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The Impact of *Robinia pseudoacacia* on Ground Vegetation and Plant Nutrient Matter in Donau-Auen National Park

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Abstract

We investigated the influence of Black Locust (*Robinia pseudoacacia L.*) on ground vegetation and plant nutrient matter in the riparian forest of Donau-Auen National Park.As a legume, *Robinia pseudoacacia* is able to change soil nutrient availability by fixing atmospheric nitrogen in the soil (see HECKER 2000). It may be assumed, that a change in resource availability can affect the species composition of a habitat.Especially in environments with low content of soil nitrogen, such as dry grassland or dry forests, the presence of *Robinia pseudoacacia* can have a great influence on the plant community (see NENTWIG 2010).The aim of this thesis was to examine the relationship between Black Locust, soil nitrogen content and species composition of the habitat in Donau-Auen National Parkand evaluate the hypotheses mentioned above.To assess the influence of the tree on the local ecosystem, 34 plots were selected within four areasnear Stopfenreuth, Orth and Hainburg. In addition to vegetation surveys (spring and summer), soil samples were taken and analyzed for physical and chemical soil parameters. Data analysis was conducted with univariate and multivariate statistics.

The influence of Black Locust on the availability of nitrogen in the soil was proven to be significant. The NO_3-content showed the highest response while the C/N-ratio appeared to remain unaffected by the presence of *Robinia pseudoacacia*. Nevertheless, the ground vegetationseemed to be influenced by the neophyte, wherebyboth the availability of nitrogen and the increased exposure to light due to reduced shading underBlack Locust appears to be relevant. Near the tree some nitrophilous species gained abundance while some photosensitivespecies thinned out.This speciesshift can perhaps be assumed to affect the naturally high biodiversity of the habitat in Donau-Auen National Park.

Keywords

Invasive Species, Biodiversity,Black Locust, Nitrogen Fixation, Vegetation-Soil Effects

Introduction

Robinia pseudoacacia, also known as Black Locust, is a neophytic tree that originates from North-America and was brought to Europe in the 17th century as an ornamental plant and forest tree. As a legume,Black Locustis able to change soil nutrient availability by fixing atmospheric nitrogen in the soil. Especially in habitats with low content of soil nitrogen, such as dry grassland or dry forests, it is known that this can affect the soil chemical properties, nitrogen-cycling and species composition of the local vegetation (see BERTHOLD 2005; BÖHMER et al. 2000; CASTRO-DIÈZ et al. 2009; KOWARIK 1992; RICE et al. 2004;WANG et al. 2012). Changes of species assembly in these cases are based on the increased nitrogen availability, promotion of nitrophilous species and consequently supplanting of oligotraphent species, which often entails an endangerment of the local biodiversity. Moreover, the tree is suspected of having allelopathic qualities, which are very difficult to detect (see DIERSCHKE 1994) and therefore were not estimated in this study. Compared to other trees in the study area (such as *Acer*, *Fraxinus*, *Quercus*) the leaves of *Robinia pseudoacacia* shoot relatively late and do not offer much shade. Theincrease of radiation intensity under Black Locustshould also be considered as an influencing factor for ground vegetation cover.

The present study aimed to investigate the effects outlined above in the naturally nitrogen-rich habitat of Donau-Auen National Park. In this context, the questionwas explored how the neophytic tree impacts soil nitrogen availability and ground vegetation.Additionally, the significance of density and age of the *Robinia pseudoacacia* population should be assessed in this regard. The study sites are located in a protected area in which the tree was introduced for reforestation and bee pasture before the national park was established. In the riparian forest of the study area Black Locust partly forms pure stands and is considered as a problematic species because it is feared to endanger the rich biodiversity of the habitat (see NATIONALPARK DONAU-AUEN GmbH 2009). Until now, the tree is not directly impacted by intensive control measures in Donau-Auen National Parkbut is being targeted for use as fuel wood (personal information from Dipl.-Ing. Bernhard Posch, ÖBf, 11/02/2013).

