

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,800

Open access books available

122,000

International authors and editors

135M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Non-Native Invasive Species as Ecosystem Service Providers

Barbara Sladonja, Danijela Poljuha and
Mirela Uzelac

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/intechopen.75057>

Abstract

Non-native or alien species present a range of threats to native ecosystems and human well-being. Many such species have selective advantages over native species, such as faster growth and reproduction rates, higher ecological tolerance, or more effective dispersal mechanisms. However, these species are often inadvertently demonised without sufficient awareness of the ecological principles—disturbance, niche and competition—that contribute to species dominance in an ecosystem. Non-native species can provide services useful to humans, particularly in facilitating many contemporary needs of modern civilisation. In the present paper, the available records on the influence of non-native invasive species and the relationship between services lost and new services acquired due to their presence will be discussed.

Keywords: ecosystem service providers, new services, non-native invasive species

1. Introduction

An invasive alien species (IAS) is any species that is not native to that ecosystem and is capable of propagating itself, whose introduction causes or is likely to cause harm to the environment, economy, or human health [1]. IAS, as well as other species, are affected by climate changes. Predicted environmental changes, such as changing in precipitation and temperature, nutrient availability and soil disturbance, may enhance the susceptibility of habitats to invasion by non-native plant species [2]. Many studies have tried to predict future distributions of invasive species taking different approaches [2–4]. Since introduced species are more spread in disturbed ecosystems with reduced competition, it is crucial to consider the natural and

human factors, such as economic activity, urbanisation, land use, overpopulation, migration, etc., associated with the occurrence of IAS [5]. In general, the invasion process is a complex series of events, reliant upon both the invasive capabilities of the species and the invasibility of the ecosystem [5]. Global environmental changes additionally complicate a continuous battle of governments and managers to detect and control invasive species [3].

The ecological influence of invasive alien species is manifested in different ways. Alien plant species inhabit the area of native species, alter the conditions in their habitat as well as the structure of their communities and interbreed with native species. Alien animal species can also compete for food and shelter with native species and transfer different diseases. Invasive species in general are highly adaptable to a new habitat, tolerate a wide range of climate



Figure 1. Negative effects of *Ailanthus altissima* on archaeological sites in Croatia.

conditions and usually occupy marginal and degraded habitats. They grow fast and have a high reproductive rate to ensure future survival. Although the economic cost of ecological damages caused by IAS is significant, their direct influence on human activities and sites is also relevant [3] (Figure 1). Some IAS also have a direct negative influence on human health, such as invasive allergens (e.g. *Ambrosia artemisiifolia* L.) [6], species that causes skin irritation [7], obstructions in freshwater traffic caused by water plants [8] or decreasing crop production caused by invasive weed species and diseases [9].

A fraction of established exotics become serious pests (e.g. the Eurasian zebra mussel *Dreissena polymorpha* Pallas), while others become well fitted and contribute to global and/or specific

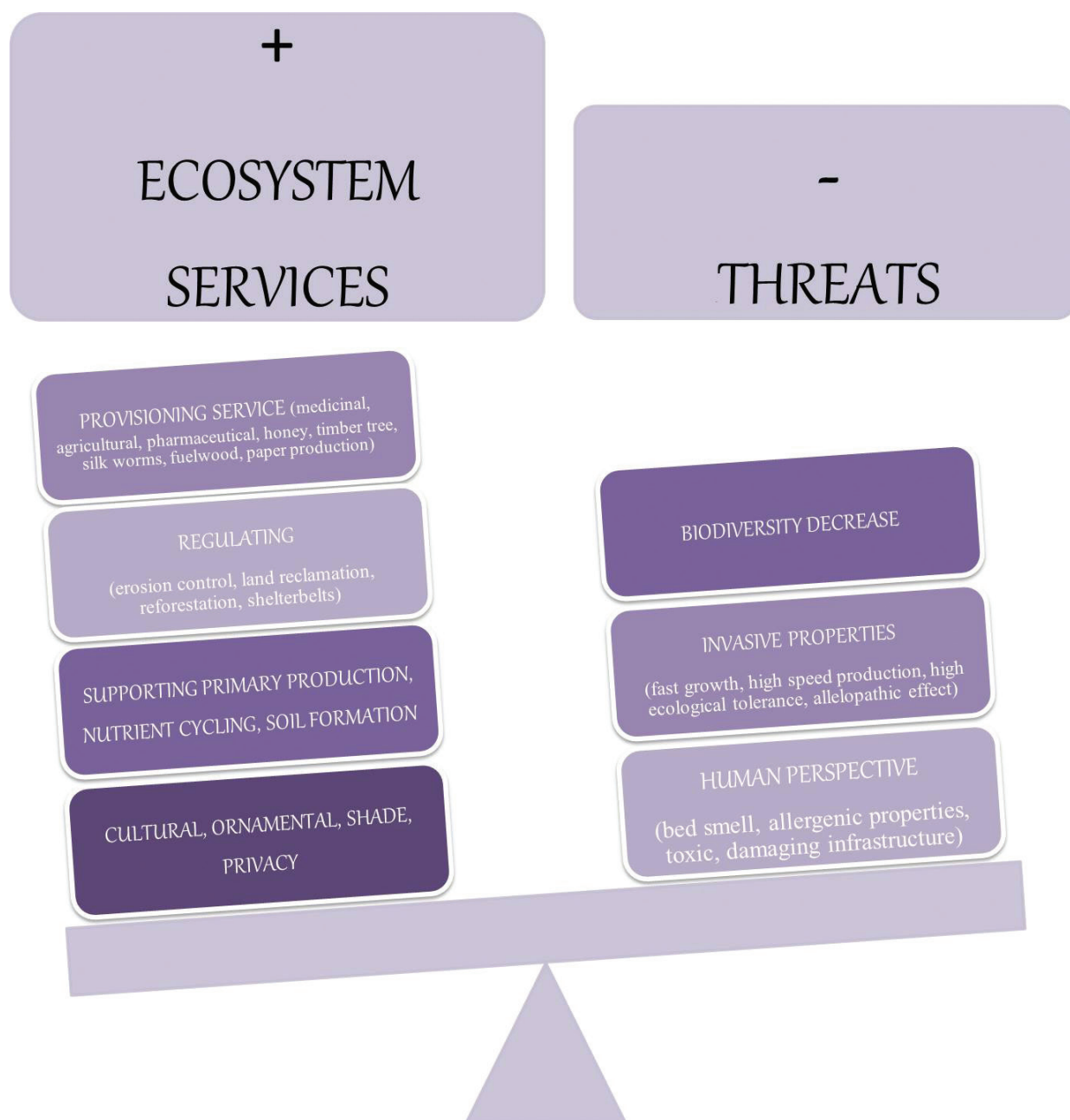


Figure 2. Positive and negative effects of alien invasive species on the scale.

ecosystem services (e.g. the persimmon fruit *Diospyros kaki* L. in the Mediterranean area). For example, *D. polymorpha* has both numerous negative and positive effects on natural ecosystems. Negatives include the economic costs of damage due to clogged water pipes and the fouling of ship hulls and aquaculture cages. This mussel is a predator that significantly decreases plankton abundance as a result of filter feeding. Studies have shown that other filter feeding species may experience competition for resources in the presence of *D. polymorpha*. On the other hand, filtration as a feeding mode may increase water clarity and therefore improve habitat characteristics [10].

