Doctoral (PhD) thesis abstracts

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Hungarian University of Agricultural and Life Sciences
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NATURAL AND SOCIAL SCIENCE ASPECTS OF NATIONAL DISTRIBUTION OF *A. ALTISSIMA*

Doctoral (PhD) thesis abstracts

DEMETER ANDRÁS

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1. Background and objectives of the research

Nowadays, the issue of invasive species is receiving increasing emphasis in nature conservation. The 2011 Biodiversity Strategy, adopted during the Hungarian EU Presidency, included the control of invasive species among its main objectives, including the suppression of animals and plants that are not native to a given area but whose populations are rapidly increasing, thereby endangering other species and their habitats.

During my master's degree, I based my thesis on a 5-year period of summarizing the expenses related to the black locust (*Robinia pseudoacacia*) and tree of heaven (*Ailanthus altissima*) as invasive plant species. Although the black locust occupies vast areas in Hungary, it is very divisive among the affected groups, as it is considered an economic tree species and there are significant financial interests attached to it. Tree of heaven, on the other hand, occurs sporadically in smaller areas, and its assessment is much more uniform, and I could count on greater helpfulness from the experts. Therefore, and because of my previous research related to the species, I thought it would be worthwhile to deal with *Ailanthus altissima* during my doctoral research. In order to gain a deeper understanding of the problems related to the spread of the species in Hungary, I supplemented the previous approach with ecological and social science research methods. I hoped that comprehensive research could provide a basis for organized action against the species and could also assist decision-makers in their work..

The complexity of our research was partly due to the combined use of natural and social science methods. The objectives of the natural science research part were **(C1.)** to carry out a botanical survey of *Ailanthus altissima*-dominated plant communities selected in different areas of the country, and to examine the similarity and difference of the vegetation of the sites based on the surveyed variables; **(C2.)** to determine the abundance of *A. altissima* in the different vegetation layers of the selected quadrats; **(C3.)** to examine the diversity of vegetation layers as a function of the abundance of *A. altissima*, and **(C4.)** to examine the relationships between the surveyed biotic and abiotic variables.

The objectives of the social science research part were **(C5.)** to explore the knowledge, presence and perception of the species among local governments, institutions of particular importance in terms of the spread of *A. altissima*, and to learn about the control methods applied by local governments at a national level, and **(C6.)** to explore the experiences and attitudes of the most relevant state organizations: state forestry and national park directorates regarding *A. altissima*, and to learn about the control methods applied so far.

<u>The following research question and hypothesis belong to Objective **C1.**:</u>
K1. How similar are the study sites in terms of their floristic composition?
H1. We assume that strong habitat transformation favors the appearance of similar, nitrophilous, generalist plant species in different areas of the country.

<u>The following research question and hypothesis belong to Objective **C2.**:</u>
K2. To what extent has *A. altissima* spread in the different layers of the studied stands?
H2. Since we searched for areas in which *A. altissima* is dominant at the canopy layer, we assume that the species is less abundant at the shrub and herb layers due to its rapid growth and strong closure ability.

The following research question and hypothesis belong to Objective **C3.**:
K3. To what extent did the cover of *A. altissima* determine the diversity of different layers, the investigated environmental soil parameters and other variables?
H3. We assume that it transforms habitats more favorable for the species, displacing certain plant species, reducing the number of native plant species in the habitat.

The following research question and hypothesis belong to Objective **C4.**:
K4. What are the relationships between the examined biotic and abiotic variables in *A. altissima*-dominated stands?
H4. We assume that nitrophilic species appear under *A. altissima* due to its strong environmental shaping properties.

The following research question and hypothesis belong to Objective **C5.**:
K5. How familiar are Hungarian local governments with *A. altissima*?
H5. Local governments are mostly unfamiliar with the species, and are not aware of its harmful effects on the environment.
K6. What do they think about its aggressive spread?
H6. We assume that they are unaware of the negative ecological effects of the species.
K7. Do they protect themselves against it? If so, what methods do they have for this?
H7. Local governments are unaware of effective methods of control, or are unable to apply them.
K8. Do they cooperate with other organizations?
H8. There is no specific cooperation between local governments and other interested groups regarding the control of *A. altissima*.

The following research question and hypothesis belong to Objective **C6.**:
K9. How much do state forestry and national park directorates consider the national spread of *A. altissima* a problem?
H9. State forestry and national park directorates are aware of the problem and assess it as serious through their own criteria.
K10. What methods do they use for control and how successful are they?
H10. State forestry and national park directorates also use chemical methods to control *A. altissima*, as they know that this is currently the most effective.
K11. What amounts have been spent and from what sources on the control of *A. altissima*?
H11. Forestry departments tend to use their own resources, while national park directorates use grant funds to a much greater extent. Probably several hundred thousand HUF per hectare.
K12. What do they consider important for the effective control of the species?
H12. Both state forestry and national park directorates would need additional resources to control the species.

2.Materials and methods

We tried to examine the effects of the national invasion of *Ailanthus altissima* in a complex way: from both a natural science and a social science perspective.

During the natural science research, we collected field data from areas with different characteristics in the country, then we systematized and evaluated them.

The citizen science part was based on a quantitative questionnaire. We compiled two types of questionnaires. One was for the local governments, a target group that is probably less familiar with the species, but is very important, while the other, a questionnaire containing much more professional questions, was given to employees of state forestry and national park directorates. We collected, systematized and evaluated the responses received. We aimed for nationwide coverage in the case of both local governments and national park directorates and state forestry.

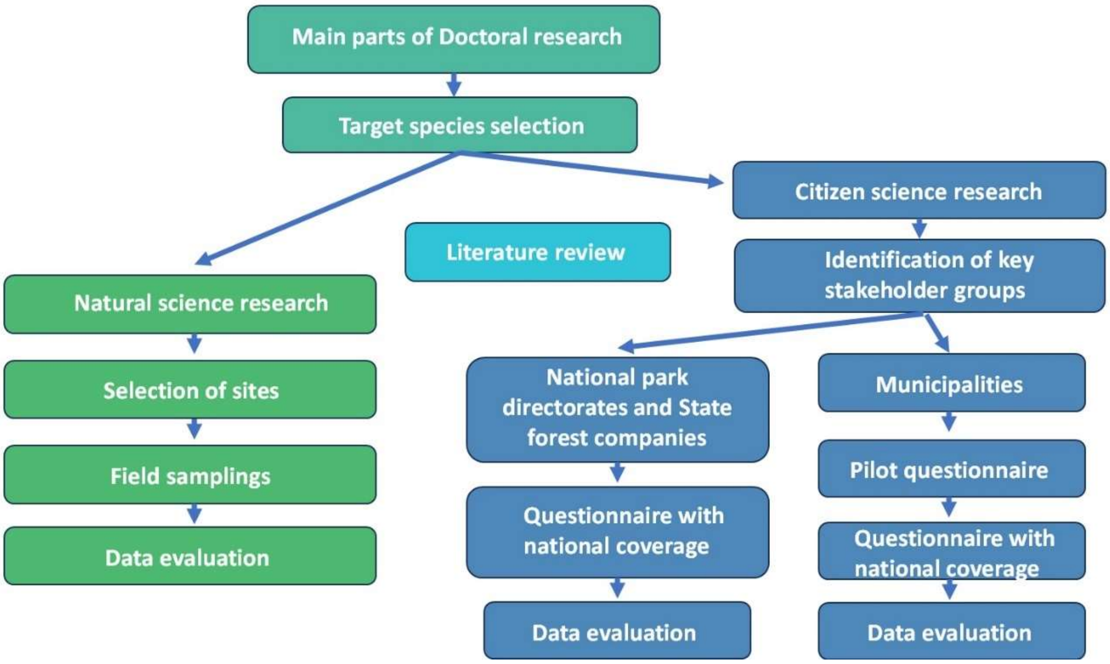


Figure 1: Flowchart of doctoral research.
Source: own compilation

Based on the recommendations of foresters and professional conservationists, 9 sites in Hungary (Pannian Biogeographic Region) were selected as sites for the **natural science research.** The main criteria for selection were that the canopy layer of the given plant communities should be heavily infected with *A. altissima* (at least 70% *A. altissima* cover) and that they should have different growth conditions. Sites close to roads were excluded to avoid the impact of such disturbance on our results. Finally, the following sites were selected: Bócsa (B), Fóti-Somlyó (F), Galgahévíz (G), Gyermely (GY), Isaszeg (I), Makád (M), Tök (T), Tököl (TL), Várvölgy (V) (2. ábra).

