



Distribution and Challenges of an Invasive Exotic Species, *Prosopis juliflora* (Sw.) DC. (Fabaceae) in Ethiopia, East Africa.

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Abstract: Ethiopian farmers in the dry areas are suffering a lot by the spreading of *Prosopis juliflora* into their farmlands. In contrary, different countries of the world are using the plant stem, leaves and pods for different purposes. The plant has been introduced for combating desertification in most areas of the world. However, in contrary to its purpose of introduction it escaped out of control and is invading farmlands, pasture lands, rangelands, and irrigation schemes and caused many land cover changes in Ethiopia. Due to the fact that the tree has been introduced, but the knowledge and experiences surrounding its wise management and use has not. The plant is fast growing, drought resistant and invasive. Nowadays, it is repeatedly reported to be one of the invasive and a problematic tree heavily infests most agricultural as well as potential rangelands in Afar region as well as in other parts of the country. It is observed that the species has been increasing in density and area coverage from year to year even from month to month. The thorny nature of the plant, remarkable ability to withstand adverse condition, non-browseable nature, and above all, the nomadic nature of the people have paved the way to invade most potential lands of the region. *P. juliflora* shows a great depressive effect on the number, density, and frequency of native vegetation. It has two main ecological opportunity behaviours: seed dormancy and allelopathic effect. It possesses allelochemicals that inhibit germination, growth and survival of other species.

Keywords: Afar, allelopathic. challenges, Ethiopia, *Prosopis juliflora*,

1. INTRODUCTION

Over the last century, forest plantation using exotic trees has developed as an integral and crucial part of many national economies and environmental programmes. Planted trees and woody shrubs have proved

vital in improving the livelihoods of the world's poor. As a result, countries, international organizations, developmental programmes and industries have been exchanging forest productive materials on large scale¹. Concern about deforestation, desertification and fuel wood shortages in the late 1970s and early 1980s prompted a wave of projects that introduced *Prosopis juliflora* and other hardy tree species to new environments across the world². In contrast, nowadays a separate agenda is focused on invasive alien plant species, which are the second next to habitat destruction to biodiversity threat.

Prosopis juliflora (Sw.) DC. is an evergreen tree native to North and South America³ and the most aggressive tree weed that causes great devastation to subtropical grasslands. It has survived where other tree species have failed and in many cases became a major nuisance. It has invaded and continues to invade millions of hectares of rangeland in South Africa, East Africa, Australia and coastal Asia². In 2004 it was rated one of the world's top 100 least wanted species⁴.

P. juliflora shows better survival and growth rate under drought and arid areas. Dissemination mechanisms of seeds and the ability to germinate immediately after dispersal give great opportunity to grow faster and makes it a more adapted species to drought condition^{5,6}. The plant accumulates long-lived dormant but viable seeds in the soil serving as a source of new plants in the event of disturbance that might eliminate the above ground stands⁶.

The invasive woody plant, *P. juliflora*, was thought to have been introduced to Ethiopia during the establishment of irrigation water development project at Middle Awash from Sudan^{6,7}. In contrast to this Demissew⁸ reported that its first introduction is believed to have been in the late 1970s at Goro nursery, Dire-dawa, possibly from India. In Afar, it may have been introduced possibly from Dire-dawa or independently from Kenya or Sudan by foreigners working in the Middle Awash irrigation project in the late 1970s and early 1980s⁸.

It reported that the species has been increasing in density as well as area coverage from year to year even from month to month in Afar Region⁹. Currently, this noxious tree heavily infests most agricultural as well as potential rangeland of the Afar Region⁹. The thorny nature of the plant, remarkable ability to withstand adverse condition, non-browseable nature, and above all, the nomadic nature of the people have paved the way for the species to invade most potential lands of the region.

In areas of Ethiopia, where *P. juliflora* has invaded, the environment is very hot, with limited rainfall and saline soils. Few plants can thrive there, but these conditions are conducive for *P. juliflora*. There are no natural enemies, pests or diseases. Also, the *Prosopis* tree introduced to Ethiopia are particularly bushy, thorny and weedy. The life style of the nomadic local people has helped, as the animals eat the pods and travel long distances, disseminating seeds to new areas through droppings⁸. There is little knowledge and experience on how to manage and utilise these plants, and there have been few policies or strategies in place for quick action this helped *P. juliflora* to become an invader. This paper presents the literature on the distribution and challenges of *Prosopis juliflora* with special focus on the Ethiopian situation.

