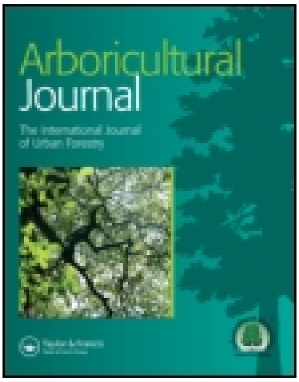

Arboricultural Journal: The International Journal of Urban Forestry
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tarb20

Ailanthus altissima (tree of heaven): Spread and harmfulness in a case-study urban area

Francesca Casella[a] & Maurizio Vurro[a]
[a] Institute of Sciences of Food Production, National Research Council, Bari, Italy
Published online: 07 Nov 2013.

Arboricultural Journal: The International Journal of Urban Forestry, 2013
Vol. 35, No. 3, 172–181, http://dx.doi.org/10.1080/03071375.2013.852352

Taylor & Francis
Taylor & Francis Group

Ailanthus altissima (tree of heaven): Spread and harmfulness in a case-study urban area

Francesca Casella and Maurizio Vurro*

Institute of Sciences of Food Production, National Research Council, Bari, Italy

Among the woody and shrubby weeds colonising non-crop areas in the Apulia Region (South Italy), *Ailanthus altissima* (tree of heaven), an exotic invasive species, is one of the worst, because of its fast growth and root-sucker production. It reaches the heart of protected areas and spreads everywhere in urban and peri-urban areas creating dense stands. As there are no official monitoring protocols for weed mapping, a method based on real-time global positioning system (GPS) on satellite maps was set up. Due to this method, the distribution, spread, size, density and harmfulness of *A. altissima* were assessed across the wide urban area of Bari (South Italy) by mapping all the individual plants and areas/stands of plants. In Bari, along a total of 76 km of roads mapped, 170 very large (diameter > 18 cm), 231 large (diameter 8–18 cm), 130 medium (diameter 3–8 cm), 53 small (diameter < 3 cm) single plants, and 70 high, 63 medium and 13 low density areas were detected. This indicated that *A. altissima* (tree of heaven) was very widespread in the study area. Moreover, 35 types of damage or potential risks were recorded covering functional, environmental, health and safety and aesthetic aspects and then classified according to frequency and location. The real-time GPS method proved to be very useful for providing a speedy and accurate record of the data.

Keywords: invasive species; weed mapping; woody weeds; *Ailanthus altissima*; tree of heaven

Introduction

Preliminary studies regarding the presence, spread and harmfulness of woody and shrubby weeds in urban and non-crop areas of the Apulia region (South Italy) led to the identification of *Ailanthus altissima* (Miller) Swingle as the most widespread, invasive and damaging species of those surveyed. The other species surveyed were *Robinia pseudoacacia*, black locust; *Ficus carica*, fig tree; *Capparis spinosa,* caper; *Hedera helix*, ivy; *Rubus ulmifolius,* blackberry. *A. altissima* (family: Simaroubaceae) was intentionally introduced into Europe from Asia in the eighteenth century for the breeding of *Phylosamia cynthia*, a moth used to replace the silkworm (Celesti-Grapow, Pretto, Carli, & Blasi, 2010). Due to its rapid growth, it was subsequently used also for ornamental purposes and the consolidation of banks and escarpments.

According to Richardson et al. (2000), it is considered "invasive" because it quickly spreads spontaneously without direct intervention by humans. It produces reproductive offspring in very large numbers and at considerable distances from the parent plant. It thus has the potential to spread over a considerable area.

The species is pervasive and able to adapt to any type of soil and water regime. It tolerates prolonged drought, saline and acid soils, nutrient deficiency and air pollution (Kowarik & Saumel, 2007 and references cited therein).

*Corresponding author. Email: maurizio.vurro@ispa.cnr.it

The species reproduces by seed and asexually. The dried fruit (the samara) has membranous wings and is transported over long distances by wind and water. One plant can produce up to 300,000 samaras per year (Sheppard, Shaw, & Sforza, 2006). *A. altissima* spreads also by an extended and vigorous root system, generating numerous suckers and progeny plants. The invasive capacity of this species is due to these multiple propagation mechanisms. The samaras enable rapid colonisation of new areas, in which plants can then begin to spread further by vegetative means, causing the rapid consolidation of the species (Sattin et al., 1996). Young seedlings grow very quickly forming highly dense stands out-competing other species and reducing their growth. In just 2 years, it can form a tree several feet in height and has a considerable vigour (Feret, 1985).