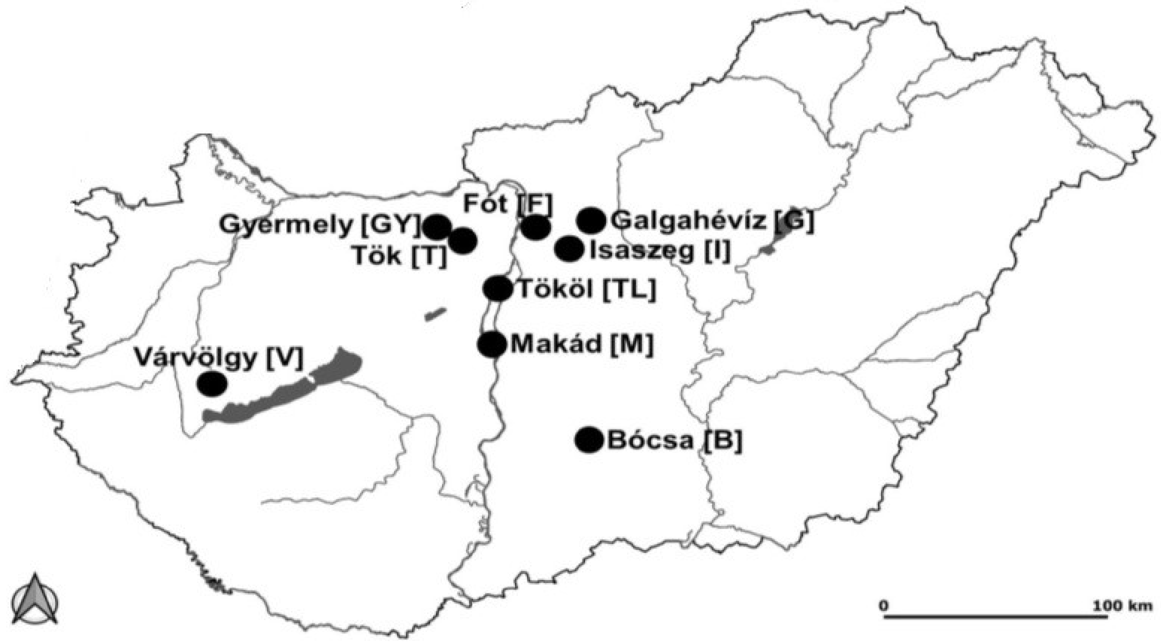


Figure 2: Location of sample areas (source: own editing).

The **botanical survey** was conducted in the summers of 2016 and 2017, in June and July. A total of 50 quadrats were selected for investigation, and at least 3 quadrats were recorded at each site. After selecting the quadrats, the corners of the square, 10×10 m quadrats were clearly marked with a colored marker, and the GPS coordinates of their center were recorded. Subsequently, the percentage cover of each vascular plant species was visually estimated in each quadrat at each layer (canopy, shrub and herb).

During the field sampling, the following data were also collected: exposure, slope, height of the *A. altissima*-dominated stands, the average and maximum diameter of *A. altissima* trees (at a height of 130 cm); the total and species-specific vegetation cover (%) at the different layers were recorded for each quadrat. The height of the trees was measured using a triangulation method and a laser height meter. The diameter of the trees was measured using a 5 m long measuring tape along the diagonals of the quadrats, measuring the diameter of at least 10 individuals.

Soil samples were collected in the summer of 2017. Three samples of approximately 100 cm3 each were taken randomly from each study site in the 0–10 cm layer quadrats. The laboratory analysis of the samples was carried out at the Department of Agrochemistry of the Hungarian University of Agricultural and Life Sciences.

Statistical analysis and visualization were performed using the PAST (PAleontological STatics) 4.05 statistical software package.
In order to better understand the similarities between the vegetation of the different study sites, we analyzed the data we collected with distance-based classical cluster analysis (UPGMA – Unweighted Pair-Group Mean) using the Euclidean average distance.
In order to overview the distribution of *A. altissima* between individual areas and layers, we created a radar diagram with a polar grid type and fine grid density, and the areas are separated by a red line for better transparency.

Diversity was also examined using the diversity module of PAST, specifically for the most commonly used Shannon and Simpson diversity indices, as well as its evenness.
To analyze the relationship between vegetation, environmental and soil parameters, we used a linear (Pearson) correlation method – univariate menu correlation module – and the results were expressed as r (degree of freedom) and p value (significance).

In frame of our **social science studies**, we compiled a thematic questionnaire consisting of 14 questions for the institutions and local governments that play an important role in the spread of the species, in which the questions were classified into the following units:
-General questions about the tree of heaven: recognizing the species from a picture, its positive and negative properties;
-Questions about the occurrence and spread of the species;
-Questions about the suppression of the species;
-Questions about the identification of local governments (it was voluntary and conditional, but in the end we did not name those who contributed to this).
The questionnaire could also be filled out online using Google. In cooperation with Pilisi Park Erdő, we first sent it out on a pilot basis to the 91 local governments that are in contact with them. Here, we did not strive for either national coverage or representativeness.

After the pilot questionnaire, we raised it to a national level and sent the questionnaire in several installments starting on 2018.04.07 to 2500 local governments with email addresses.

We compiled a more detailed questionnaire for the professional groups that are particularly sensitive to the spread of *A. altissima*: state forestry and national park directorates.
The questions related to the following topics:
- Their perspective and attitude regarding the national spread of *A. altissima*
- Their efforts and methods to prevent and control the spread of the species,
- Cooperation with other groups,

Questions regarding their future plans, suggestions and identification regarding control (it was voluntary and conditional, but in the end we did not name those who contributed to this)
The questionnaire was sent via email, between 2018.03. 19. and 2018.04. 03. 03. to all Hungarian state forestry and national park directorates from the mailing system of the then Ministry of Agriculture. In the case of state forestry, we requested that the questionnaire be completed at the forestry level.
The answers to the questionnaires were recorded in Excel spreadsheet, and after cleaning, some of the open questions were coded for statistical analysis. The answers of the employees of the national park directorates and the state forestry were arranged in a table and a comparative analysis was performed. In the case of some overlapping questions, the answers of the local governments were also compared with those of the other two groups. In addition to the basic statistical methods, for nominal variables, we used the Chi^2 test and Fisher's exact test, as well as Cramer's V-value to detect correlations ($p<0.05$). For ordinal and interval variables, we used the Mann-Whitney U-test for comparison, since the Kolgomorov-Smirnov and Shapiro-Wilk tests did not show a normal distribution. Our analysis was performed using the IBM SPSS Statistics 29 software.

In the case of the local government questionnaire, after the group of questions on the recognition of the species and knowledge of its characteristics, we only considered the responses of those local governments that recognized the species in our analyses. For the questions related to the presence of the species, we narrowed the evaluation to only those respondents who indicated the presence of the species in their area in all three groups.

