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Invasive Alien Plant Species: A Tool for Restoring Degraded Lands or a Threat to Native Ecosystems!

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ABSTRACT

Global decision-making organizations confront significant challenges in implementing scientific management of plant species invasions of native flora due to extensive gaps in knowledge on the distribution and impact of invasive plant species on ecosystems. Invasive alien species (IAS) can indeed, have both positive and harmful effects on ecosystems. When applied properly, IAS has the potential to hasten the restoration process, deliver ecosystem services, and strengthen weakened ecosystems. Native species may be displaced when IAS becomes invasive. They also have the potential to disrupt ecosystem functioning. Therefore, before deciding to use IAS in restoration, it is essential to thoroughly weigh the advantages and disadvantages. Managing invasive plant species and using them to restore ecosystems at the same time requires the development of effective solutions. This article examines the benefits and drawbacks of IAS for ecologically restoring damaged land. The article is useful for learning about the effects of IAS on deteriorating land.

Keywords *Native flora; Invasive alien species; Restoration; Weakened ecosystem; Effective solutions.*

Introduction

A species is considered invasive when it appears outside of its natural habitat, spreads quickly, and poses a threat to the health of humans, other species, communities, or entire ecosystems. They go by a variety of names, including exotic, foreign, introduced, non-native, and non-indigenous species. All invasive species, though, are not dangerous. According to Singh et al. (2022), invasive alien species (IAS) are subsets of alien species of plants, animals, fungi, viruses, and bacteria that pose a threat to ecosystems, habitats, or species that are important to the economy or environment. According to Richardson et al. (2011), invasive species refer to non-native species that can establish self-sustaining populations across multiple generations. These species can produce a significant number of offspring at a considerable distance from their original introduction site, thereby enabling them to spread over extensive geographical areas. Consequently, invasive species have the potential to adversely impact the habitats they invade. An invasive plant species is characterized by its ability to establish and proliferate in a new habitat, often resulting in detrimental effects on the environment. Native flora can experience a competitive disadvantage when confronted with invasive species, resulting in alterations to ecological processes and a reduction in ecosystem resilience (Ladouceur et al., 2022).

Different stages in the process of invasion

There are five stages of invasion, according to Catford et al. (2009): the first is the movement of plants or plant propagules to the new location, known as *transport*; the second is their arrival in the new location, known as *introduction*; the third involves the survival of the introduced plant, known as *colonization; and* the fourth stage, known as *naturalization*, involves survival and reproduction, allowing the pioneer population to be seen. The fifth stage of *spread* includes the dispersal of propagules and the spread of population outside of the area where they were first introduced.

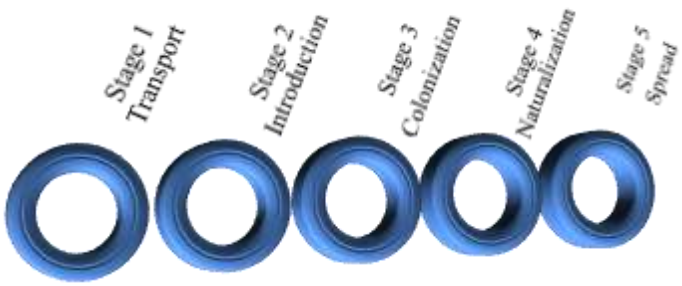

Figure 1 Different stages in the process of invasion

How do alien species invasions take place?

The process of invasion can be summarized as follows (Pysek P. and Richardson 2010).

1. For the invasion to take place, a taxon must overcome various geographic and climatic barriers through intentional or accidental transport.
2. Establishment occurs because successful reproduction overcomes all the barriers.
3. Survival and persistence in overcoming the biotic and local environmental barriers
4. Expanding the size of the population to spread to new regions will overcome the dispersal and habitat barriers.
5. adapting to the abiotic environment and biota in the new area.

