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GUIDING PRINCIPLES FOR SUSTAINABLE MANAGEMENT OF INVASIVE WOODY SPECIES IN PROTECTED AREAS

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All photos in this booklet are by Francesca Casella

Cover photo: Murgian grassland with *Stipa austroitalica* infested by *Ailanthus altissima* by Francesca Casella

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PREFACE

This informative brochure aims at informing and sensitising readers on the issue of invasive alien species and on the best practices to be implemented for their sustainable control.

After an introduction devoted to define the functions of natural areas, we briefly describe the phenomenon of biological invasions of alien plant species, their negative impact in natural areas, and some guidelines on possible ways of managing the problem. After mentioning the most widespread species in our territories, with particular reference to woody species and to tree of heaven (*Ailanthus altissima*), one of the most threatening and harmful at national and local level, guiding principles regarding the possible control techniques are provided, which can at the same time be effective and suitable for the use in natural areas.

Natural protected areas are well-defined and legally-recognized geographical areas, managed by official institutions (National, Regional, local bodies), with the aim of achieving the long-term conservation and promotion of nature with associated ecosystem services and cultural values. They are regarded as one of the most important approaches for conserving biodiversity globally. The physical, geological, geomorphological and biological formations, or groups of them, which have significant naturalistic and environmental value, constitute the natural heritage (Figure 1).

Figure 1. Pulo di Altamura, Alta Murgia National Park (South Italy)

The special protection and management regime to which protected natural areas are subjected has the following purposes:

a) to conserve animal or plant species, plant or forest associations, geological peculiarities, paleontological formations, biological communities, biotopes, scenic and panoramic values, natural processes, hydraulic and hydrogeological equilibria, ecological balances;
b) to apply management or environmental restoration methods suitable for achieving integration between man and natural environment, also by safeguarding anthropological, archaeological, historical and architectural values and agricultural, forestry, pastoral and traditional activities;
c) to promote educational and training activities, scientific research, even interdisciplinary, as well as permissible recreational activities;
d) to defend and restore hydraulic and hydrogeological equilibria.

In Europe, the term 'protected area' covers a wide variety of designations, characterized by different management regimes, from highly protected sites with limited access to visitors, to parks with a high number of visitors, and large areas with rather intense human presence, including dwellings and important economic activities. In some European protected areas, such intense human presence is reflected by the large extension of agro-ecosystems.

Currently the system of protected natural areas is classified as follows:

- National Parks (Figure 2): consisting of terrestrial, river, lacustrine or marine areas that contain one or more intact ecosystems, even partially altered by anthropic interventions, one or more physical, geological, geomorphological, biological formations of international or national importance for naturalistic, scientific, aesthetic, cultural, educational and recreational values to require the State intervention for their preservation for the current and future generations;
- Regional and interregional natural parks: composed of terrestrial, river or lacustrine areas, and possibly stretches of sea facing the coast, having naturalistic and environmental value, which constitute a homogeneous system, identified by the naturalistic settings of the places, from the landscape and artistic values and from the cultural traditions of the local populations, within one or more neighbouring regions;
- Nature reserves: including terrestrial, river, lacustrine or marine areas that contain flora and fauna of naturalistic relevance, or one or more ecosystems, important for biological diversity or for genetic resources conservation; natural reserves can be national or regional, based on the importance of the naturalistic elements;

- Wetlands of international interest: consisting of marshy areas, swamps, peat bogs, natural or artificial aquatic areas, permanent or transitory, including areas of sea water whose depth does not exceed six meters when there is low tide, which for their characteristics can be considered of international importance under the Ramsar Convention;
- Other protected natural areas: areas that are not included in the previous classes (e.g. oases of environmental associations, suburban parks); they are divided into areas of public management, (established with regional laws or equivalent provisions) and privately managed areas, established with formal public provisions or with contractual acts such as concessions or equivalent forms.

Figure 2. Alta Murgia National Park, dry grassland with *Stipa austroitalica*

The official list of protected areas is established by the Ministry of the Environment and the Protection of the Territory and the Sea (Decree April 27th 2010, n.115).

Europe has a particularly long history of land protection measures, and is the region of the world with the largest number of protected areas, which has grown rapidly over the last decades. To a large extent this was due to the Natura 2000 programme of the European Union which focused on extending the existing network of legally protected areas to other habitats of conservation value. As a result, Europe has over 120,000 nationally

designated protected sites with around 21 % of its territory (1,228,576 km^2) receiving some form of legal protection.

The strong influence of humans on nature in Europe, begun as early as the Neolithic (ca. 3000-1100 BC), over the centuries has radically altered the natural ecosystems of this region, through for example the harvesting of natural resources, the establishment of settlements, and the cultivation of land. As a consequence, Europe is characterized by a particularly high human density (the average for EU member states is 112 inhabitants per km^2), much higher than that recorded in most other regions of the world. Such density is associated with extensive urbanization, high levels of transport infrastructures and a high degree of land fragmentation.

As a result of all these characteristics, on average European PAs are very small in size compared to other regions of the world. Most of the protected areas in Europe (90 %) are smaller than 1,000 ha and 65% ranges between one and 100 ha; the largest protected area is the Yugyd Va National Park in Russia, which covers 1,8 million ha. The high and still growing level of fragmentation of natural areas poses concerns whether the existing protected area systems can maintain their biodiversity values under the impact of climate changes.

Nature reserves typically revolve around the protection of a single species, community or landscape that holds some biological or cultural value. This necessarily means that reserves are threatened areas; if the site was not threatened there would be no need for preservation or protection. As granting a site reserve status is largely a legal process that limits the types of activities that can occur within the area, it does remove some of the more immediate threats such as the anthropogenic conversion to non-habitat and resource harvesting. However, legal protection does nothing to ameliorate the context from which the site was originally threatened. There is no magic preservation bubble that appears to seal off the area from the outside influences that may continue to threaten the biological integrity of the system. In fact, threats to the system may already be present within the protected boundaries.

The threat, impact and management problems associated with alien plant invasions in protected areas are increasingly being recognized as a major issue. Protected areas face numerous challenges, including human population growth, land conversion and associated disturbances, higher levels of trade, tourism-related issues, wildfire management, poaching, illegal harvesting of resources, and climate change. Furthermore, among the main impediments to action in Europe there are: limited resources, lack of awareness, institutional and legal impediments.

The scientific community agrees that invasive species pose a threat to biodiversity and that the study and management of biological invasions are needed to limit the occurring serious decline of biological diversity of life and forestall one of the greatest extinction events in our planet's history. Protected areas are part of an approach to conserve biodiversity and slow its loss, and should play a major role in combating invasions, not only by improving the efficacy of invasive alien species management within their territories, but also raising awareness at all levels, improving the capacity of practitioners to deal with invaders, implementing site-based prevention efforts, enforcing early detection and rapid response frameworks, and catalyzing action also beyond the park boundaries. Protected areas can thus be reservoirs of biodiversity, but also sentinels of invasions as well as of other emerging threats to biodiversity, champions of best practices, and catalysts of actions also at a broader scale than that of the protected areas.

