INVENTORY AND MAPPING OF INVASIVE SPECIES *AILANTHUS ALTISSIMA* (MILL.) SWINGLE IN URBAN AND PERI-URBAN AREAS: A NEW METHOD OF STUDY AND INTERPRETATION

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Abstract
Invasive species of plants are increasingly common, especially in anthropic modified ecosystems, becoming even dominant and replacing indigenous vegetation. Urban and peri urban areas with roads, railways and water channels, are risk zones for spreading them. Tree-of-Heaven (Ailanthus altissima (Mill.) Swingle) is a rapidly expanding species, so it was introduced into the List of invasive alien species of Union concern (Regulation (EU) 1143/2014), being subject to restrictions and measures set out in the Regulation. In Romania, the species is common in warmer areas, on cliffs (such as those in the Danube Gorges), on the roadside, in the forest skirt, especially on degraded anthropic land; it is cultivated as ornamental and behaves well in various abiotic conditions. There is research on the distribution of species in Romania, habitat types and protected areas in which it is found, correlation with climate change, its impact on biodiversity, but our study pursued the enlargement of the Tree-of-Heaven in urban and peri-urban areas (southern Timisoara), trying to establish the possible "hot spots" of species spread, in which we could control its enlargement. For the mapping of the species, a five-stage measurement scale was proposed and used, including criteria relating to abundance, the presence of mature fructifying trees, shoots and seedlings. The data gathered from the field are cartographically illustrated and interpreted statistically. The study followed the validation of the proposed working method, its ability to illustrate the situation in the field, so as to constitute a fast, usable and non-specialised inventory and mapping protocol, i.e. a monitoring protocol of the expanding species over time for the proper management of concrete disposal and control actions applicable to other species of similar woody plants. The results can be used to informing and raise awareness of the urban and rural population so as to avoid the cultivation of the species for ornamental purposes.

Key words: invasive alien species, Ailanthus altissima, urban and peri-urban areas, Timișoara, measurement scale

INTRODUCTION

Ailanthus altissima (Tree-of-Heaven) is one of the intensely studied species, due to its biological and ecological characteristics, which are among the most invasive and adaptable plants facing Europe and North America, but also Australia, New Zealand and other regions of the world. The species is native to Asia, being brought to Europe around the year 1740 for ornamental purposes. Since then, it has spread to many areas of Europe (ENESCU *et al*., 2016), but many states have not yet completed a full inventory of the areas invaded or sensitive to the spread of this species. In Romania, the inventory and mapping of invasive and potentially invasive species is currently taking place through the *Adequate management of invasive species in Romania, according to EU Regulation 1143/2014 regarding the prevention and management of the introduction and spread of invasive alien species (POIM2014+ 120008) Project.*

A. altissima was and still is cultivated for its ornamental value, for its ability to grow in xeric biotopes, to fix degraded lands as well as for its resistance to pollution effects (STRATU *et al*., 2016). It is used as a natural pesticide, as a source for the production of paper and furniture, wood for fire and, last but not least, as a medicinal plant with multiple effects: anti-bacterial, anti-viral, anti-fungal, anti-proliferative, anti-protozoal, anti-inflammatory, antioxidant

(KOŽUHAROVA *et al*., 2014). On the other hand, the pollen of the species is considered as an emerging aeroallergen worldwide (MOUSAVI *et al*., 2019).

The species is successful in interspecific competition due to its ability to produce "one or more potent inhibitors of seed germination and seedling growth. Inhibitor activity is highest in bark, especially of roots, intermediate in leaflets, and low in wood. *Ailanthus* seeds also contain one or more inhibitors. (...) The strong herbicidal effects of allelochemical(s) from *Ailanthus* may have potential for development as natural-product herbicides" and "may contribute to the aggressiveness and persistence of *Ailanthus* in certain habitats" (HEISEY, 1990b). These biochemical characteristics allow the species to install in different habitat types, with considerable negative effects on biodiversity (BOSTAN *et al*., 2014). Detailed studies show the species as "an ecosystem transformer, which alters plant communities in open areas and forests" proving the transformative effect of the species on soil and litter invertebrate communities, i.e. "an overall impact of *A. altissima* invasion on the soil food web structure that could accelerate the mineralization of organic matter and potentially favour nitrophilous plant species in understory plant communities" (MOTARD *et al*., 2015).