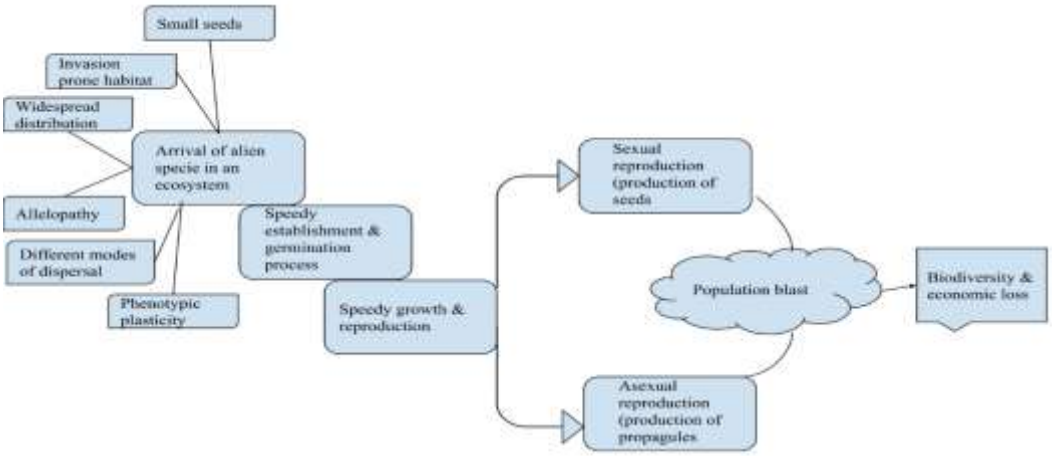

Figure 2 Systematic diagram of the life cycle of invasive alien species in an ecosystem

World's Most Invasive Plant Species Table 1 mentions some of the invasive species that are commonly found in various parts of the world (Lowe et al., 2000; Luque et al. 2013)

Table 1 Invasive plant species found in the world.

S.N.	Botanical Name	Common Name	Plant Type	Country of Origin
1	*Acacia mearnsii*	Australian acacia, black wattle	Legume	Australia

2	*Ardisia elliptica*	shoe button Ardisia	Tree	India, Sri Lanka, Indochina, Malaysia, Indonesia, and New Guinea.
3	*Arundo donax*	Arundo grass, bamboo reed, reed grass, river cane	Grass	Tropical\Mediterranean regions of Eurasia, Southern Asia, and Europe
4	*Cecropia peltata*	Snakewood tree, Trumpet tree	Tree	Central and South America, Caribbean islands, Malaysia, Africa, and the Pacific Islands
5	*Chromolaena odorata*	Bitter bush	Shrub	South America and Central America
6	*Cinchona pubescens*	Quinine, quinoa, red cinchona,	Tree	Costa Rica, Panama, Venezuela, Colombia, Ecuador, Peru, and Bolivia
7	*Clidemia hirta*	Clidemia, faux soap bush, Vuti	Shrub	Tropical America, South and Central America, and the Caribbean islands
8	*Eichhornia crassipes*	Floating water hyacinth, Jal kumbhi, water hyacinth, water orchid,	Weed	Present on all continents except Antarctica.
9	*Euphorbia esula*	Euphorbia, faitours-grass, Hungarian spurge, leafy spurge,	Herb	Europe and temperate Asia
10	*Hedychium gardnerianum*	Awapuhi kahili, Jin Jiang hua, Garland-lily, wild ginger	Herb	Northern India, Nepal, and Bhutan
11	*Hiptage benghalensis*	Chandravalli, Madhalata, Madhavi, Madhumalati,	Shrub	India, Southeast Asia, and the Philippines
12	*Imperata cylindrica*	Cogon grass,	Grass	Tropical and subtropical Asia, Micronesia, Melanesia, Australia, Africa, and Southern Europe, Asia
13	*Lantana camara*	Ach man, angel lips, big sage, blacksage, lantana, lantana wildtype	Shrub	Central and South America, tropical and sub-tropical countries worldwide.
14	*Leucaena leucocephala*	subabul, wild mimosa, wild tamarind,	Tree	Southern Mexico and northern Central America (Belize and Guatemala), naturalized throughout the tropics including parts of Asia
15	*Lythrum salicaria*	Purple loosestrife, rainbow weed	Herb	Europe, temperate Asia, and northwest Africa
16	*Melaleuca quinquenervia*	Bottlebrush tree, broadleaf paperbark tree	Tree	New Caledonia, Papua New Guinea, and coastal eastern Australia
17	*Miconia calvescens*	Bush currant, cancer vert, purple plague, velvet tree	Tree	South America
18	*Mikania micrantha*	American rope, Chinese creeper, mile-a-minute weed,	Creeper	North, Central, and South America.
19	*Mimosa pigra*	Catclaw, Putri malu, Semalu gajah,	Shrub	Tropical America, Mexico, Central America, and Northern Argentina
20	*Morella faya*	Candleberry, fayatree, fire bush, fire tree	Tree	Azores, Madeira Islands, and the Canary Islands