One of the main threats to biodiversity conservation on a global scale is represented by biological invasions of plant species, i.e. by the uncontrolled spread of allochthonous, non-native species, also known as exotic or alien, introduced voluntarily or accidentally by man outside their original distribution area. In many cases the alien species hardly adapt to the new environment and quickly die, but sometimes they survive, reproduce and settle, living with the species of the new habitat. In some cases the alien species adapt and spread widely, so as to constitute a real threat, causing serious damage not only to natural ecosystems but also to human activities, agriculture and animal husbandry, disturbing the local ecology with effects on human health and serious socio-economic consequences. Allochthonous species that have such a negative impact are defined as invasive species.

Although invasive alien species (IAS) are more concentrated in disturbed areas where human activities are more intense (urban and agricultural systems), in natural areas the introduction of invasive species poses a serious threat to the conservation of biodiversity and the integrity of ecosystems as these invaders enter into competition with native species. Among the most threatening plant IAS in Europe there are: *Acacia deablata*, *Ailanthus altissima, Ambrosia artemisiifolia, Arundo selloana, Carpobrotus edulis, Fallopia japonica, Heracleum mantegazzianum, Impatiens glandulifera, Paspalum paspaloides, Prunus serotina* and *Robinia pseudoacacia*.

Generally, the phenomenon of biological invasions is rapidly increasing and, as in the whole world, the number of IAS in Europe has grown considerably in recent decades; natural systems, weakened and altered in their structure and functionality, may no longer be able to bear the stronger and stronger changes induced by man, including the introduction of new species. Some habitats are naturally more vulnerable than others: plant species invasions are more frequent in nutrient-rich substrates, such as coastal and river environments, as well as in anthropogenic areas, such as agricultural or urban areas.

The introduction of alien plant species may be due to accidental escape from gardens, accidental introductions and intentional introductions made

to obtain naturalized populations of alien species for forestry, agricultural, commercial and ornamental purposes (Figure 3).

Figure 3. Ornamental *Ailanthus altissima* trees close to Bari old town and sea-front

While many ecosystems are losing native species, many are adding alien species of which some are invasive. A major concern is that the ecosystems of the world are becoming more homogenized, with cosmopolitan species dominating and many native species, especially those endemic to relatively small areas, declining towards extinction. There is a European "Red list" indicating endangered and threatened species, which require appropriate measures to improve their conservation status (https://www.iucn.org/regions/europe/our-work/european-red-list-threatened-species).

Only in recent times the phenomenon of biological invasions has been taken into consideration at political-regulation level. As the challenges posed by the IAS are common to all Member States, "Preven-

tion and management of the introduction and spread of invasive alien species" have been addressed in the relevant Regulation (EU) no. 1143/2014 of the European Parliament and of the Council. The Legislative Decree December 15, 2017, n. 230 provided the adaptation of the national legislation to the provisions of the Regulation (EU) no. 1143/2014, and regulates mandatory actions to prevent, early detect, and eradicate spreading SAI.

Among European countries, Italy is one of the most affected by biological invasions, due to factors including the favourable climatic conditions. The phenomenon is increasing strongly in all environments due to the increase in trade, transport, and tourism related to the globalization of economies. Moreover, climate change may lead to the spread of alien species, as well as affecting the distribution of native species. Unfortunately, despite the increasing awareness, Italy still lacks an overall and integrated national strategy that enables it s to effectively tackle the problem.

Impact of invasive alien plant species

Ecological impact

Invasive alien plant species represent a serious environmental emergency and are considered the second most important threat to biodiversity after habitat loss. They can affect biological diversity in various ways and cause ecosystem degradation (for example they can transform a grassland habitat into a thicket or wood or acidify soil). They can pose a major threat to habitats and native species through transmission of diseases and competition for light, water, nutrients and space, reducing or avoiding their growth. The introduction of exotic species can alter the balance between native species and the allocation of resources in a particular area: the new dynamics and biological interactions can also cause the extinction of some indigenous species. Invasive species typically have faster growth than native species, and often also have higher leaf area.

The loss of genetic purity of a species is an important concern, especially for those rare and or threatened species which may face extinction, and have been given sanctuary in protected areas. The hybridisation between alien and native species can lead to genetic swamping and loss of native species' genetic diversity. Genetic pollution is the uncontrolled, undesirable gene flow from non-native species into wild

indigenous populations, for example by cross-pollination. That risk is increased when a rare species hybridises with an abundant species, producing fertile offspring that can back-cross. Invasive species may swamp native species through hybridisation. For example, the native species *Hyacinthoides non-scripta* (bluebell), an iconic species in the British Isles, is being threatened by its congener *Hyacinthoides hispanica* and its hybrid with the native *Hyacinthoides massartiana*. Both the introduced and hybrid species are naturalised, and are frequently found within 1 km of *H. non-scripta*. Thus conservation plans should strive to isolate rare species from cross-compatible congeners.

Hybridisation negatively impacts on the fitness of a population, such as through out-breeding depression and introduction of unwanted phenotypes which can lead to extinction.

Island biodiversity is particularly vulnerable to the impact of invaders. The relatively small selection of species on islands and the lack of defence against mainland invasions put island species especially at risk.

Ecosystem services

If ecosystems are in good condition, they provide a range of important services (cultural, recreational and environmental services). The arrival of invasive plant species can disrupt an ecosystem's equilibrium, alter its structure and affect the provision of services, for example, by altering water or soil quality, or interfering with pollination.

Human health

Some invasive alien species pose a threat to people as potential carriers of disease, and can also cause allergies and skin damage. In Europe, plants are the main culprit in terms of causing allergies. The pollen produced by *Ambrosia artemisiifolia* (common ragweed – a herbaceous species, invasive in many European countries) is highly allergenic and can induce allergic rhinitis, asthma, or dermatitis. As a result, high medical costs have been reported in areas with large infestations in both its native and introduced range. Giant hogweed's toxic sap can cause burns to skin and even blindness.

Cost of invasions

Ecosystems degradation constitutes loss of "natural capital", so the costs of lack of action are potentially immense.

Plant IAS can seriously affect the development and productivity of some human activities; the main costs are due to eradication and control actions and to damage in the agriculture, forestry, fishing, infrastructure and human health. Invasive alien species are also a major economic and social concern. It was estimated that the damage and control cost of IAS in Europe is €12 billion per year. The real figure is likely to be much higher, as many countries have only recently started to document costs in relation to IAS.

Responsible and rational planning to manage our environmental heritage is important to ensure biodiversity and ecosystem services conservation.