Invasive alien species are considered the second-most significant cause of global biodiversity loss after direct habitat destruction and have adverse economic, social and environmental impacts (Chornesky & Randall, 2003), from the local level upwards. In addition to the severe ecological effects on natural areas, *A. altissima* causes serious economic consequences in urban and non-crop areas due to the many kinds of direct and indirect damage it can cause. It is the most common species, together with *R. pseudoacacia*, along the railways where it damages embankments and power lines and has proved to be harmful on ancient buildings and among archaeological remains (Celesti-Grapow & Blasi, 2004).

In Italy, *A. altissima* (tree of heaven) is now firmly established in all the regions and its spread is alarming in many urban areas, parks and protected areas (Celesti-Grapow et al., 2010). Control is difficult because of its great reproductive and propagation capacity. In particular, this is because of the production of numerous basal and radical shoots, and its highly developed and hard to eradicate root system.

Detailed data-traced studies on the quantification of *A. altissima* and an evaluation of the negative impacts in urban areas are rare. This situation is despite *A. altissima* conspicuously and prolifically colonising a broad array of habitats (Kowarik & Saumel, 2007).

The target identification and detection of spread and degree of harmfulness is basic for a management programme of an invasive species. For this reason, it is essential to develop a monitoring system supported by mapping and collection of an inventory of data. Such a system is also needed to record the position of the harmful weeds, to identify the spread early on, to assess changes and trends over time, to plan and optimise treatments and to measure their short- or long-term effects, and to assess whether the management and control programmes employed are achieving their goals. In natural protected areas, monitoring of invasive species is critical to quantifying the impact of such species on the original ecosystem.

Considering the highly invasive character of the species and the absence of official methods for monitoring, the aim of this study was to develop a mapping method, effective on a large scale, suitable for the overall quantification, assessment of spread, distribution and harmfulness of *A. altissima* in the study area.

Methods

Mapping tools

The instruments used for mapping were a portable computer powered by the car's battery and a wireless Bluetooth GPS antenna (Sycell model). The laptop was equipped with a Bluetooth port and two sets of software: Google Earth Pro to view satellite online maps and BluSoleil, a communication interface connecting the GPS via Bluetooth to Google

Earth Pro. This system enabled the car's movements to be geo-referenced in real time by displaying the routes followed on the maps.

By means of Google Earth, areas and specific points of interest were reported and saved on satellite map routes. Contextually different colours, sizes, titles and comments were assigned to the points. The latitude, longitude and altitude of each point were also recorded.

Mapping method

A. altissima was mapped as follows:

- All the routes were indicated on the maps with a continuous line.
- Each plant or nucleus of a few plants found was plotted with a green "pin" in the corresponding position.
- Four different gradations of green from light to dark were used to indicate four diameter classes of plants: <3 cm, 3–8 cm, 8–18 cm and >18 cm, respectively.
- If the infestation covered a wide area, it was plotted as a polygon.
- To indicate plant density (from a visual estimation), the polygons were allocated one of three categories represented by three different colours: yellow, for areas with sparse trees (corresponding to not more than 1 plant/m^2); orange, for dense areas (1–5 stems-plants/m^2) or an alternation of very dense and sparse areas; and red, for very dense areas (more than 5 stems/m^2).

Other woody weed species were plotted with a red pin. Route lengths were calculated in kilometres, and plants and infested areas were counted and classified according to size and plant density, respectively.

The geographic coordinates of all the points and the electronic KMZ maps were acquired and inventoried.

Mapped areas

A. altissima plants were monitored in a wide urban area of the Apulia Region: the city of Bari. Numerous surveys were conducted in autumn by driving along the streets of the urban and peri-urban areas of Bari city. The routes followed touched many different representative types of urban environments: central districts and peripheral neighbourhoods, the old town, public and private green areas and gardens, high-speed roads, wide and narrow streets, tree-lined avenues, uncultivated areas, stations, parking places, industrial areas, paved and dirt roads, and residential areas.

Harmfulness assessment

The types of damage caused by *A. altissima* were collected, recorded and classified according to type (functional, environmental, health and safety, and aesthetics), site (urban, industrial, street, railway and airport) and frequency (very frequent, found more than 30 times; frequent, found 10–30 times; infrequent, found 6–10 times; sporadic, found <5 times).

Results

Surveyed areas

The sites of investigation were condensed into 10 major routes (Table 1) which included all the districts of the city.

Table 1. Plants and infested areas censused in the 10 urban routes in and around Bari city.

