CLIMATIC, HYDROLOGICAL AND SOIL CHARACTERISTICS AS A DRIVING FORCE OF BIOLOGICAL INVASION: A CASE STUDY OF HUNGARY

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Abstract

Invasive plants are a serious threat to biodiversity, biological invasion is a significant problem in protected areas. In order to control their spread, we need to identify the soil, hydrological and climatic conditions which provide favorable conditions for their occurrence. Soil conditions, such as pH level, organic matter and calcium carbonate content and the rooting depth can influence the occurrence of invasive plant species. Many plant species can be associated with surface water, and thus distance from surface water can also be a determining factor for biological invasion. Mean annual temperature and precipitation are climatic factors that can also influence the spread of invasive plants.

We mapped the occurrence one of the most aggressively spreading non-native plants of Eurasia (*Ailanthus altissima*, *Asclepias syriaca*, *Elaeagnus angustifolia*, *Robinia pseudoacacia*, *Solidago* spp.) in Hungary, using field photos from the EUROSTAT Land Use and Coverage Area Frame Survey (LUCAS) and CORINE Land Cover databases, and investigated with geostatistical methods (ANOVA test in R statistics) how spatial characteristics of infection are related to soil and climatic characteristics and habitat types of Hungary.

We found that all the considered soil, hydrological and climatic factor had significant effect for the spread of the investigated invasive plant species. Our results confirm that environmental preference differs between the examined species, climate change may also have a different role on the occurrence.

Introduction

Invasive species are a serious threat to natural habitats, undemanding to their environment and therefore more successful at displacing native species from their natural habitat and invading anthropogenic areas. Biological invasion is the main problem in protected habitats [1–4].

The most effective control against invasive plants is to prevent their spread [5–7]. To find the most effective way to prevent the spreading of invasive species, we need to explore the environmental factors that influence their spread. The environmental (geographical) factors influencing invasion may be the quality and water management of the soil, or even temperature and amount of precipitation [7–12]. In this study, we investigated the influence of soil parameters such as organic matter content, pH, calcium carbonate content, rooting depth; climatic parameters such as mean annual temperature and mean annual precipitation, and distance from surface water on the occurrence of the most aggressively spreading invasive plant species: Tree of heaven (*Ailanthus altissima*), Common milkweed (*Asclepias syriaca*), Russian olive (*Elaeagnus angustifolia*), Black locust (*Robinia pseudoacacia*) and two invasive goldenrod species (*Solidago canadensis, Solidago gigantea*)). The two goldenrod species are mentioned as *Solidago* spp.

Experimental

The study was carried out in the territory of Hungary. The distribution of invasive species was obtained using the National GIS Database of Invasive Plant Species, which is a point-based database. A point is invaded if at least one individual of the plant is present at that point. If the plant is not detected at the point, it is considered as a non-invaded point [8] (Figure 1.). For the analysis of the environmental parameters, we used the Digital, Optimized, Soil Related Maps and Information in Hungary (DOSoReMI.hu) database [13].

Using ArcGIS software, we overlaid the environmental parameters (soil, hydrological, and climatic data) with the invaded and non-invaded points. This method was used to determine the environmental parameters at the given points. For statistical analysis, one-way ANOVA model was used and performed using Rstudio software.