21	*Pinus pinaster*	Cluster pine, Maritime pine	Tree	Western Mediterranean Basin and the southern Atlantic coast of Europe
22	*Prosopis glandulosa*	Honey mesquite, Mesquite-Busch, Texas mesquite	Shrub/tree	Southwestern United States and Northern Mexico
23	*Pueraria montana var. lobata*	Akataha, foot-a-night vine, Japanese arrowroot, Kudzu,	Climber	*East Asia, China, Japan, and Korea*,
24	*Rubus ellipticus*	Asian wild raspberry, broad-leafed bramble, Ceylon blackberry, golden evergreen raspberry	Herb	China, Nepal, India, Pakistan, and the Philippines
25	*Schinus terebinthifolius*	Brazilian holly, Brazilian pepper tree, Christmas berry, Mexican pepper,	Shrub/tree	Argentina, Paraguay, and Brazil
26	*Spathodea campanulata*	African tulip tree, fireball, flame of the forest, fountain tree, Indian Cedar	Tree	Africa
27	*Tamarix ramosissima*	Salt cedar, Tamarix	Tree	Asia and Europe

Significance of invasive alien species in a degraded ecosystem

It is unproductive to universally condemn alien species when trying to restore ecosystems. If alien species offer crucial ecological or socioeconomic functions, their presence can be tolerated or even utilized to advantage in areas where it does not unreasonably harm neighboring ecosystems. Non-native species have the potential to benefit the environment and the economy by accelerating or improving restoration. When alien species are present, risk is always a concern, but when the goal of restoration is the reassembly of a biological community, greater risk-taking is justifiable.

Blumenthal (2006) investigated the spread of alien invasive plant species in ecosystems that are primarily home to native species. This has been linked to several factors, such as their ability to adapt to better soil resource availability (Davis et al., 2000) and their ability to grow quickly and reproduce copiously. The availability of soil resources can be enhanced through both natural and anthropogenic disturbances, leading to significant implications for plant communities (Cole et al., 2021). Former studies have indicated that increased levels of soil nutrients tend to benefit fast-growing invasive species, which are characterized by their ability to exploit resources, as opposed to slower-growing native species that exhibit higher resource use efficiency. Numerous researchers have observed this pattern in various ecosystems, including tropical forests (Burke & Grime, 1996; Stohlgren et al., 1999; Hobbs, 1989; Ostertag & Verville, 2002; Daehler, 2003; Funk, 2008; Ostertag et al., 2008; Cole et al., 2021). This could be a good alternative or addition to traditional methods of restoration like pulling weeds by hand or using chemicals (Blumenthal et al., 2003; Corbin & D'Antonio, 2009) if dominant native and invasive species react differently to changes in resource availability. This would allow changing the levels of nutrients in the soil to help native species grow and stop non-native invasive species from spreading.

The environmental impact of invasive plant species is often viewed as negative, but it is important to acknowledge that there may be potential positive implications associated with their presence (Rai and Singh, 2020). Examples illustrating the impacts are mentioned below.

1. The positive impact of invasive plant species is their potential to enhance biodiversity. This phenomenon occurs due to the ability of these species to generate novel habitats and food resources for indigenous species. This phenomenon can provide notable benefits in ecosystems that have experienced substantial degradation.
2. The restoration of degraded soils necessitates the utilization of invasive plant species. These plants possess the capacity to sequester heavy metals and other pollutants within their own tissues, rendering them well-suited for this purpose. The utilization of this methodology facilitates the remediation of contaminated soils, thereby rendering them suitable for the necessary ecological restoration endeavors.
3. The existence of specific invasive plant species can contribute to the facilitation of ecosystem services, encompassing erosion control, water purification, and pollination, among others. This phenomenon possesses the capacity to confer benefits upon both Homo sapiens and other species within the animal realm.

According to a 2013 study by Barney et al., some invasive plant species have cultural value because people use them for food or medicine (Maema et al., 2016). The utilization of the invasive plant species known as kudzu (*Pueraria montana*) has been employed as a means of soil remediation to address the issue of soil contamination caused by lead and various other heavy metals. Kudzu can accumulate various metals within its tissues, subsequently facilitating their extraction from the soil. The utilization of the invasive plant species *Tamarix spp*., commonly known as salt cedar, has been observed in the southwestern region of the United States to offer shade and refuge for indigenous avian and mammalian species. Salt cedar (*Tamarix spp.)* exhibits

rapid growth rates and can establish dense populations, thereby offering valuable habitats for indigenous species. Gaggini et al. (2018) studied invasive species like *Impatiens glandulifera* and found that it tends to increase the soil's fungal and bacterial diversity as it invades any degraded area. *Fallopia japonica* (Japanese knotweed) is yet another species that can survive in stressful acute salt conditions (Rouifed et al., 2012).

It is imperative to acknowledge that the favorable attributes of invasive plant species ought not to be exaggerated. Usually, the adverse consequences of invasive plant species surpass the beneficial ones. Nevertheless, it is imperative to contemplate the potential advantageous facets of invasive plant species during the formulation of management strategies.