During data collection and analysis, we followed the ethical guidelines of social science research, ensuring voluntary participation, confidentiality, the integrity of the participants, and anonymity.

3. Results

During the botanical surveys, a total of 163 species were found in the sample areas. 15 in the "A" layer, 30 in the "B" layer, and 158 in the "C" layer

Based on the distance-based classification analysis, the recorded stands can be classified into two large groups (Figure 3). The smaller group (A – G, GY, T) on the right side of the figure is distinguished from the vegetation of the other study sites due to the characteristic and/or mass occurrence of plant species (*Acer negundo* in the canopy; *Acer negundo, Cornus sanguinea* and *Ligustrum vulgare* in the shrub layer; and nitrophilous *Chaerophyllum tenulum* and *Urtica dioica* in the herb layer). The group containing stands from several study sites (box B) is distinguished from the former due to *A. altissima*. Among the larger group of study sites, the Tököl (TL) area was distinguished from the other habitats by the prevalence of *Populus canadensis* at the uppermost canopy layer, while the Isaszeg (I) area was distinguished from the other habitats by the prevalence of the nitrophilous *Bromus sterilis*.

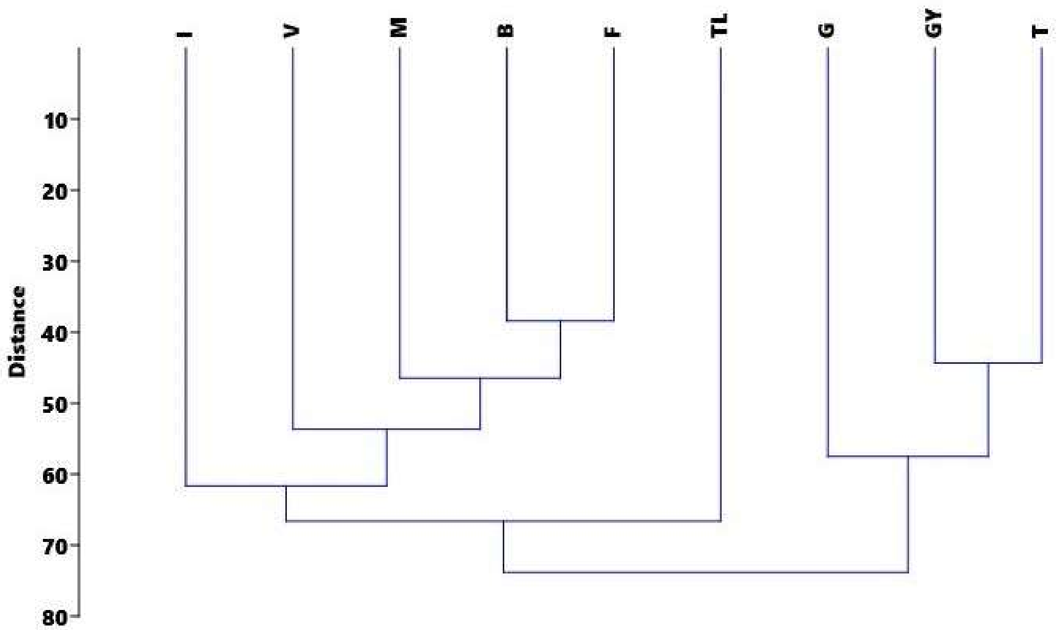


Figure 3: UPGMA analysis of the vegetation of the study sites (box plots – main separable groups) (Source: Demeter et al. 2021)

The cover of *A. altissima* was typically the most extensive in the canopy layer of the studied stands (Figure 4). Its average cover in the canopy layer ranged between 38.33% (TL) and 104.60% (M). In the shrub layer, the cover of the species was higher in most places than in the herb layer. At one site (V), the invasive species appeared massively not only in the canopy layer, but also in the shrub and herb layers. The lowest cover of *A. altissima* was 3.17% (G), the highest 66.13% (TL) in the shrub layer, while in the herb layer these variables were 2.00% (M) and 23.00% (V).

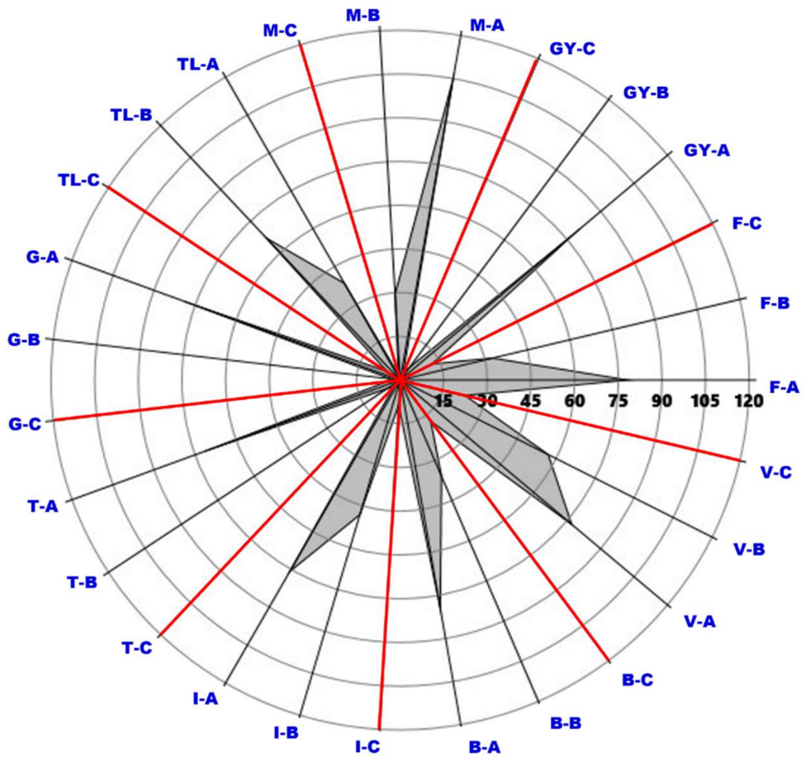


Figure 4. Polar diagram of *Ailanthus altissima* cover % by study site and forest layer (C – canopy layer; S – shrub layer; F – herb layer; see Abbreviations for study site abbreviations in the List of Abbreviations). (Source: Demeter et al. 2021)

Shannon and Simpson diversity values were lowest at the canopy layer and highest at the herb layer (Figure 5). In two stands, *A. altissima* was monodominant (I and V) at the canopy layer, so their diversity cannot be interpreted. In stands with also very low canopy diversity, one tree species (*Celtis occidentalis* – F, *Robinia pseudoacacia* – F and B) is present with low cover. Shannon diversity values were lower than 1.02 at the canopy layer, 0.49-2.00 at the shrub layer and 1.65-2.84 at the herb layer. Simpson diversity values were 0.63 at the canopy layer, 0.22 and 0.84 at the shrub layer, and 0.65 and 0.90 at the herb layer.