Management of invasive alien species issue

Invasive plant species management should include the following activities:

- establishment of research projects to understand more about invasive plants, their distribution and abundance, temporal trends and assessment of their impact in order to manage them from an informed perspective;
- development, trial and dissemination of sustainable methods and technical advice for the removal of invasive alien plants that will limit indirect impacts on native biodiversity, re-invasion and water quality issues (soil erosion, herbicides etc.);
- consideration of the potential for using biological control agents to limit spread of invasive alien agro-forestry species where such agents do not negatively affect the economics of production (e.g. seed feeders/ pathogens where seeds are not a valued crop);
- identification, screening and promotion of alternative species in agro-forestry that are preferably native or, if alien, have a low risk of invasion and are easy to contain within agricultural systems;
- dissemination of information to raise public and stakeholders awareness and skills through:
  - personalized training (short courses, workshops, etc.),
  - specific training on control techniques,

    - production and dissemination of educational material concerning the identification, impact assessment and management of invasive plant species,
    - environmental educational programs for schools;
- data collection, management, archiving, sharing and activities coordinated through:
    - creation of a central office, with the task of elaborating a national strategy, to coordinate data and information, to create and maintain a national information system of alien species, to share results,
    - drafting of a black list of the most harmful invasive plant species on a risk analysis basis;
- development of environmental policy for invasive alien species management to solve problems on a global, national and regional scale through:
    - a national action plan,
    - the simplification of authorization procedures,
    - the definition of responsibilities for eradication and control,
    - the adoption of guidelines and best practices,
    - the adoption of regulations on trade and introduction of alien plant species,
    - the obligation of a technical support for species recovery plans.

Invasive alien plant species control options

Prevention, early detection and immediate control are the best tools to tackle the problem of invasive species. Effective application of these principles, however, requires a greater understanding of the causes and mechanisms of invasion, of the models that allow an alien invasive species to settle and spread to a given area. Measures to prevent, eradicate or limit the spread of invasive exotic plant species must be proportionate to the impact on the environment, adapted to specific circumstances and defined after an assessment of costs and benefits. It is always advisable to try to allocate more resources for prevention, early diagnosis and immediate interventions, rather than for control and management.

Prevention

Since all newly introduced species are potentially invasive, proper prevention at source (i.e. place of origin or export) and destination (through

border controls and quarantine measures) is the most effective way to stop the entrance of IAS.

Prevention at source is particularly indicated where there are outbreaks of infection and in cases where it is difficult to intercept species transported by unaware vectors, such as real clandestine "hitchhikers". In the importing country, border checks and quarantine measures are needed to prevent or minimize the risk of introducing allochthonous species that are, or might be, invasive. Training for customs services is also encouraged to facilitate detections at customs.

There is currently an official list of alien invasive plant species of European concern (http://ec.europa.eu/environment/nature/invasivealien/list/index_en.htm) for which special containment measures are regulated in the aforementioned Regulation (EU) n.1143 / 2014.

Preventing the introduction and colonization of invasive alien plants is easier than eradication. However, absolute exclusion of unwanted species is recognized as an unrealistic goal. Establishing buffer zones and restricting or regulating access to fragile areas can be a good way to reduce invasive plant species and their impacts.

General prevention measures that all citizens can implement to prevent IAS spread are:

- to avoid using allochthonous plants, their seeds and other propagation organs for ornamental purposes, restorations and nursery;
- to prevent the plants from reaching the stage of seed production (herbaceous plants, young trees) and eliminate seed-producing individuals (sexually mature tree plants);
- in case of building yard and ground movements in general, do not use land outside the yard; when it is not possible to use land without seeds and propagules of IAS, it is necessary to monitor the area to quickly identify the occurrence and to proceed immediately with an eradication operation; cleaning the operating machines, tires and working bodies when operating in areas with presence of IAS;
- to compost the plant material deriving from direct control (the wooden material can be chipped). In the oxidation phase make sure to reach temperatures of 60-65°C which guarantee seed and propagule inactivation; if it is not possible to control the composting process, the plant material must necessarily be given to industrial composting plants;
- to provide for design, neatness and maintenance of handwork to avoid the establishment of IAS.

General prevention measures for public administration are:

- carrying out IAS monitoring activities in agreement with other European member states; set up a national gathering information point and implement a dedicated GIS (Geographic Information System);
- promoting the local territory care in order to avoid the increase of abandoned areas where IAS may establish and then spread;
- sensitizing the population to IAS related issues in order to increase knowledge and make them more aware;
- promoting *citizen science*, i.e. the involvement of citizenship in monitoring and data collection activities.

Early detection

Stopping IAS is the first goal, but if an incursion occurs, then early detection and timely eradication are crucial to prevent establishment. When IAS are detected, notification needs to be given to the responsible authorities to trigger rapid eradication actions.

Eradication

Eradication is the complete, long-term elimination of an IAS within a defined area.

When exotic invasive species are identified, eradication actions should be swiftly activated: the greatest chances of success are obtained in the early stages of development and establishment of the invasion when populations are still small and rather localized. Such interventions are much cheaper and more effective than late interventions and must be followed by monitoring and environmental restoration actions.

If feasible, eradication is the best way to deal with invasive species already established in a territory.

Eradication can fail because of different reasons such as: limited budget; the invasion extent is greater than initially thought; search and control costs are too high; preventing long distance seed dispersal and managing a long-lived seed bank further hampers success; a lack of permission from land-owners to remove plants even with small distributions.

Containment

If prevention methods fail and the alien has established in a wide area, options include containment and control. Containment is the restriction of the distribution and spread of an IAS in a defined area. The requirements for containment are the reduction of long distance dispersal and the timely detection of new foci.

Control

In the case of invasive species permanently located in the territory and widespread, those should be contained under the level of no damage. Control is the suppression of IAS abundance within a given area, typically to below an acceptable threshold level that still allows the values of the protected area to be maintained.

The control methods employed can be physical, chemical and biological, possibly integrated with each other, always respecting sustainability and regulations.

To optimize control interventions, it is useful to make an overall assessment of the infestation and to record locations and extents of infested areas by mapping, either hand-drawing maps or using more technological tools.

Environmental restoration

The consequences of the spread of alien species in natural areas leads to the need to carry out interventions of environmental restoration of habitat/ecosystems. To this end, it is therefore considered necessary to carry out restoration interventions especially in the most degraded and anthropic areas by the use of native local species. Large-scale restoration of the pristine, native-species-only landscapes may not be feasible.

In addition, it is appropriate to create nurseries for the reproduction and breeding of native species, and structures for the collection and disposal of alien species to reduce their spread and avoid reintroduction in nature.

Management plan

An effective plan clearly states the overall goals and objectives of management in natural protected areas, and includes an assessment of the current situation and available resources. The management plan should not only identify those plant species that currently, or potentially, pose threats to goals and values, but should also list high value areas, and prioritize species or populations for management. It should also include details on treatment options, planned management actions, methods for monitoring, and evaluating and adapting results.