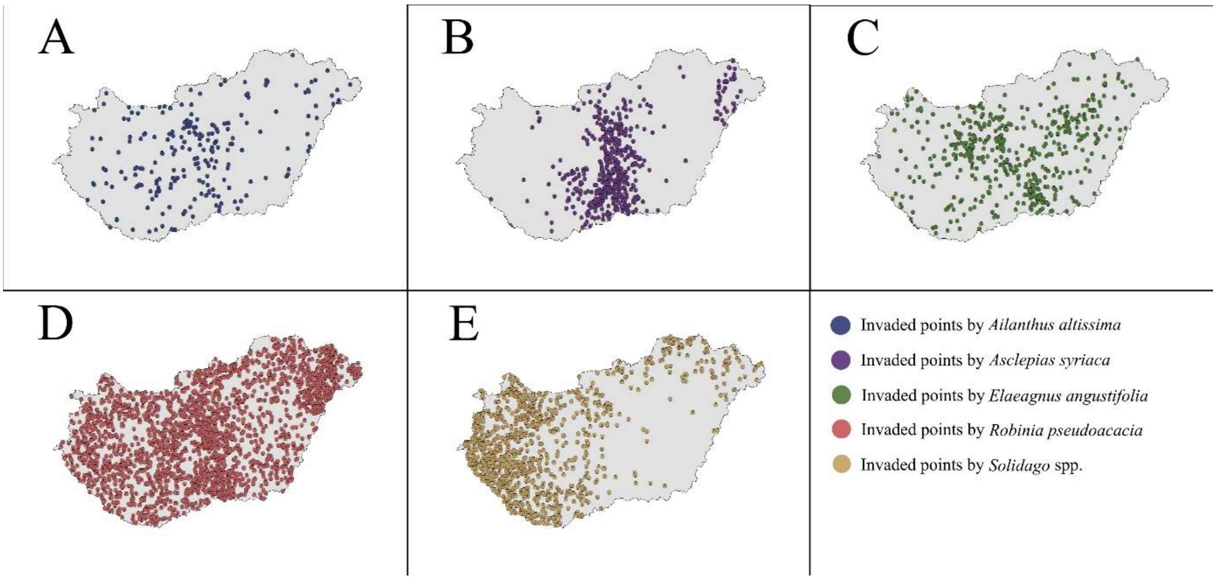

Figure 1. Distribution of the investigated invasive plant species in the territory Hungary, where A, *Ailanthus altissima;* B, *Asclepias syriaca;* C, *Elaeagnus angustifolia;* D, *Robinia pseudoacacia* and E, *Solidago* spp.

Results and discussion

The results show that all the considered environmental parameters have an influence on the occurrence of invasive plants studied. All soil and climatic factors (except mean annual precipitation) have significant impacts on the spread of *Ailanthus altissima*. The organic matter content was significantly lower, soil pH, calcium carbonate content, rooting depth, distance from surface water and mean annual temperature was significantly higher at the invaded points. In the case of *Asclepias syriaca*, all soil characteristics and climatic factors had a very high significant effect. Organic matter content and mean annual precipitation were significantly lower, soil pH, calcium carbonate content, rooting depth, distance from surface water and mean annual temperature were significantly higher at the invaded points by *Asclepias syriaca*. To *Elaeagnus angustifolia* we found that the soil pH, calcium carbonate content and mean annual temperature were significantly higher and mean annual precipitation was significantly lower at the invaded points. All soil characteristics (except calcium carbonate content) showed significant differences between invaded and non-invaded points by *Robinia pseudoacacia*. Organic matter content of the soil and soil pH were significantly lower, rooting depth and distance from surface water were significantly higher at the invaded points. Mean annual temperature was significantly lower at the invaded points, but we found no difference in the case of mean annual precipitation. Examining *Solidago* spp. we found significant differences in all of the investigated soil and climatic characteristics (except rooting depth) between invaded and non-inveded points (Table 1.).

		Environmental Parameters						
		Organic matter content	pH	Calcium carbonate content	Rooting depth	Distance from surface water	Mean annual temperature	Mean annual precipitation
		p-value	p-value	p-value	p-value	p-value	p-value	p-value
Invasive Plant Species	*Ailanthus altissima*	<0.001	0.005	0.008	<0.001	<0.001	0.002	0.395
	Asclepias syriaca	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Elaeagnus angustifolia	0.070	<0.001	0.008	0.078	0.324	<0.001	<0.001
	Robinia pseudoacacia	<0.001	<0.001	0.181	<0.001	<0.001	0.035	0.052
	Solidago spp.	<0.001	<0.001	0.009	0.386	<0.001	<0.001	<0.001

■ The enviromental parameters of the invaded points have significantly lower values than those of the non-invaded points.

■ The enviromental parameters of the invaded points have significantly higher values than those of the non-invaded points.

Table 1. Differences between invaded and non-invaded points as a function of the soil, hydrological, and climatic parameters for the invasive species investigated.

The results confirm that this method is well applied to investigate which environmental parameters influence the spread of invasive plants. The results show that these species are well tolerant of soils with low organic matter content and that high calcium carbonate content has a positive effect on their occurrence (Figure 2.). This does not necessarily mean that these plants prefer soils with low organic matter content and high calcium carbonate content. The results explain that invasive plants can grow well in poorer quality habitats where native species do not [4,13].

The results show that high precipitation has a positive effect on the occurrence of *Solidago* spp., but high temperatures inhibit its spread. In contrast, the opposite is true for *Asclepias syriaca* and *Elaeagnus angustifolia*. These plants prefer drier and warmer habitats [12] (Figure 2.).