Ailanthus altissima is considered a transformer for sandy grasslands and semi-natural forests in Hungary, where it has been monitored at population level since 1998 (TÖRÖK *et al*., 2003). The species is also present in Hungarian nature reserves.

Existing research worldwide describes aspects of morphology, ecology, distribution, habitat requirements, population biology, genetics, physiology, impacts, management and uses of this species, which has become invasive on all continents except Antarctica (KOWARIK & SÄUMEL, 2007). Although it prefers anthropic disturbed biotopes with altered vegetable carpet from warmer and sunny areas, the species extends and resists in very varied habitats, even in densely closed forests (KOWARIK, 1995), in meadows (SÎRBU *et al*., 2016), sand dunes (ANASTASIU & NEGREAN, 2006), saline soils (STRAT, 2013) and dumps (LAZAR & STERIAN, 2004). In some areas of southwestern Romania, Tree-of-Heaven quickly colonizes the rock and slopes with a southern exhibition, endangering sensitive natural reserves (IMBREA *et al*., 2008; IMBREA *et al*., 2014; NICULESCU *et al*., 2018). Its biochemical composition is involved in the tolerant response of the *Ailanthus altissima* to drought and salinity (FILIPPOU *et al*., 2014).

Among natural habitats, numerous are those that were considered as sensitive to the expansion of the *Ailanthus altissima* species, in European Alpine and Continental biogeographical regions, mostly riparian forests, oak dominated woodlands, beech forests (CAMPAGNARO *et al*., 2018; NICOLIN *et al*., 2014).

In Romania, the species has been inventoried in different areas of the country and in a wide variety of habitats (ANASTASIU & NEGREAN, 2005; ARSENE *et al*., 2015; NICOLIN *et al*., 2015; RĂDUȚOIU & STAN, 2013; SÎRBU & OPREA, 2010), assigning a new association to the plant communities dominated by Tree-of-Heaven (*Balloto nigrae - Ailanthetum altissime* – cf. SÂRBU & OPREA, 2010). The species is also commonly encountered in protected areas (GRIGORESCU *et al.*, 2016; DUMITRAȘCU *et al*., 2014; DOROFTEI *et al.*, 2005; GOIA *et al*., 2014).

The expansion of the species is increasingly observed in forest habitats, including in Romania, in clearings or areas on which the woody vegetation has been eliminated. *A. altissima* is a species with rapid germination and growth, similar to other invasive species. Frequently, the spatial association between Tree-of-Heaven (*Ailanthus altissima*) and black locust (*Robinia pseudoacacia*) (CALL & NILSEN, 2003) is observed. Even if other invasive species are installed around them, both species colonize fresh clear-cuts, establish, and remain; coppice management, which consists of repeated clear cuttings, favours the spread of both invasive species (RADTKE *et al*., 2013).

In addition to rapid growth, *A. altissima* is less demanding in humidity and soil trophicity, compared to many woody species. "Generative (seed-borne) and vegetative (clonal ramet) offspring of *A. altissima* are able to grow in light conditions well below the requirements of shade-intolerant tree species" as Tree-of-Heaven was considered (KNÜSEL *et al*., 2017). By clonal ramets, the species is able to colonise even undisturbed forests. "The possible ecological benefits of establishing a ramet bank in a resource-poor habitat are considered in terms of space occupation of a pioneer species" (KOWARIK, 1995). "*A. altissima* is less successful in heavily canopied forests (high forests), but coppicing, cultivation, browsing or any natural disturbance (e.g. frost, fire, stem or root damage) will stimulate its expansion and colonisation" (FEHÉR & BORLEA, 2018). "Consequently, the colonisation frontier of *A. altissima* should be intensively monitored in both forest openings but also in closed canopy forests in the vicinity of seed-bearing *A. altissima*" (KNÜSEL *et al*., 2017).