In rapidly changing environments, the effects of both non-native and native species may vary with time [11]. The truth is that most human and natural communities consist of both native and new species and new ecosystems are constantly being formed. Many eradication attempts have failed in the past [11], and we must accept novel ecosystems with dynamic living components. Moreover, sometimes, the eradication of one species will not result in the desired outcome because species interactions can be altered [12].

In this chapter, different aspects of the impacts of non-native invasive species are discussed in order to reopen the debate on new complex ecosystems that include both native and non-native species (**Figure 2**) (**Table 1**).

Ecosystem services provided by invasive species			
Ecosystem service	Species	Origin	Reference
Reducing environmental pollution and phytoremediation	<i>Ailanthus altissima</i> (Mill.) Swingle	China	[19, 89, 90]
	<i>Potamogeton illinoensis</i> Morong	North America	[91, 92]
	<i>Artemisia vulgaris</i> L.	Euroasia	[93, 94]
Bioenergy	<i>Panicum virgatum</i> L.	Central and Eastern USA	[26–28]
	<i>Arundo donax</i> L.	Euroasia	[95, 96]
	<i>Paulownia tomentosa</i> (Thunb.) Steud.	China	[31, 38–40]
	<i>Jatropha curcas</i> L.	Central America	[97–99]
Art	<i>Alliaria petiolata</i> (M. Bieb.) Cavara and Grande	Europe	[40]
	<i>Morus alba</i> L.	North China	[100]
	<i>Lonicera maackii</i> (rupr.) Maxim	Western Asia	[100]
	<i>Chamaedaphne calyculata</i> (L.) Moench	Temperate and subarctic regions of the Northern Hemisphere	[100]
	<i>Mahonia bealei</i> (Fortune) Carrière	China	[100]
	<i>Rosa multiflora</i> Thunb.	Eastern Asia	[100]
	<i>Hedera hibernica</i> (G. Kirchn.) Bean	Atlantic region	[44]
	Honey plants	<i>Robinia pseudoacacia</i> L.	North America
<i>Impatiens glandulifera</i> Royle		Pakistan to India	[60, 61]

Ecosystem services provided by invasive species			
Ecosystem service	Species	Origin	Reference
Land reclamation and erosion control	<i>Ailanthus altissima</i> (Mill.) Swingle	China	[19, 63, 64]
	<i>Casuarina equisetifolia</i> L.	Malaysia, Vietnam, Australia and French Polynesia	[65, 69, 70]
	<i>Crassostrea gigas</i> Thunberg	Asia	[73, 74]
Fibre source	<i>Spathodea campanulata</i> P. Beauv.	Africa	[101]
	<i>Ailanthus altissima</i> (Mill.) Swingle	China	[18, 19]
Medicinal use	<i>Spartina alterniflora</i> Loisel	Atlantic coast of the South and North America	[102]
	<i>Opuntia stricta</i> (Haw.)	Caribbean region	[80]
	<i>Ricinus communis</i> L.	North-Eastern Africa	[80, 103]
	<i>Datura stramonium</i> L.	North America	[104, 80]
	<i>Schinus molle</i> L.	Peru	[80, 105, 106]
	<i>Eriobotrya japonica</i> (Thunb.)	China	[80, 107]
	<i>Catharanthus roseus</i> L.	Madagascar	[80, 108, 109]
	<i>Ailanthus altissima</i> (Mill.) Swingle	China	[83, 84, 86]
	<i>Sambucus canadensis</i> L.	North and Central America	[80]
	<i>Melia azedarach</i> L.	Australasia, Indomalaya	[80, 110–112]
Pharmaceutical use in agriculture	<i>Argemone ochroleuca</i> L.	Central America	[80]
	<i>Ailanthus altissima</i> (Mill.) Swingle	China	[9, 87]
Ornamental	<i>Chrysolina hyperici</i> Forster	Europe and Asia	[113]
	<i>Paulownia tomentosa</i> (Thunb.) Steud.	China	[31]
	<i>Robinia pseudoacacia</i> L.	North America	[48–50]
	<i>Pueraria montana</i> var. <i>lobata</i> (Willd.)	Asia	[114]

Table 1. Overview of the most relevant ecosystem references provided by invasive species and related references.

2. The most common myths about non-native invasive species

There are several myths concerned with non-native invasive species.

The most widely spread myth is that **invasive species intend to dominate ecosystems and exclude others more than native species do**. The truth is that only a minority of species introduced to a habitat will spread on their own (naturalise) and only a small percentage of those will spread enough to be called invasive [13]. All species rely on certain conditions for survival; therefore, it is not simply the origin of a species that determines invasiveness, but the interaction between a species' traits and the community of which it is a part [14]. One such example is the domination of a forest by alien trees in Puerto Rico for the first three or four decades of

the invasion. However, these forests are also a habitat in which native trees can begin to thrive again. This case will be further explained below in the chapter on land reclamation [15].

The second myth implies that **all native species are good and useful and all from outside are invasive**. This is not true for several reasons. First, many local species could and would become invasive when introduced to another habitat [13]. On the other hand, invasiveness is linked to the role of human activity in spreading species and changing the environment. Any species' distribution relies on certain conditions for survival which must be met. Many species that we nowadays consider local have been relocated from around the world, both accidentally and intentionally. A few hundred years ago, European explorers brought turkeys, potatoes, corn, tobacco and tomatoes from America to Europe. In turn, species such as horses, cows, sheep, goats, pigs, wheat, soy and grapes were transferred from Europe and the Middle East to America. Plants used in horticulture for ornamental purposes also play a major role in the global spread of species. From these examples, we can see that non-native species should not always be targeted as something bad and unwanted.

Another myth considers ecosystems to be static organisations. There is also a false idea that ecosystems were previously rich in diversity and the introduction of an alien species is responsible for any such losses. Ecosystems are dynamic and are subject to many human and natural disturbances, including fires, climatic changes, flooding, tropical cyclones, construction, tree logging, mining and pollution. As ecosystems change, older inhabitants may die, thus creating a new niche for new organisms to move in. Successions, both primary and secondary, are natural changes in ecological communities which have happened in the past and which will continue to occur in the present and future. However, currently, these changes may be occurring faster due to disturbances, and we can expect an increased dynamism in natural processes.

3. Complete role of non-native invasive species

Biological invasions must be considered within the larger set of environmental issues [3]. Knowing the complex ecology and different potential harms and benefits to society, in general invasive species, can teach us important lessons about how we use the planet [13]. Some authors [16] state that alien species as newcomers in urban areas are not a threat to urban ecosystems; in contrast, there is a chance for increasing biological diversity and thus achieving conservation objectives [12]. In the past half century, biological invasions together with other related environmental problems have become interesting study subjects because they provide natural experiments at temporal and spatial scales [3]. There has been an explosive development in the science of invasion in recent years, and many symposiums, articles and books have been prepared. However, there is still substantial controversy regarding the role of invasions in natural as well as human-shaped environments.

4. Ecosystem services provided by invasive species

Not all non-native species are invasive. There are numerous examples of introduced organisms that are not a threat but have been beneficial. There are many systems trying to list

and categorise biological services to humans. One of the most used is the Millennium Ecosystem Assessment from 2005 [17]. Its objective is to assess the consequences of ecosystem change for human well-being and create a scientific basis for environmental conservation and sustainable use of those systems. According to this system, ecosystem services are divided into four categories: provisioning, regulating, cultural and supporting. Invasive species can provide one or several of these services and make itself beneficial to the ecosystem [18]. It is sometimes difficult to isolate different services as there is continual interaction between them.