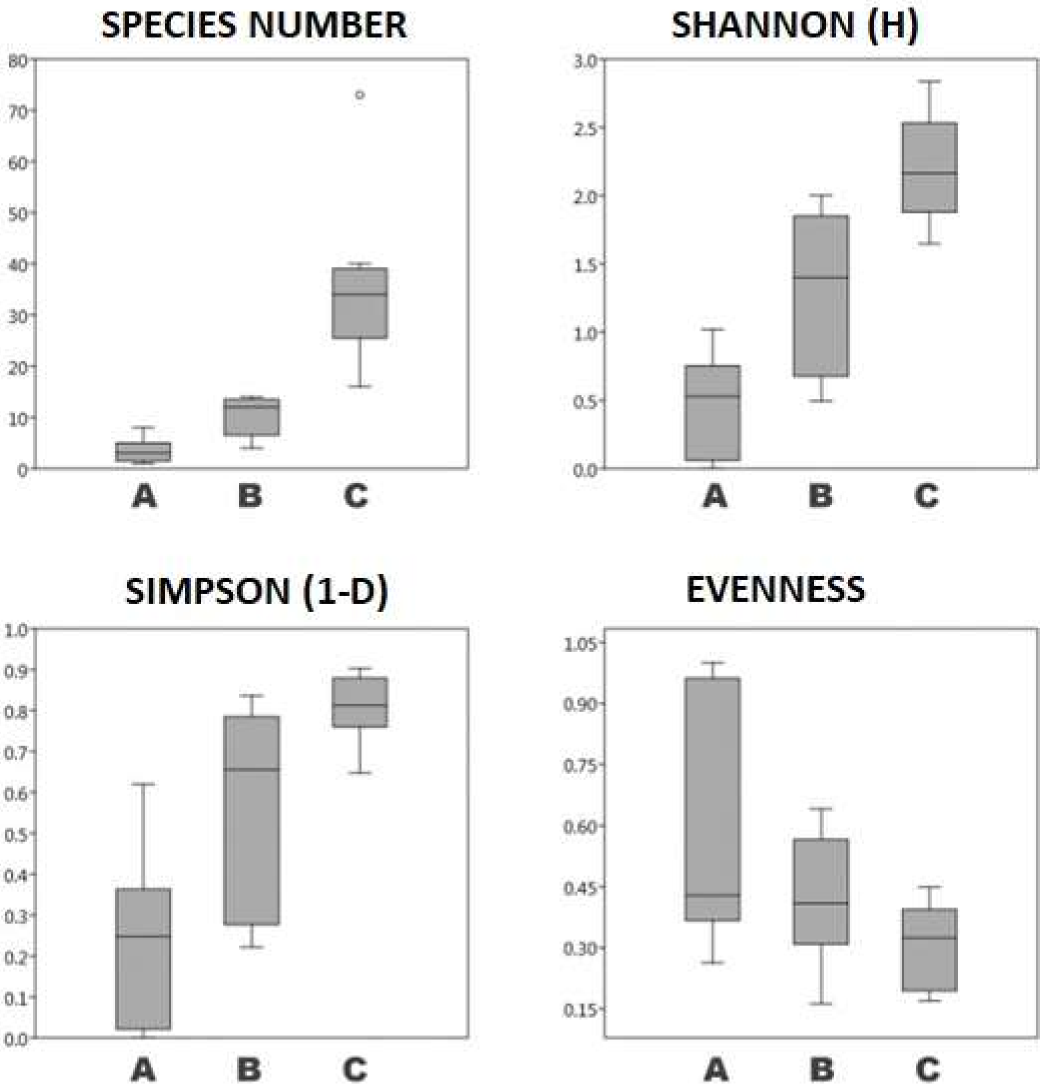


Figure 5. Species number, Shannon and Simpson diversity and Shannon evenness of vegetation layers. (Source: Demeter et al. 2021)

Regarding the dendrological data of the stands and the environmental factors (Figure 6), we found a positive correlation between slope angle and average diameter, slope angle with herb layer-species richness, MASL with Soil humus, stand height with MASL, diameter and stand height with maximum diameter. In addition, we found a very strong positive correlation between average diameter and maximum diameter. Among the examined soil parameters, we found positive correlations between the following: Soil humus with Total N, Soil humus with $CaCO_3$, Soil humus with KA; Total N with soil KA, Soil pH with KCl and Soil pH with H_2O.

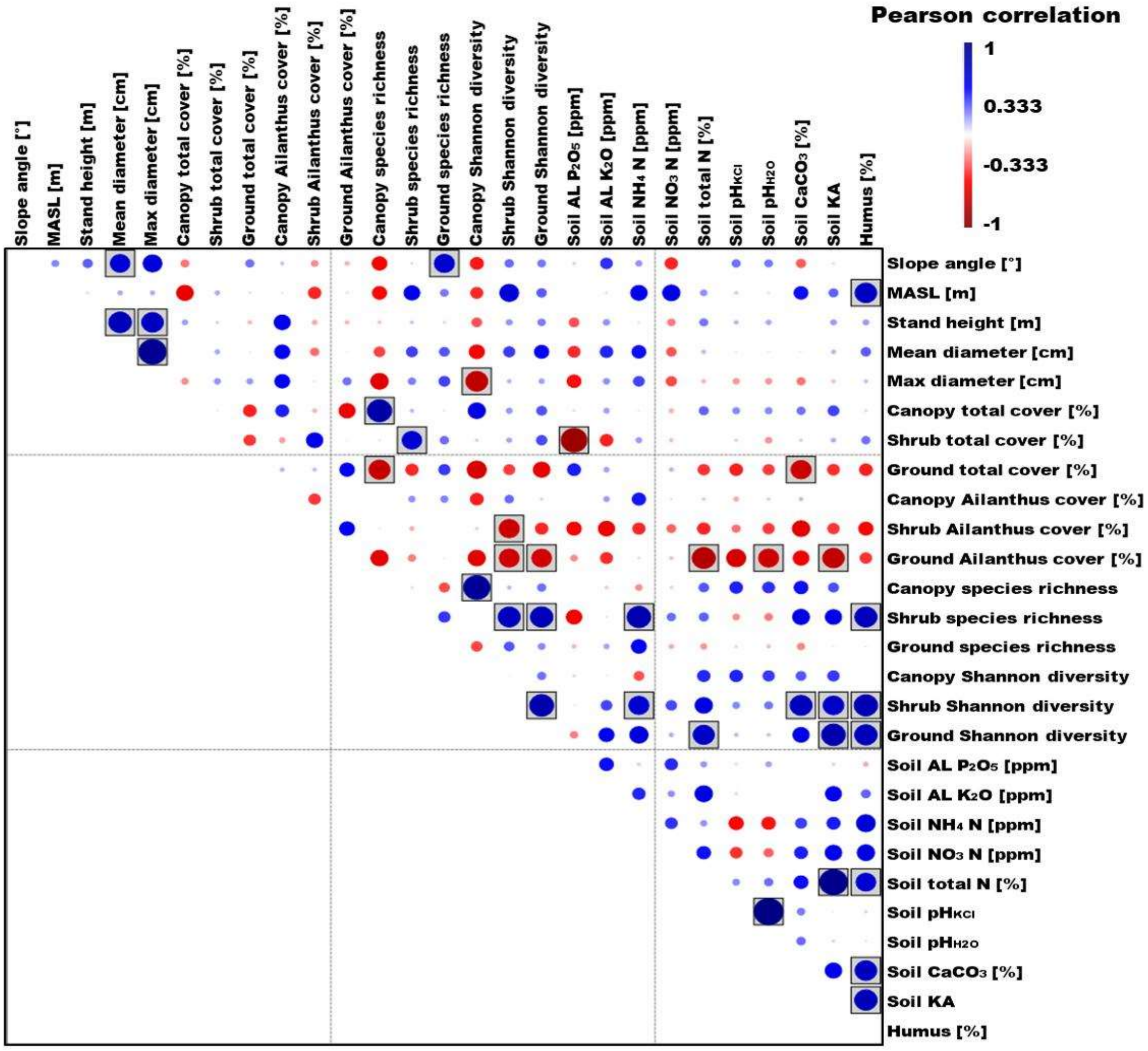


Figure 6. Linear (Pearson) correlation of the studied biotic and abiotic factors (circle size scaled proportionally, blue – positive correlation, red – negative correlation, boxed – $p<0.005$ significance). (Source: Demeter et al. 2021)

Of the 2,500 municipalities surveyed, 221 responded, representing a return rate of 8.8%.