Ailanthus altissima is considered dioecious (KOWARIK & SÄUMEL, 2007); male plants are rarely cultivated because of the unpleasant smell of flowers. Female plants produce impressive amounts of fruit. "*A. altissima* is able to disperse long distances into fields and into mature forests, and can reach canopy gaps and other suitable habitats at least 100 m from the forest edge; it is an effective disperser and can spread rapidly in fragmented landscapes where edges and other high light environments occur" (LANDENBERGER *et al*., 2007).

Frequently, like other invasive plants, the species colonizes the edges of the rivers. Its fruits (samaras) are anemochore, "turbulent winds appear to be necessary for seed release" (LANDENBERGER *et al*., 2007). In aqueous environments, floating samaras remain buoyant, with similar germination rates, so the „secondary dispersal in water may transport seeds long distances to suitable habitats" (KAPROTH & MCGRAW, 2008). SÄUMEL & KOWARIK (2010) proved that "hydrochory is an effective dispersal agent in wind-dispersed tree species, extending wind-related transport distances by several times. In this way, rivers are expected to link urban propagule sources with natural habitats downstream. Urban habitats may function as starting points for invasions along urban-rural gradients. Planting native tree species along river corridors would help prevent invasion risks and contribute to implementing principles of ecological design in urban greenways".

Global climate change may influence the spreading of invasive species (DRAGOTĂ *et al*., 2011; DOROFTEI & ANASTASIU, 2014).

The expansion of the species can be hardly controlled, involving high costs in conditions where it is necessary to repeat the treatments over several years. CONSTÁN-NAVA *et al*. (2010) show that "only the cut stump with glyphosate application treatment was able to reduce the long-term growth and spread of *A. altissima*". Other types of herbicide were also tested; "herbicide injection with imazapyr not only produced 100% mortality in the targeted *A. altissima*, but it also translocated and produced mortality in 17.5% of neighbouring trees within 3 m. Herbicide injection with glyphosate killed small and medium-size trees, but it was not effective in killing large trees" (LEWIS, 2007). Biological control of *A. altissima* was also studied, a fungus, *Verticillium albo-atrum*, being considered as a possible biocontrol agent for invasive *Ailanthus* (SCHALL & DAVIS, 2009).

MATERIAL AND METHODS

This study was carried out during a season of vegetation (2019) and pursued the establishment of *Ailanthus altissima* in a given area and in the same year (as a basis for future monitoring), especially as similar research is few, based on the premise that the spread rate of the species in different types of ecosystems is not sufficiently known. MCAVOY *et al*. (2012) achieved a road survey in Virginia, trying to establish the mean density of Tree-of-Heaven along different types of roads and physiographic regions. They proved that “populations bordering roadsides could serve as seed sources for further local and landscape spread”. Even though Tree-of-Heaven is well known as an invasive plant and some cities have eliminated the species, there are numerous urban and peri-urban areas in which *A. altissima* is frequent and even dominant. LANDENBERGER *et al*. (2009) showed, for this species, spatial patterns of abundance across a typical urban-to-rural land use gradient.

In this case study, it was established as a study area the southern part of Timisoara (45°47′58″N 21°17′38″E), along the Bega Canal and all districts south of it (Figures 1 and 2).