4.1. Environmental conservation

Non-native species can be useful catalysts for ecosystem restoration and increase the structural heterogeneity or complexity of an area. Such species can also function as biocontrol agents by limiting the spread of agricultural pests [12].

Some IAS, such as *Ailanthus altissima* (Mill.) Swingle, tolerate poor, dry soils, support relatively high levels of air pollution and may be able to sequester some pollutants [19].

Moreover, IAS are a good solution in disturbed sites. They can adapt rapidly to the novel ecological conditions due to their ability to tolerate and adapt to a broad range of biotic and abiotic conditions [12].

4.2. Bioenergy

The world's energy needs are growing every day, and according to the US Energy Information Administration (EIA) projections, between 2015 and 2040, the world's energy consumption will grow by 28% [20]. Conventional fuels such as natural gas, coal and nuclear energy are limited and unsustainable in the long run. In the USA, the US renewable energy initiative announced a new impetus for the identification of biofuel crops as important sources of energy [21].

In October 2014, the European Council set a new framework for climate and energy in which the EU committed to having 27% of energy obtained from renewable sources by 2030. One of the main energy policy targets of the European Union is to increase renewable energy sources by enhancing the development of biofuel cropping systems in order to produce biomass for energy [22]. Biofuel crops, particularly using non-native species, must be introduced with an understanding of possible risks to the environment. The policies may conflict because traits deemed ideal in a bioenergy crop are also commonly found among invasive species.

Before cultivation of biofuel crops, it is necessary to ensure that such plants do not "escape" from plantations and become invasive. Therefore, biofuel crops should be subjected to a Weed Risk Assessment (WRA) before cultivation [23]. There are many WRA systems used around the world to predict the invasiveness of a plant species [24]. The Australian WRA system has been tested in several countries since its introduction in 1997 and is internationally recognised as one of the best systems to determine the risk of invasion [24, 25].

A great number of plant species have been proposed for biofuel cultivation in different countries. *Panicum virgatum* L., commonly known as switchgrass, is native to most of the central and eastern USA [26]. Since the 1990s, there has been growing interest in using this plant for

bioethanol in California and the Pacific Northwest. This species could become invasive if it is not properly managed or due to changes in local climate parameters [27]. *P. virgatum* is known for its ability to improve soil quality, sequester carbon and mitigate greenhouse gas emissions [28]. It grows in a wide range of suitable habitats, from 5 to 25°C mean annual air temperature and 300–1500 mm mean annual precipitation, and has relatively low nutrient requirements [26, 28]. Such attributes make this plant very suitable for cultivating in marginal and highly disturbed lands with poor soil. Deep fibrous root systems, slow decomposition rates and root biomass make *P. virgatum* a great agent for carbon sequestration [29, 30].

Paulownia tomentosa (Thunb.) Steud., known as princess tree, is another proposed biofuel crop. *P. tomentosa* is native to eastern and central China where it is used as an ornamental tree. It was introduced to the USA in the 1840s and soon become very invasive, covering disturbed natural areas, forests and river banks [31, 32]. The first record of *P. tomentosa* in the EU was in the 1980s; currently, this species appears less invasive. The EU Regulation on invasive species did not include *P. tomentosa* on the list of Invasive Alien Species of Union concern [33] although recent studies have shown significant spread. The species population has been recorded in urban areas, along railways, and near industrial sites in several European cities in Austria, SW Germany, Switzerland, Italy and SW Slovenia [34–36]. In Croatia, it has also been noticed at several sites near large cities, but currently does not show traits of invasiveness [37].

P. tomentosa became important as a biofuel crop because of its fast growth rate and high wood quantity generated in a short time period [38]. Timber biomass contains high cellulose and hemicellulose concentrations which are the main source of ethanol production [39]. Therefore, this species is highly preferred for the production of raw material for biofuel [40]. Studies have shown that the calorific value of *P. tomentosa* timber biomass is higher than that of coal (20.90 and 14.64 kJ/g, respectively) and thus more environmentally friendly [38, 41].

4.3. Turning invasive species into art

Invasive weeds can be used as material for art activities. Invasive removal programmes of some weeds result in plants that are usually dismissed as unwanted. However, if the act of weeding can be replaced into an act of harvesting, it changes the purpose and gives it a new meaning. Some plants have strong and flexible fibres that can be used for natural basketry [42]. Another attractive example of artistic approaches to invasive species is their use in art photography, in which they are used for making paper on which the photos of the shadows of rare or threatened plants are printed [43]. Some artists use invasive species [white mulberry, *Morus alba* L.; Irish ivy, *Hedera hibernica* (G. Kirchn.) Bean; multiflora rose, *Rosa multiflora* Thunb.; Amur honeysuckle, *Lonicera maackii* (Rupr.) Maxim.; leatherleaf mahonia, *Mahonia bealei* (Fortune) Carrière] for the production of pigments, ink, wood blocks, paper or other kinds of fibre [44].

Sustainable or science art is a great tool to communicate complex scientific concepts, such as the complex relationships between native and invasive species, to the wider public. In that sense, IAS also can be used for public education on possible negative impacts of the spread of non-native species. Thus, attractive collages of invasive species prepared from invasive plant materials are a great example of art with an environmental message [45].

4.4. Honey plants

Insect pollination is an important ecosystem service to agriculture and horticulture [46]. In the past decade in Europe, studies have shown a decrease in wild pollinator diversity due to the use of pesticides, habitat degradation and climate change [47]. To help solve this problem, some invasive alien plant species can serve as pollination providers.

Robinia pseudoacacia L. also known as black locust, is a species native to North America where it was used to control erosion, for reforestation, and as an ornamental tree. Nowadays it has been widely naturalised all across Europe, South Africa, Asia, Australia and New Zealand [48–50]. Currently, in Europe, this species is not listed on the list of Invasive Alien Species of Union Concern but is already considered invasive in most EU countries [50]. *R. pseudoacacia* is pioneer, fast-growing species that tolerates a diverse range of soil and climate conditions [51, 52]. The flowering period occurs in late spring with fragrant white to yellow flowers. These flowers contain fruit nectar which attracts bee pollinators, from which they then produce a honey [53]. *R. pseudoacacia* honey is one of the most highly prized types of honey for taste and flavour. The liquid honey is transparent, and the aroma is fruity, light and refreshing [54]. Because this honey contains a higher ratio of fructose than glucose sugar, it slowly crystallises and can remain as a liquid for several months. This helps bees to survive all winter [55].

Impatiens glandulifera Royle or Himalayan balsam is a perfect example of a species used as an ornamental plant that “escaped” from its native habitat [56]. Originally from North-West Pakistan to northern India, it has naturalised and invaded most countries of the EU, part of North America and New Zealand [57]. A large population has been recorded in the UK, Germany, Sweden, Austria and throughout the Baltic [56, 58, 59]. *I. glandulifera* is listed on the list of Invasive Alien Species of Union concern; within 18 months from the listing, the member states have an obligation to establish effective management measures [33]. It grows mainly in riparian zones, disturbed areas, river banks and forest edges. On the other hand, *I. glandulifera* flowers have the highest sugar nectar production per flower than any native European plant species, which attracts bumblebees, honeybees and moths [60, 61]. Flowering starts in August and thereby fills the gap between the end of the summer and the autumnal crop season [62]. In the future, this plant may serve as a significant seasonal pollen and nectar resource for honeybees and other insects.

4.5. Land reclamation

Nowadays we are increasingly faced with rapid land degradation due to anthropogenic intervention, pollution and pesticide use, deforestation, natural disasters and climate change. Land and soil reclamation is a slow process that often takes several years and greatly depends on conditions in the natural environment.

