsky's hogweed will completely extinct in the region.

This work was carried out with the financial support of the RFBR and the Government of the Republic of Tatarstan, project № 18-44-160021.

References

Chadin I., Dalke I., Zakhozhiy I., Malyshev R., Madi E., Kuzivanova O., Kirillov D. & Elsakov V. 2017. Distribution of the invasive plant species *Heracleum sosnowskyi* Manden. in the Komi Republic (Russia). *PhytoKeys*, **77**: 71–80.

Afonin A.N., Luneva N.N., Li Yu.S. & Kotsareva N.V. 2017. Ecological-geographical analysis of distribution pattern and occurrence of cow-parsnip (*Heracleum sosnowskyi* Manden.) with respect to area aridity and its mapping in European Russia. *Russian Journal of Ecology*, **48** (1): 86–89.

Seregin A.P., Bochkov D.A., Shner J.V., Garin E.V., Pospelov I.N., Prokhorov V.E., Golyakov P.V., Mayorov S.R., Svirin S.A., Khimin A.N., Gorbunova M.S., Kashirina E.S. et al. 2020. «Flora of Russia» on iNaturalist: a dataset. *Biodiversity Data Journal*, **8**: e59249.

Prokhorov V.E., Rogova T.V. & Kozhevnikova M.V. 2017. Vegetation Database of Tatarstan. *Pytocoenologia*, **47** (3): 309–313.

Phillips S.J., Anderson R.P. & Schapire R.E. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, **190**: 231–259.