Vzorci razširjenosti invazivne vrste *Robinia pseudacacia* v severovzhodni Sloveniji

Distribution patterns of the invasive species *Robinia pseudacacia* in NE Slovenia

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Povzetek: V prispevku se ukvarjamo z vrsto *Robinia pseudacacia* L., ki se je v Evropi pojavila na začetku 17. stoletja in jo sedaj tudi v Sloveniji štejemo med invazivne vrste. Raziskava je potekala na območju severovzhodne Slovenije, v Prekmurju. Njen namen je bil poiskati razloge za trenutni vzorec razširjenosti vrste *R. pseudacacia* na tem področju. Najprej smo v letu 2009 na terenu skartirali vzorčno območje 4 x 3 km v merilu 1:5.000, kjer se vrsta pojavlja na Ravenskem (nižinski predel Prekmurja). Nato smo analizirali različne dejavnike, ki bi lahko vplivali na razširjenost vrste v regiji: oddaljenost od cestnega omrežja in vodnih teles, nadmorsko višino, rabo zemljišč, vrsto in kakovost zemljišč. Izvedli smo prostorsko vzorčenje na naključno izbranih 1800 točkah na tem območju. Na teh točkah smo ugotovili podatke o prisotnosti *R. pseudacacia* in izračunali potencialne dejavnike, ki bi lahko vplivali na njeno prisotnost. Statistične odnose smo nato določili s splošnim linearnim modelom (GLM). Ugotovili smo, da se *R. pseudacacia* največkrat pojavlja na travnikih in pašnikih. Določen vpliv na njeno pojavljanje ima oddaljenost od cestnega omrežja, ki do neke mere ugodno vpliva na pojavljanje vrste, medtem ko bližina vodnih teles zmanjšuje verjetnost njenega pojavljanja. Med nadmorsko višino in prisotnostjo vrste nismo našli povezave, saj očitno ta dejavnik ne vpliva na razširjenost vrste na raziskovanem območju.

R. pseudacacia se širi naravno, hkrati pa jo zasajajo tudi kmetje. Naši rezultati kažejo, da tudi človekove odločitve vplivajo na njeno širitev.

Ključne besede: GLM; invazivna vrsta; *Robinia pseudacacia*; prostorska razširjenost

Abstract: *Robinia pseudacacia* L. was introduced into Europe at the beginning of the 17th century and is now considered to be an invasive species also in Slovenia. Our study area was located in northeastern Slovenia, within the Prekmurje region. The aim of our study was to find explanations for the current occurrence pattern of the species in that location. Areas dominated by *R. pseudacacia* have been mapped in a scale of 1:5.000 in the lowland area of Prekmuje, across a sample plot of 4 by 3km in 2009. We analyzed potential factors that can influence the distribution of the species within the region: distance to the road network, distance to water bodies, elevation, land use, soil type and soil quality. We performed a spatial randomized sampling technique stratified for prevalence on the resulting maps in order to collect observations on the relationship between *R. pseudacacia* presence and the potential influenting factors. The statistical relationships were then established by a generalized linear model (GLM).

R. pseudacacia was found to occur mostly in parcels designated as meadows and pastures. Distance from the road network seems to facilitate the occurrence of the species to a certain degree. Distance from water bodies seems to decrease *R. pseudacacia* presence. We did not find a relative relationship between elevation and species presence, this factor apparently does not influence the distribution of the species in this region.

R. pseudacacia expands naturally but it is also being planted by farmers, therefore, its expansion is directed as well. Our results also show that human decisions affect the species expansion.

Key words: GLM; invasive species; *Robinia pseudacacia*; spatial distribution

Introduction

The migration of species has always existed, however the rate of human-assisted introductions of new species is currently significantly higher than previously. Globalization has greatly increased the speed in the spread of harmful species through travel and tourism, the agricultural, horticultural and pet industries. Due to socioeconomic and environmental effects worldwide biological invasions have been increasingly recognized as a major problem. Therefore, efforts have been made to map and predict the spatial distribution of invasive species.

Many authors have frequently used terms such as "alien", "naturalized" and "invasive" in an imprecise and erroneous way. This has resulted in confusion within English literature on plant invasions. Richardson et al. (2000), have made a literature review and defined a set of key terms which conceptualizes the naturalization/ invasion process of plant species. In this paper we have adopted their term for "invasive" plants, as naturalized alien plants that produce reproductive offspring, often in large numbers, at considerable distances from parent plants and have a potential to spread over a considerable area.

The species chosen for this study was *Robinia pseudacacia L.* (Black locust). *R. pseudacacia* is a deciduous tree that belongs to the *Fabaceae* family. The species produce white flowers and smooth legumes that make it easier to distinguish this species from other species in the *Robinia* genus. In forests stands it can grow up to 30-35 m in height, in juvenile trees the bark is smooth with suberous lenticels, while in older trees the bark is very thick and grey-brown, yellowish in the cracks. *R. pseudacacia*, is native to North America, was introduced into Europe at the beginning of the 17th century and is now being considered to be an invasive species also in Slovenia (Bartha et al. 2008).