After a complete census and mapping of the target species, decisions to prioritize interventions should consider the environmental damage caused, and the value of the threatened asset. Invasive alien plants that are fast-growing and disruptive to ecosystems or occur within the most highly valued sites (such as communities of rare species), may be the highest priority species or areas considered for active management. The difficulty of control of a particular IAS should also be considered, giving higher priority to infestations in high quality sites which are controllable with available technology and resources. A high priority may be given to eliminating one or two IAS over their entire invaded range, and to keeping several sites of high biodiversity or ecological importance free of a larger suite of damaging IAS.

There are many factors to take into account when prioritizing sites and species for management: species invasiveness, seed entrance and dispersal, habitats vulnerability, dissemination corridors (roadsides), limited financial resources, etc.

Current technology

Having access to and utilizing current technology can assist a protected areas manager in a variety of ways. The latest technologies include remote sensing (which uses images from planes, satellites, drones or space probes for environmental monitoring purposes), mapping software, or invasive plant control equipment; and much can be accomplished simply by using a computer (or a smart-phone) with Internet access. The Internet can serve as a portal, enabling one to discover what may be invasive in a country or region (through access to global invasive species database); to find a regional IAS expert (Daisie 2012); to identify possible IAS, and search for control options and best management practices (i.e. search for 'species

name' and 'control'). By now there are also many "apps" to indicate the presence of weed species: environmental surveillance is an action that can involve ordinary citizens, students, or hikers, if properly informed and sensitized. Additionally, open source GIS (Geographic Information System) software packages and smart-phone applications are available and can assist in species identification and mapping, and services such as Google Earth may provide baseline maps. Today there are many technologies that can assist in IAS assessment and management that only a few years ago did not exist or were prohibitively expensive, so funding for equipment and technologies will always be desired.

Among the woody or shrubby invasive alien species in Europe (table 1) there are *Acacia dealbata, Ailanthus altissima, Amelanchier spicata, Amorfa fruticosa, Buddleja davidii, Prunus serotina and Robinia pseudoacacia* (EPPO Lists of Invasive Alien Plants - https://www.eppo.int/ACTIVITIES/invasive_alien_plants/iap_lists, CABI Invasive Species Compendium - https://www.cabi.org/ISC/). They are considered to pose the greatest threat to native species and European ecosystems, and therefore highly recommended for control.

Among the aforementioned species, in Italy there are tree of heaven (*Ailanthus altissima*), black locust (*Robinia pseudoacacia*), wild black cherry (*Prunus serotina*), indigo bush (*Amorfa fruticosa*). Another species, a great competitor in southern Italy woods, is *Acacia saligna.*

The most widespread IAS in all Italian Regions is *A. altissima*.

Ailanthus altissima: ecology and characteristics

Little attention is given to the negative impact of the invasive exotic plant species *Ailanthus altissima* (Figure 4) and currently no regional or national control action is carried out for this threatening and highly competitive species. *A. altissima* represents a serious threat to biodiversity at local and European level, which could further worsen in the future, unless concrete actions are taken to avoid the introduction and spread of this species and to eradicate or contain populations already introduced.

A. altissima (tree of heaven) is a woody IAS. It has been transported across ecological barriers becoming established in natural or semi-natural ecosystems or habitats outside their native range. Its introduction was, and can still be deliberate, to satisfy human needs, or accidental (often as a result of the increased globalization of human activities).

The exotic *A. altissima* is one of the most harmful and widespread woody invasive species in Europe (www.europe-aliens.org). It reaches the heart of protected areas and spreads across the natural environment rapidly and spontaneously (without direct intervention by humans), producing reproductive offspring in very large number and at considerable distances,

having the potential to spread over a considerable area. In just two years it can form a tree several feet high. It has considerable vigour. The invasive capacity of this species is explained by its ability to reproduce equally well both by seed and asexually. The samara is the dried fruit with membranous wings; it is transported over long distances by wind and water. One plant can produce up to 300,000 samaras per year. *Ailanthus* also spreads by an extended and vigorous root system, generating numerous suckers and progeny plants. The invasiveness of this species is due to multiple propagation mechanisms: a) samaras allow rapid colonization of new areas, in which plants begin to spread by vegetative means, causing the rapid consolidation of the species; b) young seedlings grow very quickly forming highly dense stands displacing and out-competing native species by heavily shading them in the growing season and/or reducing their growth thus causing serious direct and indirect damages to ecosystems, producing severe ecological, environmental and economic effects.

Figure 4. Dense stand of *Ailanthus altissima* grown by a ruin

The species is able to adapt to any type of soil and water regime, from stony and sterile soils to rich alluvial bottoms, tolerates prolonged drought, saline and acid soils, nutrient deficiency and air pollution.

Once established, it is very hard to eradicate. Its management is very difficult because of its fast growth and mechanical treatments are ineffective due to root-suckers and resprouting shoots. The management methods of *A. altissima* are not officially established, so this contribution is aimed at providing an effective strategy to contain uncontrolled distribution through eco-compatible control techniques suitable for use in natural and man-made areas (urban areas, archaeological sites, etc.).

Table 1. Main characteristics of woody and shrubby invasive alien species in Europe (ref.: EPPO Global Database, CABI Invasive Species Compendium)

Name	Origin	Invasive in	Reproduction	Negative impacts
Acacia dealbata (mimosa tree)	Australia	France, Portugal	It proliferates abundantly by seeds and produces root suckers. Propagules can remain viable for more than one year	Replacement of native vegetation, disruption of water flow leading to stream banks erosion
Ailanthus altissima (sumac tree, tree of heaven)	China	All European member states	It reproduces abundantly by seeds which readily germinate; it is adaptable to different environments; it has rapid growth and abundant root sucker production	Replacement of native vegetation by dense stands and allelopathic compounds
Amelanchier spicata (dwarf serviceberry)	North America	Estonia, Latvia, Lithuania, Finland, Sweden	Seeds are dispersed naturally by small mammals, bears and birds. Propagules can remain viable for more than one year and it reproduces asexually by suckers	Alteration of the structure of both plant communities and landscape, ecosystem change, habitat alteration
Amorfa fruticosa (false indigo-bush)	North America	Czech Republic, France, Germany, Greece, Italy, Hungary, Lithuania, Poland, Romania, Slovenia, Spain	It has a high reproductive capacity, fast-growing in disturbed habitats. It has propagules that can remain viable for more than one year and it also reproduces asexually	Replacement of the native flora through formation of dense thickets, change in successional patterns and biodiversity loss. Significant effect on the composition of soil invertebrates. Particularly invasive in riparian and alluvial habitats
Buddleja davidii (butterfly bush)	China	France, UK and in most Europe	It is tolerant of a broad range of environmental conditions, capable of prolific seed production (millions of seeds), grows rapidly, and has a very short juvenile period. Plants readily reproduce asexually from stem and root fragments	Spread to both disturbed and wild lands and competition with native wild, agricultural, and forestry species