A significant number of responses were received from Pest County, while only 1 was received from Békés County.

The majority of the representatives of the responding municipalities (131, or 59%) recognized the species, while the majority of the others confused it with the staghorn sumac (*Rhus typhina*).

Respondents representing settlements with a larger population (including Budapest districts) recognized *A. altissima* at a significantly higher percentage than those representing smaller settlements.

Respondents representing municipalities in Budapest and Pest County recognized *A. altissima* at a significantly higher percentage than respondents from the Western and Eastern regions.

The most common indicated negative impact of the species was that it displaces native species, the second most common response was related to the allelopathic properties of the species, while the third most common was its economic damage.
Significantly more respondents indicated some negative impact (displacing native species, releasing anti-germination compounds into the soil, causing agricultural damage) among those who recognized the species (Table 2). There was an even stronger correlation between indicating a negative impact and the presence of the species in the settlement.
Regarding positive impacts, at least 30% of respondents indicated some options (provides shade, is a good honey producer, does not know of any positive impact). Significantly fewer respondents indicated exotic appearance as a positive impact among those who recognized the species.

Table 2. Opinions of the responding municipalities on the impacts of *A. altissima*

Impact Categories	Type of Impacts	Did the Respondent recognise the species?		Chi^2 Test *p* Value (Cramer's V Value)
		Yes (N:131, 100%)	No (N:90, 100%)	
Negative impacts	It displaces native species	95%	87%	0,037* (0,140)
	Releases anti-sprouting compounds into the soil	32%	17%	0,01* (0,173)
	Many people allergic to it	9%	11%	0,634
	It causes a lot of damage in the agricultural sector	28%	12%	0,005* (0,191)
	I am not aware of any negative effects	5%	9%	0,196
Positive impacts	It is a good honey making plant	34%	30%	0,498
	It provides timber that sells well	12%	6%	0,097
	It has an exotic look	18%	32%	0,012* (0,170)
	It provides a species rich habitat	2%	0%	0,239
	It gives shade	40%	48%	0,281
	I am not aware of any positive effects	30%	30%	0,971

* significant difference between the two groups of respondents ($p<0,05$)

A small proportion of those who recognized *A. altissima* indicated that it was not present or that they did not know whether the species was present in their locality. The majority of those who recognized it (105 people, or 80% of those who recognized it) therefore confirmed the presence of the species. They most often encountered it in rural areas, gardens and along roads (Figure 11).

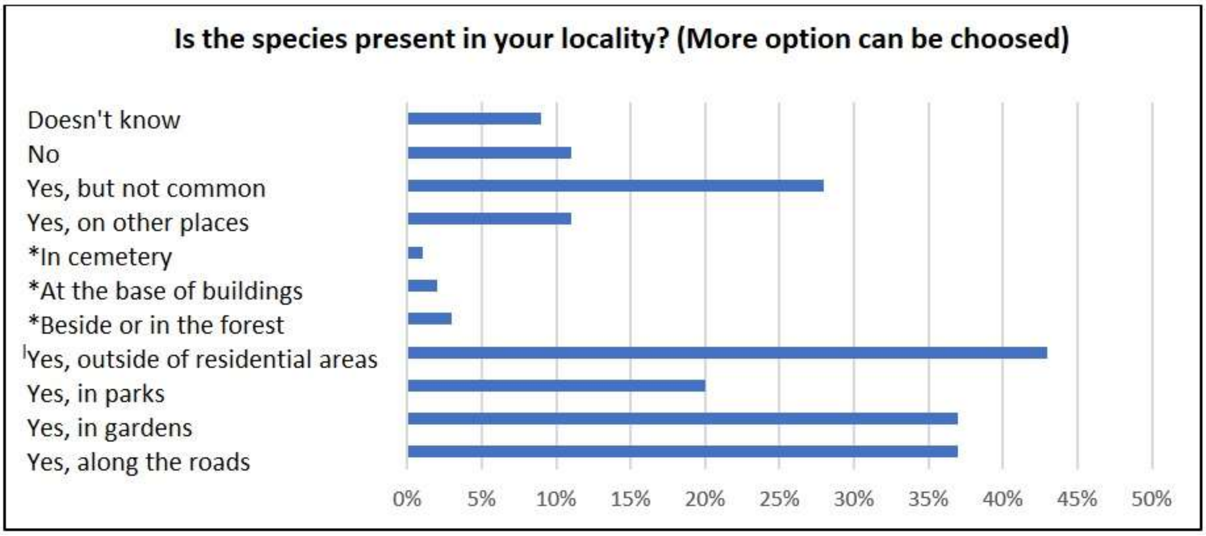


Figure 11. Distribution of responses from municipalities that recognize *A. altissima* regarding its spread

From this group of questions onwards, we focused mostly on the responses of those municipalities that had recognized the species and confirmed its presence in their settlements.
A small number of them indicated that the municipality had a tool to monitor the appearance and spread of *A. altissima* (e.g. regular surveys), or a municipal measure or decree aimed at its control, and 36% indicated that their municipality applied some control method (mostly mechanical). Respondents representing settlements with larger populations indicated the control of the species at a significantly higher rate than those representing smaller settlements.
The following sources were used by local governments dealing with the reduction of the species:

• Local government budget, own resources, forest, green space, and park maintenance framework: 29 responses;
• public works program, during the maintenance of public areas 4 responses;
• with the help of an environmental NGO 2 responses.

When summarizing the responses to the following question, we also took into account those who did not recognize the species. The majority of municipalities would have liked to know more about the ecological effects of *A. altissima* and possible ways to protect against it. We found a significant correlation between the presence of the species and the need for further information.
The majority of municipalities that recognized *A. altissima* also considered it important to involve the population, local forestry and nature conservation in the fight against the species.
The majority of respondents who recognized the species and indicated its presence indicated that eradication could be carried out within the framework of a public works program (a state-funded temporary employment program).

National park directorates and state forestry, i.e. experts who know the species and deal with it in practice, mostly assess the spread of the species in Hungary as a serious problem. No one gave a positive answer.

The impacts indicated by the respondents are summarized in Table 3. The national park directorates identified all of the negative impacts as ecological (ecological, environmental damage). On the other hand, a third of the state forestry indicated positive, mostly ecological (e.g. soil protection, green space, game hiding, wide-tolerant species) impacts, and a smaller proportion indicated economic benefits (bee pasture, timber). Negative impacts were indicated in a large proportion, predominantly due to ecological aspects, and a third due to economic aspects.

Table 3. Assessment of the impacts of *A. altissima* among Hungarian national park directorates and state forestry departments

Impacts indicated	Groups		Chi^2 /Fisher's Exact Test *p* Value (Cramer's V Value)
	NPDs (N:10, 100%)	SFUs (N:110, 100%)	
Postitive	10%	35%	0,164
Positive ecological	10%	25%	0,450
Posivtive economic	0%	15%	0,355
Negative	100%	96%	1,000
Negative ecological	100%	92%	1,000
Negative economic	0%	38%	0,014* (0,221)

* significant difference between the two groups of respondents ($p < 0.05$).

Table 4. shows the responses regarding the factors influencing the national spread of the species. Passive (involuntary) human behavior towards the species was the strongest reason according to both groups. National park directorates mentioned human activity as the second most important reason, while state forestry departments mentioned the characteristics of the species. A significant difference was found in the indication of human activity (inappropriate management, planting), which was a serious factor according to the national park directorates, but was only indicated by state forestry departments at a rate of one-third.