2. INVASIVE ALIEN SPECIES

Alien species are non-native or exotic organisms that occur outside their adaptive and dispersal ranges¹. IUCN⁴ defines invasive alien species as an alien species, which becomes established in natural, or semi natural ecosystems or habitats, and threatens native biological diversity. According to CBD¹⁰, invasive alien species are species introduced deliberately or unintentionally outside their natural habitat, where they have the ability to establish themselves, invade, out-compete natives and take over the new environment.

Invasive species are widely distributed in all kinds of ecosystems throughout the world, and include all categories of living organisms. Nevertheless, plants, mammals and insects comprise the most common types of invasive alien species in terrestrial environments¹¹.

Invasive species have now affected every ecosystem types on the planet and considered as the second greatest global threat to biodiversity, after habitat destruction¹¹. Their impact on native species are directly competing for resource such as food and breeding sites as well as indirectly by altering habitat and modify hydrology, nutrient cycling and other ecosystem processes. These impacts dramatically change the ecosystem both positively and negatively. Biodiversity threats and habitat destructions are interacting phenomena; habitat destruction can make areas more vulnerable to invasive species, and species invasions can result in the destruction of habitats. In addition to their threat to biodiversity and ecosystem services, they have significant social, ecological and economical impacts. They reduce agricultural yields, grazing areas, water availabilities, and contribute to spread of vector borne diseases.

Differences between native and exotic plant species in their resource acquisition and consumption may cause a change in soil structure, its profile, decomposition, nutrient content of soil, moisture availability, etc¹¹. As a result, they are a serious hindrance to conservation and sustainable use of biodiversity, with significant undesirable impacts on the goods and services provided by ecosystems. Plant invasions now operate on a global scale and undergoing rapid increase in this century due to interaction with changes such as increasing globalization of markets, rise in global trade, travel and tourism. Furthermore, it is anticipated that the problem will be exacerbated in the future by climate changes, which is likely to favour species that are opportunistic.

According to Raghubanshi *et al.*¹¹, invasive alien species have unique characteristics over the native ones:

- They do not need special environmental requirement for seed germination.
- They have rapid seedling growth and produce seeds for longer period of time as long as environmental conditions permit.
- They are also highly tolerant to climatic and edaphic variations and have an ability to compete and drive off other species from their habitat.

In 2004, IUCN identified 81 invasive alien species 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.

Invasive plant species in Ethiopia: Ethiopia is one of least developed countries in the world. Every year millions of people are at risk of starvation due to food shortage¹². The situation is worst in arid and semi-arid parts of the country, which economically marginalized, where the rainfall is inadequate, recurrent droughts are experienced and infrastructure is undeveloped. These conditions make it difficult for local people, dependent on their livestock as a source of food, income, and savings, to secure their livelihoods. The added impact of invasive species can further intensify food insecurity and increase vulnerability to hazards and risks.

Ethiopia like other countries of world has also involved in exotic trees planting. Invasive Alien Species are of a great concern in Ethiopia, posing particular problems on biodiversity of the country, agricultural lands, rangelands, national parks, waterways, lakes, rivers, power dams, roadsides and urban green spaces with great economic and ecological consequences.

In Ethiopia, there are about 22 invasive alien species¹³. Among these invasive alien species mesquites (*Prosopis juliflora*), parthenium weed (*Parthenium hysterophorus*), water hyacinth (*Eichhornia crassipes*), cactus (*Euphorbia stricta*), lantana weed (*Lantana camara*) and acacia species, are causing major problems in the country. They have been identified by the Environmental Policy and the National Biodiversity Strategy and Action Plan as a major threat to biodiversity of the country and economic well being of its people. However, little attempt has been made in terms of research and management of IAS. Their high seed production capacity and spread, adaptation to wide climatic and soil conditions, spread by animal movement and their association with pastoralists way of life and overgrazing are challenges to their management in Ethiopia¹⁴.