Route	Type	Length (km)	Infested areas[a] (no.)			Plants[b] (no.)			
			A	B	C	I	II	III	IV
1	Urban	5.419	2	18	20	19	18	23	5
2	Urban	7.361	2	5	4	12	13	26	7
3	Urban	1.516	1	1	3	0	1	5	3
4	Urban	8.946	4	12	9	10	19	46	16
5	Urban	4.130	0	5	8	5	15	22	10
6	Urban	4.956	3	4	4	1	12	8	9
7	Urban	4.697	0	4	3	1	10	55	84
8	Urban	10.100	1	7	13	2	23	31	30
9	Urban	12.454	0	4	4	2	4	10	5
10	Peri-urban	16.301	0	3	2	1	15	5	1
Total	–	75.882	13	63	70	53	130	231	170

Notes: [a] Plant density: A, sparse trees; B, dense or dense/sparse trees; C, very dense trees.
[b] Trunk diameter (cm): I, < 3; II, 3–8; III, 8–18; IV, > 18.

The urban area of Bari was inspected along nearly 76 km of roads (Table 2 and Figure 1). Along this route, 170 very large, 231 large, 130 medium and 53 small sized plants were found. Furthermore, 70 very dense, 63 medium density and 13 scattered areas of plants were recognised. Infested areas contained scalar-sized plants, predominantly medium and small.

Harmfulness

Thirty-five different types of damage caused by *A. altissima* were observed in the different environments and on different types of structures (Table 2). These were visually determined, classified and grouped. According to type, 20 functional, 3 environmental, 7 health and safety, and 5 aesthetic types of damage were recorded. Over the location dimension, the number of different types of damage is as follows: 28 in the urban districts, 7 in the industrial areas, 12 on the roads, 8 on the railways and 6 in the airport. According to the frequency of occurrence, 10 very frequent, 14 frequent, 8 infrequent and 3 sporadic sets of damage were estimated.

Discussion

The mapping system used proved to be suitable to map *A. altissima* in the surveyed urban and peri-urban areas. The method allowed for the easy acquisition of all the data on the location, distribution and spread of the species. It also allowed the data collected to be quantified, the calculation of the route length, and a count of plants and the areas of plants surveyed. The method can also be used on a larger scale, in any type of environment (including natural areas), for any species (weed or not) and also for several species simultaneously. It is also possible to easily display and record other characteristics, such as plant size or density, and notes or comments on the map.

Compared with other commercial systems, the system used here enables work to be done directly on the PC which has many advantages such as having a large and high-resolution monitor, surfing faster in high-resolution maps, getting a wide overall view that is useful to plan routes in progress, the ability to easily match any referenced data to other

Table 2. Classification, site and frequency of the damage caused by *A. altissima* plants, recorded in non-crop areas.

Type of damage	Site[a]	Frequency[b]
Functional		
Infestation of shoulder, median strip and parking space	S	V
Difficulty in visualisation of road signs	S	F
Obstructions of cycle lane	U/S	F
Obstacle to cleaning operations and lower efficiency of cleaning machines	U	V
Physical and chemical damage to architectonic, historic, artistic and archaeological manufactures	U	V
Economic damage and increase of maintenance costs	U/S/I/R/A	V
Damage to railway tracks and ballast	R	F
Street lighting reduction	U	F
Accumulation of waste and garbage	U/I	V
Damage to wearing course	S	F
Trouble in inspection and maintenance of civil and industrial infrastructures, railway and airport areas	U/I/R/A	F
Damage to pipes	U	N
Video surveillance cameras concealment	U	N
Damage to parking places	U/A	F
Decrease in fast water outflows	S/U	N
Canals, manhole and water drainage channel obstruction	S/U	N
Walkways obstruction	U/A	F
Damage to power lines	U/R	S
Damage to fence and railings	U/I	N
Potential obstacle to railway switch	R	S
Environmental		
Loss of biodiversity	U	F
Habitats alteration	U	F
Habitat degradation	U	F
Safety and health		
Hazards due to reduction of drivers view	S	V
Risk of fire along the streets	S	V
Damage to pavements and footpath	U	F
Worsening of hygienic conditions	U/S/I	F
Skin irritation caused by bark, roots and leaves contact	U	N
Branches break hazard	U/S	N
Fire on civil infrastructures	U/I	S
Aesthetic		
Overall aesthetic damage to the urban area	U/R/A	V
Degradation and neglect	U/I/S/R/A	V
Damage of public and private green areas	U	V
Vegetation anthropisation – landscape monotony	U/S/P/R	V
Aesthetic damage of archaeological sites	U/P	N