Although R. pseudacacia is considered as invasive (Morimoto et al. 2009; Kleinbauer et al. 2010), it is still being planted in many European countries due to its economic importance, such as timber (Huntley 1990; Rudolf & Brus 2006), honey production (Huntley 1990; Rudolf & Brus 2006), soil erosion control (Torelli 2002), ornamental use (Huntley 1990; Rudolf & Brus 2006), and homeotherapy uses due to essences derived from its flowers (Bartha et al. 2008).

The most common approach to identify potential invaded areas is to extrapolate from already invaded areas in order to find similar locations (Goslee et al. 2006). The prediction of the distribution patterns for invasive species in locations outside their native range is fundamental for early warning systems (Zhu et al. 2007). The aims of this study were to develop a model to identify the critical influencing factors for the current occurrence pattern of the species in the study site and to predict the spatial distribution of *R. pseudacacia* for invaded areas. The regional distribution pattern of *Robinia pseudacacia* was studied in NE Slovenia, within the Prekmurje region. It is important to focus on understanding the distribution and quantitative prediction of the invasion processes in order to develop preventive policies.

Methodology

Study area

This research was conducted in the Northeast of Slovenia, in the Prekmurje region. This region lies at low altitudes (from 150 to 400 m), is open towards the Pannonian plain and has the most continental climatic features in Slovenia (Ogrin 2009). This region is considered one of the most important agricultural areas in Slovenia (Gabrovec & Kladnik 1997), being half of the territory occupied by agricultural land, the rest of the territory is occupied by forests, vineyards and orchards (Petek 2009). The study region can be divided into three geographical areas; the hilly area of Goričko, the floodplains of the Mura River, known as Ravensko, and the lowlands known as Dolinsko. In the lowland part of this region a sample plot of 12km^2 was chosen for this research.

Field survey

The data was collected through qualitative methods such as mapping of the invaded areas. A map was generated by manually drawing polygons around the areas where the species was known to occur and also in areas where the species was not present. Ortho-photographs of the study area were used as a backdrop. The polygons were then digitized in ArcGIS software.
A total dataset of 310 *R. pseudacacia* polygons were thus mapped in the field.

Sampling

A spatially random sample of three times the number of recorded polygons with presence of the study species were used to establish statistical relationships. The same number of points were settled for the areas where the species was absent. The sampling was generated in ArcGIS 9.3, and was used to model the species distribution. In order to predict the species distribution within the study area a 6 m sized mesh was produced.

Potential factors

Spatial data such as distance to the road network, distance to water bodies, elevation, soil type, soil quality and land use (orchard, meadow, forest, field, urban, pasture) were used for analysing the *R. pseudacacia* distribution.

Distances to roads and water bodies were calculated from the road network and water bodies' data layers from the Surveying and Mapping Authority of the Republic of Slovenia. Euclidean distances were calculated from each point to the nearest road and water body. Elevation values were masked from the Digital Elevation Model (DEM) to the study site. DEM with 12.5 m x 12.5 m resolution, acquired from the Surveying and Mapping Authority of the Republic of Slovenia was used.

Land use types were taken from the Land Cadastre Map from the Surveying and Mapping Authority of the Republic of Slovenia. Due to the rarity of some land use types within the study area we grouped the land use types in six land categories, "field", "orchard" ("vineyards" were included into this category), "pasture", "meadow", "forest" and "urban" (this category included all the building areas and areas that are occupied by human activities, e.g. playground, courtyard...).

From the same dataset information about the soil quality was taken, based on taxation of real estate. The soil type information was extracted from the Slovenian Pedological Map from the Ministry of Agriculture, Forestry and Food. All the data layers were projected in the Slovenian Coordinate System (D48_Slovenia_TM).

Model creation and accuracy assessment

Statistical methods were used to relate the distribution of the study species with the environmental and socioeconomic predictors. A generalized linear model (GLM), an advanced and extended method stemming from linear regression, was fitted using the R statistical environment (R development team 2008) to explain the *R. pseudacacia* distribution. The response variable was represented by the presence/absence of the species and environmental and socioeconomic factors were used as explanatory variables. This model enabled us to model species response to landscape variables using a logit link function between the response and predictor variables. Non-linear effects of the explanatory variables were tested by means of second-order polynomials (Dullinger et al. 2009). The Chi^2 test was performed to identify which of the explanatory variables had a significant contribution to the model.

The final model was then used to assess the occurrence probability of the species at the study site. A prediction map was prepared in ArcGIS 9.3, based on the best predictor variables. The "area under the receiver operating characteristic (ROC) curve" (AUC) was used to measure the accuracy of the model (Somodi et al. 2010). Results from the spatial prediction were compared to the known *R. pseudacacia* locations.