Table 4. Main factors influencing the national spread of *A. altissima* according to the surveyed professional groups

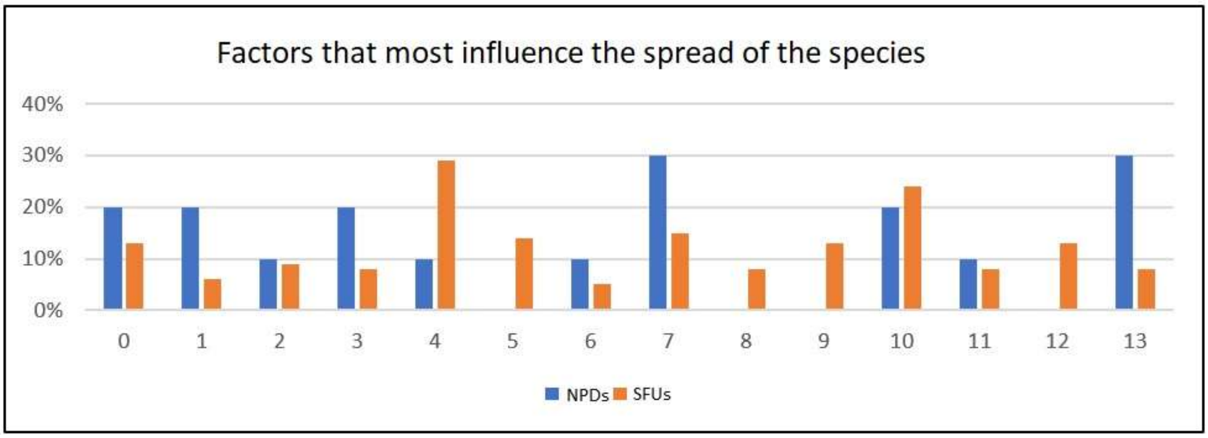
Factors influencing the spread of the species	Groups		Chi^2 /Fisher's Exact Test *p* Value (Cramer's V Value)
	NPDs (N:10, 100%)	SFUs (N:110, 100%)	
Human inaction (ignorance, laziness, opening up of soil cover)	90	61	0,09
Human activity (improper management, planting)	60	21	0,013* (0,252)

Factors influencing the spread of the species	Groups		Chi ^{2} /Fisher's Exact Test *p* Value (Cramer's V Value)
	NPDs (N:10, 100%)	SFUs (N:110, 100%)	
Favourable environmental conditions (also Climate change)	30	30	1,000
Characteristics of the species (undemanding, prolific)	30	39	0,74

* significant difference between the two groups of respondents (p<0,05)

National park directorates and state forestry departments also overwhelmingly confirmed the presence of the species in the areas they manage.

We then summarize the responses of those who indicated that *A. altissima* occurs in the areas under their management.



When asked what most influences the spread of *A. altissima* in the areas they manage, the most common responses from national park directors were soil surface opening and human activity (negligence, introduction, planting in parks), while according to state forestry departments, the strongest factors were the proximity of infected areas and the competitive properties of the species (Figure 15).

Figure 15. Percentage distribution of factors that most influence the spread of *A. altissima* in a given area (0: did not answer, does not know; 1: its spread is not problematic; 2: lack of control; 3: difficult control (expensive, difficult); 4: infectious area nearby (including ownership); 5: method of silviculture (wood use, method of forest regeneration); 6: site conditions; 7: open soil surface, reduction of closure; 8: linear facilities; 9: climate change; 10: species characteristics; 11: uncultivated (land) areas; 12: spread by wind, animals, machines; 13: human activity)

A. altissima was not used at all by national park directorates, and to a lesser extent by forestry departments (firewood and wood chips).

In both groups, only 10% indicated that they were not involved in controlling the species, and did not indicate that they planned to do so in the future. Based on this, the species still caused a problem for about 90% of them, or was likely to become more problematic in the future.

Half of the national park directorates and nearly half of the state forestry departments involved in the control of *A. altissima* used both chemical and mechanical methods (Table 5). In most cases, chemical treatment was necessary, as the species tolerates mechanical damage very well. According to the majority of respondents, post-treatment had to be continued for 2 or more years in order to effectively control the species. Post-treatment was mostly carried out by national park directorates using a combination of chemical and mechanical methods, or only chemical methods, while forest management companies used only chemical methods to a greater extent. The answers of the two groups of respondents did not show a significant difference in terms of any of the questions.

Table 5. Correlations between respondent group and eradication methods used for *A. altissima* (only for organizations that reported the presence of the species).

Eradication	Groups		Chi^2 /Fisher's Exact Test *p* Value (Cramer's V Value)
	NPDs (N:7, 100%)	SFUs (N:83, 100%)	
Uses eradication methods	86	88	1,000
Mechanical	57	65	0,696
Chemical	57	73	0,392
Biological	14	10	0,535
More than one method	50	58	1,000
Control after eradication	86	65	0,417

The responses regarding the spatial extent of *A. altissima* infestation and eradication, as well as the cost of treatments, are presented in Table 6.

In the case of national park directorates, the infected area was largely protected area, which is not so surprising, since they mainly manage protected areas. The size of the treated areas was almost three times that of the forest enterprises, based on the median values. The national park directorates also reported double the median values in terms of the proportion of permanently cleared areas, but the difference was not significant. The greater success could explain the much higher cost per hectare of suppression (4.6 times the forest enterprise median). However, the forest enterprises spent proportionally more on post-treatment, based on the median values. However, these differences did not prove to be significant either.

Table 6. Area of *A. altissima* in the areas under management of the affected groups, area affected by eraditcation, eraditcation and post-treatment costs

N (there is *A. Altissima*)	Indicators related to the	Min	Max	Median	Mann-Whitney U Test

		Eradication of							*p* Value
NPDs	SPUs	*A. Altissima*	NPI	ERD	NPI	ERD	NPI	ERD	
6	61	Area of eraditacion (ha)	1,5	0,1	113	700	29	10	0,395
4	61	Ratio of permanently eradicated area (%)	5	0	100	100	65	30	0,213
4	60	Cost of eradication (thousand HUF/ha)	38	10	750	490	350	76	0,073
1	46	Cost of follow up control (thousand HUF/ha/year)	8	5	8	490	8	50	0,085
5	69	Ratio of used own resource (%)	0	10	100	100	5	100	0,04*

* significant difference between the two groups of respondents (p<0,05)

The majority of the responding state forestry departments carried out the control of *A. altissima* almost exclusively (median: 100%) from their own resources. Those that also used grant funds most often used LIFE and KEOP funds, less often NFM support, public works program, ROP, INTERREG, KMOP and EKV.

A small part of the responding national park directorates carried out the control exclusively from their own resources, most often using LIFE and KEHOP funds, less often VEKOP and INTERREG grant funds. The difference between the two respondent groups was significant in terms of the proportion of their own resources used.

Based on the medians of the responses, the biggest problem for national park directorates was the idol trees in the areas of private and state forestry, while for the latter group, the ones on the areas of public roads, residents and municipalities were the most common. Based on the Mann-Whitney U-test, only the problem affecting private forestry companies showed a significant difference between the two respondent groups.

According to the national park directorates, the national park directorates managed the species most appropriately, followed by the state forest management companies. According to the latter group, their own management was also most appropriately, followed by the national park directorates. Only in the case of state forestry was there a significant difference between the two groups, as a much higher percentage of them thought that this group managed the species appropriately.

Regarding the cooperation between the different groups involved, the national park directorates cooperated most with the state forestry companies to control *A. altissima*, and secondarily with other national park directorates. State forest directors cooperated most with other forest management companies and national park directorates (Table 8), but there was no significant difference between the two respondent groups in either case.