The Impact of Invasive Plants: Economic and Environmental

Invasive alien species refer to organisms that have been introduced into an ecosystem, either through natural means, unintentional occurrences, or deliberate actions, in a habitat that is not their native environment (Pejchar and Mooney 2009; Shackleton et al. 2019; Bartz and Kowarik 2019). Following a specific duration, individuals undergo adaptation to their novel surroundings, subsequently initiating the process of colonization. According to the United Nations Development Programme (UNDP), these species are identified as the second most significant contributor to the decline of global biodiversity. The phenomenon of globalization has facilitated increased access to previously inaccessible regions, diverse cultural experiences, and interactions with individuals from various backgrounds (United Nations, 2021).

According to IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), these incursions are becoming more frequent and significantly threatening the survival of approximately one million species worldwide (IBPES, 2019). These factors can give rise to a multitude of issues, including functioning as predators that impede the proliferation of indigenous species, modifying habitats by inducing physical and chemical alterations in the soil, engaging in competition for resources and territory, hybridizing with native species, and introducing novel parasites and diseases.

Economic Impact Related to Invasive Plant Species

Several economic consequences are associated with IAPS, including the cost of their management. Cost involves the mechanical, biological, and chemical methods through which the IAPS are controlled or removed. Moreover, monetary funds are allocated toward research and monitoring initiatives (Lorenzo and Morais, 2023). Crop productivity also gets reduced because of IAPS, which may lead to job losses, particularly in sectors such as forestry. The presence of IAPS affects international trade and tariffs, which has additional economic effects (Haines, 2016).

Indirect Economic Effect refers to the secondary effects that arise because of a particular economic event or activity.

The concept of indirect economic impacts refers to the secondary effects that arise because of a particular economic activity or event. The activity itself does not directly cause these effects. The quantification of indirect economic impacts caused by invasive species can pose greater challenges and, in certain instances, result in significantly more devastating consequences. Illustrative instances encompass the deprivation of ecosystem services, namely the escalation of flooding and the diminished capacity to withstand climate change. Additionally, there is a decline in biodiversity, reduced resource generation, repercussions on tourism and recreational activities, as well as a decrease in property values (Souza, 2018).

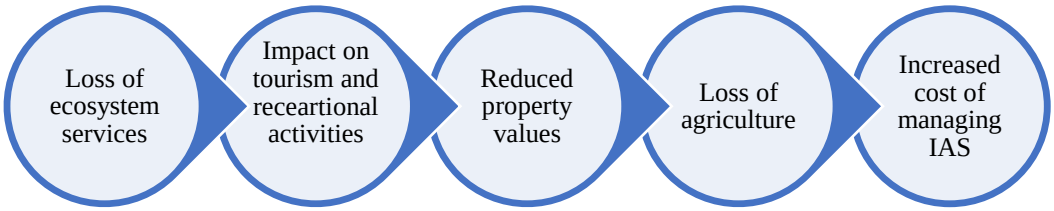

Figure 4 Economic impacts posed by invasive plant species.

The economic costs associated with invasive species exhibit a notable reduction when financial resources are allocated toward proactive measures such as prevention and early detection. Once an invasive species proliferates, the cost and efficiency of its management increase exponentially.

Turbelin et al. (2023) conducted a study that aimed to assess the economic implications of invasive species in comparison to natural hazards. The researchers utilized data from version 4.1 of the InvaCost database to quantify these costs. The findings indicated that the economic losses incurred globally due to biological invasions, amounting to $1,208 billion, were comparable in scale to the economic losses resulting from storms ($1,913.6 billion) and earthquakes ($1,139.4 billion). These results underscore the urgency of implementing measures and policy reforms aimed at safeguarding the global economy. The research also showed that the costs associated with invasions increased more quickly than the costs associated with natural disasters, as shown by a significant 702% increase in reported losses between the years 1980–1999 and 2000–2019.

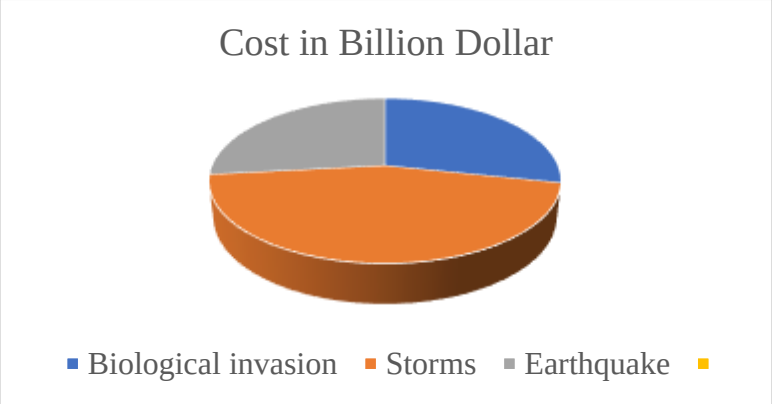

Figure 3 Comparison between the global economic cost of biological invasion, storms, and earthquake

Environmental impact related to invasive plant species.