Methods

Study Sites and Experimental Design

The research areas are located in the riparian forest near Stopfenreuth, Orth and Hainburg on three non-flooded areas behind the Marchfelddike and one area in the flooded-forest in front of the dike (see Figure 1). This sampling design accommodates the assumption that frequent flooding leads to modified transportation of dissolved and solid matter (see BLUME et al. 2010). Therefore, the main focus of the study lies on the non-flooded areas, while the flooded areaprovides an additional view on different environmental conditions.Each of the four areas intrinsically shows similar physical soil parameters and relief position.

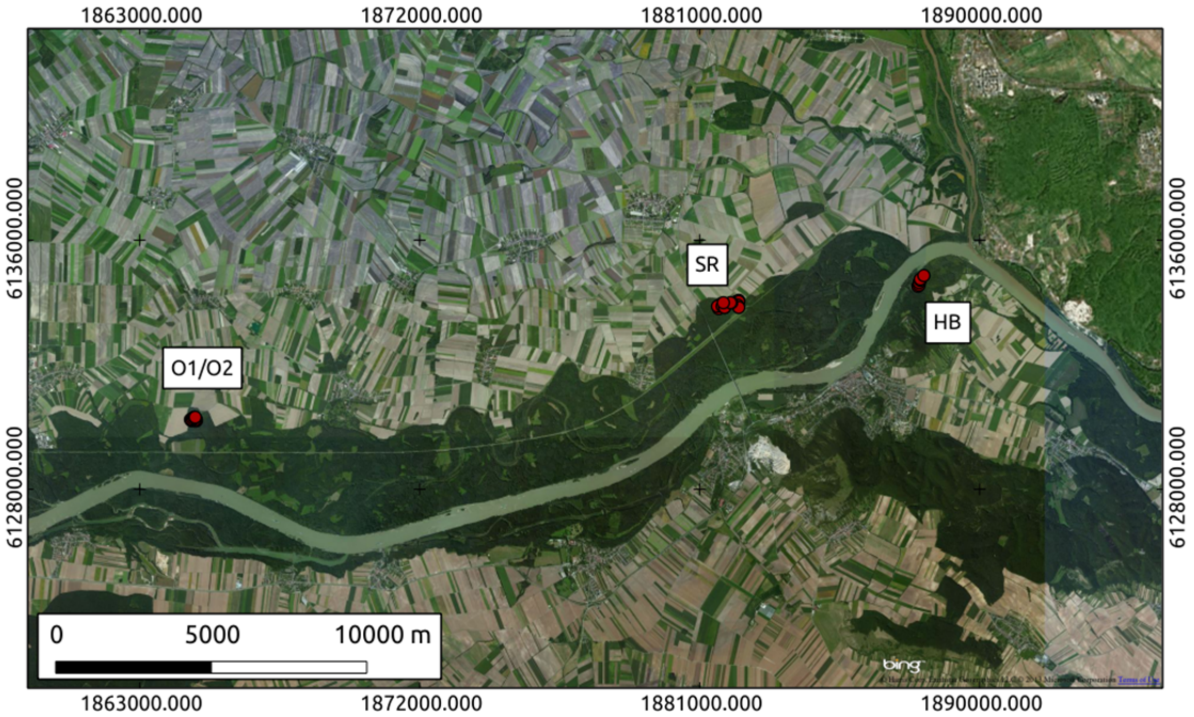

Figure 1: Study Areas (Database: Bing maps © Harris Corp. Earthstar Geographics LLC © 2013 Microsoft Corporation)

In Stopfenreuth (SR), 18 plots with varying density and age of *Robinia pseudoacacia* were selected in a mixed Oak-Ash-Elm forest. In Orth (O), two areas with extremely different vegetation cover could be investigated in close proximity to each other. The area O1 (5 plots) hosts a dense Black Locust forest, while O2 (5 plots) hosts a pure Oak-Hornbeam forest. The 6 plots in Hainburg (HB), the only research area not protected by the Marchfeld dike, were placed in a mixed Maple-Ash-Poplar forest with varying density and age of Black Locust.

By analyzing soil parameters as well as surveying the species composition of the ground vegetation, the study aimed to monitor the potential changes associated with thedensity and age of present *Robinia pseudoacacia*.