Table 8. Percentage distribution of collaborations between different stakeholder groups

Stakeholder groups	Groups		Chi^2 /Fisher's Exact Test p Value (Cramer's V Value)
	NPDs (N:7, 100%)	SFUs (N:83, 100%)	
Municipalities	14%	14%	1,000
National park directorates	29%	33%	1,000
State forestry companies	71%	43%	0,239
Private forestry companies	0%	17%	0,590
Public road management company	14%	5%	0,339
Residents	14%	4%	0,281

* significant difference between the two groups of respondents (p<0,05)

Based on the answers to the question group regarding future plans, opportunities and cooperation, both groups largely believed that the reduction of the species should be addressed in the future, which almost half of the forestry enterprises would implement from their own resources, and the other half partly from grant funds. The majority of the responding national park directorates would rely on both grant and own resources, and certainly not solely on their own resources.

Based on the answers of the state forestry enterprises, an average of 72 million HUF would be needed for the complete reduction of *A. altissima* for the areas under their management. The answers ranged from 15 thousand HUF to 1.3 billion HUF.

Based on the answers of the national park directorates, they would need an average of 80 million HUF. The values given were between 5 million HUF and 175 million HUF.

Based on the responses of the national park directorates, all tools are highly needed for the effective future control of *A. altissima*, but financial resources are the most important, and knowledge expansion is the least important (probably because this is largely available). State forestry departments also consider all factors to be very important, ranking them lower, but national strategy is the least important.

4. Conclusions and recommendations

Conclusions

Natural science research section:
(C1)
(K.1.) Based on the evaluation of the study sites, the role of *A. altissima* was very significant in all stands, therefore its appearance may have serious negative effects on diversity.
(H.1.) I accept the hypothesis, because *A. altissima* significantly re-established its environment everywhere.
(C.2.)
(K.2.) The cover of *A. altissima* was typically the largest in the canopy layer of the studied stands, smaller in the shrub layer, and the smallest in the herb layer. The larger trunk diameter of *A. altissima* and the lower Shannon diversity of the canopy level may indicate that the presence of *A. altissima* may displace tree species from the stand in the long term, and presumably indicates older stands.
This may indicate older stands, and one of the main considerations in selecting the sample areas was the dominance of *A. altissima* in the canopy layer.
(H.2.) I accept the hypothesis, since the species was most abundant in the canopy layers.
(C.3.)
(K.3.) Shannon and Simpson diversity values were negatively correlated with *A. altissima* cover values. Thus, the values of the two examined diversity indices were higher where the abundance of *A. altissima* was low, while they were lower where the presence of *A. altissima* was more severe.
(H.3.) I accept the hypothesis because the abundance of *A. altissima* negatively influenced the diversity of the given level.
(C.4.)
(K.4.) Based on the observed *A. altissima* abundance relationships in the canopy layer, it can be assumed that *A. altissima* trees in the herb layer and the shrub layer originated from the internal propagule pool of the stand. Those stands where the trunk diameter of the species was the largest in the canopy layer were presumably the earliest colonized by this invasive species. The nitrophilous species that were abundant in the herb layer confirmed that the mass proliferation of *A. altissima* in an area could potentially be beneficial for nitrophilous plant species in the understory.
Based on our results, the cover of *A. altissima* in the shrub layer was negatively correlated with the Shannon diversity of the shrub layer. The cover of *A. altissima* in the herb layer was significantly and negatively correlated with the following variables: shrub layer Shannon diversity, herb layer Shannon diversity, total soil N and soil KA. The mass presence of *A. altissima* in the herb layer was not only negatively correlated with the diversity of the herb and shrub layers, but also had an unfavourable effect on several soil parameters, such as soil pH and total N content. Based on the examined relationships, it can be stated that the condition of both the shrub and herb layers, as well as their Shannon diversity, showed a positive correlation with several soil parameters, such as the humus and N content of the soil, while they were also relatively strongly correlated with each other.
(H.4.) I accept the hypothesis, because nitrophilic species were common in the sample areas.

Social science research section

(C5.)

(K.5.) In our research, we found that only 59% of the respondents representing local governments recognized *A. altissima*. Those representing settlements with larger populations recognized the species in a significantly higher proportion (based on the Chi^2 test ($p<0.05$)). These settlements are likely to have a larger budget and employ more experienced experts in the subject (e.g. head gardener).

(H.5.) I partially accept the hypothesis, as *A. altissima* was recognized in a proportion approaching half.

(K.6.) Regarding the effects of the species, the vast majority (91%) indicated that it displaces native species, the second most common response (26%) was related to its allelopathic effect, and its economic damage was also indicated (22%). Based on the Chi^2 test, significantly more respondents indicated some negative effect (displaces native species ($p=0.037$), releases anti-germination compounds into the soil ($p=0.01$), significant damage to the agricultural sector ($p=0.005$)) among those who recognized the species. There was an even stronger correlation ($p=0.001$) between indicating a negative effect and the presence of the species in the settlement. Regarding the positive effects, at least 30% of respondents indicated some possibilities. Based on the Chi^2 test, significantly fewer respondents indicated the exotic appearance as a positive effect among those who recognized the species ($p=0.012$).

(H.6.) I do not accept the hypothesis because the vast majority of them have marked the essence of the invasive effect of the species.

(K.7.) Only a small proportion of the municipalities that recognized the species and reported its presence (36%) dealt with the control of *A. altissima*, despite the fact that it is found almost everywhere. The possible reasons for this are mostly that it was not yet widespread or that the municipalities did not consider its presence to be a problem. We found a significant ($p<0.05$) correlation between the rate of control and the size of the settlement in terms of population. The use of mechanical methods, which is commonly used in the treatment of other species, clearly predominates, but for this species, are often ineffective without chemical treatments and may even promote its proliferation.

The former may indicate a lack of knowledge of more effective treatments, but also the difficulties of chemical treatment (availability of glyphosate-based agents, conditions for their use).

(H.7.) I accept the hypothesis, since the answers show that the species is eradicated in a small proportion and not properly.

(K.8.) The majority of municipalities that recognized *A. altissima* also considered it important to involve the population and, in a similar proportion, local forestry and nature conservation in the fight against the species.

(H.8.) I accept the hypothesis because there are no collaborations with other organizations specifically suitable for suppressing the species.

(C.6.)

(K.9.) Experts familiar with the species and those who deal with it in practice mostly assessed the spread of the species in Hungary as a serious problem, and no positive response was received. All national park directorates attributed negative ecological effects to the species. State forestry departments indicated negative effects in a high proportion, predominantly ecological, and a third due to economic aspects. Passive (involuntary) human behavior (inappropriate management, planting) was the strongest reason according to both groups. A