Some invasive species can be used to control erosion on slopes or along edges of traffic lanes, for reclamation of landfill sites and mine spoils, the establishment of protective forest shelterbelts and the conversion of disturbed land back to its original state [63, 64]. *A. altissima* is known for its ability to grow in barren, inhospitable and highly disturbed sites. It is also suitable for afforestation of the arid sites, as its root system contributes to soil drainage, slowing water run-off. Due to its resistant but soft and easy wood, it contributes to soil stabilisation because it generates lower pressure on the soil [19, 63].

Casuarina equisetifolia L. is an evergreen conifer-like tree native to Malaysia, Vietnam, Australia and French Polynesia. It was introduced in Florida, USA, in 1898 by the US Department of Agriculture plant explorer for coastal landscaping and erosion control [65]. Today it is one of the most invasive species in South Florida, self-seeding in disturbed areas [66]. *C. equisetifolia* colonises sandy habitats near shores and barrier islands, ruderal habitats and vacant lots and is extremely resistant to salt spray [67, 68]. Salt resistance and desiccation avoidance in countries such as Egypt, China and India turned out to be a benefit for the reforestation of coastlines [69, 70]. Thus, *C. equisetifolia* controls the movements of sand dunes, reduces wind erosion and finally starts the process of land reclamation. Florida is often affected by hurricanes and heavy storms which erode sands offshore. Native species usually are not able to colonise the beach as rapidly after such natural disasters [71]. In the future, invasive species such as *C. equisetifolia* can potentially help in this initial colonisation of new coastal plant communities.

Introduced species may in some occasions act like ecosystem engineers and help with the re-establishment of a new habitat [15]. *Crassostrea gigas* Thunberg or the Pacific oyster is an oyster native to Asia that settles on rocky coastlines in dense aggregations. Since the eighteenth century in the European Wadden Sea, oyster fisheries overexploited the native oyster *Ostrea edulis*. *C. gigas* was introduced in Europe and Australia for the aquaculture industry but today has become highly invasive in Scandinavian coastal waters, North America and Australia [72]. This oyster is known for its high rates of growth and reproduction. It acts as an ecosystem engineer by colonising un-vegetated mudflats, generating new solid reefs [73]. Consequently, new reefs are increasing densities of native invertebrate species relative to native oyster beds [74].

Recently in Puerto Rico, a large area of the native forest was destroyed by farming. In attempts to nurture back this degraded land, native trees do not have pioneering potential as soil and climate conditions are often poor and inhospitable. On the other hand, *Spathodea campanulata* P. Beauv., also known as the African tulip tree, has colonised the area instead [75]. *S. campanulata* is native to tropical forests in sub-Saharan Africa and was introduced in Puerto Rico in the 1920s. Soon it became the prevailing tree on abandoned farmlands, but studies have shown that *S. campanulata* forests provide new habitat to native species [76]. Several native forest fauna populations have recovered, such as the endangered frog *Peltophryne lemur* Cope and parrot *Amazona vittata* Boddaert [77, 78]. The leaf litter in *S. campanulata* forests can bring back forest invertebrates to deforested sites and other animals like bats and reptiles [76]. According to past experiences, these new forests remain dominated by alien trees for the first three or four decades. After 60–80 years of growth, Puerto Rican forests will become mixtures of both alien and native trees [15].

4.6. Fibre sources

Wood fibres are extracted from trees and used to make materials including paper. Different plant species or species' blends are best suited to provide the desirable sheet characteristics. Among different tree species, some non-native and also invasive species have the potential to be used as a fibre source. *Ailanthus altissima* has potential as a raw material for papermaking [19]. It produces paper with properties similar to those of *Eucalyptus globulus*, the most common species used for this purpose in temperate regions [18]. This tree species has several desirable properties (tolerance of poor soil, drought and pollution) for use in degraded environments and so can be used simultaneously for paper production and aid in conservation issues.

Paulownia tomentosa (Thunb.) Steud. is also thought to have potential for paper production, especially considering its extremely rapid growth rates [39].

4.7. Medicinal use

Plants used in herbal medicine have been discovered and used in traditional practices since historic times. For example, since 1968, in Africa, weeds and exotic plants have been used as medicines by specialist and non-specialist healers [79], a practice which has been conducted for centuries.

Some invasive alien plants are used by local inhabitants as a substitute for scarce indigenous plants. A study conducted in the Waterberg District investigated medicinal usage of several invasive plants in the South African Republic. It revealed that *Schinus molle* L., *Catharanthus roseus* L., *Datura stramonium* L., *Opuntia stricta* Haw., *Opuntia ficus-indica*, *Sambucus canadensis* L., *Ricinus communis* L., *Melia azedarach* L., *Argemone ochroleuca* and *Eriobotrya japonica* species are used for treatment of various diseases such as chest complaints, blood purification, asthma, hypertension and infertility. These plants inhabit poor land sites and are adaptable to different environments and climate conditions. Due to its high regenerative capacity, they are difficult to eradicate. Therefore, these invasive alien plants can be utilised by communities to combat various diseases in humans, thereby reducing pressure on heavily harvested indigenous plants [80].

Ailanthus altissima, a plant known for its useful ecosystem services, can also be used for medicinal purposes. *A. altissima*, known as the Tree of Heaven, is a deciduous wood native to central China that was introduced to Europe and America in the mid-eighteenth century. It was planted as an ornamental tree throughout cities because of its resistance to pollution, fast growth and ability to thrive in nutrient-poor conditions [81]. Due to its rapid growth and prolific seed production, it quickly escaped cultivation and soon became one of the most invasive species in the world [82]. *Ailanthus altissima* produces toxins in its roots, bark and leaves which inhibit the growth of other nearby plants. Chemical analysis revealed the presence of alkaloids, terpenoids and aliphatic bioactive compounds as major constituents of the plant [83]. From plant extracts, scientists isolated quassinoids, ailanthone and 6- α -tigloyloxychaparrinone, which have shown strong activity against strains of *Plasmodium falciparum* in vitro [84]. The major quassinoid constituent, ailanthone, has potent anti-amoebic activity against *Entamoeba histolytica* both in vitro and in vivo [85]. On the other hand, fresh plant parts can also have active medicinal usages, like fresh stem bark for the threat of diarrhoea and dysentery; root bark for heat ailments, epilepsy and asthma; fruits to threat ophthalmic diseases; and leaves used in lotions for seborrhoea and scabies treatments [86]. In Asia, extracts of *A. altissima* bark and fruits are used as an antimicrobial, anthelmintic and amoebicide [85].

4.8. Pharmaceutical use in agriculture

Some invasive plants have, due to their chemical composition, herbicidal properties. Their high invasive potential is determined by many properties, such as tolerance for a wide span of ecological conditions and pollution; high reproduction, growth and regeneration rates; and a production of secondary metabolites with herbicidal and insecticidal activities. For example, the main component responsible for a herbicidal effect in *A. altissima* is shown to be ailan-

thone, a chemical in the group of quassinoids [9] mainly present in the Simaroubaceae family. Several studies have shown that ailanthone is toxic for many plant species, including weeds, crops and trees [9, 87]. It is believed that, by producing and releasing ailanthone through its tissues largely through the roots, *A. altissima* has an allelopathic effect on nearby plant species, slowing their growth and outcompeting them [9]. Considering its high phytotoxicity, ailanthone shows potential as a possible future natural product herbicide, although its nonselectivity observed in multiple studies would present an obstacle if not resolved in some way. In addition, its rapid biodegradability could be a positive feature from the conservational aspect as it has a short, lasting effect in the environment but a negative one if possible applications as a herbicidal compound would be taken into account [88].