Vegetation Surveys and Soil Samples

To assess the influence of the tree, 34 plots at approximately 300 m² with varying density and age of *Robinia pseudoacacia* were selected in the forest stands. Vegetation surveys took place in April and June 2012. All woody species were recorded. Using a nested sample design, herbaceous species were sampled on randomly selected squares of 1x1 m. To evaluate the influence of Black Locust, the trees of each investigation site were classified into groups of density (loose-middle-dense) andage (young-middle-old).In addition,mixed soil samples were taken. For each site,tensampleswere extracted with a hollow drillfrom the upper 40 cm of the soiland mixed in a container.Approximately 500 grams were retained from that mixed soil matter, hermetically sealed and cooled. Within 24 hours,the samples were analyzed in the laboratory for NO_3 and NH_4.Thereafter, C/N ratio and standard parameters such as grain size, pH-value and moisture were evaluated.

Statistical analysis

The collected data was analyzed with univariate and multivariate statistical methods using the open source software R. Various correlation and regression analyses, cluster analyses and ordinations (NMDS, CCA) were generated to estimate the influence of Black Locust on soil nitrogen and carbon as well as on the ground vegetation species composition.In the NMDS diagram isolines generated with the R-function \`ordisurf´ (see SIMPSON 2011) illustrate to what extent the environmental parameters influence the species composition of each investigation site.

Results

Soil analyses did not detect any NH_4in the studyarea. NO_3 therefore represents all mineral nitrogen that was considered in the analyses. The findings show a significant elevation of total soil nitrogen content due to the presence of *Robinia pseudoacacia*(see Figure 2a) while C/N ratio does not significantly vary with presence or absence of the tree (see Figure 2b). On closer inspection, the NO_3-content conspicuously increased under Black Locust and was also positively correlatedwith the density (cor = 0.512, p = 0.0053) and the age (cor = 0.317, p = 0.099) of the trees (see Figure 2c and 2d). A regression analysis showed similar results (see Figure 3).