According to Dubale¹⁵ plants like the water hyacinth also block water ways for irrigation, navigation, electricity generation, fishing and livestock watering. They increase water loss. Some pose risks to livestock and humans in the invaded areas by impairing mobility or causing injuries. The spread of invasive plant species is a growing concern in Ethiopia national parks, lakes, rivers, power dams, and urban green spaces - causing huge economic and ecological losses⁶. The Environment Policy of the country, the Forest Resource Strategy and the National Biodiversity Strategy and Action Plan, recognize invasive plant species to be growing threats to the biodiversity of the country and socio-economic welfare of the people. At the national level, the policy or strategy for the control and management of invasive species is not clear¹⁶, and little attempt has been made in terms of their research and management. The example of *P. juliflora* in the Afar region, nonetheless shows the socio-economic and environmental risks that can arise if invasive species are left unmanaged, and advocates for a strong policy and strategy in Ethiopia to deal with them.

3. ORIGIN OF *Prosopis juliflora*

P. juliflora reported to be originates from Peru; it occurs naturally in dry areas of South America and Central America and Mexico². It has been introduced into many tropical areas, including north-eastern Brazil, Africa, Australia, Southeast Asia and the Indian subcontinent. *P. juliflora*, is one of 44 species of *Prosopis*, was described by De Candolle under the name of *Prosopis juliflora*. The specific name *juliflora* comes from *julus* meaning whip like; referring to the long inflorescence, and *flora* being flower⁹.

The introduced species to Ethiopia was *P. juliflora*, which belongs to the family Fabaceae¹⁷. The plant is predominantly xerophilous spiny and sometimes unarmed evergreen tree with height of 3-15 meters depending on genetic difference and other environmental factors, but under favourable environmental conditions some individuals may reach³ up to 20m. *P. juliflora* landraces often have multi-stemmed, coppiced and prostate shrub forms with long branches and a crown that even touches the ground and have erect, flat topped and decumbent tree forms. *P. juliflora* produces coppices except those stumped at 10 cm below the ground⁶.

The invasive woody plant, *P. juliflora*, which is an evergreen tree native to North and South America³ and the most aggressive tree weed that cause great devastation to subtropical grasslands. The exact time and place of introduction was not clearly known but according to the report of Hailu *et al.*⁶ it was thought to be introduced to Ethiopia during the establishment of irrigation water development project at Middle Awash from Sudan. In the 20 years since it began to be planted in Ethiopia, it has spread like a weed; thorny bushes causing trouble to rural people and their animals. Some call for eradicating *P. juliflora*. Others make charcoal and support their families by selling it⁸. This species is now commonly found in Afar National Regional State and is spreading to Oromia, Amhara, Somali, and Dire-dawa Regions. Nowadays it is repeatedly reported as one of the invasive and problematic species in Afar Region as well as in the country.

4. CHARACTERISTICS FOR THE SUCCESS OF THE PLANT

According to Hailu *et al.*,⁶ *P. juliflora* is equipped with a number of biological characteristics that foster its rapid invasion of new areas. These include:

- A production of many, small and hard seeds capable of surviving passage through the digestive system of animals, entering into the soil to form soil seed banks and remaining viable until favourable conditions for germination and seedling establishment appear;
- Attractive and rewarding pods for animals, containing fleshy and sweet mesocarp embodying the numerous small seeds, which is sought after by both domestic and wild animals, meant for long-distance dispersal;

- Accumulation of dormant but long-lived viable seed reserves that would serve as sources of regeneration of new *P. juliflora* plants in the event of disturbance that might eliminate the above-ground stands;
- Production of a mixture of seeds, a few capable of germinating immediately after dispersal to exploit the favourable conditions that might exist at the time of dispersal, while the majority remain dormant for spreading germination over time and space; and
- Great ability of fast coppice growth from stumped/damaged trees, making it a very strong competitive invader combined with its sexual reproduction.

Combinations of all these characteristics make *P. juliflora* a powerful noxious invader in different areas including Ethiopia. Therefore, any effort in the management, control or elimination of *P. juliflora*, which does not take these biological characteristics, is bound to fail.

5. DISTRIBUTION

According to Mwangi & Swallow¹⁸ in the 1970s and 1980s tropical and subtropical regions experienced increasing shortage of fuel wood and other timber in rural communities, coupled with increasing environmental degradation, soil erosion and desertification. To address these problems exotic woody shrub and, in particular, woody legumes were promoted for use in agricultural systems and to revegetate degraded lands.