Table 1. (*Segue*)

Prunus serotina (black cherry)	North America	Belgium, Czech Republic, Denmark, Germany, Italy, Netherlands, Poland, Switzerland, UK	It is an aggressive colonizer. It has rapid growth, persists in shaded sites, has a hermaphrodite reproductive system, high seed production and the ability to disperse its seeds through avian and mammalian vectors	Development of dense thickets that can change abiotic site conditions and considerably inhibit growth of seedlings of other tree species, thus reducing vegetal biodiversity and making natural and artificial forest regeneration and production difficult. Leaves, bark and seeds are poisonous and may cause sickness or even death among some animals.
Robinia pseudo-acacia (black locust)	North America.	Cyprus, France, Germany, Greece, Hungary, Netherlands, Switzerland, UK	Is an aggressive, thorny pioneer species. It is adaptable to environmental extremes such as drought, air pollutants and high light intensities. It propagates easily by seed, coppice and root suckers. It is capable of producing 5-7 m deep roots which can spread radially about 1 to 1.5 times the tree height.	Although it is considered a weed species and a strong competitor against more desirable species, it has been widely planted in some central European countries where it is an important timber species. The popularity as an ornamental, forestry, and land reclamation species have ensured that it has been widely introduced. At the same time, it has become naturalized or invasive across many regions, so there is a risk that it will become invasive where conditions are suitable.

Common control methods

The objectives of IAS management actions may be eradication, containment and/or control of the IAS, depending on the extent of the infestation, condition of the surrounding environment, and available resources. When deciding if and how to plan management actions, it is necessary to analyze the set of costs and benefits for each strategy, including any potential off-target impacts, any possible risks to human health, the environmental damage deriving from non-intervention, the costs in the case of late intervention, and environmental safety.

When selecting a control method, we must keep in mind that the ultimate purpose of the work is to preserve native species, communities, and/or functioning ecosystems.

Common control methods are reported in the table 2. Each tool, technique and method has different characteristics determining the advantages and disadvantages.

Chemical control

On January 22th 2014 Italy adopted the National Action Plan for the Sustainable use of agro-chemical products with the specific aim of reducing the negative effects on human health, environment and biodiversity, caused by the exposure to agro-chemicals, including herbicides. Therefore, chemical control against alien plants (to be implemented only if other control methods are ineffective or not practicable), can't ignore the aims of the National Action Plan, both in crop and non-crop areas. In any case, agro-chemicals must be used exclusively on plant species and with control methods for which they are registered, and using only approved equipment.

Intervention criteria

Interventions on *A. altissima*, and other invasive woody species, aim at the reduction of degradation key pressure caused by the unfavourable impact of IAS.

Intervention criteria must respect the following objectives:

- halt the loss of EU biodiversity and strengthen its conservation, fulfilling the EU Biodiversity Strategy to 2020,
- safeguard and improve the conservation status of EU's most important natural habitats and wild species,
- sustain the biological functionality of natural ecosystems reducing the vulnerability against actual or expected climate change effects,
- provide an innovative, eco-friendly and sustainable chemical strategy to eradicate and control woody IAS able to increase efficacy and minimize herbicide use, implementing the Directive on the Sustainable use of pesticides,
- enhance environmental and human health protection from risks and impacts posed by exposure to chemicals in Natura 2000 sites.

The techniques to be used are described in the following paragraph. They are: endotreatment, injection, cut stumps and spaced cuts with sponge.

Treatment have to be distinguished in "first interventions" on the flora treated and "maintenance actions", when further treatments are necessary. In general, the control of invasive vegetation would be facilitated if carried out continuously.

Halt dissemination

Within a control plan it is important to stop the species' dissemination, thus reducing the incidence of new infestations. Otherwise, while treatments occur, new plants will emerge thus frustrating the efforts. For this purpose, big female plants with flowers or seeds will be treated first. Indeed female trees produce thousands of flowers/seeds that, when ripe, are dispersed far away from the plant by wind and water.

Treat natural areas

Another criterion to manage interventions is based on a susceptibility approach: the site of treatment will be chosen according to the habitat vulnerability and priority under the EC Habitat and Wild Birds Directives. Where *Ailanthus* is growing wildly, threatening biodiversity and altering ecosystems, it is fundamental to stop its spread and eradicate all plants

Table 2. Common control methods for woody weeds

Method	Advantages	Disadvantages
Manual and mechanical Manual (hand weeding/ pulling, girdling) includes human labour using: shovels, picks, axes, saws, machetes, root talons, weed wrenches. Mechanical (cutting, mechanical clearing of brush, tilling) includes use of machinery: chainsaws, earth-moving equipment, shredder, chipper, brush-cutters.	Little training is needed for the use of most tools and they can be used in a variety of situations and conditions. Tools are relatively low cost and can provide very specific targeted control minimizing damage to desirable plants and animals	Is time and labor intensive; makes it difficult to adequately control IAS when populations are large or widespread; is not effective on resprouting species; it is necessary to know the biology of the weed before cutting; tools may be sharp and dangerous and training is needed for safe use; large machinery can damage natural habitats and can't be used for hard-to-reach natural areas; tilling or turning-over the soil can badly disturb soils.
Biological Use of another species, such as herbivorous insects, or fungal pathogens, to control an invasive species	Biological control agents spread over very large areas and landscapes (appropriate against widespread weeds), can move into hard-to-reach areas, avoid chemical use and are safe for use in areas too ecologically sensitive for chemical or mechanical control, can be low cost, are self-reproducing organisms (no need to repeatedly treat infestations once agents are established)	Biological control requires expertise of specialized scientists, governmental approval, special skills, and years of effort before rewards are produced. Few IAS have biological control agents available; requirement of specialized natural enemies; may not work in all instances or conditions; risks of unintended consequence to native species and communities.

Table 2. (*Segue*)

Grazing	May be useful in areas where herbicides cannot be applied. A grazing plan is necessary.	Can cause significant damage to a system, and promote the spread and survival of invasive weeds. Overgrazing can reduce native plant cover, disturb soils, weaken native communities, and allow exotic weeds to invade. The invasive species is often unattractive and then grows quickly.
Chemical Use of specific chemicals (herbicides) to kill undesirable plants	May be able to treat large populations at a lower cost than other methods; may be specific to the target IAS; achieve good control; is not labor and/or time intensive; is effective on resprouting species and in the absence of an available biocontrol agent.	Chemicals may remain in soil or water; may contaminate groundwater sources; may have off-target or unintended impacts on desirable native plants and communities; may have health exposure issues for applicators; may be expensive; require application equipment, protective equipment, and applicator training; are not suitable for hard-to-reach or wide natural areas.

which can be source of new infestation. Natural areas will be treated before non-natural ones and priority habitats and vulnerable sites (grasslands, pseudo-steppe, limestone pavements, calcareous rocky slopes and other priority habitat types) will have precedence over others, thus guaranteeing their restoration (Figure 5).