Fig. 1: *Ailanthus altissima* along the Bega canal

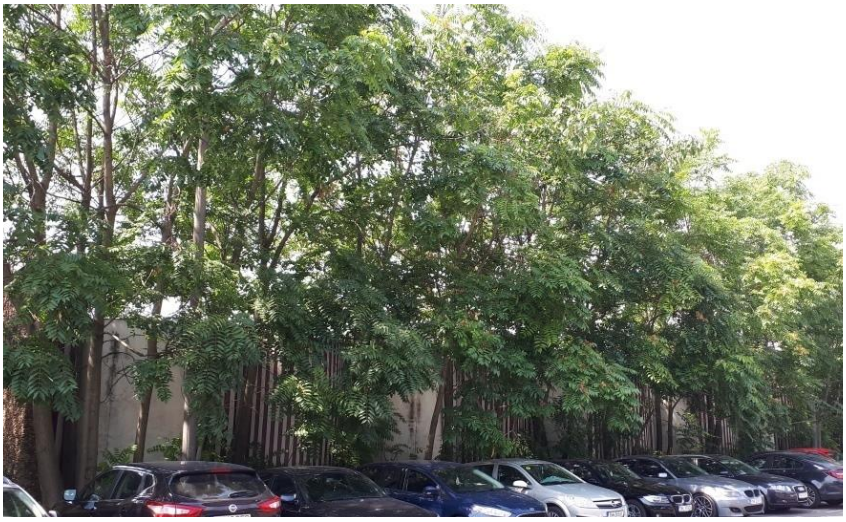


Fig. 2: *Ailanthus altissima* planted as ornamental in Timisoara

Timişoara is located in western Romania, in a plain area with moderate temperate continental climate and sub-Mediterranean influences. The geographical position, soil, drought and increased warming in recent years (MIRCOV *et al.*, 2017) favours many invasive thermophilic and xerophilous species, which are found on impressive surfaces, e.g. *Ambrosia artemisiifolia*, creating economic and human health problems. For this area, previous studies on anthropophilic species are few (COSTE & ARSENE, 2003), focussed, in recent years, on *Ambrosia artemisiifolia* (IANOVICI, 2011; IANOVICI *et al*., 2013; SĂRĂȚEANU *et al*., 2010).

The first mention of the species *A. altissima* in Timisoara, in the modern period, is made by BUJOREAN in 1942. In 1884, the species was identified in the Banat in the Deliblat area (Serbia nowadays), at about 120 km from Timisoara (BORBÁS, 1884). In Hungary, the species has been present since the early years of the 19th century (KORDA, 2018), including the villages of Banat, a province that was part of the Habsburg Empire. Some current invasive species have been cultivated, already decades ago, along the streets of Timisoara (e.g. *Fraxinus pennsylvanica, Acer negundo, Quercus rubra*) and it is likely that Tree-of-Heaven was planted in the same way, because we identified several locations where tree of the same age alignments appear. Most commonly, it was planted sporadically, by the inhabitants, attracted by the appearance and strength of the species. The study area comprises important pathways for the spread of invasive species and sensitive, disturbed anthropic surfaces (Bega canal, railways, roads, abandoned land, industrial areas and land under construction).

For the inventory and mapping of the species, cartographic images (Google Earth), GPS mobile app coordinates, mobile phones for photographs, field sheets and a five-step measurement scale were used, with the intent to establish a simple working method also useable by non-specialists. Information on the date and location were noted in the field sheet: the total number of individuals, of mature trees, of female trees with fruit, of shoots and seedlings, height and phenophase, habitat type, sample surface, GPS coordinates and grades in assessment scale. For the mapping of the species, a five-stage measurement scale was proposed and used, including criteria relating to abundance, the presence of mature fructifying trees, shoots and seedlings (Figure 3):