In comparison to mainland areas, invasive alien plant species (IAPS) have a more significant impact on ecosystem functioning in island environments (Pysek et al., 2012). Research has provided evidence that IAPS has an impact on the functioning of an ecosystem through three fundamental mechanisms. Firstly, they lead to a decrease in the biological diversity of vernacular plants and animals. Secondly, they cause significant alterations in the physico-chemical properties of soils, primarily through allelopathy. Lastly, they contribute to the increased sensitivity of ecosystems to changes in fire patterns.

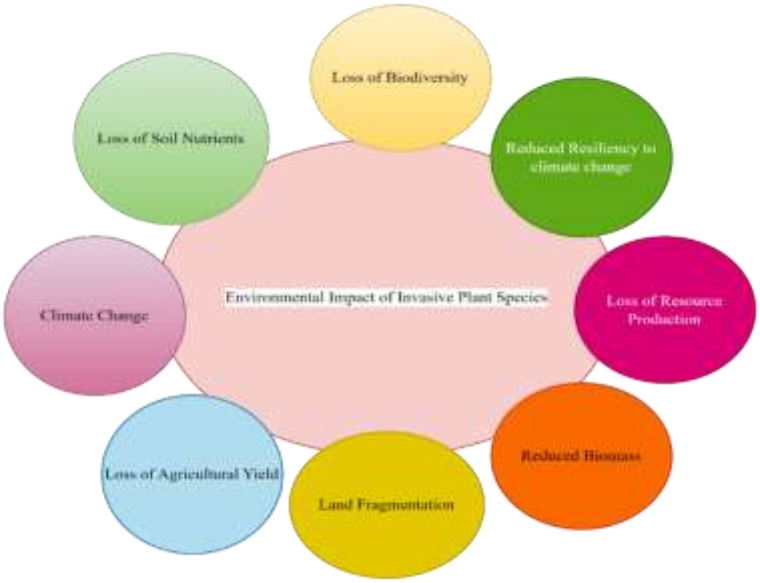

Figure 4 Impact of Invasive Plant Species on the Environment

A well-documented effect of IAPS introduction and dissemination is the dwindling variety of native plant species. Ecosystem services, ecology, and the climate could all take a hit if biodiversity continues to decline. An "invasion meltdown" could occur if introduced alien plant species (IAPS) compete fiercely with native plant species (LFS) for vital nutrients that drive ecosystem function. One invasive species' entry into a new habitat might pave the way for other invasions of non-native species, according to the invasion breakdown concept put out by Simberloff and Von Holle (1999). It is worth noting that there is a fairly regular pattern globally in the initial impact of IAPS, which is the reduction in biodiversity.

According to Gan (2009), local wildlife is negatively impacted by the presence of IAPS. In Chinese wetlands, *Spartina alterniflora* is displacing native macrophytes such as *Scirpus mariqueter* and *Phragmites australis*. Because of this, bird populations have declined because birds are no longer able to forage freely or migrate as easily (Gan, 2009). According to Pejchar and Mooney (2009), soil erosion can occur because of changes in soil stability caused by IAPS. Soil in grassland ecosystems can undergo significant changes with the introduction of invasive non-indigenous alien plant species (IAPS) such as *Centaurea stoebe*, *Euphorbia esula*, and *Bromus tectorum* (Gibbons 2017). An invasive alien plant species (IAPS) in the Mediterranean ecosystem, *Acacia dealbata*, has been reported to reduce native plant diversity by damaging soil chemistry and microbial function (Lazzaro, 2014).

Huangfu and Li (2019) say that IAPS *Flaveria bidentis* grows better in soils that have more nitrogen than *Amaranthus retroflexus*, a non-native species that competes with it, and Bidens sp., a native species that also grows there. It was hypothesized that *Flaveria bidentis* exhibits a capacity to regulate the increased nitrogen levels in the soil, thereby facilitating its growth through interactions with other non-native and native plant species. The proliferation of *Opuntia stricta* in the African region has had a detrimental impact on both the environment and the economy. When there is a decrease in the availability

of fodder and a corresponding decline in the welfare of livestock, these phenomena can also harm the sustenance of the indigenous population (Shackleton et al. 2017).