Figure 5. Dry grassland with *Stipa austroitalica* infested by Ailanthus altissima

Thanks to the census and mapping phase, information about the location of the infested areas will be obtained. This will allow prioritization of intervention, quickly detecting the most vulnerable ecologically threatened natural areas, needing urgent control.

Treat non-natural areas

The eradication of the invasive vegetation should be continuous and complete. In previous on-the-spot investigations many infested areas have been found along roadsides of both main and secondary streets

crossing natural protected areas, in private farms, houses, abandoned old farmhouse and ruins. In particular, streets are pre-established corridors that favor seeds spread also very far through cars and tracks passage. So, as well as in the protected areas, invaders have to be eradicated also in such public and private areas which are usually strictly connected to the most important natural areas. Moreover, to avoid further infestations or re-infestation after the first interventions, *Ailanthus* should be controlled in all inhabited centers with the partnership of Municipality Administrations. This action should be performed for the entire area of the Region.

Information about the location of the infested sites in private areas also need to be obtained through a census phase or a specific detection system. Then interventions must be carefully planned according to the location.

As most infested areas are private, important aspects to be considered are the sensitization and involvement of farm/land owners who have to provide the required authorizations.

Treat resprouts

A. altissima is a re-sprouting species, as well as *R. pseudoacacia* and *A. cianophylla*. Even after treatments that cause the plant death, a part of the root or the root collar can still be alive and generate new sprouts. Leaving re-sprouting trees alive would mean incomplete control, so treatments to halt re-sprouting plants will be carried out after the appearance of sprouts. The re-sprouting rate depends mainly on the plant size. According to our previous experience, we could expect that 1/10 to 1/5 of the larger plants could re-sprout, whereas for the smaller plants the rate could be lower. We expect to treat twice or even three times as it is almost never possible to obtain a complete control of invasive and aggressive pests with just a single intervention.

Monitoring areas after treatments is extremely important in order to identify possible re-sprouts and to carry out the completion treatments to have a lasting and low-cost action. In this phase, the involvement of the owners of the infested areas is essential in the maintenance action. It is therefore appropriate to provide for adequate awareness-raising measures.

Sustainable control methods

A. altissima control is achieved by means of an innovative eco-friendly and sustainable strategy, based on low volume localized and pinpointed stem application techniques combining the use of mechanical and chemical methods. These means allow maximum efficacy, minimal herbicide use, minimal risks of exposure to, and dispersal of herbicides, in compliance with the "Directive on the Sustainable Use of Pesticides" and involve in most cases the use of common and easy to use equipment and tools.

As explained above, tree of heaven is hard to remove. Its management is very difficult because of fast growth and the most common control methods are ineffective. Hand pulling can be carried out only on very young seedlings before the root system has developed (Figure 6). At present for *A. altissima* there are no biocontrol agents available in Italy. Mechanical removal (cutting) is the technique mainly used in public

Figure 6. Hand-pulling of young seedlings of *Ailanthus altissima*

areas, but is costly and ineffective due to root suckers and re-sprouting shoots resulting in greater density. Moreover, if applied in natural areas, the passage of large mechanical equipment in natural areas may create serious damage to the native vegetation and habitats, and in some of them (slopes and rocky areas) it would even be impossible. Girdling the cambial tissue on the stem induces heavy root sprouting. Chemical spray control could be the most effective and cheap treatment for this species, but it is poorly eco-friendly because of the release of large amounts of herbicides in the environment making it particularly dangerous for sensitive areas such as parks and Natura 2000 sites. In fact, spraying herbicides has negative consequences including drift of the droplets that harm or kill non-target plants and affect animals and humans. On large trees the problem is much more serious. In conclusion, all commonly used methods are ineffective for *A. altissima* control or unfeasible in natural areas.

In the scientific literature there are many publications showing that the combined use of mechanical and chemical treatments seems to be the best option.

An innovative approach is the use of stem herbicide applications suitable for direct introduction of the herbicide into trunks, increasing effectiveness and leading to kill tree of heaven applying very low volumes of product, thus reducing the risks and impacts of pesticide use on environment and human health.

The sustainable control methods proposed have already been applied on a large scale within the LIFE Alta Murgia Project *"Control and eradication of the invasive exotic plant species Ailanthus altissima in the Alta Murgia National Park"* (LIFE12 BIO / IT / 000213) and proved to be very effective for *Ailanthus* control, leading to the plant's desiccation and death, with medium to long term effect. They are easy to perform and require simple tools or sometimes more complex, but easy to use tools; they have been developed and tested with the aim of minimizing the volumes and doses of herbicides; they are based on maximum localization, thus making them safe for humans and the environment and suitable for use in controlling natural and urban areas.

The methods are:

- endotreatment (endotherapy),
- injection,
- cut stump application,
- spaced cuts with sponge.

Endotherapy

Currently used for protecting ornamental trees from fungi and insects, it is here used as a treatment for direct control of woody weeds (endo-treatment). The technique is accomplished on large trees by making 3 cm-deep drill holes at the base of the trunks and by injecting a water soluble systemic herbicide that will be translocated up and downwards to foliage and roots through the lymphatic vessels. Endotherapy is accomplished by specific pressurized "endotreatment systems" provided with injecting needles.

The development of this method applied to the elimination of undesirable plants allows improved localization and efficacy of the product, accuracy of the dosage, and the distribution of the product in all parts of the tree, thus considerably reducing the volumes of herbicide used, the dispersal of products in the environment, the washing action of rainfall, pollution, effects on non-target species, risk of toxicity to humans, animals and useful insects.

Injection

Injection consists of making downward drill holes in the trunk and then applying in it 2 ml of herbicide by pipettes or by a syringe (Figure 7). Holes can be done as well by the tip of a chainsaw.

Figure 7. Drill holes (left) and chainsaw holes (center), filled with herbicide (right).

Cut stump application

The systemic herbicide is applied by a squeeze bottle directly onto the cambial region of the cut surface, soon after the plant is cut at the base (Figura 8).

Spaced cuts with sponge

This technique consists of making a downward 3x3 cm-cut in the bark of medium size trees and then placing a little piece of flat sponge in it (Figure 9). The sponge will soon be soaked with the herbicide. The use of a little sponge in the spaced cuts keeps the tissues wet for long and avoid herbicide drip and evaporation.

Figure 8. Herbicide application on cut stumps

In the case of endotreatment, injection and spaced cuts with sponge the plant die standing on and is to be cut down later on.

Compared to traditional control methods these techniques have many important advantages such as low drift, no off-target effects, and selectivity.

