Review Article
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Invasive alien plant species in Ethiopia: ecological impacts on biodiversity a review paper

Abstract

Ethiopia has great geographic diversity and climatic variability. This has created diverse and suitable ecosystems, which are home to large number of flora, fauna and microbial species. However, there are threats to biodiversity by invasive alien plant species (IAPS). They cause threats to biodiversity, economic and health problems in Ethiopia. This paper addresses the ecological impacts of IAPS on biodiversity in the major types of ecosystems, and discusses the reasons why IAPS in Ethiopia constitute a threat to biodiversity locally and globally, examine the ecological impacts on biodiversity, discuss its use and suggest mitigation measures of the IAPS in Ethiopia. Recently, there are about 35 IAPS in Ethiopia. Some of these species include *Prosopis juliflora*, *Parthenium hysterophorus*, *Eichhornia crassipes*, *Lantana camara*, and *Acacia* species, which are the major threats to biodiversity losses. Water bodies, wetlands, disturbed vegetation types (e.g. *Acacia-Commiphora* vegetation type), agro-ecosystems, road sides, urban green areas, range lands are under threat of IAPS nowadays in the country. To minimize and control such invasions, different strategies are being applied such as eradication by utilization of *P. juliflora* in Afar Region for example, and mechanical control of *P. hysterophorus* in different parts of the country. For use of sustainable ecosystem services, strategies such as integrated management strategies, participation of all stockholders and multidisciplinary research approaches within and across countries should be designed to reverse the situations.

Keywords: biodiversity, ecosystem, Ethiopia, impact, invasive, plants

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Introduction

Ethiopia has great geographic diversity, and macro and micro -climatic variability. However, there are threats its biodiversity by habitat conversion, invasive species, unsustainable utilization of biodiversity resources, replacement of local varieties and breeds, climate change and pollution, demographic change, poverty, and lack of awareness and coordination.[1] Invasive species are either indigenous or non indigenous species that can heavily colonize a particular habitat.[2] Alien species are non-native or exotic organisms that occur outside their adaptive ranges and dispersal ranges.[3,4] IAS are all categories of living organisms (plants, mammals and insects) which comprise the most common types in terrestrial environments.[4] They are also widely distributed in all kinds of ecosystems throughout the world. IAS have the ability to establish themselves, invade, out-compete natives and take over the new environment.[3,5] They are now affecting every ecosystem types on the planet and they are the second greatest global threat to biodiversity after habitat destruction.[4,6] They are pausing threats to ecosystems of the earth, and the services that they provide to humanity are under risk.[5] IAS have induce impacts on native species directly competing for resource such as: food and breeding sites indirectly by altering habitat and modify hydrology, nutrient cycling and other ecosystem processes. Their impacts are on native biodiversity in ecosystems like agricultural and range lands, national parks, water ways, lakes, rivers, power dams, road sides and urban green spaces with huge economical as well as social consequences. These dramatically change the ecosystem both positively and negatively. Across impact types, the positive impacts reported by most authors were found to be largely outweighed by negative impacts.[7–9]

IAS are creating complex and far-reaching challenges that a threat to not only biodiversity, but also food security, health and economic development. The problems of IAS in developing countries are higher than in developed nations.[3,10] According to Lowe et al.,[6] in 2004, IUCN identified 81 IAS in South Africa, 49 in Mauritius, 44 in Swaziland, 37 in Algeria and Madagascar, 37 in Kenya, 28 in Egypt, 26 in Ghana and Zimbabwe and 22 in Ethiopia.[11] Recently, there are more than 35 IAPS identified in Ethiopia. Some of these IAPS include: Mesquites (*Prosopis juliflora*), Parthenium weed (*Parthenium hysterophorus*), Water hyacinth (*Eichhornia crassipes*), Lantana weed (*Lantana camara*), *Acacia species*, and *Orobanche* and *Cuscuta species* that are identified as major plant invaders. Recent surveys found also emerging plant invaders such as Cryptostegia grand flora, Parkinsonia aculeate, Mimosa diplorotricha, Mimosa pigra, Agrimonies Mexicana and Nicotine glauca.[1] Therefore this review paper aims to discuss the reasons why IAPS in Ethiopia constitute a threat to biodiversity locally and globally, examine the ecological impacts of some IAPS on biodiversity and take up lessons learned elsewhere or in Ethiopia and discuss on the use and management of IAPS. Thus, the paper addresses relevant scientific information's based on evaluation of data collected from different journals, manuals and various report works.