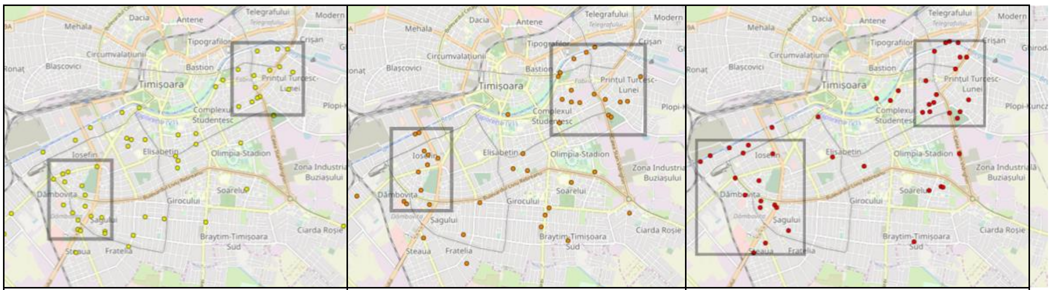
I	II	III	IV	V
Isolated individuals, few (~ 1-5), usually young (shoots/saplings), without fruition	Small-sized individuals (~ 5-10 shoots/saplings), usually young, without fruition, or isolated trees, at the beginning of fruition	Few individuals, minimum a mature tree, with fruition, possible with shoots and saplings (± cleaned) *or* Conspicuous, compact, with shoots and saplings (from shooting after the removal of mature trees)	Groups/clumps with many shoots and saplings, usually with more mature trees, with fruition, *or* Many individuals, of all ages, distributed relatively evenly on the surface unit	The species is dominant, it forms compact groups, with mature and young trees, shoots and saplings

Fig. 3: The five-stage measurement scale for *Ailanthus altissima* degree of invasivity.

Different distribution maps, used for interpreting the data, were made in QGIS3, separated for the 5 classes/colours.

RESULTS AND DISCUSSION

In the 11 searched districts, 237 areas were identified (usually between 50-100 m^2 in the more central districts, and up to 500 m^2 on the outskirts of the city) in which the species *A. altissima* is found. The locations that have been included, according to the five-stage measurement scale, in category I (blue) are 38 and, in category II (green), 24. In these locations, were mostly identified young individuals, often isolated, or small clumps, without fruition. These areas are important to pursue the spread of the species, especially because many of these young individuals come from the germination of seeds from mature female trees, even if they are not found in their immediate vicinity. Monitoring these areas over time can lead to more precise estimates of the source of the disseminated fruit and the distance travelled by them from the mother tree. Class III (yellow) comprises the most points (77) and they correlate as distribution with classes IV – Orange (48) and V – Red (50), the last two being areas where mature trees with fruition are present, frequently in large numbers (Figure 4):



Class III	Class IV	Class V

Fig. 4: Distribution of points of 3 classes, marking areas where *A. altissima* shows high density

In 175 points were identified mature fruit trees, which are sources of infestation of the surroundings. In 18 points, the number of individuals (mature and young) was between 50 and 100, in 5 points, their number passed 100 and, in one case, passed 200 (the mature and young trees were counted from the seeds; where the shoots came from the same individual, they were not counted further; in some situations, it was not possible to count accurately because of the density of the shoots). The maximum height of the trees does not usually go above 15 m. Older male trees are fewer, but they exist in all districts.

The most common habitats for *A. altissima* are the edges of the roads, the land in front of the houses and around the housing blocks, junctions, cemeteries, private gardens, abandoned land, industrial areas and old factories, parking lots, the banks of the Bega canal, peripheral areas of the city. In very few situations, the mature trees were pruned in such a way that they did not produce fruit or shoots were cleaned. In some districts, the surface with soil available for germination is reduced, so the density of the species is much smaller.

Even though some inhabitants know the popular name of the species, sometimes by confusion with *Rhus typhina*, over 9/10 of those we have discussed with do not know that the species is invasive and those who responded in the affirmative rely on their own observations. In Timisoara, population awareness actions took place for *Ambrosia artemisiifolia*, at the time of alarming growth in the number of allergic people. Informing the population about *A. altissima*, presenting measures to prevent and combat the spread of the species, is necessary. Local authorities must implement *Regulation 1143/2014 on Invasive Alien Species*. According to the classification proposed by BLACKBURN *et al*. (2011), *A. altissima* is “a fully invasive species, with individuals dispersing, surviving and reproducing at multiple sites across a greater or lesser spectrum of habitats and extent of occurrence (Category E)”. Methods of prevention, early detection, rapid eradication, followed by an integrated control methodology and strategy within a dedicated management plan are gathered in BRUNDU (2017). Because the frequency of occurrence of the species is high (with few exceptions, less than 2 km from one location to another), the entire area studied should be monitored (Figure 5). This can be done through volunteers (NIMIS *et al*., 2019) and by making applications available (e.g. DRIENOVSKY *et al*., 2017) reporting the presence and abundance of the species, respectively reporting of mature trees with fruit or clusters of larger sizes. In public areas, the shaping of crowns of mature trees could be a solution for controlling the dissemination of the species in a first phase. Monitoring corridors for invasive plant species (water courses, railways, roads) and hot spots, as sources of infestation, at the boundary between urban and peri-urban areas, requires increased attention (SÄUMEL & KOWARIK, 2010). The presence of the species on some large, fenced surfaces can be identified with drones and other methods of interpreting aerial images (HERBEI *et al*., 2015a; HERBEI *et al*., 2015b).