P. juliflora is native to arid and semi arid zones of South Americas, Central America and Asia. Recently, the plant has been introduced and naturalized in many countries. In America, it has been introduced to Brazil, Hawaii, and in some Caribbean islands. In Oceania, it has been introduced to Australia, New Guinea, and Marquises islands. In Asia, it has been observed in Jordan, Saudi Arabia, Bahrain and Qattar, United Arab Emirates, Iraq, Iran, Kuwait, India, Pakistan, Srilanka, Thailand, Vietnam, Indonesia, Philippines and in many arid and semiarid African countries².

The main reasons for introducing *P. juliflora* round the world have been combating desertification and utilization of a fast growing fuel wood and fodder species that thrives in harsh arid and semi-arid conditions¹⁸. The first record of *P. juliflora* introduction to West Africa and pacific island was in 1820s, to India and Pakistan was in 1870s, and to Australia and South Africa was before³ 1900. In recent decades *P. juliflora* has attracted much attention because of its ability to survive in extremely arid, saline, inhospitable locations and produce excellent firewood, charcoal, animal fodder. The combination of its long life cycle, ability to survive droughts, high seed production and dormancy of seeds make *P. juliflora* an extremely resilient invader which can quickly take advantage of suitable environment and dominate entire ecosystems.

Distribution in Africa: Based on its merits *P. juliflora* has been introduced and naturalized in different parts of the world (Africa, Asia, and Australia) during the last 100-150 years². It was introduced in 25 countries in African continent. Including Sudan, Ethiopia, Eritrea, Kenya, Tanzania in East and Horn of Africa, Namibia, Zimbabwe, South Africa in the South Africa, Morocco, Algeria, Tunisia, Libya, Egypt in North Africa, Cape Verde, Senegal, Gambia, Mauritania, Mali, Burkina Faso, Niger, and Chad in the Sahel region of Western Africa, Ghana and Guinea-Bissau and Nigeria in West Africa¹⁸.

Pasiecznick *et al.*², reported that the earliest introduction in Africa was to Senegal in 1822, followed by South Africa (1880) and Egypt (1900). The first documented introduction of *P. juliflora* in Kenya was in 1973, when seeds imported from South America for rehabilitation of saline soil¹⁸. *P. juliflora* was introduced to central Sudan in 1980 because of its many favourable attributes, including adaptability, fast growth rate and wide range of utility¹⁹.

Random introductions of poorly documented *P. juliflora* germplasm into Africa coupled with little transference of the technologies whereby it is utilized commercially in its native range, have led to the under-utilization of this forest resource and it is causing detrimental effect in most African countries. As indicated by UNEP²⁰ the problems caused by these organisms are more severe in Africa because of the following main reasons:

- **Weak policy and institution environment:**-there are gaps, overlaps, and inconsistencies in existing policies, regulations, and institutional arrangements regarding to alien invasive species to implement proper management actions. For instance, *P. juliflora* plantation was recommended in Ethiopia to control desertification under the national plan to combat desertification while the forest research recognized it as a threat to biodiversity.
- **Unavailability of information:**-in most African countries there is inadequate sharing and exchanging of information about their biodiversity and the status of alien invasive species among private sectors, civil societies, general public and governments. Although there is increasing body relevant information globally, different African countries are not linked to the global information source.
- **Inadequate implementation of prevention and control:**-although prevention of the introduction of invasive alien species practiced in some extent, most African countries lack mechanism of monitoring and detecting of invasive species except in Agricultural field.
- **Lack of capacity:**-to tackle the problems of invasive alien species countries in Africa lack institutional arrangement and organization, human and physical resources. For example, in Ethiopia the Ministry of Agriculture and Rural Development has been given power to control the imports and exports, inspect, survey and treatment of lands with regard to the imported plants and their products. But, it lacks the means to implement the rules and regulations.

Distribution in Ethiopia: Ethiopia has complex landscape and geomorphic types, and wider climatic range from desert to cold alpine. The altitude of the country goes from 116m below sea level to 4533 m above sea level. Because of this natural condition there are a number of native and exotic species found within the diverse ecosystem of the country.