4.9. Ornamental

Many non-native species have been introduced for intentional ornamental and horticultural purposes (e.g. *Ailanthus altissima* and *Paulownia tomentosa*) [31, 48, 81]. Such species, due to their reproductive potential and regenerative capacity, soon increase in density. After some years of their uncontrolled spread, the cultivation loses importance; thus legal introduction and commerce are stopped.

5. Conclusion

IAS management must take into account all impacts of new species in a certain ecosystem. Natural resource management bodies should base their management plans on the real effects of a particular species in an ecosystem and not on traditionally repeated claims of non-selective negative effects of alien species. All species have some useful potential in an ecosystem, and many have easily defined services. Although some non-native species can cause serious problems that should be taken into account, a wider perspective on the role of each species in an ecosystem is needed. Their role is also mixed with new challenges arising from other environmental changes such as climate changes and human interventions. Land managers must focus more on the function of a species in an ecosystem than on their origin. As our understanding of biological invasions is growing, our capability to describe the ecological and economic consequences is more precise enabling the environmental managers to make objective decisions about IAS management.

Acknowledgements

This study was supported by the Municipality of Poreč.

Conflict of interest

The authors declare no conflict of interest related to the present paper.

Author details

Barbara Sladonja^{1*}, Danijela Poljuha¹ and Mirela Uzelac²

*Address all correspondence to: barbara@iptpo.hr

1 Institute of Agriculture and Tourism, Poreč, Croatia

2 External Associate, Poreč, Croatia

References

- [1] Pejchar L, Mooney HA. Invasive species, ecosystem services and human well-being. *Trends in Ecology and Evolution*. 2009;**24**:497-504
- [2] Hufnagel L, Garamvölgyi Á. Impacts of climate change on vegetation distribution No. 2 – Climate change induced vegetation shifts in the New World. *Applied Ecology and Environmental Research*. 2014;**12**(2):355-422. DOI: http://dx.doi.org/10.1566/aeer/1101_355422
- [3] Richardson DM, editor. *Fifty Years of Invasion Ecology: The Legacy of Charles Elton*. Chichester: Wiley-Blackwell; 2011. 456 p
- [4] Garamvölgyi Á, Hufnagel L. Impacts of climate change on vegetation distribution No. 1 – Climate change induced vegetation shifts in the Palearctic region. *Applied Ecology and Environmental Research*. 2013;**11**(1):79-122. DOI: http://dx.doi.org/10.1566/aeer/1101_079122
- [5] Chikuruwo C, Masocha M, Murwira A, Ndaimani H. Predicting the suitable habitat of the invasive *Xanthium strumarium* in southeastern Zimbabwe. *Applied Ecology and Environmental Research*. 2017;**15**(1):17-32. DOI: http://dx.doi.org/10.1566/aeer/1101_017032
- [6] Oswald ML, Marshall GD. Ragweed as an example of worldwide allergen expansion. *Allergy, Asthma and Clinical Immunology*. 2008;**4**:130-135
- [7] Burrows EG, Tyrl RJ. *Toxic plants of North America*. 2nd ed. Hoboken, New Jersey: Wiley-Blackwell; 2013. 1390 p
- [8] Celesti-Grapow L, Blasi C. The role of alien and native weeds in the deterioration of archeological remains in Italy. *Weed Technology*. 2004;**18**:1508-1513
- [9] Heisey RM. Identification of an allelopathic compound from *Ailanthus altissima* (Simaroubaceae) and characterisation of its herbicidal activity. *American Journal of Botany*. 1996;**83**:192-200
- [10] Strayer DL. Twenty years of zebra mussels: Lessons from the mollusk that made headlines. *Frontiers in Ecology and Environment*. 2009;**7**:135-141. DOI: 10.1890/080020
- [11] Davis MA. Don't judge species on their origin. *Nature*. 2011;**15**:154-155

- [12] Schlaepfer MA, Sax DF, Olden JD. The potential conservation value of non-native species. *Conservation Biology*. 2011;**25**:428-437
- [13] Zinn L, Schramm J, Meitzner Yoder LS. Towards a deeper understanding of native and introduced species. In: Grant T, editor. *Teaching about Invasive Species*. Toronto: Green Teacher; 2014. pp. 7-11
- [14] Shea K, Chesson P. Community ecology theory as a framework for biological invasions. *Trends in Ecology and Evolution*. 2002;**17**:170-176
- [15] Zimmer C. Alien species reconsidered: finding a value in non-natives. *Yale Environment*. Published at the Yale School of Forestry & Environmental Studies. 2011;**360**. Available from: https://e360.yale.edu/features/alien_species_reconsidered_finding_a_value_in_non-natives [Accessed: Jan 15, 2018]
- [16] Zisenis M. Alien plant species: A real fear for urban ecosystems in Europe? *Urban Ecosystems*. 2014;**18**:335-370. DOI: 10.1007/s11252-014-0400-1
- [17] Millennium Ecosystem Assessment. *Ecosystems and Human Well-being: Biodiversity Synthesis* [Internet]. 2005. Available from: <https://www.millenniumassessment.org/documents/document.354.aspx.pdf> [Accessed: Dec 22, 2017]
- [18] Sladonja B, Sušek M, Guillermic J. Review on invasive Tree of Heaven (*Ailanthus altissima* (mill.) Swingle) conflicting values: Assessment of its ecosystem services and potential biological threat. *Environmental Management*. 2015;**56**:1009-1034. DOI: 10.1007/s00267-015-0546-5
- [19] Baptista P, Costa A, Simoes R, Amaral M. *Ailanthus altissima*: An alternative fiber source for papermaking. *Industrial Crops and Products*. 2014;**52**:32-37. DOI: 10.1016/j.indcrop.2013.10.008
- [20] U.S. Energy Information Administration. *Today in Energy* [Internet]. 2017. Available from: <https://www.eia.gov/todayinenergy/detail.php?id=32912> [Accessed: Dec 15, 2017]
- [21] Raghu S, Anderson RC, Daehler CC, Davis AS, Wiedenmann RN, Simberloff D, Mack RN. Adding biofuels to the invasive species fire? *Science*. 2006;**313**:1742. DOI: 10.1126/science.1129313
- [22] Crosti R, Capdevila-Argüelles L, Zilletti B. Ecosystem services and invasive bioenergy plants in the mediterranean basin; A preliminary outlook in Spain. In: *3er Congreso Nacional Sobre Invasiones Biológicas (EEI 2009)*; 24-27 November 2009. Zaragoza: GEIB; 2010. pp. 285-287
- [23] Crosti R. Invasiveness of biofuel crops and potential harm to natural habitats and native species. In: *30th Standing Committee to the Bern Convention*; 6-9 December 2010; Strasbourg: Council of Europe; 2009. p. 23
- [24] Roy H, Schonrogge K, Dean H, Peyton J, Branquart E, Vanderhoeven S, Copp G, Stebbing P, Kenis M, Rabitsch W, Essl F, Schindler S, Brunel S, Kettunen M, Mazza L, Nieto A, Kemp J, Genovesi P, Scalera R, Stewart A. Invasive alien species – Framework for the identification of invasive alien species of EU concern. *European Commission*. 2014;**298**