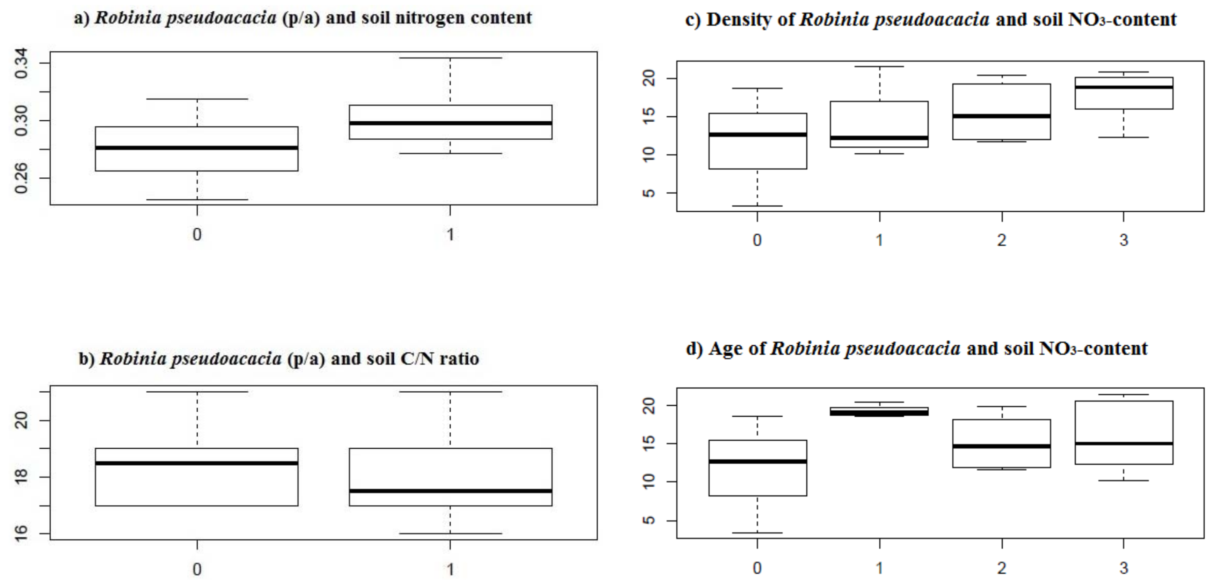

Figure 2: *Robinia pseudoacacia* and Soil Nitrogen

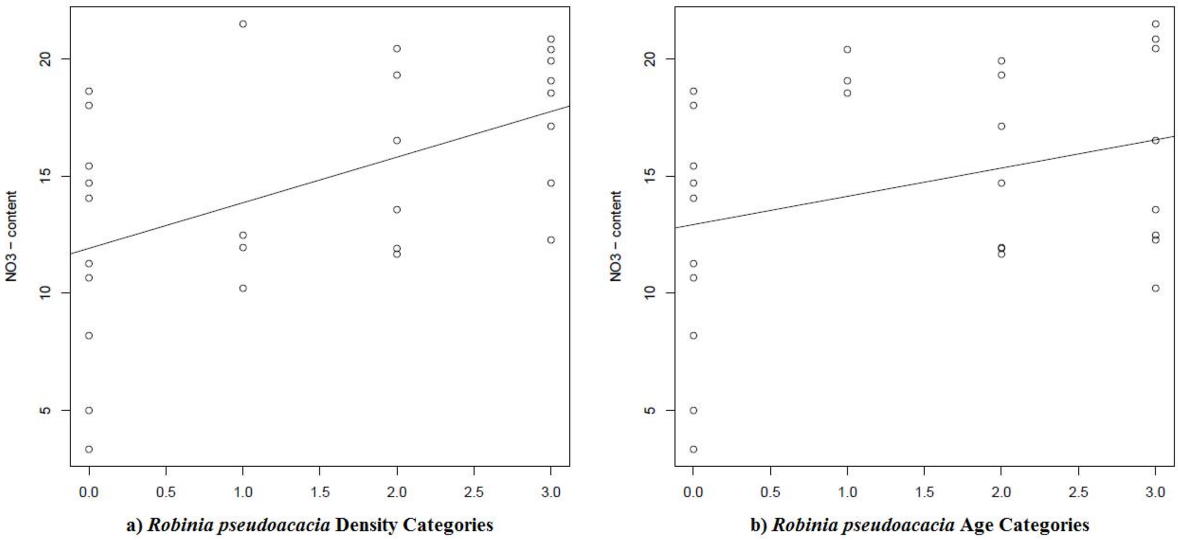

Figure 3: Density / Age of *Robinia pseudoacacia* and Soil NO3-Content

The NMDS (non-metric multidimensional scaling) of the investigation sites (SR: 1-18, O1: 19-23, O2: 24-28, HB: 29-34) and the environmental parameters post-hoc plotted on the diagram showed a significant influence of C/N ratio, Black Locust density and sand content on the species assembly. Black Locust age and NO_3-contentwere not identified as significantly influencing variables (see Table 1).Figures 4, 5 and 6 show the influence of the significant environmental parameters on the NMDS ordination diagram.

Table 1: Influence of Environmental Parameters on Vegetation Assembly

Environmental parameter	Non-parametric fit (R^2)
C/N	**0.50** (p=0.002) **
Density (*Robinia pseudoacacia*)	**0.32** (p=0.029) *
Sand	**0.36** (p=0.030) *
Age (*Robinia pseudoacacia*)	0.11 (p=0.236)
NO_3	0.09 (p=0.541)
Significance codes (999 permutations): ** (p ≤0.01), * (p ≤ 0.05)	