The introduced species become dominant over the native species in new habitat in relatively short time and become very aggressive by suppressing previously established species⁶. This is mainly because the newly introduced species have freed from antagonistic factors such as harsh climatic and edaphic conditions, pathogens and predators.

A very good example of such exotic species which have been introduced in most tropical and sub-tropical countries including Ethiopia is *P. juliflora*. The plant has been cultivated for shade, timber, forage, food, and firewood². However, contrary to its purpose of introduction, the plant escaped out of control and has invading farm lands, pasture lands, rangelands, irrigation schemes and causes for many land use/ land cover changes.

According to Demissew⁸ *P. juliflora* in Ethiopia it is called 'Weyane/Dergi-Hara' (Afar), 'Biscuit' (Dire-dawa), elsewhere; mesquite, algarrobo, Prosopis. They came originally from the Americas, there are many species, often confused, but work by the Ethiopian Agricultural Research Organisation (EARO) and the Henry Doubleday Research Association (HDRA) has confirmed that *P. juliflora* is the one commonly found in Ethiopia.

As stated in Demissew⁸ *P. juliflora* was planted over large areas until 1982, continued by the Food for Work Programme from 1986 to 1988. Some planting still continues, with *P. juliflora* seedlings being grown for living fences and shade trees.

The plant was introduced to Ethiopia by an English person from Sudan in 1970s through the Middle Awash Irrigation Project^{6,7} and was planted over a large area of the Middle Awash rift valley by local people in 1980 as wind break, shade and shelter around their village. According to Shetie⁹ the Amibara district of the Afar National Regional State is thought to be the putative starting point of the spread of *P. juliflora* in Ethiopia. In contrast to this Demissew⁸ reported that its first introduction is believed to have been in the late 1970s at Goro nursery, Dire-dawa, possibly from India. In Afar, it may have been introduced possibly from Dire-dawa or independently from Kenya or Sudan by foreigners working in the Middle Awash irrigation project in the late 1970s and early 1980s⁸.

Since 1980s the plant has spread rapidly in eastern Ethiopia, from the Middle Awash Valley into the Upper Awash Valley and Eastern Hararghe and some localities of Raya Azebo plains of South Tigray. The invasion has also reported in the town of Arba-minch and neighbouring localities in South region of the country⁷. It is clear that the spread of *P. juliflora* in Ethiopia has increased in the last decade, both in terms of area coverage and plant density⁸. It stretched and covered large amount of areas in Ethiopia.

According to Hailu *et al.*⁶ report the species is dispersed in the country due to the following factors: (1) following Awash River with the rainy and seasonal floods, (2) livestock and wildlife routes (mobility routes) through their droppings, (3) highway through different agents, (4) following irrigation canals and dry weather roads. Therefore, all such kinds of exposed areas are invaded by this species and so that Afar people are suffering from the effect of this species since 1980.

6. CHALLENGES OF THE PLANT

Invasive alien species have been introduced worldwide intentionally due to their economic, environmental or aesthetic values or unintentionally while people move from place to place⁷. However, these alien species come out of control and become invasive to the new area and cause both ecological and socio-economic impacts. The impacts of invasive alien species are often extensive. The effects of these species can result change in the availability of resources and ecosystem structure and function. The change in ecosystem function can brought about extinction of indigenous species²¹. Indigenous species may be threatened directly by the increase of invasive species.

P. juliflora is considered as an alien invasive species from economic viewpoints in most countries because it is in conflict with human needs and rapidly invade many types of land uses. The effect of *P. juliflora* on native biological diversity depends on the ecosystem to which it spread and the economic damages or benefits. For example, in India *P. juliflora* was introduced to serve as a source of fire wood but there spread beyond the ranges has provoked the Indian to call it “mad tree” because of its undesirable and unrestricted spread in rangelands.