Role of IAPS in Ecological Restoration

IAPS poses a significant risk to the health of ecosystems and global biodiversity. The introduction of alien plant species causes the displacement of native species, modifies the ecosystem, and decreases the services offered by an ecosystem (Gupta et al., 2021; Heshmati, 2019). In-situ conservation practices can benefit ecorestoration practices. IAPS speeds up the re-establishment of vegetation on degraded lands. This is quite significant in degraded lands where ecological restoration is taking a very long time or the native plant species have become extinct (Atkinson, 2022).

IAPS can develop or re-develop the habitat for animal species that are indigenous to an area. This may be helpful for endangered or threatened animal species. IAPS also improves the soil quality of water retention in degraded lands. This may be beneficial to indigenous and non-indigenous species (Benayas et al., 2009).

There are risks associated with the use of IAPs in ecological restoration. The term "invasive alien species" refers to foreign organisms that can displace native species. Invasive alien species, also known as IAPs, can harm native species when they interfere with ecosystem processes. A case-by-case analysis is required before deciding whether to use invasive alien plants (IAPs) for ecological restoration. It is essential to weigh the benefits and drawbacks associated with adopting restoration practices (Brudvig and Catano, 2021).

Prospects of IAPS in the Ecological Restoration of Degraded Lands

The role of IAPS in ecological restoration is a highly debatable topic. More research and development strategies are needed to find out the role of IAPS in benefiting degraded lands. IAPs can, on the one hand, have several detrimental effects on ecosystems (Bullock et al. 2011), such as:

- Outcompeting native species
- Modifying nutrient cycles
- Interfering with pollination networks
- Increasing risk of fire
- Limiting the supply of water

IAPs, however, may also offer some potential advantages for ecological restoration (Brudvig and Catano, 2021), including:

- quickly covering the ground to stabilize the soil.
- Nitrogen fixation
- Generating biomass that can be used to make items like fuel
- Attracting beneficial insects and pollinators

Depending on the IAP species, the ecosystem under consideration, and the restoration objectives, the relative relevance of these positive and negative effects will change. IAPs may be a useful restorative tool in some circumstances but a significant barrier in others.

In general, before making a choice, it is crucial to thoroughly weigh the advantages and disadvantages of employing IAPs in ecological restoration. The optimal course of action will change based on the circumstances; there is no universal solution.

According to Huang et al. (2019), IAPs in ecological restoration have the following potential:

- As a restoration tool, there are a variety of ways to use IAPs to rehabilitate degraded lands. For instance, they can be utilized to improve soil quality, cover bare spots, and draw pollinators. IAP use, however, carries possible dangers that should be carefully considered because they may harm ecosystems as well.
- As a source of bioproducts, IAPs can provide a range of bioproducts, including chemicals for industrial use, biomass for fuel, and fiber for textiles. This might offer financial motivation for employing IAPs to restore degraded lands.
- As a framework for comprehending invasion, insights into the causes of invasion and the ways that invasive species affect ecosystems can be gained from research on IAPs. This information could be utilized to create more efficient management plans for invasive species and to stop further invasions.

Conclusion

There is a general lack of clarity regarding the likelihood of usage of IAPS in ecological restoration. IAPs can perform multiple functions, including serving as an origin of bioproducts that are a tool for restoration, and an illustration for comprehending invasion. In every circumstance, it will be necessary to conduct a thorough evaluation of the relative significance of these prospective rewards and hazards. Both societal acceptance and economic considerations need to be considered when choosing the future course of action for the IAPS administration. The abolition of the IAPS involves a significant amount of money for management purposes. Because the influence of IAPS on environments varies widely depending on the socio-ecological contexts in which they are utilized, future research must incorporate a cost-benefit analysis to safeguard the benefits to livelihoods. Using phytoremediation technology and biotechnological advances to use the biomass of the chosen IAPS may help with their long-term environmental management and get rid of harmful substances like heavy metals and particles at the same time.