Invasive alien plant species

A species is considered an "invasive alien species" when it spreads beyond its natural area of distribution. According to Richardson et al.,[12] Kueffer et al.,[13] and Shine et al.[4]

Alien plants*:* plant taxa occurrence in a given area results from their introduction (intentionally or accidentally) by human activity. (Synonyms: "exotic plants").

Weeds*:* Plants (not necessarily alien) that is undesirable from a human point of view (synonyms: "pests").

Invasive plants: Alien plants that recruit reproductive offspring, often in very large numbers, spread rapidly.

Invasive alien species: an alien species which threatens ecosystems, habitats or species. (1) Alien species that escape from human control go beyond the intended physical boundaries and cause environmental damage (2) Covers alien species that remain under human control but damage native ecosystems. Such damage is linked to species being alien, but not to invasiveness.

Native invasive (or) local invasive*:* species that get into modified habitats by their own means and then go through population explosions, loss to biodiversity and economics.

Historical perspectives of invasive alien plants

Plant invasion is a strong threat to the species diversity around the world during the 21st century after habitat loss. Large number species of IAP are introduced to native country in the world and few of these become problematic; they are introduced in to a country either through human or natural (e.g. winds, birds, animals, water).[5,14] Thousands of plant species have been transported by humans to areas far from their natural habitats; accidentally or intentionally (e.g. agro-forestry, horticulture, forestry, and animal husbandry purposes). However, invasions by IAPS are one of the largest threats to the ecosystems of the earth, and the services.[15] Few aggressive IAPS which are threatening biodiversity in Ethiopia and elsewhere in the world are discussed in the following sections.

*Prosopis juliflora (*Sw.*)* DC. Fabaceae

It is a perennial evergreen multipurpose dry land tree or shrub native to the Caribbean, North and South America. It Introduced to Africa in 1822 in Senegal; South Africa (1880), Egypt (1900) and Kenya was in 1973.[16] It introduced to Eritrea from the Sudan, probably during the early 1980s. It introduced in Ethiopia in the late 1970s at Goro nursery- Dire-Dawa. *Prosopis* was planted over large areas until 1982, continued by the Food for Work Programme from 1986 to 1988. This species is now commonly found in Afar, Oromia, Amhara, Somali, Dire-Dawa regions and Sothern Nations and Nationalities. Nowadays, it is repeatedly reported to be one of the invasive and problematic trees in the Afar Region and progress to Rift Valley of Ethiopia.[17]

Parthenium hysterophorus, in the family heliantheae: asteraceae

It is a perennial herb. *Parthenium* genus has 16 species native to northern South America, Central America, Mexico, Texas, and Florida, Mexico. It introduced to Ethiopia accidentally in the 1970s when drought induced famine triggered a massive multinational relief effort. It was first reported from Ethiopia in 1988 at Dire- Dawa and Harerge, Eastern Ethiopia and subsequently found near Desse, Northeastern Ethiopia as well.[18,19]

Eichhornia crassipes, (Mart.) Solms in A. DC. (Pontederiaceae)

Water hyacinth is native to South America and it is originally from the Amazon Basin its entry into Africa, Asia, Australia, and North America was facilitated by human activities and lack of naturally occurring enemies. It introduced in to Kenya (1957), Lake Victoria in East Africa, and began to cause problems in 1990.[3,4] Zimbabwe (1937), Mozambique (1946), Ethiopia (1956), Rwanda and Burundi colonized in the late 1950s, Tanzania were infested in 1955 and 1959, Zambia (1960s), Uganda (1988-89), Malawi (1996).[20] Water hyacinth has also spread to West Africa and Cameroon (1997-2000), Nigeria (almost all water bodies).[20] Water hyacinth in Ethiopia has also been marked on a large scale in many water bodies of the Gambella area, in Blue Nile Watershed, and Lake Tana.[21,22]

Lantana camara L. (Verbenaceae)

A shrub IAPS introduced to Ethiopia from native Tropical America and the West Indies. But, no clear year of introduction from native range has been indicated in literatures regarding this species in Ethiopia. *Lantana* has been introduced throughout the tropics and subtropics as an ornamental, often used as a hedge plant. It is a cosmopolitan weed and in many countries it has been declared a noxious weed.