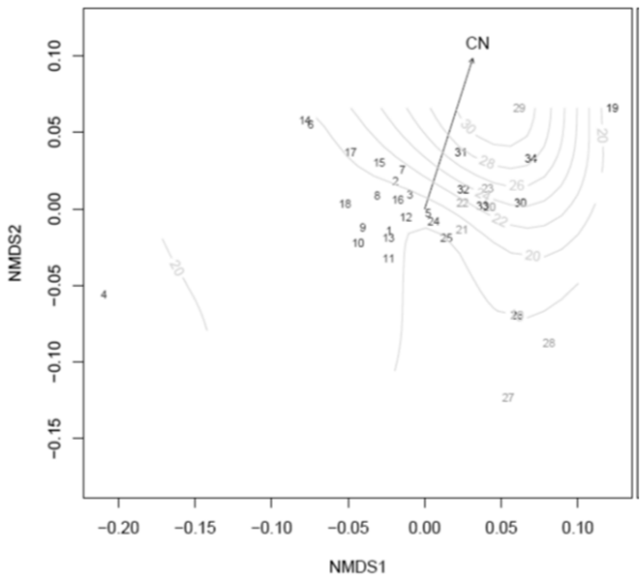

Figure 4 Influence of C/N on Ground Vegetation Assembly

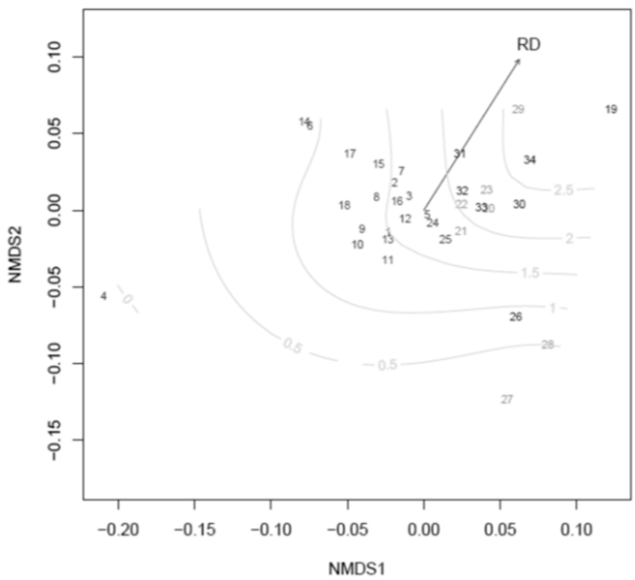

Figure 5: Influence of Density of *Robinia pseudoacacia* on Ground Vegetation Assembly

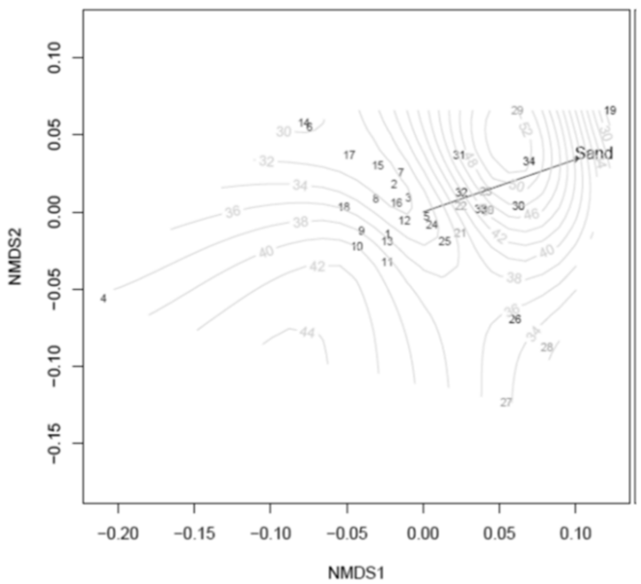

Figure 5: Influence of Sand on Ground Vegetation Assembly

A closer assessment of the influence of *Robinia pseudoacacia* (density and age) on vegetation composition was provided by a CCA (constrained correspondence analysis).The results show that the density of Black Locustseems to have a stronger impact on the sites in O and HB, while the sites in SR appear to be stronger influenced by the age of the trees. On sites located in the lower part of the diagram there are no exemplars of Black Locust.