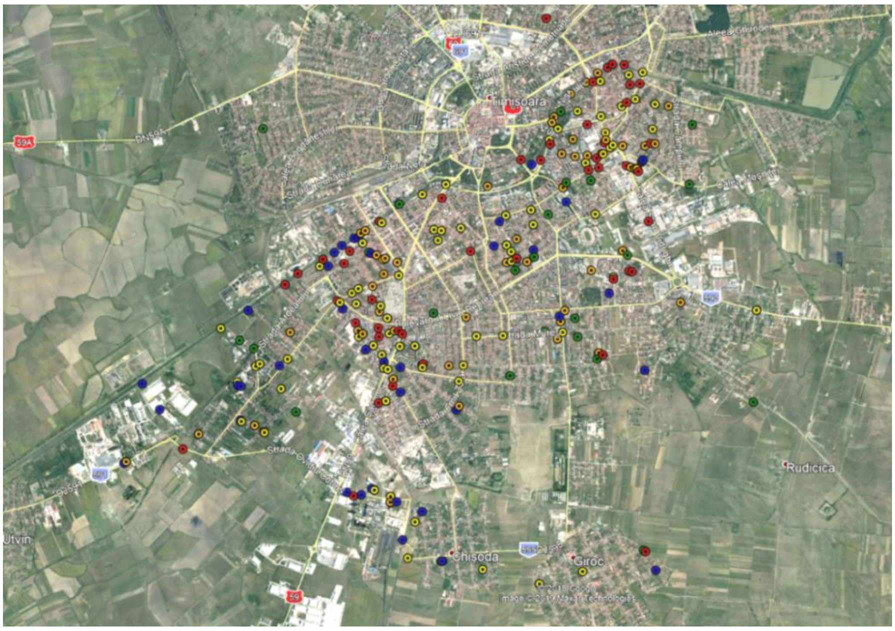


Fig. 5: General map of *A. altissima* distribution in the area studied, with the 5 classes of abundance (according to the scale in Fig. 3)

CONCLUSIONS

In the southern half of Timisoara, *Ailanthus altissima* frequency is high and some hot spots are found, with fruitful spontaneous mature trees and large densities of seedlings and shoots. In the 11 searched districts, 237 areas were identified in which species *A. altissima* is found. Of these, in 175 locations, there is at least one mature tree with fruition, which represents sources of infestation of the surroundings. In 18 points, the number of individuals (mature and young) was between 50 and 100, in 5 points their number was above 100 and, in one case, above 200.

The study method proposed by us can be used in similar situations or for the monitoring of the species, even with the help of citizens, on the basis of minimal training; therefore, it constitutes a fast, usable and non-specialised inventory and mapping protocol. Most inhabitants do not know that this species is invasive, so information actions are necessary. Because the frequency of occurrence of the species is high (with few exceptions, less than 2 km from one location to another), the entire area of the city must be monitored. Implementation of integrated control methodology and strategy could reduce the risk of infestation of other areas. Due to the high costs that would be necessary for the eradication of the species, the shaping of the crowns of mature trees could be a solution for controlling the dissemination of the species in a first phase. The results make an important contribution by signalling the current degree of infestation and they can be used to inform and raise awareness of the urban and rural population so as to avoid the cultivation of the species for ornamental purposes.

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