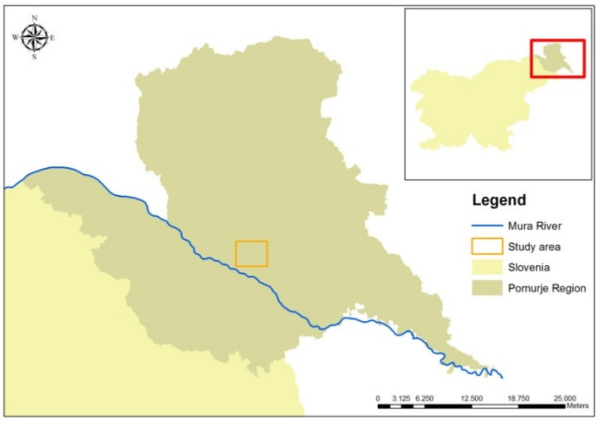

Figure 1: Overview of study area.

Results and discussion

The model was run with all six variables (elevation, distance to the road network, distance to water bodies, soil type, soil quality and land use); however elevation was dropped in the course of model selection. Details of the best model can be seen in the table 1. The AUC value obtained was 0.8912, this indicated spatial agreement between the model prediction and actual *R. pseudacacia* sites from the training data.

Meadows and pastures are significantly more likely to be invaded by *R. pseudacacia* than other land use types (fields, forests, orchards and urban). We suggest that areas with highest agricultural potential as fields are still maintained for agricultural purposes so they do not contribute to *R. pseudacacia* occurrence.

Dystric Fluvisols are significantly less susceptible to *R. pseudacacia* than Dystric Cambisol and they also differ in this manner from Urban Soil.

Close to the roads there is a higher probability of species occurrence and this probability decreases when the distance to the road network ranges between 100-300 meters. When the distance from the road network is higher than 300m the probability of the species occurrence increases. The reason for this is that they planted *R. pseudacacia* near to the roads, on strips along road banks and the most propitious surfaces used for agriculture are near to the roads. Here *R. pseudacacia* does not invade or is not being planted. It appears on less fertile soils, where the road network is not so dense. The distance to water bodies has a negative influence on the species occurrence in lowland Prekmurje, in contrast to what was showed by other studies (Bartha et al. 2008; Akamatsu 2008).

As it can be seen in Figure 2 that the predictions resulting from the predictive model correlate well to the field observations, most observations fall into the predicted category with a higher probability than 0.68. Some field observations which were outside this probability were included in the next category (0.36-0.68).

Table 1: GLM results showing the importance of the variables in *R. pseudacacia* presence Asterisks refer to significance level: '***' - p< 0.001, '**' - p<0.01, '*' - p< 0.05, '**.**' - p<0.1.

Variable	Estimate value	Pr(>|z|)	Sig. Level
(Intercept)	-1.715e+02	0.62536	
Land Use: Forest	1.873e+01	0.99681	
Land Use: Meadow	2.295e+00	1.01e-08	***
Land Use: Orchard	9.872e-02	0.94301	
Land Use: Pasture	4.934e+00	1.70e-07	***
Land Use: Urban	2.133e+00	0.05461	.
Dist_water	6.151e-05	0.94773	
Dist_road	-5.100e-03	0.02569	*
Soil type: Dystric Fluvisol	-1.548e+00	0.00148	**
Soil type: Urban Soil	-1.782e+01	0.98327	
I(Dist_road^2)	1.295e-05	0.09009	.
I(Dist_water^2)	-2.323e-06	0.04251	*

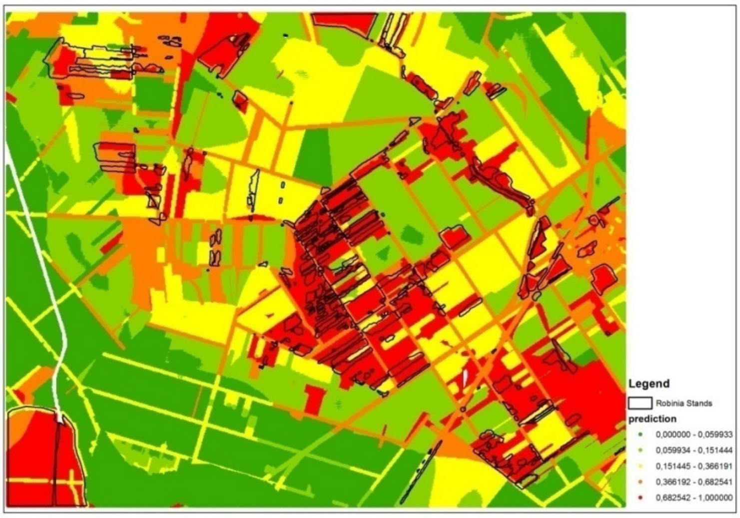

Figure 2: Comparison between result of predictive model and field map.

Conclusion

Our results indicate that land use plays an important role in the distribution of the species across the study area. This approach permits us to analyze the impact of different factors in the distribution of *R. pseudacacia*. The species is spreading in the study region and we expect that areas with lower quality for agricultural production are the most prone to future invasion. Prediction can thus be useful in order to avert future invasions and appears as a valuable tool for landscape management.

Acknowledgements

The fieldwork conducted for this paper was supported by the TransEcoNet project implemented through the CENTRAL EUROPE Program and co-financed by the ERDF. The authors acknowledge financial support from the state budget through the Slovenian Research Agency (project No. L1-9737 and P1-0236). We wish to extend special thanks to Julia Ellis Burnet for her careful review of the English content.

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