Notes: [a] Site of damage recording: A, airport; I, industrial area; R, railway; S, street; U, urban area; P, peri-urban. [b] Frequency: V, very frequent (more than 30 times); F, frequent (10–30 times); N, infrequent (6–10 times); S, sporadic (<5 times).

features and information useful for the ongoing investigation, and the ability to enter all data directly into your PC. Due to the availability of the satellite view, it is possible to precisely map plants or areas of plants from a distance that are not directly accessible, but which are clearly seen on the maps and from the street. For those areas visible only along their frontages, it is possible to identify the actual boundaries and extensions. Google Earth

Figure 1. Global view of the satellite map of *A. altissima* infestation in Bari city realised by the Google Earth software. The followed paths are given, too. See Methods section for mapping details.

also gives the possibility of calculating the length of the routes followed. The maps are automatically updated periodically thus highlighting all the changes which have occurred. There is also a "time slider" feature through which it is possible to get satellite images from the past and so acquire information about how infestations have evolved prior to the survey. The maps provide photographic images submitted by other users. The "street view" function allows sites to be viewed in 3D (among those available). This feature is very useful in the case of plants distant from the road and not readily recognisable because they are devoid of leaves: viewing 3D images related to a season in which the plants were in leaf helped in identification.

The system allows the geographic coordinates of the plants and areas of plants to be recorded. This information can then be used to evaluate the population's evolution over time and to manage and assess interventions and control/eradication programmes.

Plants and infested areas surveyed are distributed patchily, creating a continuous network throughout the urban area. Infested areas almost always include scalar-sized plants among which smaller ones arise annually from seeds or roots of larger plants. On the other hand, in other patches, plants may appear all the same size because of them being cut back totally and then re-growing.

The plant proved to be widely spread across habitats. It was observed in arid places, although preferring wet areas close to water sources. As well as in different microclimates, for example, the species was found both in sunny and in shaded areas.

A. altissima plants were found in many different types of urban environments: public and private, open areas and confined spaces. In particular, they were present among ruins, in open places, railways and roadsides. It was also observed in the most challenging habitats such as small sidewalk cracks, wall fissures, rocks and vertical walls, manholes, grids and shaded soil covered with pine needles.

The species proliferates in flower beds, gardens, historic squares, tree-lined avenues and green spaces. It grows mainly in residential districts and suburbs characterised by gardens and wide roads, and in vacant or abandoned building areas (Figure 2). It appears absent in the city centre and the old town, probably because there are no visible private gardens or because human footfall and traffic are continuous. In such districts, seeds sometimes accidentally reach the inner courtyards enclosed by the buildings giving rise to plants that over time reach considerable size and become extremely difficult to remove. In the industrial district, the species was hardly present, only occurring along abandoned streets, which was much less than expected.

Despite the results showing that some *A. altissima* trees are found on average every 104 m along the urban route, *A. altissima* is sporadically and poorly managed in the urban areas. The success and vigour of the species is particularly evident here. On roadsides and in many private gardens or courtyards, spontaneously occurring plants are not controlled, which makes later management difficult.

In the case-study city, as in many others, there are tree-lined roads of very old ornamental *A. altissima*, which is likely to be the source of the infestation that still exists and is increasing.

Some infestation affects the historical, artistic and cultural heritage of the city, for example, within archaeological areas, churches and ancient walls (Figure 3). These infestations are particularly hazardous for several reasons: the potential harmfulness to sites of great artistic and historical value; the serious economic and environmental problems consequent upon the use of herbicides; and particularly difficult and costly eradication programmes. Plants growing on ancient buildings and archaeological remains pose a severe threat to their conservation. Moreover, such sites play an important role as a source of income for the tourist industry.

A. altissima grows in railway stations, sidings and along lines, around the harbour and the walkways to the airport. The species was found on the ring road and on all the main

Figure 2. Infestation of tree of heaven in the urban area of Bari.

Figure 3. Young plants of *A. altissima* grown on the ancient walls of the old town of Bari.

roads linking the city with neighbouring municipalities, with plants growing on asphalt and ramps. At a regional level, there are several stretches of road where traffic signs are not visible because of vegetation and where plants grow on the hard-shoulder and also on the median strip.

A. altissima can seriously harm the balance of all urban green areas due to its invasiveness, abundant reproduction (already apparent from its early life stages), the absence of natural enemies and the presence of favourable environments which can be colonised.