Geographical distribution and sensitive ecosystems for invasive alien plant species

Geographical distribution: IAS have invaded and affected native biota in virtually every ecosystem type on Earth. They have contributed too many hundreds of extinctions, under island conditions, freshwater ecosystems. All ecosystems can be invaded potentially; some appear more vulnerable than others. Evolutionarily and geographically isolated ecosystems, notably oceanic islands are particularly vulnerable. Because the natural bio-geographical barriers of oceans, mountains, rivers, and deserts, which provided the isolation essential for unique species and ecosystems to evolve and have lost their effectiveness. Habitats such as urban-industrial areas, habitats suffering from periodic disturbance, harbors, lagoons, estuaries and the fringes of water bodies are under threats of IAPs.[3] Systems with low diversity, for example some arid ecosystems, are more susceptible to invasion than species-rich systems with well established species interactions. However, species rich landscapes can also be susceptible to a greater range of invaders because of the greater diversity of habitats typical of such landscapes.[3,23] The most obvious and severe invasion regions of alien plants in Africa are in sensitive wetland and aquatic ecosystems.[21] In Ethiopia; disturbed ecosystems, along road sides, agricultural lands, and grass lands, in Vegetation ecosystems: Desert and semi-desert, *Acacia-Commiphora* woodland and bush land, freshwater lakes, lake shores, marshes, swamps and flood plain vegetation, dry Evergreen Afro-montane forest and grassland complex, and *Acacia* wooded grassland of the central rift are under threat of IAPS in Ethiopia.[1,24,25] Many evidences prove that disturbances in the natural ecosystems provide the great opportunities to the alien invaders to establish themselves (Table 1). The frequency of the alien herbal plants increased in the areas of human interference such as forest fragmentation. Moreover, population pressure, over-stocking, overgrazing and deforestation have facilitated the disturbance of the Ethiopian ecosystem and enhanced the effect of weed invasion by threatening biodiversity of the country.[19] According to[21] and Beilfuss[26] the distribution of IAPS in Ethiopia is indicated in different regions across the country (Table 2).

Causes for invasion of alien plants

As indicated above the causes of introduction are two types: For example, human (intentional) introduction of *P. juliflora* in Ethiopia and natural (unintentionally) introduction of *P. hysterophorus* in India, Kenya, Ethiopia and other elsewhere. After natural invasion by some alien plant species, there is a "lag phase" that may range from decades to centuries before "an exponential phase" of its fast spread. The species are in a given time may appear to be non-invasive for a while then may suddenly begin to spread rapidly (E.g.

P. hysterophorus). Introduction cause is closely linked to the history of civilization. Colonization in particular led to massive transoceanic movements and exposed ecological systems, as well as indigenous communities; to quite new stresses and threats in the world. In the modern era of globalization, the 'four Ts': Trade, Transport, Travel and Tourism have cause and sharply accelerated the rate of species movements. Global markets support the increased flow not only of investment money but also of goods.[4] According to Mc Neely et al.,[3] there are three steps for invasion of IAS: (1) introduction – intentional or unintentional, (2) establishment–survives but doesn't spread, (3) spread: (3a) Naturalization – becomes part of the flora/fauna of its new habitat (3b) invasion–expands and impacts on species, ecosystems, people and development. Species invasions have three main elements: (1) source population is where the species finds its natural habitat, where it forms part of the native ecosystem (though other invaded ecosystems often are a secondary source) and (2) pathways are the routes by which species move from one political unit to another, either within a country or between countries. (3) destinations are where the new species arrives. Climate change also aggravates IAS to colonize easily and vice versa.[27] Climate change can facilitate IAS as new species, that may become invasive, will be entering regions due to climate change, species hierarchies in ecosystems will change leading to new dominants that may have invasive tendencies, and climate induced stress in an ecosystem will facilitate invasive pathways. Alternatively, IAS can facilitate climatic stress by increasing ecosystem susceptibility to climatic perturbation, through reducing the number of species and their functional types within the ecosystem.[28]

Table 1 Identified and prioritised Invasive Alien Species in Ethiopia (Source: GEF, 2002)