According to Abdillahi *et al.*²¹, unrestricted spread of *P. juliflora* will result in several risks and environmental impacts. These risks and impacts can be:

- Loss of native plants through competition as well as occupation of their natural environment and habitats Reduction of available nutrition of livestock and destruction of rangelands, thus resulting in adverse impact on a large segment of citizens depending on cattle breeding as a source of living.
- Ground water depletion as the plant have well developed roots and can absorb water from very deep up to 15 meters and sometimes reaching ground water layers which constitute the main source of water resources.
- Caused problems to breeders, because consumption of leaves by camels lead to their sickness, causes flatulence, diarrhea and sometimes constipation as well as eating their solid seed pods may result in falling out cattle teeth and reduction of their ability to graze⁹. Studies on *P. juliflora* tree in India revealed that their spread resulted in destruction of many endangered herbaceous mammals such as the grey hare and desert fox. Their thick thorns prevent mature birds from maneuvering and

hunting prey²¹ Moreover, in Ethiopia the thornⁿ is damaging *animal hooves* and vehicle tyres²². The thorn of *P. juliflora*, on penetrating the eye cause more inflammation than expected from physical injury.

Although the seed pods are indeed palatable to livestock, the chemical content is thought to cause problems for goats, cattle and camel. A diet high in pods can cause mortality in sheep and goats due to digestive problems like impaction. Cattle can die if they feed heavily on *P. juliflora* leaves over a prolonged period of time owing to its tannin contents¹⁸. Mwangi & Swallow¹⁸ have reported that ingestion of *P. juliflora* pods by livestock causes tooth decay and death through indigestion in absence of supplementary feeds in the dry seasons.

According to El-Keblawy and Al-Rawai^{23,24} the effect of *P. juliflora* on the associated flora depends significantly on the density and size of the canopy. Larger individuals and greater densities have significantly greater negative impacts on the associated plants. Annuals were inhibited more than perennials. The number of annuals with significant reductions in density and frequency under *P. juliflora* canopies was greater than the number of perennials. El-Keblawy & Al-Rawai^{23,24} also noted that density of *P. juliflora* seedlings are greater under the canopy of the same species than away from them, indicating little or no self allelopathic effect (auto-inhibition) under field conditions.

Invasion of grasslands, protected forests and nature reserves has alarmed ecologists. Invasion of irrigation channels and agricultural land has affected the agricultural community, and landowners and large, commercial farmers have seen their income threatened.

In countries such as Cape Verde and parts of Mauritania or Niger, *P. juliflora* was reported to be the only effective vegetation cover and thus is an important source of fuel wood and fodder²⁵. However, in South Africa and Australia it invaded the high potential rangelands and became the main cause for production loss in livestock, and high clearance cost²⁵. The effect of *P. juliflora* to the biodiversity depends on the ecosystem to which it spread, and the economic damage and benefit depends on the socio-economic environment of the invaded land and its potential alternative uses.

Allelopathy of *Prosopis juliflora* Leaves: *Prosopis* inhibits the germination or growth of many plant species growing in its vicinity through allelopathic substance(s) exuded from its leaves, roots or fruits²⁶. This may be due to slow decomposition and heavy accumulation of leaf litter below *P. juliflora* may possibly result in accumulation of toxic substances in the soil layers, inhibiting growth of other species.

The experiment by Nakanol *et al.*²⁷ showed that when lettuce seeds were incubated in a concentric circle around freeze-dried mesquite leaves in a dish containing agar culture medium, the growth, especially radicle growth, of the seedlings was inhibited, the more strongly the closer they were to the leaves. Furthermore, a potent substance was isolated from the exudates of the freeze-dried mesquite leaves and identified as L-tryptophan by spectral analyses²⁷. This result indicates that allelopathic substance inhibiting the lettuce growth is exuded from the mesquite leaves. So, due to this *P. juliflora* dramatically reduces understory herbaceous cover and plant species richness.

Impacts of *Prosopis juliflora* in Ethiopia: Invasive Alien Species (IAS) are of a great concern in Ethiopia, posing particular problems on biodiversity of the country, agricultural lands, range lands, national parks, water ways, lakes, rivers, power dams, roadsides and urban green spaces with great economic and ecological consequences.

In the Ethiopian context in the 1970's the plant was wrongly introduced by Ministry of Agriculture to high quality pasturelands and irrigable areas, including the Awash River basin in the Afar National Regional State of Northeast Ethiopia⁸. Local people were not informed about the invasive nature of the plant at first and were not advised on management practices to minimize its spread²⁸. As a result, the plant rapidly invaded vast areas of pastoral and agro-pastoral lands, affecting both the biodiversity and socio-economic environment.