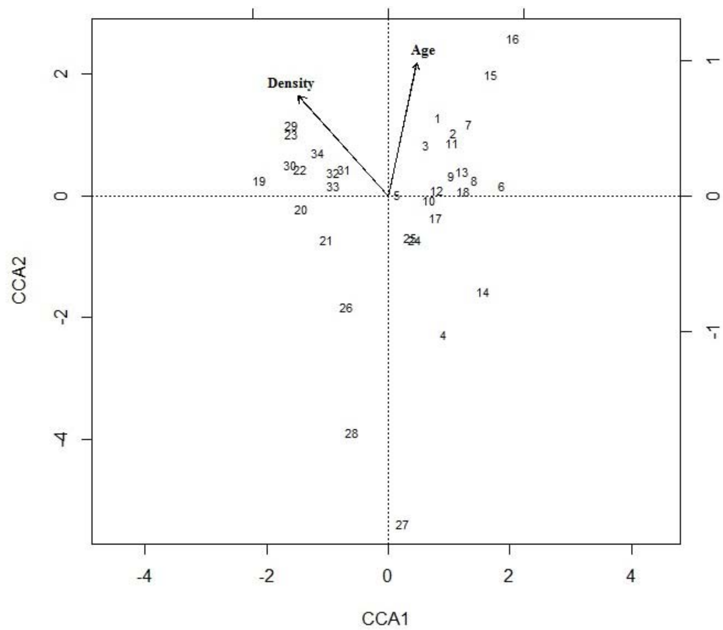

Figure 6: CCA of Investigations sites influenced by Density and Age of *Robinia pseudoacacia*

As the ordination diagrams (NMDS, CCA) showed, *Robinia pseudoacacia* appears to influence the species composition of the ground vegetation cover. Further detailsregardingthe occurring changes could be identified by a closer examination of the vegetation data (see Table 2). The abundance of some nitrophilous species, such as *Sambucus nigra* and *Urtic adioica* increased considerably with rising density of Black Locust. This expansion, however, only seemed to apply to extremely nitrophilous species (N9) which are tolerant to light. Other nitrophilous species such as *Aegopodium podagraria* (N8)show a slight increase. Furthermore, some species such as *Allium ursinum, Anemone ranunculoides, Galium odoratum,* or *Polygonatum latifolium* seemed to be restrained by *Robinia pseudoacacia*.These species are nitrophilous or moderately nitrophilous but alsofairly photosensitive, which might be the reason for their decline beneath Black Locust. Other species, e.g. *Viola odorata*, also seem to avoid sites with Black Locust even though there are noapparent site specific reasons.

Table 2: Site Demands (Nitrogen, Light) and Abundance of Species compared to Density of *Robinia pseudoacacia*

Scale value*	Species	Coverage of Robinia**	Coverage of Species***
N9, L7	*Sambucus nigra*	I	6.5
		II	136.7
		III	176.1
N9, x	*Urtica dioica*	I	4
		II	4
		III	73.5
N8, L5	*Aegopodium podagraria*	I	121.6
		II	227.2
		III	269.3
N8, L2	*Allium ursinum*	I	845.9
		II	828.3
		III	159.2
N8, L5	*Viola odorata*	I	20.4
		II	26.1
		III	2.5
N8, L3	*Anemone ranunculoides*	I	13
		II	17.7
		III	0.2
N5, L3	*Polygonatum latifolium*	I	8.8
		II	7.5
		III	1.2
N5, L2	*Galium odoratum*	I	3.7
		II	2
		III	0.5

* N – Nitrogen:1 = indicate nitrogen poorest sites, 2 = between 1 and 3, 3 = occurs more frequently on nitrogen poor sites, 4 = between 3 and 5, 5 = indicatemoderately nitrogen rich sites, 6 = between 5 and 7, 7 = indicate nitrogen rich sites, 8 = indicatehighly nitrogen rich sites, 9 = concentrate on extremely nitrogen rich sites, x = indifferent.
L – Light: 1 = deeplyshaded sites, 2 = between 1 and 3, 3 = shaded sites, 4 = between 3 and 5, 5 = half-shaded sites, 6 = between 5 and 7, 7 = half-light site, 8 = light site, 9 = bright light site, x = indifferent.
Scale Values based on ELLENBERG (1992)
** I: no *Robinia pseudoacacia*, II: 1-10 *Robinia pseudoacacia*, III: >10 *Robinia pseudoacacia*.
*** cumulatedpercentage coverageof the species over all 34 investigation sites

Discussion

Nitrogen and Carbon

As no NH_4 was found in the soil samples,a high activity of nitrifying micro-organismswas assumed, which converts NH_4 into NO_2 und NO_3 (see BLUME et al. 2010).The ratio between carbon and nitrogen (C/N) does not vary with presence or absence of *Robinia pseudoacacia*. A possible reason can be found in the fact that mineral nitrogen in the study area only represents a very small part of total nitrogen. Therefore, the increasedmineralization due to Black Locust may not be reflected in total C/N ratio.