Scientific names	Common names	Scientific names	Common names
E. crassipes	Water hyacinth	*P. juliflora*	Mesquite, Prosopis, WoyaneZaf (Amh)
L. camara	Lantana, Wefkolo (Amh)	*P. hysterophorous*	Parthenium, Congress weed, White top, Feremsisa (Orm)
P. hysterophorous	Parthenium, Congress weed, White top, Feremsisa (Orm)	*Striga species*	Striga
P. juliflora	Mesquite, Prosopis, Woyanezaf (Amh)	*E. crassipes*	Water hyacinth
Striga species	Striga	*L. camara*	Lantana, Wefkolo (Amh)
*Acacia species**	Fullsa (Orm)	*Acacia species**	Fullsa (Orm)
Orobanche species	Orobanche , Atequrit (Amh)	-	-
Cuscuta campestris	Cuscusta	-	-
A. mexicana	Argemone, Nech Lebash (Amh)	-	-
Verbesina encelioides	Verbesina	-	-
Opuntia species	Opuntia, Qulqual (Amh)	-	-

* Probably a native species= like *A. drepanolobium*, Orm=Afaan Oromo, Amh=Amhari

Table 2 Distribution of IAPS across regions in Ethiopia

Oromia	Somali	Afar	Tigray	Amhara	South	Gambela
P.hysterophorus	*P.hysterophorus*	*P. juliflora*	*Striga species*	*Striga species*	E.crassipes	E.crassipes
P. juliflora	*L. camara*	*P.hysterophorus*	*Orobanche species*	*Orobanche species*	P. juliflora	-
Striga species	*P. juliflora*	*Acacia species*	*P.hysterophorus*	*P.hysterophorus*	A. mexicana	-
L. camara	-	-	*Opuntia species*	*Opuntia species*	P.hysterophorus	-
E. crassipes	-	-	*P. juliflora*	*P. juliflora*	-	-
Orobanche species	-	-	-	*E. crassipes*	-	-
Acacia species	-	-	-	-	-	-
Argemone mexicana	-	-	-	-	-	-
Mimosa pigra	-	-	-	-	-	-
M. diplotricha	-	-	-	-	-	-
Opuntia species	-	-	-	-	-	-

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Properties of invasive alien plants

IAS is one of the most significant drivers of environmental change worldwide. Four key features are associated with invasive plants; (1) show prolific seeding and early age of first reproduction, (2) have unpalatable foliage, (3) can easily establish in degraded environments, and (4)have an ability to regenerate profusely from direct seeds, stems or roots. These features make them good competitors amongst other plant species and allow their survival and abundant establishment.[29]

Parthenium hysterophorus: A deep tap root and an erect stem that becomes woody with age. Large plants can produce up to 15,000 seeds on average and 100,000 seeds which can be distributed by floating on still or flood waters or in mud adhering to animals, vehicles and machinery. In India, 200,000 seeds per m^2 in the soil. In some areas, more than 340 million *Parthenium* seeds can be present per hectare in the surface soil, compared to 120,000 native grass seeds. Dormant in the soil for several years if conditions favorable. Allelopatic chemicals have been observed to exhibit an inhibitory effect both on the germination and growth of a wide variety of crops including pasture grasses, cereals, vegetables, other weeds and even tree species.

Prosopis juliflora: Have characteristics of rapid biomass accumulation, nitrogen fixing root ability, tolerance of arid conditions and saline soils, coppicing abilities, ability to stay dormant for longer time in a media (e.g. soil) and germinate during favorable conditions, number of seeds/pod is high.[30] Allelopatic chemicals are other characteristics of *Prosopis* species which are used to adapt to compute with other neighbor species in harsh conditions.

Lantana camara: Forms extensive, dense and impenetrable thickets in forestry plantations, orchards, pasture land, waste land and in natural areas. However, *lantana* showed less vegetative growth, less reproductive success and more browsed in the forest. So*, L. camara* is less successful in the forest gaps than at the edges of the forests and hedges. The rapid spread of *lantana* is associated with human induced disturbance. Fruits are widely dispersed by many birds including introduced species. In areas where natural fires occur they stimulate thicker re-growth. It tolerates a wide range of climates. It grows well on poor soils.[31] It produces also allelopatic chemicals from its plant parts.

