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Prosopis juliflora Distribution, Impacts, and Control Methods Available in Ethiopia

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Abstract: *Prosopis juliflora* is one of the most popular damaging foreign species that are invasive harming the environment and the economy in arid and semi-arid environments. It is threatening pastoral and agro-pastoral livelihoods in particular as it spreads quickly through rangelands, croplands, and forests. Parts of national parks and wildlife refuges have been invaded by Prosopis, endangering biodiversity. Its quick spread throughout the environment is encouraged by several factors. Among the key factors are its adaptability to a wide range of climatic conditions, efficient mechanism for dispersal, allelopathic effect, prolific nature, presence of a significant in the soil ecosystem, there is a seed bank., and quick and strong coppicing abilities. Prosopis can have negative crop yield, animal and human health consequences, and the composition and diversity of plant species. The tree has potential uses for fuel, charcoal, fodder, food, bio-char, bio-control, windbreaks, shade, building and furniture materials, and soil stabilization, despite its drawbacks. Through carbon sequestration, it can also be used to treat various diseases and improve environmental conditions. On the other hand, effective control methods and management of this weed have been identified as manual, mechanical, chemical, biological, and utilization control methods. To get them under control, it is urgent to create management plans that are both economically and environmentally sound. Therefore, this review's goal was to investigate Prosopis' distribution, effects, advantages, and potential management strategies.

Keywords: *Prosopis juliflora*, Control Method, Beneficial Effects, Distribution, Impact

1. Introduction

An evergreen, quick-growing mimosa tree or shrub is called Prosopis juliflora L. that is a native of the Caribbean, South America, and Mexico, is one of a worst woody invasive tree/shrub in the world [1, 2]. At maturity, the plants grow to a height of 12 meters and a trunk diameter of 1.2 meters, forming impenetrable spiny thickets [1]. *P. juliflora* has recently emerged as the Ethiopia, Kenya, and the remainder of eastern Africa's pastoral and agro-pastoral communities are plagued by the worst weed [3, 4]. *P. juliflora* has been identified as Ethiopia's top-priority invasive weed by EIAR and other governmental and non-governmental entities [5].

According to the available evidence, some international development organizations intentionally introduced *P. juliflora* back in the early 1980s to Ethiopia to combat the problem of desertification in overgrazed arid and semi-arid areas of Eastern Africa [6]. Since then, the Afar and Somali Regions in the country's east and southeast, as well as the region around Dire Dawa city, have been the most negatively impacted areas in terms of coverage. In the primarily dry lands of Central, East, and North Ethiopia, Amhara, Oromia, Southern Nations Nationalities and Peoples (SNNP), and Tigray Regions are also moderately affected [7]. Worst of all, it has a negative impact on the ecosystem, causing impenetrable shrubby thickets, invading waterways, reducing the water table, depriving plants of moisture and nutrients from other species, and generating "green deserts" that are basically lifeless rather than achieving the intended goal [8].

Due to *P. juliflora's* invasive nature, its rapid spread is seen as a serious threat, especially to pastoralists' ability to survive in the environment. It can invade pasturelands, irrigated agricultural land, and irrigation canals, ultimately leading to the irreversible eradication of native tree species and natural pasture grasses [9]. A few of its negative effects include disrupting the ecology by displacing beneficial native species, expanding onto roads, villages, homes, water sources, crops, and pastureland, wounds brought on by thorns that harmed animal and human health, and several human fatalities [3, 4]. *P. juliflora* invasions have the potential to drastically degrade rangeland quality and forage grass productivity. Because of soil erosion and decreased livestock productivity, pastoralists now have access to a smaller number of lower-quality rangeland areas [10-12]. Important forage plants are outcompeted by *P. julifora*, which lowers long-term forage availability and, consequently, the sustainability and quality of livestock production [13].

P. juliflora invasions produce positive environmental, social, and economic effects despite their negative effects [14]. This has resulted in contentious issues with the genus [15, 16]. Some proponents tout it as a "wonder plant," while others demand its eradication or weigh its advantages and disadvantages, as in the phrase "Boon or bane" [17]. Yibekal, A. T. [18] reviewed the Ecological and Economic Dimensions of the Contradictory Invasive Species *P. juliflora* and Policy Challenges in Ethiopia. He pointed out that there hasn't been a clear strategy or policy for managing *P. juliflora* or invasive species in general. *P. juliflora* is identified as a severe danger to biodiversity and the financial health of society in plans such as Ethiopia's Environmental Policy (EPE), the Biodiversity Strategy and Action Plan (NBSAP), and the country's Forest Resource Strategy [19]. Despite these plans, the *P. juliflora* tree was recommended as a potential tree to combat desertification in the country's National Action [20, 21] highlighting the current policy conundrum regarding *P. juliflora.*

The possibilities for a productive discussion between various parties are restricted by divergent perspectives, conflicting perceptions, and unclear policies. This is made worse by difficulties distinguishing between morphologically similar species, as well as by a general lack of information about the spread, scope of the invasion, benefits, effects, and effective control strategies. Prior to suggesting detailed management recommendations for the species in Ethiopia, it was important to present a summary of *P. juliflora* in this essay. This review could aid in managing management priorities, enhance comprehension of other classes of woody invasive species, and offer direction [22, 23]. In order to better understand *P. juliflora*, this review will look at its prevalence, probable distribution, negative impacts, and effective preventative methods.

1.1. General Objective

Reviewing the prevalence, consequences, and available controls for *Prosopis juliflora* in Ethiopia.

1.2. Specific Objectives

1) To examine *Prosopis juliflora's* distribution in Ethiopia.
2) To examine *Prosopis juliflora's* effects in Ethiopia.
3) To review the *Prosopis juliflora's* control options that are available in Ethiopia.