significant difference (p= 0.013) was found in the indication of human activity (inappropriate management, planting), which was a serious factor according to the national park directors (60%), but was indicated by the other group in a third of the proportion.
Both groups confirmed the presence of the species in the areas they manage in a high proportion (over 70%). According to respondents, the opening of the soil surface and human activity in national park directorates, and the proximity of infected areas and the competitive properties of the species in state forestry departments, influenced its spread the most.
(H.9.) I accept the hypothesis because both groups considered the aggressive spread of the species a serious problem and most of them confirmed its presence in the areas they managed. According to the national park directorates, it caused ecological damage, and according to the state forestry departments, it caused ecological and economic damage.
(K.10.) Of the two groups, those where *A. altissima* was present were predominantly concerned with the control of the species (86% in the case of national park directorates, 88% in the case of state forestry). Here, half of the national park directorates and more than half of the state forestry departments used both chemical and mechanical methods. 14% of the former group and 10% of the latter indicated that they also used biological methods. A follow-up treatment lasting 2 or more years was required in a higher proportion of both groups, which was carried out using combined (mechanical and chemical) or chemical methods only.
(H.10.) I accept the hypothesis, since both groups are familiar with and use chemical treatment.
(K.11.) Based on the responses received, national park directorates spent much higher amounts (median: 350 thousand HUF/ha) on the control of *A. altissima* than state forestry (median: 76 thousand HUF/ha), but this was not statistically significantly different. In their previous study, Demeter et al. (2015) estimated the cost per hectare at approximately 570 thousand HUF based on budget data sent by the Kiskunság National Park Directorate. Kocsis (2015) shares his experience with *A. altissima* eradication in the Kisalföld region, funded by the KEOP grant. In his report, he mentions costs ranging from 75,000 (mechanical removal) to 333,520 (bark application) HUF per hectare, depending on the treatment method.
In the case of national park directorates, the cost of post-treatment was much lower (median: 8 thousand HUF/ha/year) than in the case of state forestry (median: 50 thousand HUF/year/ha), and the proportion of permanently cleared areas was also twice as high (national park directorates: 65%, state forestry: 30%). This difference could also result from the higher abatement costs of national park directorates.
We found a significant difference (p= 0.04) in the proportion of resources spent on abatement, where national park directorates used their own resources in a very small proportion, while state forestry used their own resources in the vast majority.
(H.11.) I partially accept the hypothesis, because the national park directorates did indeed spend several hundred thousand HUF per hectare on reduction, but mainly from grant funds. State forestry departments spent much less, which can also be explained by the large proportion of their own resources.
(K.12.) Both groups largely (90%) believed that the suppression of the species should be addressed in the future.
To completely suppress *A. altissima*, state forestry departments would need an average of 72 million HUF, and national park directorates an average of 80 million HUF for the areas under their management. According to both groups, financial resources are of paramount importance for the protection against the species.

(H.12.) I accept the hypothesis, since the answers of the two groups overlapped in the priority need for financial resources. It is true that they also considered national strategy, human resources, cooperation and knowledge expansion to be equally important.

Recommendations

The spread of *A. altissima* in Hungary is causing increasingly significant problems, primarily in the fields of nature conservation and forestry. The relevant branches and partly also the local governments are aware of the problem, but the knowledge and financial and physical possibilities for control are often lacking.

- For this reason, I consider it important to raise awareness among local governments and the public, as well as to make them aware of the possibilities of prevention and control at their own level. The information found on invaziosfajok.hu is already providing significant help to those interested, but it would be worthwhile to devote additional resources to actively conveying information at a national level through further campaigns and media appearances.
- The use of safer practices by managers of potential spread routes (e.g. in forestry, the opening of closed stands may be a potential site for the appearance of the species, or the mechanical impact of road operators on shoot formation) should be given priority.
- Combined (mechanical and chemical) treatment is currently the most suitable method for actively controlling the species. However, this requires permits for the use of machinery and chemicals, as well as effective (so far the most proven, glyphosate-based) materials, and significant human and financial resources. Sharing these burdens and cooperating with different stakeholders operating in a given area (e.g. local government, nature conservation, forestry, road management) would be very important.
- The efficient utilization of the harvested stocks of the species (e.g. timber, biomass) could be of great help in generating financial resources, of course without motivating or inducing deliberate cultivation. Here, the first step could be to localize and destroy older, seed-bearing individuals.
- The example of tree of heaven may also be instructive in that, before planting non-native woody species in Hungary in the future – especially if this is done at the stand level – the invasive potential of the given tree species experienced so far should be assessed. If it has behaved as an invasive species in at least one region where the given species is not native, then its planting in Hungary should not be supported, and should even be explicitly prohibited.
- Testing and later applying new methods of biological control may provide additional opportunities. Therefore, research in this direction may be very useful in the future.

5. New scientific results

1. The novelty of our research lies in the fact that we examined both the ecological and social science aspects of the national spread of *Ailanthus altissima*, the former by means of a vegetation survey at 9 locations, and the latter at a national level with the involvement of the most relevant stakeholder groups: local governments, national park directorates and state forestry.

2. We found that the cover of *A. altissima* was typically highest in the canopy layer of the studied stands, lower in the shrub layer, and lowest in the herb layer. The Shannon and Simpson diversity values of the given layer were negatively correlated with its cover.

3. We found that *A. altissima* cover in the herb layer was significantly and negatively correlated with the following variables: shrub layer Shannon diversity, herb layer Shannon diversity, total soil N and soil KA, and also had an unfavorable effect on soil pH.

4. We found that a larger proportion of respondents representing municipalities recognized *A. altissima*, and a significantly higher proportion of respondents representing settlements with larger populations. The vast majority of those who recognized the species believed that it displaces native species. Significantly more respondents reported some negative impact among those who recognized the species. We found an even stronger correlation between reporting a negative impact and the presence of the species in the settlement.

5. We found that only a minority of municipalities that recognized and reported the species were concerned with its control, despite the fact that it is found almost everywhere. We found a significant correlation between the rate of control and the size of the settlement in terms of population. The use of mechanical methods was clearly predominant during control.

6. We found that both national park directorates and state forestry departments confirmed the presence of *A. altissima* in their managed areas to a large extent, and the vast majority of them dealt with the control of the species. Half of the national park directorates and more than half of the state forestry departments did this using chemical and mechanical methods. Biological methods were used by both groups in a rate of over 10%. A minimum of 2 years of post-treatment was required in most cases.

7. We found that, based on median values, national park directorates spent several times more per hectare on *A. altissima* control than state forestry, but in the former case the cost of post-treatment was much lower and the proportion of permanently cleared areas was twice as high. We found a significant difference in the proportion of resources spent on control, where national park directorates used their own resources to a very small extent, while state forestry used their own resources to the vast majority.

8. We found that both groups believed that the suppression of the species should continue in the future. For its complete suppression, state forestry departments would need an average of 72 million HUF, and national park directorates an average of 80 million HUF for the areas under their management. According to both groups, financial resources are of paramount importance for the protection of the species.

6. Relevant publications

Demeter A., Saláta D., Czóbel Sz., Csépányi P., Tibor Limp T., Tormáné Kovács E. (Accepted in 2025): Perception of Stakeholder Groups on *Ailanthus altissima* in Hungary. Land 14

Demeter A., Saláta D., Tormáné Kovács E., Szirmai O., Trenyik P., Meinhardt S., Rusvai K., Verbényiné Neumann K., Schermann B., Szegleti Zs., Czóbel Sz. (2021): Effects of the Invasive Tree Species Ailanthus altissima on the Floral Diversity and Soil Properties in the Pannonian Region. Land 10(11), 1155; Q2 https://doi.org/10.3390/land10111155

Demeter A., Falvai D., Trenyik P., Czóbel Sz. (2017): Ecological indicator based comparative study of tree of heaven (Ailanthus altissima) stands' herb layer. Columella - Journal of Agricultural and Environmental Sciences 4 (1): 15-20. DOI:10.18380/SZIE.COLUM.2017.4.1.15

Demeter A., Czóbel Sz., Limp T., Csépányi P., Kovács E. (2017): Pest-közeli önkormányzatok viszonya egy inváziós fajhoz, a mirigyes bálványfához, Természetvédelmi Közlemények 23, pp. 168–181, 2017 DOI: 10.17779/tvk-jnatconserv.2017.23.168

Demeter A. & Czóbel Sz. (2016): A mirigyes bálványfa (Ailanthus altissima (Mill.) Swingle) hazai kutatásainak áttekintése és inváziójának mértéke a hazai élőhelyeken, Természetvédelmi Közlemények 22, pp. 20–32, 2016 DOI: 10.17779/tvk-jnatconserv.2016.22.20

Demeter A., Sarlós D., Skutai J., Tirczka I., Ónodi G., Czóbel Sz. (2015): Kiválasztott özönfajok gazdasági szempontú értékelése – a fehér akác és a mirigyes bálványfa. Tájökológiai Lapok 13: 193-201.