Impacts of invasive alien plants on biodiversity

Among the invaders that will have the largest impacts are those that directly modify ecosystems. They have cascading effects for resident biota (plants, animals and micro-organisms). Exotics can affect ecosystems by altering system-level flows, availability or quality of nutrients, food, and physical resources (e.g. living space, water, heat or light). Many literatures suggest that introduced ecosystem engineers either: increase habitat complexity or heterogeneity which tends to cause abundances and /or species richness to raise or decrease complexity tends to have the reverse effect on ecosystem services. Ecosystem services can be categorized into four main services in general; (1) Provisioning service (e.g. food, freshwater, fiber, fuel, genetic resources, (2) Regulating services (e.g. air quality regulation, climate regulation, water regulation) (3) Cultural services are non-material benefits, (e.g. aesthetic values, recreation/tourism, spiritual/ religious values, (4) Supporting services. Overarching, indirect, and occur on large temporal scales (e.g. photosynthesis, primary production, nutrient cycling.[32] IAPS threats to these ecosystem services; IAPS pose a global threat to the conservation of biodiversity through: their proliferation and spread, displacing or killing native flora and fauna and affecting ecosystem services. They are particularly damaging in geographical or ecological islands, which are rich in endemic species, Invasive plants smother, outcompete and displace indigenous species, changing the composition and function of entire ecosystems.[21] IAS and other native invasive plants can affect entire systems in Ethiopia and elsewhere in the world (Table 3).

Table 3 Invasiveness and ecosystem effect status of top 20 Invasive Plants Species in Ethiopia (Source: Rezene and Taye, 2014)

Species	Ecosystems highly affected*	Distribution status
P. hysterophorus	1,2,3,4,5,6,7,8	High
P. juliflora	1,2,3,4,5,6,7,8	Moderate
Opuntia ficus-indica	3,4,5,6,	Moderate
O. stricta	3,4,5,6,	Moderate
M. diplotricha	1,2,3,4,5,6,8	Moderate
M. pigra	3,4,7	Low
Cryptostegia grandiflora	2,3,4,7,8	Low
L .camara	1,2,3,4,5,6,8	High
A. drepanolobium	1,3,4,	Moderate
A. saligna	2,3,4,5,	Low
Parkinsonia aculeata	2,4,5,6	Low
Nicotiana glauca	1,2,3,4,5,6,	Moderate
Argemone ochroleuca	1,2,3,4,5,6,	High
Xanthium strumarium	1,2,3,4,5,6,	High
X. spinosum	1,2,3,4,5,6,	Moderate
Psidium guajava	8	Low
Senna didymobotrya	1.2.3.4.5.6.8	High
S. occidentalis	2,4,5,	Moderate
Calotropis procera	1,2,3,4,5,6,7,8	Moderate
Ricinus communis	2,4,5,6,	Moderate

1, Cultivated land; 2, Roadside; 3, Grazing areas; 4, Non-cultivated land; 5, Rural villages; 6, urban areas; 7, Riverside; 8, Forest areas.

Parthenium hysterophorus: It aggressively colonizes: natural and manmade ecosystems, disturbed sites and causes major negative impacts on grassland habitats, open woodlands, riverbanks, flood plains, wildlife parks, and open field of settlement areas, bare areas along road sides, crop fields, and gardens heavily stocked areas around yards and watering points etc. The allelochemicals released from the weed or from seed leaching inhibit germination of other plants and the growth of pasture grasses, legumes, cereals, and vegetables, other weeds and even trees. *Parthenium* affects nodulation in legumes due to inhabitation of activity of nitrogen fixing and nitrifying bacteria Viz., *Rhizobium*, *Actynomycetes*, *Azotobacter* and *Azosprillium*. It was reported to cause yield losses of up to 40% in several crops and is reported to reduce forage production by up to 90% in India.[33] *Parthenium* produces enormous quantity of pollen (on average 624 million/plant), It is carried away at least to short distance in clusters of 600-800 grains and settle on the vegetative and floral parts, including stigmatic surface inhibiting fruit setting in crops like tomato, beans

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and maize when its pollen grains are deposited on the stigmatic surfaces.[33] In Ethiopia, the yield in *Sorghum bicolor* grain was reduced by 40-97% when *P. hysterophorus* was left uncontrolled throughout the season.[34] The weed poses serious health hazards to livestock and if eaten can spoil their milk and meat. Some farmers in Ethiopia also claim that they have lost livestock during dry periods when there was little available grazing and the animals had eaten *Parthenium* out of desperation. *Parthenium* can also cause severe allergenic reactions in people who come into contact with the weed on a regular basis.[34] It induces to alter in the physical and chemical properties of soil such as soil texture, soil pH, soil organic matter, soil nitrogen, soil potassium, and soil phosphorus.[33]