References

1. Singh, J.S., Singh, S.P., Gupta, S.R. 2022. Biological invasion: process, impacts, and prevention, in Ecology Environmental Science and Conservation, ISBN 978-93-837-4600-2, S. Chand Publishing.
2. Richardson, D.M., Pysek, P., Carlton, J.T. 2011. A compendium of essential concepts and terminology in invasion ecology. In: Fifty Years of Invasion Ecology: The Legacy of Charles Elton, Richardson D.M. (ed) Chichester, U.K., Wiley-Blackwell pp. 409-420.
3. Ladouceur, E., Shackelford, N., Bouazza, K., Brudvig, L., Bucharova, A., Conradi, T. et al. 2022. Knowledge sharing for shared success in the decade on ecosystem restoration. Ecological Solutions and Evidence, 3, e12117.
4. Catford, J.A., Jansson, R., Nilsson, C. 2009. Reducing redundancy in invasion ecology by integrating hypothesis into a single theoretical framework. Diversity and Distribution, 15, 22-40.
5. Pysek, P., Richardson, D.M. 2010. Invasive species, environmental change and management, and health. Annu. Rev. Environ. Resour. 35,25–55.
6. Lowe, S., Browne, M., Boudjelas, S., De Poorter, M. 2000. 100 of the World's Worst Invasive Alien Species A selection from the Global Invasive Species Database. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), 12pp. First published as a special lift-out in Aliens 12, December 2000. Updated and reprinted version: November 2004.
7. Luque, G.M., Bellard, C., Bertelsmeier, C., Bonnaud, E., Genovesi, P., Simberloff D., & Courchamp, F. 2013. Alien species: *Monster fern makes the IUCN invader list*. Available via http://www.iucngisd.org/gisd/100_worst.php
8. Blumenthal, D.M. 2006. Interactions between resource availability and enemy release in plant invasion. Ecology Letters, 9,887–895.
9. Davis, M.A., Grime, J.P., Thompson, K. 2000. Fluctuating resources in plant communities: a general theory of invisibility. Journal of Ecology, 88, 528-53
10. Cole, R.J., Soper, F.M., Litton, C.M. et al. 2021. Restoration benefits of soil nutrient manipulation and weeding in invaded dry and wet tropical ecosystems in Hawaii, Restoration Ecology, 29, No. 5, e13390
11. Burke, M.J.W. Grime, J.P. 1996. An experimental study of plant community invasibility. Ecology 77, 776– 790.
12. Stohlgren, T.J., Binkley, D., Chong, G.W. et al. 1999. Exotic plant species invade hot spots of native plant diversity. Ecological Monographs 69, 25– 46.
13. Hobbs, R.J. (1989). The nature and effects of disturbance relative to invasions. Pages 389– 401. In: JA Drake, HA Mooney (eds) Biological invasions a global perspective. Wiley, New York.
14. Ostertag, R., Verville, J.H. 2002. Fertilization with nitrogen and phosphorus increases the abundance of non-native species in Hawaiian montane forests. Plant Ecology 162, 77– 90
15. Daehler, C.C. 2003. Performance comparisons of co-occurring native and alien invasive plants: implications for conservation and restoration. Annual Reviews in Ecology, Evolution and Systematics 34,183– 211.
16. Funk, J.L. 2008. Differences in plasticity between invasive and native plants from a low-resource environment. Journal of Ecology 96, 1162–1173.
17. Ostertag, R., Giardina, C.P., Cordell, S. 2008. Understory colonization of eucalyptus plantations in Hawai'i in relation to. light and nutrient levels. Restoration Ecology 16, 475– 485.
18. Blumenthal, D.M., Jordan, N.R., Russelle, M.P. 2003. Soil carbon addition controls weeds and facilitates prairie restoration. Ecological Applications 13, 605– 615.

19. Corbin, J.D., D'Antonio C.M. 2009. Effects of exotic species on soil nitrogen cycling: implications for restoration. Weed Technology 18, 1464– 1467.

20. Kumar Rai, P., & Singh, J. S. (2020). Invasive alien plant species: Their impact on environment, ecosystem services and human health. Ecological indicators, 111, 106020. https://doi.org/10.1016/j.ecolind.2019.106020

21. Maema, L. P., Potgieter, M., Mahlo, S. M. 2016. Invasive Alien Plant Species Used For The Treatment Of Various Diseases In Limpopo Province, South Africa. African journal of traditional, complementary, and alternative medicines, 13(4), 223–231. https://doi.org/10.21010/ajtcam.v13i4.29

22. Gaggini, L., Rusterholz, H., Baur, B. 2018. The invasive plant *Impatiens glandulifera* affects soil fungal diversity and the bacterial community in forests. Appl. Soil Ecol. 124,335–343.

23. Rouifed, S. 2012. Invasive knotweeds are highly tolerant to salt stress. Environmental Management, 50(6),1027–1034.

24. Pejchar, L., Mooney, H.A. 2009. Invasive species, ecosystem services and human well-being. Trends Ecol. Evol. 24(9), 497–504.

25. Shackleton, R.T., Shackleton, C.M., Kull, C.A. 2019. The role of invasive alien species in shaping local livelihoods and human well-being: a review. Journal of Environment Management, 229,145–157. https://doi.org/10.1016/j.jenvman.2018.05.007.