Over 700,000 hectares of grazing land and cultivable land following the Awash River is currently either invaded or at risk of invasion in the Afar Region²⁹. This accounts for 15% of the region's productive land (4,670,316 hectares), excluding wetlands, water bodies, sandy and rocky areas (4,856,251 hectares). In the Afar people are predominantly pastoralists that depend on livestock rearing, or agro-pastoralism for their survival. However, the *P. juliflora* invasion, coupled with recurrent droughts that strike the area, has left the people unable to maintain these subsistence livelihoods.

The *P. juliflora* invasion has resulted in multiple negative effects on their food security, livelihoods and the region's environment²⁸. The invasion of *P. juliflora* has caused considerable declines in livestock production and productivity due to the loss of dry season grazing areas to *P. juliflora* plants. Palatable indigenous pasture species such as *Chrysopogon plumulosus*, *Cenchrus ciliaris* and *Setaria acromelaena* have all reduced. Indigenous trees such as *Acacia tortilis*, *Acacia senegal* and *Acacia nilotica* have also declined in the rangelands due to the invasion¹⁵.

Feeding livestock exclusively on *P. juliflora* pods for extended periods, due to lack of pasture in the invaded areas, has resulted in health problems to animals such as constipation, dental disfiguration and reduced overall productivity¹⁵. Local people call the diseases in cattle 'Harmeko'. This disease resulted in death of the cattle after prolonged loss of body condition.

P. juliflora form impenetrable thicket that prohibits free movement of people and animals. They suffer injuries from the sharp and poisonous thorns and its thorns damage eyes and hooves of animals. Cattles are died due to injury from thorns. Once they are wounded they are not able to travel and feed themselves, they lose condition and finally die¹⁴. In addition, predators (hyena, jackal, lion and leopard) attacks on livestock have increased since the *P. juliflora* invasion. In agro-pastoral areas, damage to the crop fields from wild herbivores such as warthog and bush pig has increased due to more hiding places in the thickets¹⁴.

The cost of land clearance became a common problem encountered in all farming areas affected by the invasion of the plant. Agro-pastoralists in Gewane and Amibara districts spent large amounts of money to clear the invasive plants from lands for cultivation (up to US\$100/hectare/year)²⁵. Moreover, malaria cases increased since invasion of *P. juliflora*¹⁵. This may be as a result of the moist microclimate in invaded areas provided a favourable environment for mosquito's multiplication. This observation was similar to reports from Kenya also experiencing the invasion of *Prosopis*¹⁸.

With the reduction of grazing and cultivable land, joined with recurrent droughts, people in the Afar region became highly food insecure and dependent on government food aid for their survival. In highly occupied areas people are now vulnerable to food aid on average for 5-6 months in good years and for up to 10 months in drought times¹⁵. Due to these impacts to local productivity, the majority of the pastoralists were forced to diversify their livelihoods to include crop farming, daily labour, charcoal production and trade or combinations of these.

CONCLUSION

During the last three centuries *P. juliflora* was introduced into Ethiopia for fuel and other purposes. However, the species remain largely unmanaged, under-utilised, and are today better known as invasive weeds rather than useful trees. The tree had been introduced, but the knowledge surrounding its wise management and use of the plant, had not.

It is still paradoxical that *P. juliflora* is advantageous and disadvantageous for the local people of Ethiopia. Some groups of the society are looking for techniques to eradicate it from their surrounding particularly at the seedling stages while others need it for different purposes at the matured stages. Therefore, it invites studies to adjust the pros and cons of the species to control and if possible to eradicate from where it is

undesirable, and to derive the services it gives where it is desirable at arid environments where there is no other options.

Therefore, at the current situation in Ethiopia the disadvantages of the plant may be outweighing the advantages. Thus, the pastoralists and agro-pastoralists highly recommended for the complete removal of the plant from the area. But, the dilemma on the benefit and adverse impact of *P. juliflora* can be solved by enhancing the benefits and implementing proper management options. However, complete eradication of *P. juliflora* is virtually impossible at the current state of management options but it is possible to reduce further spreading with proper and efficient utilization of the plant. In such a way that by organizing the local people to utilize the plant effectively so as to control further invasions and to diversify source of income of the local people.

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