Adane[18] reported that *P. hysterophorus* was found to be the most frequent and dominant species on road sides, grazing land and crop fields with important value indices of 102%, 77.5% and 74.5% respectively out of sampled cases in Adami Tulu-Jido Kombolcha Woreda of Ethiopia. Under crop fields, the responses of wheat and teff (63.1% for both crops); maize (6.9%) to *Parthenium* weed were less than grass weeds, like *Cynodon dactylon* L. (72.5%) in the study area. The result showed that some species have greater sociability or resistance than other species. In Southern Ethiopia at Gedeo Zone, the impact of *P. hysterophorus* weed on biodiversity was also assessed. It showed that in highly infested areas the impact was more visible than the moderate and low infested areas.[19] These samples indicated lower diversity index (H') (highly infested area) as compared to other sites where the calculated Shannon Diversity Index was high (where invasion was low).

***Prosopis juliflora*:** Although there are few quantitative findings in the study area. *P. juliflora* are threatening endemic plant species in Afar Region of Ethiopia, such as *A. prasinata*, *Boswellia ogadensis*, *Euphorbia doeloensis*, *E. ogadensis* and *Indigofera kelleri*.[17] These habitats which harbor threatened plant species also harbor many globally threatened and vulnerable mammal and bird species. Because of disruption of ecosystem integrity in the area, these threatened wild animals are further endangered.

Abyot & Getachew[30] reported also that *Prosopis* replaced the local biodiversity in several spots in Afar region, mainly rangelands and dry riversides. In such areas, the grasslands are no more used for grazing by the livestock. The species also reduced the total biodiversity of the arid and semiarid regions by reducing their abundance, distribution, and more importantly by changing the ecosystem function from rangeland to *Prosopis* thicket. Consequently, the local Afar pastoralists who solely depend on natural pasture for their cattle in Ethiopia moved further from their home and pasture fields aggravating food and feed shortage in the region.

Prosopis has severely invaded dense *Acacia* woodlands, riverine forest and agricultural lands of Amibara Woreda, Afar. It has highly distributed in *Acacia* woodland (9.91 km^2) and least around the settlements (0.35 km^2) over the 16 years period land use/land cover changes from 1986 to 2001 in the area.[11] The number of coppices was relatively few around the settlements and higher in *Acacia* woodlands. Moreover, the density of the plant was found least in riverine forest lands (344stems/ha) and highest in *Acacia* woodlands (1774 stems/ha). This result depicts that *Acacia* and other species are under threat in the area. *Prosopis* has been blamed for injuring livestock with its poisonous thorns and causing goat teeth to rot and fall out because the small seeds get stuck between the teeth. Thousands of goats have been rendered toothless and died from starvation following teeth loss which has been decreasing their number and threaten goat breed in the region.[29] The decrease in the number of sheep and goats in the same period is estimated to be higher than one third.[17] Over the five years between 2003 and 2008 alone camel ownership in invaded areas of the Afar Region has dropped by almost one third as a result of *prosopis* invasion. The effect of the species on the number of calves and heifer is even more pronounced where the reduction rate is five fold.

***Eichhornia crassipes*:** Few studies showed quantitative impacts of water hyacinth on biodiversity in Ethiopia, In general, according to UNEP[20] threats posed by water hyacinth are: (i) loss of biodiversity, (ii) oxygen depletion and reduced water quality, (iii) breeding ground for pests and vectors and (IV) blockage of waterways hampering agriculture, fisheries, recreation and hydropower. Studies to establish the negative impact of the weed at the Wonji Sugar Estate in Ethiopia indicated that the weed inflicted multifaceted problems such as excess water loss that is estimated to be 393,660 to 2,945,160 m^3, restricting water flow.[35]

Lantana camara: It readily invades pastureland outcompeting palatable species, resulting in a reduction in carrying capacities and restricted access and movement of animals, humans and vehicles. It is also unpalatable, and in large doses (approximately 1% of total body weight) is poisonous, cause skin lesion in sheep particularly to cattle. *Lantana* is one of the known allelopathic weed plants in many parts of the world. For example, experiment conducted in Northern Ethiopia.[36] Consequently, *Lantana* leaf powder significantly inhibits seed germination, speed of germination, shoot and root length, stem thickness and biomass of wheat and maize.