- [25] McClay A, Sissons A, Wilson C, Davis S. Evaluation of the Australian weed risk assessment system for the prediction of plant invasiveness in Canada. *Biological Invasions*. 2010;**12**:4085-4098
- [26] Hartman JC, Nippert JB, Orozco RA, Springer CJ. Potential ecological impacts of switchgrass (*Panicum virgatum* L.) biofuel cultivation in the Central Great Plains, USA. *Biomass and Bioenergy*. 2011;**35**:3415-3421. DOI: 10.1016/j.biombioe.2011.04.055
- [27] Barney JN, DiTomaso JM. Nonnative species and bioenergy: Are we cultivating the next invader? *Bioscience*. 2008;**58**:64. DOI: 10.1641/B580111
- [28] Sanderson MA, Adler PR, Boateng AA, Casler MD, Sarath G. Switchgrass as a biofuels feedstock in the USA. *Canadian Journal of Plant Science*. 2006;**86**:1315-1325. DOI: 10.4141/P06-136
- [29] Al-Kaisi MM, Grote JB. Cropping systems effects on improving soil carbon stocks of exposed subsoil. *Soil Science Society of America Journal*. 2007;**71**:1381. DOI: 10.2136/sssaj2006.0200
- [30] Puget P, Drinkwater LE. Short term dynamics of root and shoot derived carbon from a leguminous green manure. *Soil Science Society of America Journal*. 2001;**65**:771. DOI: 10.2136/sssaj2001.653771x
- [31] Invasive Plant Atlas of the United States. *Paulownia tomentosa* (Thunb.) Sieb. & Zucc. ex Steud [Internet]. 2016. Available from: <https://www.invasiveplantatlas.org/subject.html?sub=2426> [Accessed: Dec 18, 2017]
- [32] Innes RJ. *Paulownia tomentosa*. Fire Effects Information System [Internet]. 2009. Available from: <https://www.fs.fed.us/database/feis/plants/tree/pautom/all.html> [Accessed: Dec 18, 2017]
- [33] Official Journal of the European Union. Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the Prevention and Management of the Introduction and Spread of Invasive Alien Species (OJ L 317) [Internet]. 2014. Available from: <http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014R1143&from=EN> [Accessed: Dec 18, 2017]
- [34] Wittenberg R, editor. An Inventory of Alien Species and their Threat to Biodiversity and Economy in Switzerland. Bern: Swiss Agency for Environment, Forest and Landscape; 2005. 417 p
- [35] Landolt E. Über Pflanzenarten, die sich in den letzten 150 Jahren in der Stadt Zürich stark ausgebreitet haben. *Phytocoenologia*. 1993;**23**:651-663. DOI: 10.1127/phyto/23/1993/651
- [36] Keil P, Loos GH. Preliminary account of ergasiophygophytic and xenophytic trees, shrubs and subshrubs in the Central Ruhrgebiet (Germany). *Electronic Publications of the Biological Station of Western Ruhrgebiet*. 2005;**3**:1-12
- [37] Flora Croatia Database [Internet]. 2017. Available from: <https://hirc.botanic.hr/fcd/> [Accessed: Dec 22, 2017]

- [38] Icka P, Damo R, Icka E. *Paulownia tomentosa*, a fast growing timber. Annals of Valahia University of Targoviste. 2016;**10**:14-19. DOI: <https://doi.org/10.1515/agr-2016-0003>
- [39] Yadav NK, Vaidya BN, Henderson K, Lee JF, Stewart WM, Dhekney SA, Joshee N. A review of paulownia biotechnology: A short rotation, fast growing multipurpose bioenergy tree. American Journal of Plant Sciences. 2013;**4**:2070-2082. DOI: 10.4236/ajps.2013.411259
- [40] Durán Zuazo VH, Jiménez Bocanegra JA, Perea Torres F, Rodríguez Pleguezuelo CR, Francia Martínez JR. Biomass yield potential of paulownia trees in a semi-arid Mediterranean environment (S Spain). International Journal of Renewable Energy Research. 2013;**3**:789-793
- [41] Paulownia Biomass Production [Internet]. 2011. Available from: <http://www.toadgully.com.au/files/Paulownia%20Biomass%20Production.pdf> [Accessed: Dec 22, 2017]
- [42] Kallis S. Weaving with invasive weeds. In: Grant T, editor. Teaching about Invasive Species. Toronto: Green Teacher; 2014. pp. 32-36
- [43] Williams R. Turning Invasive Species into Art [Internet]. 2016. Available from: <https://www.allegHENYfront.org/turning-invasive-species-into-art/> [Accessed: Jan 19, 2018]
- [44] Alien Weeds. From the Invasive Plants of Washington, DC. [Internet]. 2017. Available from: <http://alienweeds.com/art.html> [Accessed: Jan 22, 2018]
- [45] Invasive Species Initiative [Internet]. 2017. Available from: <http://www.invasivespeciesinitiative.com/emily-blair-invasive-art/> [Accessed: Jan 23, 2017]
- [46] Klein AM, Vaissiere BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, Tscharntke T. Importance of pollinators in changing landscapes for world crops. Biological Sciences.. 2007;**274**:303-313. DOI: 10.4236/ajps.2013.41125
- [47] Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin WE. Global pollinator declines: Trends, impacts and drivers. Trends in Ecology and Evolution. 2010;**25**:345-353. DOI: 10.1016/j.tree.2010.01.007
- [48] Vilà M, Basnau C, Gollasch S, Josefsson M, Pergl J, Scalera R. Hundred of the most invasive alien species in Europe. In: Drake JA, editor. The Handbook of Alien Species in Europe. 3rd ed. Berlin: Springer; 2008. pp. 265-269
- [49] Kurokochi H, Toyama K. Invasive tree species *Robinia pseudoacacia*: A potential biomass resource in Nagano Prefecture, Japan. Small-scale Forestry. 2015;**14**:205. DOI: 10.1007/s11842-014-9282-6
- [50] DAISIE. *Robinia pseudoacacia* [Internet]. 2006. Available from: <http://www.europe-aliens.org/speciesFactsheet.do?speciesId=11942> [Accessed: Dec 23, 2017]
- [51] Sitzia T, Cierjacks A, de Rigo D, Caudullo G. *Robinia pseudoacacia* in Europe: Distribution, habitat, usage and threats. In: San-Miguel-Ayanz J, de Rigo D, Caudullo G, Houston