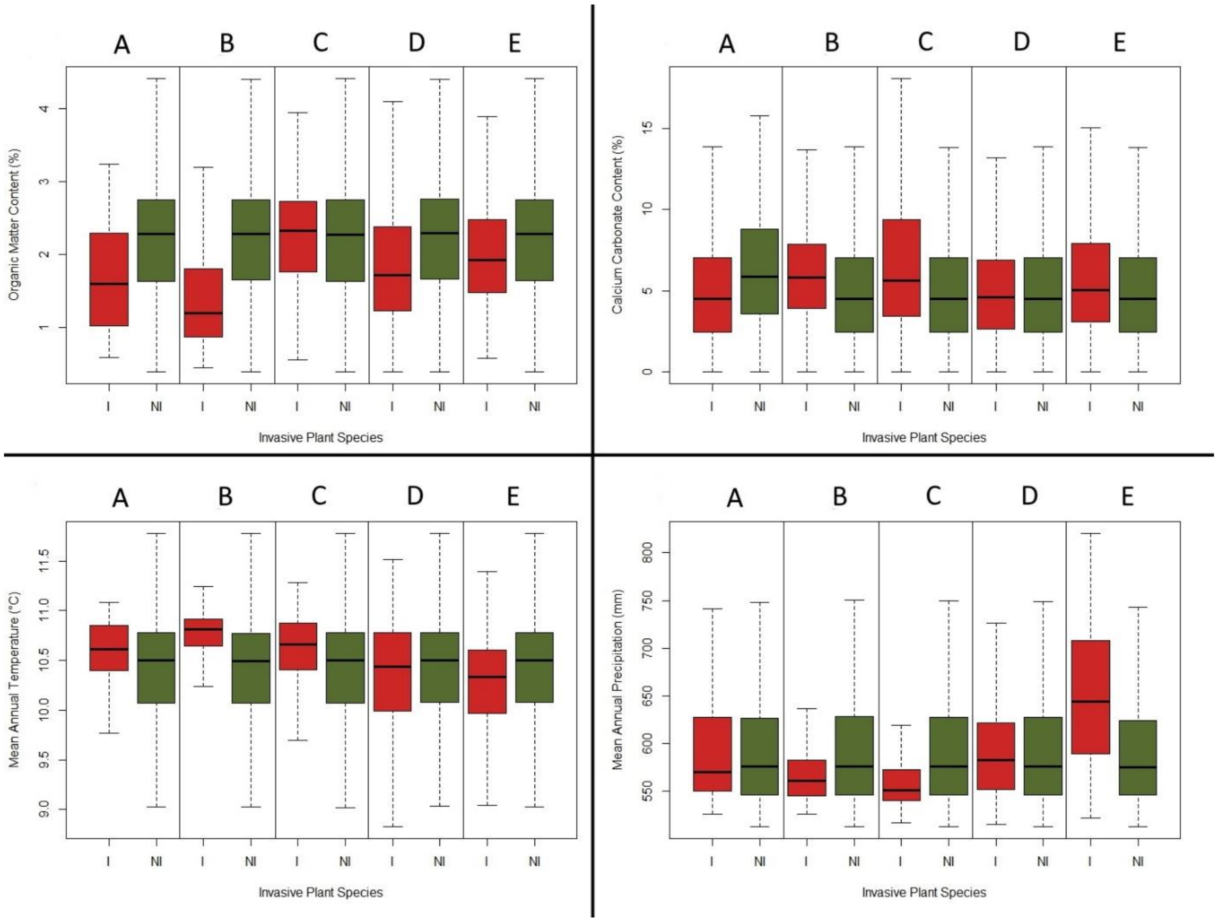

Figure 2. Differences between invaded and non-invaded points regarding organic matter content, calcium carbonate content, mean annual temperature and mean annual precipitation; (A, *Ailanthus altissima;* B, *Asclepias syriaca;* C, *Elaeagnus angustifolia;* D, *Robinia pseudoacacia* and E, *Solidago* spp.)

Conclusion

Like any other plant, the spread of invasive plants is highly dependent on environmental parameters. Some environmental factors promote, and others inhibit the occurrence of these plants [7-12]. Our results confirm that invasive plant species tolerate low soil organic matter and calcareous soils well.

The results show that *Asclepias syriaca* and *Elaeagnus angustifolia* prefer warmer and drier climatic conditions, while *Solidago* spp. prefers cooler and wetter conditions. This suggests that climate change promotes the occurrence of *Asclepias syriaca* and Elaeagnus *angustifolia*, but inhibits that of *Solidago* spp.

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