Uses of invasive alien plants

Introducing species to new locations has had tremendous contributions to societal development. Human welfare has been improved due to the introduction of many crops out of their native range.[17] Accidental and deliberate introduction of some species, however, resulted into unexpected negative outcomes. Some species turned into invasive species presenting complex and dynamic problems to society.[3]

Parthenium hysterophorus: extracts of the species have been well documented for their insecticidal, nematicidal and herbicidal properties by many researchers. However, there are few reports of these characteristic properties being used and any utilization taking place. The most practical use of *Parthenium* weed in India so far has been through the production of compost and in vermin-composting along with other weeds.[33] Composting significantly reduces allelopathic inhibitory effects of *Parthenium* on plant seed emergence in Ethiopia.[37] For example, report by showed lettuce emergence percentage was greatly reduced by fresh *Parthenium* (93%). Fresh and composted of the species reduced lettuce emergence rate by 95 and 33%, respectively. It Radicle length also reduced by 97 and 35%, respectively and plumule length (93 and 43%, respectively in Jimma Zone of Ethiopia. Their result clearly showed that composting greatly reduced allelopathic effects of *Parthenium*.

Prosopis juliflora: Initially, though the benefits of *Prosopis* are not well realized in Ethiopia, *Prosopis* provide valuable products such as timber and charcoal in USA; honey in Mexico; animal feed in Brazil; gums, fodder and firewood in north-eastern India; charcoal and human foods in South America, and firewood in Africa.[33] It is used for high quailty furniture, flooring, fiber boards, railway cross-beams etc. In Ethiopia, *Prosopis* wood can only be used for fuel wood,

charcoal, and fencing and its crushed pod for animal feed especially during dry season.[17] Flowers of *Prosopis* are excellent sources of pollen and nectar and are used to produce high quality honey. The exudates gums harvested from *Prosopis* trees are important inputs in food, pharmaceutical, chemical and manufacturing industries.[16,33] Due to its unique tolerance to the harsh environment of dry lands, *Prosopis* has become an important source of livelihood for the poor, hence sometimes referred as 'the poor man's tree'.[17]

***Lantana camara*:** It is used traditionally to treat various ailments like tetanus, rheumatism, malaria, cough, fevers, cold, rheumatisms, asthma to mention a few of animal and human diseases. Many phytochemical investigations have been done on this plant.[38,39] The plant can be also uses as hedges which protects wind erosion in dry lands. It also used for camel calves as feed because calves cannot reach to browse like *Acacia brevispica* during shortage of milk from their mother in dry season in Eastern Ethiopia.

Management of invasive alien plants

The potential irreversibility of the damage of invasion and the indecision of the costs they may imply impose countries a preventive approach to their management.[3] Prevention–not allowing a potentially invasive species to become established in the first place–is the first line of defense. The main management responses after a species has invaded are mitigation and adaptation. Mitigation can reduce or eliminate the likelihood that a species will become established or spread, and decrease or eliminate the presence of an invader. Adaptation, on the other hand, involves changes in behavior in order to reduce the impact of an invasive species.

Barriers for management of invasive alien plants

According to,[22] in Africa and specifically in Ethiopia there are a number of barriers to effective adoption of this strategy for managing IAS, (1) the policy environment within which most countries in Africa are operating is fragmented and weak, (2) the critical information required by the different stakeholders is not available, (3) the implementation of prevention and control programmes is slow or inadequate and capacity is lacking.

Efforts in the Management of invasive alien plants

There are different management strategies of IAPS after invasion: Strategies are Mechanical, chemical, biological and Fire. The relatively common control method applied in Ethiopia is the uprooting of the tree manually.

Parthenium hysterophorus: Like other weeds, control of *P. hysterophorus* weed in Ethiopia is entirely based on cultural and labour intensive practices such as tillage, hand weeding, mowing, hoeing and slashing. Unlike large-scale farms in developed and developing countries, small-scale farmers prepare their land using repeated oxen ploughing and/or hoeing. Some farmers in Ethiopia are also using chemical eradication methods.[18] *Zygogramma bicolorata* was found to be safe biological *P. hysterophorus*.[40,41] Another trial was conducted by Sintu[42] there was an evaluation of bio-control agent of stem-boring weevil (*Listronotus setosipennis) on P. hysterophorus* in Ethiopia. *L. setosipennis* was selective to control *P. hysterophorus* in relation to other plant species without affecting the native ones.