Moreover, the actual infestation is probably even worse than reported. Indeed, the number of small plants could be underestimated as the surveys were conducted by car and it is probable that, using this method, plants behind obstacles would not have detected.

Damage assessment highlights the ability of the species to negatively impact on all types of urban and non-crop environments and human activities, in many different ways. The seriousness of the damage depends on the site and context where plants grow. In the urban area, for example, in addition to the damage to buildings and systems caused by mechanical action, the lack of management of the species has a strong negative aesthetic impact and generates environmental degradation with a worsening of hygienic conditions and hampering cleaning operations. The resulting increased maintenance costs are considerable. Moreover, the infestation by invasive alien species quickly passes from urban to natural areas through natural dispersal or along corridors such as streets. The introduction of invasive alien species is the second leading cause of loss of biodiversity, after the loss of natural habitats (Chornesky & Randall, 2003). Therefore, all natural habitats can be considered seriously threatened by the presence of close infested cities.

Woody invasive alien species such as *A. altissima* are a serious threat not only for urban areas but also for nature conservation. A mapping method which is suitable to easily map the species on a large scale was therefore developed. Through mapping operations, the diffusion, distribution and harmfulness of the species *A. altissima* were assessed in the case-study urban area.

Different levels of invasion were observed: from the sporadic presence of single individuals, to the full colonisation of ruderal little disturbed to central highly disturbed environments. Based on the results obtained in the study area, a targeted strategy of invasive weed monitoring and control is necessary for containment and eradication. Early detection is desirable both to avoid irreparable harm and to reduce management and maintenance costs.

Acknowledgements

This study was carried out in a research programme on the management of woody weeds financed by Apulia Region Governorate.

Notes on contributors

Francesca Casella received her Ph.D. in Mediterranean Agronomy at the University of Bari, studying the possible use of mycoherbicides for controlling serious weeds in Mediterranean agriculture. She did her bachelor thesis on the possible use of toxins produced by fungal pathogens in grass weed management. She was a coordinator of a research project on the management of woody weeds financed by Apulia Region Governorate.

Maurizio Vurro is a senior researcher at the Institute of Sciences of Food Production, National Research Council in Bari, Italy. The main fields of scientific interest and expertise include: the use of plant pathogens and of natural bioactive metabolites in the biological control of weeds; the biological characterisation of fungal toxins and of their role in the host-pathogen interactions; and parasitic and invasive weed management. He has recently led the European project "Enhancement and exploitation of soil-biocontrol agents for bio-constraint management in crops" and is the coordinator of the Working Group "Parasitic Weeds" within the European Weed Research Society. Currently he is a coordinator of a project for the biological control of weeds in archaeological sites. He is the author of more than 80 articles in scientific journals and book chapters.

References

Celesti-Grapow, L., & Blasi, C. (2004). The role of alien and native weeds in the deterioration of archaeological remains in Italy. *Weed Technology*, *18*, 1508–1513.

Celesti-Grapow, L., Pretto, F., Carli, E., & Blasi, C. (2010). *Flora vascolare alloctona e invasiva delle regioni d'Italia* [Allochthonous and invasive vascular flora of the regions of Italy]. Casa Editrice Universitaria La Sapienza, Rome, Italy.

Chornesky, E., & Randall, J. (2003). The threat of invasive alien species to biological diversity: Setting a future course. *Annals of the Missouri Botanical Garden*, *90*, 67–76.

Feret, P. (1985). *Ailanthus*: Variation, cultivation, and frustration. *Journal of Arboriculture*, *11*, 361–368.

Kowarik, I., & Saumel, I. (2007). Biological flora of Central Europe: *Ailanthus altissima* (Mill.) Swingle. *Perspectives in Plant Ecology, Evolution and Systematics*, *8*, 207–237.

Richardson, D. M., Pysek, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: Concepts and definitions. *Diversity and Distributions*, *6*, 93–107.

Sattin, M., Zuin, M., Bacchi, M., Ferrero, A., Montemurro, P., Ticchiati, V., … Viggiani, P. (1996). *Caratteristiche biologiche ed eco-fisiologiche della fora infestante urbana* [Biologic and eco-physiologic characteristics of urban weeds]. *Proceedings 1996 S.I.L.M "Il diserbo delle aree extra agricole"* [Weed management in non-crop areas] (pp. 1–52). Padova, Italy: Guerra guru srl.

Sheppard, A., Shaw, R., & Sforza, R. (2006). Top 20 environmental weeds for classical biological control in Europe: A review of opportunities, regulations and other barriers to adoption. *Weed Research*, *46*, 93–117.