- Durrant T, Mauri A, editors. European Atlas of Forest Tree Species. Luxembourg: Office of the European Union; 2016. pp. 165-166
- [52] Carl C, Landgraf D, Maaten-Theunissen M, Biber P, Pretzsch H. *Robinia pseudoacacia* L. Flower analyzed by using unmanned aerial vehicle (UAV). Remote Sensing. 2017; **9**:1091. DOI: 10.3390/rs9111091
- [53] Institute of Food and Agricultural Sciences. *Robinia pseudoacacia* Black Locust [Internet]. 1994. Available from: <http://hort.ufl.edu/trees/ROBPSEA.pdf> [Accessed: Dec 15, 2017]
- [54] Grujić S, Grujić R, Popov-Raljić J, Komić J. Characterization of black locust (*Robinia pseudoacacia*) honey from three geographical regions of north-west Bosnia and Herzegovina. In: 7th International Congress of Food Technologist, Biotechnologists and Nutritionists; 20-23 September 2011; Opatija. 2011. pp. 274-278. DOI: 10.13140/2.1.3270.2247
- [55] Hamdan K. Crystallization of honey. Bee World. 2010;**87**:71-74. DOI: 10.1080/0005772X.2010.11417371
- [56] Beerling DJ, Perrins JM. *Impatiens glandulifera* royle (*impatiens* Roylei Walp.). The Journal of Ecology. 1993;**81**:367-382. DOI: <https://doi.org/10.2307/2261507>
- [57] Global Invasive Species Database. *Robinia pseudoacacia* [Internet]. 2009. Available from: <http://www.iucngisd.org/gisd/species.php?sc=942> [Accessed: Dec 20, 2017]
- [58] Karlsson T. Floristic notes. Svensk botanisk Tidskrift. 1978;**72**:149-159
- [59] Quezel P, Barbero M, Bonin G, Loisel R. Recent plant invasions in the Circum-Mediterranean region. In: di Castri F, Hansen AJ, Debussche M, editors. Biological Invasions in Europe and the Mediterranean Basin. Dordrecht: Kluwer Academic Publishers; 1990. pp. 51-60
- [60] Chittka L, Schürkens S. Successful invasion of a floral market. Nature. 2001;**411**:653. DOI: 10.1038/35079676
- [61] Hartmann E, Schuldes H, Kübler R, Konold W. Neophyten, Biologie, Verbreitung und Kontrolle ausgewählter Arten. Augsburg Hawksworth DL: Ecomed; 1994
- [62] Invasive Species Compendium. *Impatiens glandulifera* (Himalayan Balsam) [Internet]. 2009. Available from: <https://www.cabi.org/isc/datasheet/28766> [Accessed: Dec 20, 2017]
- [63] Enescu CM. The role of Tree-of-Heaven in Forest land reclamation. Journal of Horticulture, Forestry and Biotechnology 2014;**18**:66-69
- [64] Lee K, Han B, Cho W. The appropriate mounding height and selection of ornamental trees on consideration of the environmental characteristics in an apartment complex. Korean Journal of Environment and Ecology. 1997;**11**:137-148
- [65] Morton JF. The Australian pine or beefwood (*Casuarina equisetifolia* L.), an invasive "weed" tree in Florida. Proceedings, Florida State Horticultural Society. 1980;**93**:87-95
- [66] Elfers SC. Element Stewardship Abstract for *Casuarina equisetifolia* (Australian Pine). Arlington, Virginia: The Nature Conservancy; 1988;**1815**

- [67] Digiamberardino T. Changes in a South east Florida Coastal Ecosystem after Elimination of *Casuarina equisetifolia* [Internet]. 1986. Available from: http://wiki.bugwood.org/Casuarina_equisetifolia [Accessed: Dec 20, 2017]
- [68] Dahl N. *Casuarina equisetifolia*: Its use and future in mine rehabilitation in Northern Australia. In: Proceedings of the 3rd International Casuarina Workshop; 4-7 March 1996. Canberra: CSIRO; 1996. pp. 201-203
- [69] Midgley SJ, Byron RN, Chandler FC, Thinh HH, Vo Hung Son T, Hanh HH. Do Plants Need Passports? A Socio-Economic Study of the Role of Exotic Tree and Other Plant Species in Quang Tri Province, Vietnam. Canberra, Australia: CSIRO; 1997
- [70] Kumar V. *Casuarina equisetifolia* L.: A potential tree. International Journal of Agriculture. 2016;**3**:14-17
- [71] Pernas T, Wheeler G, Langeland K, Golden E, Purcell M, Taylor J, Brown K, Taylor DS, Allen E. Australian pine management plan for Florida. Florida Exotic Pest Plant Council. Wildland Weeds. 2013:16-19
- [72] Dolmer P, Holm MW, Strand Å, Lindegarth S, Bodvin T, Norling P, Mortensen S. The invasive Pacific oyster, *Crassostrea gigas*, in Scandinavia coastal waters: A risk assessment on the impact in different habitats and climate conditions. Institute of Marine Research. 2014;**2**:62
- [73] Walles B, Salvador de Paiva J, van Prooijen B, Ysebaer T, Smaal A. The ecosystem engineer *Crassostrea gigas* affects tidal flat morphology beyond the boundary of their reef structures. Estuarine, Coastal and Shelf Science. 2015;**154**:224-233
- [74] Ruesink JL, Lenihan HS, Trimble AC, Heiman KW, Micheli F, Byers JE, Kay MC. Introduction of non-native oysters: Ecosystem effects and restoration implications. Annual Review of Ecology, Evolution and Systematics. 2005;**36**:643-689. DOI: 10.1146/annurev.ecolsys.36.102003.152638
- [75] Martínez OJA. Flooding and profuse flowering result in high litterfall in novel *Spathodea campanulata* forests in northern Puerto Rico. Ecosphere. 2011;**2**:1-25. DOI: 10.1890/ES11-00165.1
- [76] Abelleira O. Observations on the fauna that visit African tulip tree (*Spathodea campanulata* Beauv.) forests in Puerto Rico. Acta Científica. 2008;**22**:37-42
- [77] Rivero JA, Mayorga H, Estremera E, Izquierdo I. Sobre el Bufo lemur (Cope) (Amphibia, Bufonidae). Caribbean Journal of Science. 1980;**153**:33-40
- [78] Biaggi V. Las Aves de Puerto Rico. 4rd ed. Chicago: Editorial de la Universidad de Puerto Rico; 1997. 389 p
- [79] Dold AP, Cocks ML. The medicinal use of some weeds, problem and alien plants in the Grahamstown and Peddie districts of the Eastern Cape, South Africa. South African Journal of Science. 2000;**96**:467-473

- [80] Maema LP, Potgieter M, Mahlo SM. Invasive alien plants species used for the treatment of various diseases in Limpopo Province, South Africa. *African Journal of Traditional, Complementary and Alternative Medicines*. 2016;**13**:223-231
- [81] Invasive Plant Atlas of the United States. *Ailanthus altissima* (P.Mill.) Swingle [Internet]. 2016. Available from: <https://www.invasiveplantatlas.org/subject.html?sub=3003> [Accessed: Jan 21, 2018]
- [82] Mastelić J, Jerković I. Volatile constituents from the leaves of young and old *Ailanthus altissima* (P.Mill.) Swingle tree. *Croatia Chemica Acta*. 2002;**75**:189-197
- [83] Kožuharova E, Lebanova H, Getov I, Benbassat N, Kochmarov V. *Ailanthus altissima* (Mill.) Swingle—A terrible invasive pest in Bulgaria or potential useful medicinal plant? *Bothalia Journal*. 2014;**44**:213-230
- [84] Okunade AL, Bikoff RE, Casper SJ, Oksman A, Goldberg DE, Lewis WH. Antiplasmodial activity of extracts and quassinoids isolated from seedlings of *Ailanthus altissima* (Simaroubaceae). *Phytotherapy Research*. 2003;**17**:675-677
- [85] Medicinal plants *Ailanthus altissima* [Internet]. 2014. Available from: <http://medicinal-plants.us/ailanthus-altissima> [Accessed: Jan 21, 2018]
- [86] Kowarik I, Saumel I. Biological flora of Central Europe: *Ailanthus altissima* (Mill.) Swingle. *Perspectives in Plant Ecology Evolution and Systematics*. 2007;**8**:207-237. DOI: 10.1016/j.ppees.2007.03.002
- [87] Mergen F. A toxic principle in the leaves of *Ailanthus*. *Botanical Gazette*. 1959;**121**:32-36
- [88] Sladonja B, Poljuha D, Sušek M, Dudaš S. Herbicidal effect of *Ailanthus altissima* leaves water extracts on *Medicago sativa* seeds germination. In: 3rd Conference VIVUS – On Agriculture, Environmentalism, Horticulture and Floristics, Food Production and Processing and Nutrition; Organiser: Biotechnical Centre Naklo. 14-15 November 2014; Naklo. 2014. pp. 476-481
- [89] Gatti E. Micropropagation of *Ailanthus altissima* and in vitro heavy metal tolerance. *Biologia Plantarum*. 2008;**52**:146-148. DOI: <https://doi.org/10.1007/s10535-008-0030-7>
- [90] Abbaslou H, Bakhtiari S. Phytoremediation potential of heavy metals by two native pasture plants (*Eucalyptus grandis* and *Ailanthus altissima*) assisted with AMF and fibrous minerals in contaminated mining regions. *Pollution*. 2017;**3**:471-486. DOI: 10.7508/PJ.2017.03.012
- [91] Trueman RJ, Erber L. Invasive species may offer advanced phytoremediation of endocrine disrupting chemicals in aquatic ecosystems. *Emirates Journal of Food and Agriculture*. 2013;**25**:648-656. DOI: 10.9755/ejfa.v25i9.16393
- [92] Pratas JC, Paulo PJC, Venkatachalam FP. Potential of aquatic plants for phytofiltration of uranium-contaminated waters in laboratory conditions. *Ecological Engineering*. 2014;**69**:170-176