Prosopis juliflora: The mechanical control of *prosopis* is, however, very labor intensive and expensive, and is economically feasible only for high value lands. Using mechanical control method, *Prosopis* plant was recommended to cut at 10 cm for young trees; and 40 cm for matured trees or shrubs of *Prosopis* to control coppicing. It can also serve simply for control of the spread of the species and is not effective to eradicate it by mobilizing communities. Management of *Prosopis* by utilization (e.g. fuel wood, construction, and charcoal production, feed livestock by crushing pods) is the best management options.[43]

Eichhornia crassipes: Mechanical, chemical and biological, fire after water drainage are few strategies to control *E. crassipes*. Mechanical eradication of water hyacinth at Lake Tana of Amhara Region and Awash River irrigation channels are encouraging.[1] Mechanical eradication is labour intensive and costly. Chemical eradication is not friend environmentally. Release of bio-control agents is also being considered where these technologies are not feasible.

Lantana camara: Attempts to control *L. camara* using mechanical, chemical and biological means have met with limited success. *Lantana* is difficult to control, as it will coppice and form denser thickets if it is simply slashed and left. Management by utilization can also eradicate *L. camara. Lantana* inaction can be controlled by using its biomass before the plant set seeds. The best management option is an integrated approach is required for management.

Conclusion and recommendation

Ethiopia has diverse ecosystems which are home to large number of flora, fauna and microbial species. However, there are threats to ecosystem services and biodiversity loss due to habitat conversion, invasive species, unsustainable utilization of biodiversity resources, replacement of local varieties and breeds, and climate change and pollution. Invasive alien species such as plants are exotic which are introduced deliberately or unintentionally outside their natural habitat naturally or through human activities. In new areas, invasive alien species are colonizing the native ecosystems; have either positive or negative consequences on the ecosystem services. Invasive alien species are found in all taxon or organisms and exist all over the world in all ecosystems. Recently, 35 invasive weed species are identified in Ethiopia, and they are posing negative impacts on native biodiversity, agricultural and range lands, national parks, water ways, lakes, rivers, power dams, road sides and urban green spaces with huge economical as well as social consequences. Some of these species include: mesquites (*P. juliflora*), parthenium weed (*P. hysterophorus*), water hyacinth (*E. crassipes*), lantana weed (*L. camara*), *Acacia species*, and other weeds such as *Orobanche* and *Cuscuta species* that are identified as major plant invaders. These IAPS are more aggressive in disturbed, arid and semiarid vegetation ecosystems like *Acacia-Commiphora* woodlands, aquatic, wetlands, agro-ecosystems and rangelands in Ethiopia.

IAPS have peculiar characteristics of invasiveness and distribution that overtake the native species such as number seeds they produce, reproductive outputs and some allelochemicals inhibit other native species loss. As the result, they have impacts on biodiversity, social services and health problems both on human and animals in all ecosystems in the new areas. In order to combat such threats countries in the world and Ethiopia have their own strategies to control IAPS in the native ecosystems. But, there are management barriers to implement such strategies. Mechanical, chemical, fire regime for some invasive species like water hyacinth and biological control methods

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are some methods after invasion of the species. These aforementioned methods have their own cons and prons to control IAPS. Prevention, integrated management strategies and management of the species by utilization as measure used to control *P. juliflora, P. hysterophorus* and *L. camara* in Ethiopia, are among the best management of the control measures.

The following recommendations are suggested to prevent, control the already invaded ecosystems in Ethiopia and elsewhere in the world:

a. Sustainable and multidisciplinary approach studies regarding history, properties of the invasiveness of the species and their impacts in relation to ecological impacts on ecosystems and socioeconomic consequences have to be conducted.

b. Create awareness for stakeholders about the history, cause and impacts IAPS is very important.

c. Institutions should join the efforts to better understand IAS and devise mechanisms for better prevention and control.

d. Close monitoring and management of all natural and agro-ecosystems from disturbances to reduce the arrival and colonization of IAPS. Secure quarantine measures needs to be introduced in boarder areas where tourism, trade, travels agents are flowing. Countries with IAPS countries share information and working relationships in order to control the transfer of IAPS from one to another.

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Conflict of interest

The author declares there is no conflict of interest.

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