26. Bartz, R., Kowarik, I. 2019. Assessing the environmental impacts of invasive alien plants: a review of assessment approaches. NeoBiota, 43,69–99.

27. United Nations 2021. A New Global Framework for Managing Nature Through 2030: 1st Detailed Draft Agreement Debuts Available via https://www.un.org/sustainabledevelopment/blog/2021/07/a-new-global-framework-for-managing-nature-through-2030-1st-detailed-draft-agreement-debuts/

28. IPBES 2019. Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. 1148 pages. https://doi.org/10.5281/zenodo.3831673

29. Lorenzo, P., Morais, M. C. 2023. Strategies for the Management of Aggressive Invasive Plant Species. Plants, 12(13), 2482. MDPI AG. Available via http://dx.doi.org/10.3390/plants12132482

30. Haines, A. 2016. Addressing challenges to human health in the Anthropocene epoch—an overview of the findings of the Rockefeller/Lancet Commission on Planetary Health. Public Health Review, 37,14.

31. Souza, A.O. 2018. Local ecological knowledge concerning the invasion of Amerindian lands in the northern Brazilian Amazon by *Acacia mangium* (Willd.) Journal of Ethnobiology and Ethnomedicine, 2018, 14:33.

32. Turbelin, A. J., Cuthbert, R.N., Essl, F., Haubrock, P.J., Ricciardi, A., Courchamp, F. 2023. Biological invasions are as costly as natural hazards, Perspectives in Ecology and Conservation 21(2), Pages 143-150 https://doi.org/10.1016/j.pecon.2023.03.002

33. Pysek, P. 2012. A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. Global Change Biology, 18,1725–1737.

34. Simberloff, D., Von Holle, B. 1999. Positive interactions of nonindigenous species: invasional meltdown? Biological Invasions, 1,21–32.

35. Gan, X. 2009. Potential impacts of invasive *Spartina alterniflora* on spring bird communities at Chongming Dongtan, a Chinese wetland of international importance. Estuarine Coastal and Shelf Science, 83, 211–218.

36. Pejchar, L., & Mooney, H.A. 2009. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution, 24(9), 497–504.

37. Gibbons, S.M. 2017. Invasive plants rapidly reshape soil properties in a grassland ecosystem. Msystems, 2:e00178–e216.

38. Lazzaro, L. 2014. Soil and plant changing after invasion: the case of Acacia dealbata in a Mediterranean ecosystem. Science of Total Environment, 491–498.

39. Huangfu, C., Li, K. 2019. Growing density interacts with competitor identity to modulate nitrogen form preference of an invasive plant. Ecological Indicators 107.

40. Shackleton, R.T., Witt, A.B.R., Piroris, F.M., Van Wilgen, B.W. 2017. Distribution and socio-ecological impacts of the invasive alien cactus *Opuntia stricta* in eastern Africa. Biological Invasions. 19, 2427–2441.

41. Gupta, S., Kumar, N., Verma, D. et al. 2021. Impacts of invasive alien plant species on biodiversity in the regions of Western Himalayas, India: An overview In Biological Diversity: Current Status and Conservation Policies, 1 https://doi.org/10.26832/aesa-2021-bdcp-08

42. Heshmati, I. 2019. Forthcoming risk of *Prosopis juliflora* global invasion triggered by climate change: implications for environmental monitoring and risk assessment. environmental monitoring & assessment, 191, 72.

43. Atkinson, J., Brudvig, L. A., Mallen-Cooper, M., Nakagawa, S., Moles, A. T., Bonser, S. P. 2022. Terrestrial ecosystem restoration increases biodiversity and reduces its variability, but not to reference levels: A global meta-analysis. Ecology letters, 25(7), 1725–1737. https://doi.org/10.1111/ele.14025

44. Benayas, J.M.R., Newton, A.C., Diaz, A. Bullock, J.M. 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. Science, 325, 1121–1124.

45. Brudvig, L.A., Catano, C.P. 2021. Prediction and uncertainty in restoration science. Restoration Ecology, 107, e13380.

46. Bullock, J.M., Aronson, J., Newton, A.C., Pywell, R.F., Rey-Benayas, J.M. 2011. Restoration of ecosystem services and biodiversity: conflicts and opportunities. Trends in Ecology & Evolution, 26, 541–549

47. Huang, C., Zhou, Z., Peng, C., Teng, M., Wang, P., 2019. How is biodiversity changing in response to ecological restoration in terrestrial ecosystems? A meta-analysis in China. Science of the Total Environment, 650, 1–9.