- [93] Rebele F, Lehmann C. Phytoextraction of cadmium and phytostabilisation with mugwort (*Artemisia vulgaris*). *Water Air and Soil Pollution*. 2011;**216**:93-103. DOI: 10.1007/s11270-010-0517-7
- [94] Porebska G, Ostrowska A. Metal accumulation in wild plants: Implications for phytoremediation. *Polish Journal of Environmental sciences*. 1999;**8**:433-442
- [95] Silva CFL, Schirmer MA, Maeda RN, Barcelos CA, Pereira N. Potential of giant reed (*Arundo donax* L.) for second generation ethanol production. *Electronic Journal of Biotechnology*. 2015;**18**:10-15. DOI: <https://doi.org/10.1016/j.ejbt.2014.11.002>
- [96] Krička T, Matin A, Bilandžija N, Jurišić V, Antonović A, Voća N, Grubor M. Biomass valorization of *Arundo donax* L., *Miscanthus × giganteus* and *Sida hermaphrodita* for biofuel production. *International Agrophysics*. 2017;**31**:575-581. DOI: 10.1515/intag-2016-0085
- [97] Vimal CP, Kripal S, Jay SS, Akhilesh K, Bajrang S, Rana PS. *Jatropha curcas*: A potential biofuel plant for sustainable environmental development. *Renewable and Sustainable Energy Reviews*. 2012;**16**:2870-2883. DOI: <https://doi.org/10.1016/j.rser.2012.02.004>
- [98] Parawira W. Biodiesel production from *Jatropha curcas*: A review. *Scientific Research and Essays*. 2010;**5**:1796-1808
- [99] Ndong R, Montréjaud-Vignoles M, Saint Girons O, Benoît G, Pirot R, Domergue M, Sablayrolles C. Life cycle assessment of biofuels from *Jatropha curcas* in West Africa: A field study. *GCB Bioenergy*. 2009;**1**:97-210. DOI: 10.1111/j.1757-1707.2009.01014.x
- [100] Voanews EF. Artist Gives Invasive Plant Species New Life [Internet]. 2006. Available from: <https://www.voanews.com/a/artist-gives-invasive-plan-species-new-life/4081087.html> [Accessed: Jan 1, 2018]
- [101] Abelleira O, Lugo AE, Randall MW. Post sugar cane succession in moist alluvial sites in Puerto Rico. In: Randall MW, editor. *Post-Agricultural Succession in the Neotropics*. Edmond: Springer; 2008. pp. 73-92. DOI: 10.1007/978-0-387-33642-8_3
- [102] Fang WL, Jie X, Zhi Dond QZ, Duns G, Shuang CJ. Pulping utilization of *Spartina alterniflora* (common cordgrass) based on fiber characteristics. *Applied Mechanics and Materials*. 2012:130-134. DOI: 10.4028/www.scientific.net/AMM.130-134.833-837
- [103] Scarpa A, Guerci A. Various uses of the castor oil plant (*Ricinus communis* L.) a review. *Journal of Ethnopharmacology*. 1982;**5**:117-137
- [104] Priyanka S, Anees AS, Jaya D, Vishal S. Pharmacological properties of *Datura stramonium* L. as a potential medicinal tree: An overview. *Asian Pacific Journal of Tropical Biomedicine*. 2012;**2**:1002-1008. DOI: [https://doi.org/10.1016/S2221-1691\(13\)60014-3](https://doi.org/10.1016/S2221-1691(13)60014-3)
- [105] Martins do Rosario M, Arantes S, Candeias F, Tinoco MT, Cruz-Morais J. Antioxidant, antimicrobial and toxicological properties of *Schinus molle* L. essential oils. *Journal of Ethnopharmacology*. 2014;**151**:485-492. DOI: <https://doi.org/10.1016/j.jep.2013.10.063>

- [106] Eryiğit T, Yıldırım B, Ekici K, Çirka M. Chemical composition, antimicrobial and anti-oxidant properties of *Schinus molle* L. essential oil from Turkey. *Journal of Essential Oil Bearing Plants*. 2017;**20**:570-577. DOI: 10.1080/0972060X.2017.1304286
- [107] Liu Y, Zhang W, Xu C, Li X. Biological activities of extracts from loquat (*Eriobotrya japonica* Lindl.): A review. *International Journal of Molecular Sciences*. 2016;**17**. DOI: 10.3390/ijms17121983
- [108] Gajalakshmi S, Rajeswari D. Pharmacological activities of *Catharanthus roseus*: A perspective review. *International Journal of Pharma and Bio Sciences*. 2013;**4**:431-439
- [109] Nammi S, Boini KM, Lodagala S, Babu SBR. The juice of fresh leaves of *Catharanthus roseus* Linn. reduces blood glucose in normal and alloxan diabetic rabbits. *BMC Complementary and Alternative Medicine*. 2003;**3**:1-4. DOI: 10.1186/1472-6882-3-4
- [110] Azam MM, Mamun-Or-Rashid ANM, Towfique NM, Sen MK, Nasrin S. Pharmacological potentials of *Melia azedarach* L. – A review. *American Journal of BioScience*. 2013;**1**:44-49. DOI: 10.11648/j.ajbio.20130102.13
- [111] Viqar KA, Uddin AQ, Ramzan Mir M, Shukla I, Ali Khan A. Antibacterial efficacy of the seed extracts of *Melia azedarach* against some hospital isolated human pathogenic bacterial strains. *Asian Pacific Journal of Tropical Biomedicine*. 2011;**1**:452-455. DOI: [https://doi.org/10.1016/S2221-1691\(11\)60099-3](https://doi.org/10.1016/S2221-1691(11)60099-3)
- [112] Al-Rubae YA. The potential uses of *Melia azedarach* L. as pesticidal and medicinal plant, review. *American-Eurasian Journal of Sustainable Agriculture*. 2009;**3**:185-194
- [113] Morrison KD, Reekie EG, Jensen KIN. Biocontrol of common St. Johnswort (*Hypericum perforatum*) with *Chrysolina hyperici* and a host-specific *Colletotrichum gloeosporioides*. *Weed Technology*. 1998;**12**:426-435
- [114] Invasive Species Compendium *Pueraria montana* var. lobata (kudzu) [Internet]. 2007. Available from: <https://www.cabi.org/isc/datasheet/45903> [Accessed: Jan 15, 2018]