The techniques described above can be used for all invasive trees or shrubs, and can be adapted to different cases and needs of the infested areas. The choice of the treatment type, for example, will be made depending on the total degree of infestation detected in the area, and then

Figure 9. "Spaced cuts with sponge" technique: bark cut with a blade (left), sponge insertion (center) and final result after herbicide application (right).

time by time, depending on the particular infested spot (size, habitat type, plant density and number), the characteristics of the surrrounding area (e.g. presence of walls, buildings, wells, or open spaces), the plant size and height, etc. In particular, in the case of very large plants, cut stump appli-

cation may need to be avoided not to generate re-sprouts from the roots, while endotreatment or injection could be much more effective. However, in very dense areas with small or medium size plants, cut stumps could be the best option to making the interventions quicker.

For very large plants, dense infestations and in case of re-sprouts, repeated treatments are likely to be needed to control regrowth.

Tools and equipment needed

Tools and equipment needed are the following:

for cut stump applications:
- a chainsaw to cut big trunks,
- hand saw or pruning shears for small plants,
- squeeze bottles to apply herbicide,

for injection:
- a drill to make the holes in the trunks,
- pipettes or syringes to apply herbicide,

for spaced cuts with sponge:
- knives to cut the bark,
- flat sponge,
- pipettes or syringes to apply herbicide,

for endotreatment:
- specific endotherapy systems must be used.

Personal protection equipment such as clothes, boots, gloves, eye protection, etc. will need to be used.

Herbicide characteristics

The active ingredient glyphosate (chemical formula: N-phosphonomethyl-glycine - https://echa.europa.eu/it/substance-information/-/substanceinfo/100.049.125) is a chemical herbicide at the center of an environmental and economic battle. It commands a billion dollar world market (www.georgofili.info/detail.aspx?id=4538). It is a non-selective, water-soluble, system-

ic, post-emergence herbicide for the control of annual, perennial and woody weeds (shrubs and trees) in non-cultivated areas, including natural areas.

Glyphosate is one of the most widely used herbicides. Monsanto's patent for glyphosate expired in 2000, and other companies are already selling glyphosate formulations under an assortment of trade names. The major application for glyphosate products is agriculture, but it is also used to control undesirable weeds in non-cultivated areas.

Glyphosate is transported in both the xylem and phloem of treated plants. It works by inhibiting the EPSP synthase (5-enolpyruvylshikimate-3-phosphate), an enzyme produced by plants and microorganisms but missing in humans, and responsible for the synthesis of aromatic amino acids tyrosine, tryptophan, and phenylalanine, necessary for protein formation. Such a metabolic pathway is essential for the plant's growth, but does not exist in animals. Humans and animals do not produce amino acids whose formation is inhibited by glyphosate and therefore, if in contact with the herbicide, are not affected by negative effects. That makes glyphosate a very effective broad-spectrum herbicide and contributes to its non-toxicity to birds, mammals, and fish.

Product residues present in the soil no longer have biocidal activity, starting as early as a few hours after treatment. Glyphosate is strongly adsorbed to soil particles, which prevents it from leaching, being carried in the deeper layers of the soil or being taken-up by non-target plants. Glyphosate is non-volatile when applied and it is soon degraded primarily by microbial metabolism. In plants, glyphosate is slowly metabolized.

Glyphosate degrades after a short time after application. Its metabolite is AMPA (amino metail phosphonic acid) which can be mineralized or leached. With regard to health, it must be taken into account that groundwater for human consumption receives sanitation treatments that eliminate AMPA.

As required by European regulations for all plant protection products, starting since 2012, glyphosate has undergone a periodic reassessment of health and environmental safety, based on an examination of the scientific studies available and conducted by the health authorities of the member countries and by EFSA (European Food Safety Authority). At the end of this review process, in 2015 EFSA published its conclusions, attesting that "it is unlikely that the substance is genotoxic or causes cancer and that, to have toxicity effect, a person of 60kg should eat more than 100 kg of vegetables per day containing the maximum annual residual amount (LMB) for the rest of his life". In the same year the International Agency for Research on Cancer (IARC, an agency of the World Health Organization) classified

the same product as "potentially carcinogenic to humans", inserting it in group 2A, the same to which also red meat and very hot drinks belong. However, due to the divergence of opinions between EFSA and IARC, the European Commission asked an opinion on the possible risks of the product to ECHA (European Chemical Products Agency) in 2016. In the same year, the FAO and the WHO (World Health Organization), at the end of a joint assessment, considered the risk of carcinogenicity to humans rather unlikely, following exposure to glyphosate through diet. In June 2017, ECHA informed the European Commission of its opinion, indicating that based on the available scientific information:

– there is no evidence of links between normal use of glyphosate and human cancer;
– the product should not be classified as a substance that can cause genetic damage (mutagen) or interfere with reproduction.

In light of that, the European Parliament approved glyphosate-based products on the market until 2022.

It should also be highlighted that the use of this substance to control invasive tree species in natural areas is different from agricultural use on food products, and has the purpose of preserving natural areas and the biodiversity they contain.

The broad-spectrum herbicidal activity is evident when glyphosate is applied by conventional sprayers to foliage, as there is no penetration of woody stems or bark. Selective application to particular species and the need to minimize drift of such an effective phytotoxin led to the development of the novel applications and techniques here used (cut stump application, injection, spaced cut with sponge and endotreatment).

The first symptoms of the herbicide usually occur 7-14 days after treatment with yellowing and reddening to desiccation of vegetation; completely dried plants appear within a few months.

The perennial weeds are most susceptible to glyphosate during flowering, while trees and shrubs are more sensitive in the summer-autumn period.

Liquid soluble concentrate formulations will be used pure or diluted with water according to the plant size and to the application technique used. Care should be taken and protective clothing worn to prevent accidental contact of these formulations with skin or eyes.

The following characteristics have been taken into account to select the proper herbicide (glyphosate) effective against the invasive woody species in a natural area:

– *target species*: the herbicide is effective against perennial woody plants and has already been successfully tested on *Ailanthus*. For natural areas it is best to select compounds that are specific and effective against the target species; conversely, if you use a broad-spectrum herbicide, drift, leaching and runoff should be avoided. That is possible by employing localized application methods (the sustainable methods here proposed) that minimize the herbicide dispersal into the environment;
– *activity*: as the target species generates shoots from the crown and from the roots, the selected herbicide has to be systemic and capable of moving inside the plant through the vascular system, reaching areas far from the point of application, hopefully the roots;
– *toxicity*: the selected product must not be toxic to animals and other organisms and the overall impact on the environment must be as small as possible;
– *registration*: the selected product has to be registered for use in non-crop areas;
– *formulation*: liquid concentrate are best to be applied in holes, sponges, cuts or vascular system.

Other herbicide active ingredients registered in Europe for use on woody/brush species in non-crop areas (aminopiralyd, fluroxipyr and triclopyr) have been found to be ineffective for *Ailanthus* control, or if effective, they are highly persistent in the environment making them unsuitable for use in natural areas.