Density and Age

Age assessment and classification of the age groups turned out to be very difficult. Due to former silvicultural interventions, some trees were cut, dilapidated and developed plenty of sprouts so that the age of the trees was beyond recognition. Furthermore, on most plotsthere were several trees with various ages, which is the reason for group-categories only representing an average value of each site.In all analyses the density of the *Robinia pseudoacacia* population could be evaluated as a significantimpact factor for soil NO_3-content and species composition of ground vegetation cover.In this context, the age of Black Locustalso seemed to influence soil NO_3-content but could not beidentifiedas significant regarding the vegetation cover. However, the limited relevance of the tree age could be due to thedata uncertainties outlined above. Furthermore, on O and HB the populations of *Robinia pseudoacacia* varied in density but were of similar age. Only SR featured Black Locust in all categories of density and age. The results of the CCA lead to the assumption, that thisalso may be a reason why the age of Black Locustwas not significantly influencing all investigation sites. The age differences between the individuals of *Robinia pseudoacacia*on most sites (O and HB) may not have beenlarge enough to produce a significant result in the NMDS.

NO3 and Radiation Intensity

The NMDS diagram also does not displayNO_3-content as a significant parameter affecting species assembly of the research sites, even though we detectedthat it waspositively correlated with Black Locust density. This instance might be an indicator for the ambiguous influence of soil nitrogen on species composition of the habitat which is assumed to be overshadowed by the influence of radiation intensity. In the naturally nitrogen-rich habitat of the riparian forest, sites without *Robinia pseudoacacia*also provide high levels of soil nitrogen. Therefore, the increase of nitrogen due to Black Locust almost only promotes species that are extremely nitrophilous.Moderately nitrophilous species in any case find favorable conditions in the habitat and appear to be barely affected by the presence or absence of Black Locust. Conversely, the increased radiation intensity under *Robinia pseudoacacia* seems to have an explicit impact on the species assembly of the mostly photosensitive forest vegetation. Several shade-loving species became rare on sites that were dominated by Black Locust.However, some species seemed to avoid suchsites, even though this observation could not be explained by any site specific parameters such as nitrogen availability or radiation. In these cases, allelopathic qualities of Black Locust or other environmental impacts may be involved.

Nature conservation

Robinia pseudoacacia is a pioneer plant, which needs a lot of light to grow (see HECKER 2000). Therefore, itseemsunlikely that in the dense forest of the study area the tree will spread independently to agreat extent as it does e.g. on dry grassland. Nevertheless, the occurrence of a new species always does set off a process of change (see KEGEL 1999). As KOWARIK (1992) described, the final state after successional processes could be different under Black Locust than under other trees. Concerning this, *Robinia pseudoacacia*can in fact be characterized as an endangerment for the conservation of the local ecosystem. Furthermore, the present study could find indicators for a progressive monotonisation of the ground vegetation as mentioned in BÖHMER et al. (1989).Under certain circumstances, this could threaten the rich biodiversity of Donau-Auen National Park.

Conclusion

In summary, it was proven that *Robinia pseudoacacia* affects plant available soil nitrogen content as well as ground vegetation assembly, while the latter not only seems to be influenced by soil nutrient matter but also by the altered radiation intensity due to reduced shading under Black Locust. A promotion of extremely nitrophilous species could be found in some cases, such as *Sambucus nigra and Urtica dioica*. Radiation sensitive species like *Allium ursinum* or *Galium odoratum* showed an unambiguous decline under *Robinia pseudoacacia*. Even though Black Locust is a pioneer plant, which on forest stands presumably does not spread independently to a great extent, one should not disregardthat the presence of *Robinia pseudoacacia* might constitute a long-term impairment of the local biodiversity.Since the present study does not aim to give management recommendation, further studies would be needed to pursue this issue.

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