Treatment protocol

The following protocol can also be applied in non-natural and anthropized areas (urban, archaeological, etc.) and is effective for *Ailanthus* and other woody weeds or invasive species control.

Treatment priority

Among the infested areas surveyed, key action sites will be identified and prioritised according to:
– habitat vulnerability approach,
– presence of big female plants with flowers or seeds.

Herbicide used

Glyphosate can be used, according to the product concentration:
– pure for cut stumps, injection and hack and sponge,

– diluted 1:2 for endotherapy.

Dilution may be appropriate for all techniques in case of concentrated products.

Control techniques:

- Cut stump (Figure 8):
  - Cut the plant at ground level using a chainsaw or a pruning saw.
  - Treat the whole stump surface soon after the cut with the herbicide solution applied with a laboratory squeeze bottle avoiding runoff.
  - Apply 0.5 to 40 ml of herbicide solution according to the tree size (table 3).
- Hack and sponge (Figure 9):
  - Make spaced downward cuts in the bark.
  - Place a little 2x2 cm flat sponge in the fresh cut.
  - Soak each sponge with 2 ml of the herbicide by a lab pipette or a syringe avoiding drip.
  - For trunk diameters up to 4 cm, one bark cut with the sponge will be made and 2 ml of herbicide applied per tree. Every increase of 2 cm in the diameter will require one more spaced cut with the sponge and 2 ml more of herbicide solution to be applied. For example, for a 4-6 cm diameter trunk two bark cuts are necessary, while for a 10-12 cm diameter trunk 5 bark cuts are required, with 4 ml and 10 ml of herbicide respectively.
- Injection (Figure 7):
  - Realize big drill holes in the trunk with a downward angle of 45°.
  - Inject 2 ml of herbicide solution into the holes by a lab pipette or a syringe.
  - For tree diameters up to 4 cm one drill hole will be applied. For 6 cm diameters two drill holes and 4 ml of herbicide solution will be applied. For trees with 10 cm diameter 4 drill holes will be carried out and 8 ml of herbicide solution applied.
- Endotreatment (endotherapy - only for very large trees):
  - Make 4 mm drill holes in the trunk.
  - Insert the brass injection needles of the endotherapy system into the holes.
  - Open the system valves to introduce the herbicide solution, under pressure or not, directly into the lymphatic vessels.
  - The number of holes and the amount of herbicide solution supplied will be chosen according to the size of the plant and to the presence of seeds.

Doses:

The number of cuts or holes to be used per plant and the amount of pure herbicide/herbicide solution applied to each plant will vary depending on the treatment technique and according to the diameter of the plant. They are listed in the Table 3.

Table 3. Treatment techniques, tree size, herbicide applications and amount, to control tree of heaven.

Treatment technique	Trunk diameter (cm)	Drill holes (n)	Bark cuts (n)	Hericide solution per hole or bark cut (ml)	Total herbicide solution per tree (ml)
Cut stump	1 – 40	/	/	/	0.5 - 40*
Hack and sponge	< 4	/	1	2	2
	4 - 6	/	2	2	4
	6 - 8	/	3	2	6
	8 -10	/	4	2	8
	10 - 12	/	5	2	10
Injection	< 3,5	1	/	2	2
	3,5 - 6	2	/	2	4
	6 - 9	3	/	2	6

* variable according to the diameter.

Treatment period

Cut stump technique can be carried out all year.

For application techniques with the plants standing on (injection, endotreatment and hack and sponge), treatment will be carried out from late summer to early autumn. Summer or autumn treatments are the most effective to kill suckers and roots, as the downward lymphatic flow is maximum.

Treatment efficacy

Treated plants will be observed periodically after the treatment.

For plants treated by injection, endotreatment or spaced cut, phyto-

toxicity symptoms (leaf yellowing or browning, leaf fall, necrotic branch or stem, trunk splitting, plant death) will be visible soon after the treatments. On plants which have undergone cut stump, the occurrence of resprouts/ regrowth and root suckers will be monitored after the beginning of the growing season.

Plants will be considered dead if no sprouts or new vegetation are observed during the growing season following treatment. In case of re-growth, a completion treatment with cut plus herbicide will be necessary on the new sprouts.

Safety precaution

Operators carrying out the chemical and mechanical treatments indicated in this protocol must be provided with the necessary qualifications (license for pesticides and chainsaw use, etc.). Operators must use all personal protective equipment required such as anti-cut suits, anti-accident shoes, helmets, gloves and protective glasses. It is necessary to follow all the instructions and indications on the herbicide label. Herbicide empty containers must be disposed as required by law. Care must be taken during treatments in order to avoid product dripping into the environment.

Disposal of trunks

The control protocol and the eradication plan lays down that all plants are cut before treatment in the case of cut stumps application, and after treatment in the case of spaced cuts with sponge, endotreatment and injection. In both cases, plants have to be cut at the base, if large, cut in pieces, remove from the soil, and let dry to avoid re-sprouts.

Ailanthus wood has heat-producing properties similar to birch, white oak, and other woody species.

Plants, in pieces or in trunks, must be disposed of. There are different ways to dispose of the wood produced:

– to store it locally in the form of logs and use it, directly by the land owners or by other local people, for charcoal and firewood for supplementary house heating,
– to cut up all branches and chip it up making woodchips.
  Woodchips are made by a portable shredder machine. They can be

used as an organic mulch to spread possibly on the soils close to the treated areas: as the chips decompose they improve the soil structure, permeability, bioactivity, and nutrient availability. Woodchips will also be utilized directly as a biomass solid fuel for heating in buildings or in energy plants for generating electric power from renewable energy. The newer heating fuel systems use either woodchips or wood pellets. Woodchips are less expensive than wood pellets and theoretically more energy efficient than pellets, because less energy is required for manufacturing, processing, and transporting. Woodchips as an energy source are a clean alternative to carbon emissions produced by fossil fuels and does not have waste disposal issues, since wood ash can be used directly as a mineral-rich plant fertilizer.

Also the educative approach acquired by wood availability to be used as house heating or energy source should be kept into account. For example, farmers or local population can be sensitized on *Ailanthus* and invasive species control and at the same time informed that their control lead to firewood availability.

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https://ec.europa.eu/easme/en/life
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http://www.europe-aliens.org/
Delivering Alien Invasive Species Inventories for Europe - DAISIE project website

https://www.eppo.int/
https://www.eppo.int/ACTIVITIES/iap_activities
European and Mediterranean Plant Protection Organization - EPPO web page on activities on Invasive Alien Plants

https://www.cabi.org/ISC/
Centre for Agriculture and Bioscience International - CABI Invasive Species Compendium - Detailed coverage of invasive species threatening livelihoods and the environment worldwide

http://ec.europa.eu/environment/nature/invasivealien/index_en.htm
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The International Union for Conservation of Nature - IUCN web-page on management and policies for invasive alien species