1.3. Material and Method

Secondary data were used to prepare this manuscript. Data were collected by the use of google scholar and google. com. This manuscript was abstracted from different published papers and books.

2. *Prosopis juliflora*

2.1. Prosopis juliflora Ecological Distribution

P. juliflora is a shrub that is indigenous to the Caribbean, South America, and Mexico [1]. It is a type of evergreen shrub that develops quickly after germination and has a deep root system that has ability to grow up to 40 cm in just two months [24]. This feature of *P. juliflora* aids in its ability to spread to new areas. Among the nations where it has spread as an invasive weed are Ethiopia, Kenya, Sudan, Eritrea, Iraq, Pakistan, India, Australia, South Africa, the Caribbean, the Atlantic Islands, Bolivia, Brazil, the Dominican Republic, El Salvador, Nicaragua, the United States (USA), and Uruguay [25-27]. In Asia, Australia, and other places, it has established itself as a weed.

To restore degraded soils, provide firewood and fodder, and combat desertification, governments, and international development organizations jointly introduced *P. juliflora* to Ethiopia in the late 1970s [1, 28]. However, the species quickly spread into new areas where it was neither expected nor wanted and naturalized when it was first observed in Dire Dawa at the Goro Nursery site, it was probably introduced from India [29]. According to [30] *P. juliflora* currently covers around one million hectares in Ethiopia, including roughly 700,000 ha in the Afar Region [13]. The Afar and Somali Regions in the east and southeast of the nation, as well as the region around Dire Dawa City, are the regions that have been most negatively impacted nationwide in terms of coverage. In the primarily arid lands of Central, East, and North Ethiopia, there are also mildly affected parts in the Amhara, Oromia, Southern Nations Nationalities and Peoples (SNNP), and Tigray Regions [7].

According to Rezene et al, [31] *P. juliflora* has a significant impact on crop productivity in diverse farmlands and rangeland locations throughout the national regional states of Gambella, Oromia, Afar, Amhara, and Somalia. Additionally, the East Shewa zone's Fantale district, followed by the Boset and Adama districts, is said to have the highest concentration of *P. juliflora* [32]. However, there was no infestation found in the West Arsi zone. Only a few young *P. juliflora* plants, which were specifically planted for shade, were seen in the towns of Wonji and Awash Melkasa. The Sodare (attractive recreational area for tourists) in the Adama district was heavily infested with *P. juliflora* trees [32]. According to [33] the management of *P. juliflora* weed in the around of Arba Minch and Nyangtom districts is urgently needed before it spreads to the diverse plant-home Nech Sar and Mago National Park. Yohannes, Z. A. [34] reported that *P. juliflora* is spreading quickly even in Ethiopia's highlands, where it had not previously been reported.

According to Berhanu, L., and Nejib, M [33] research, *P. juliflora* was discovered along the main road and on both sides of the road in the Gamo Gofa, Segen Area People, and South Omo zones. It extended to non-infected Districts such as Gamo Gofa Zone's Arba Minch and Abaya Districts and was not restricted to afflicted Districts [35]. In addition, it can be found in various places in the Wabi Shabelle basin, the Borena Range lands, the Dollo Odo, and the Liben Zone in southern Tigrai, as well as the Raya Azebo plains and going down the escarpments of Alamata in northern North Welo. It is also prevalent in Dire Dawa city [31]. In the Middle and Upper Awash Basin and Eastern Hararge, *P. juliflora* is ruthlessly encroaching on pastoral areas [36]. It also permeates Arba Minch town and the surrounding areas, is widespread in Liben, is present in some areas of the South Omo Valley, and crosses Kenyan boundaries [31].

P. juliflora is exceptionally drought resistant, owing to its deep taproot, which adds to its invasiveness [37, 38]. The species can thrive in a variety of environments, including dunes, clay soils, saline, and alkaline soils, elevations between 200 and 1500 m above sea level, and annual rainfall ranges from 50 to 1500 mm [39, 40]. Additionally, it can withstand and endure temperatures of up to 50°C for the air and 70°C for the soil [39]. In many newly introduced regions, interspecific hybridization also increases invasiveness [41]. *P. juliflora's* adaptability and spread across a variety of agroecosystems, includes wetlands, dry lands, and agricultural regions with irrigation, are supported by these functional characteristics, among others [42].

Many *P. juliflora* species produce large quantities of seeds that are viable for decades, grow quickly, can be coppiced after being damaged, have efficient dispersal mechanisms [42, 43] and have adaptable root systems (to depths of more than 50 m) that enable them to efficiently exploit both surface and groundwater [44, 45]. As long as the plant has access to enough water, pod production is almost constant. Both domestic and wild animals enjoy dry pods. The majority of herbivorous animals, which are the primary means of dispersal, can easily digest seeds because they are hard, smooth, and porous. Furthermore, its seeds enter the soil via animal feces, travel through the digestive tracts of animals that devour the pods, and form a seed bank ready to germinate when the conditions are favorable [1, 42]. Such seed banks are often difficult to manage and can survive longer than the lives of the individual organisms [46].

Shiferaw *et al*, [42] found a kilogram of seed contained 36, 000–37, 000 seeds in the Awash Rift Valley region of northeastern Ethiopia, compared to up to 760 seeds and 2833 seeds, respectively, in a kilogram of goat or calf droppings. As long as the plant has access to enough water, pod production is almost constant. Seeds may remain dormant in the soil for an extended period of time before proper conditions are restored. In Awash, the litter layer and the bottom 9 cm of the soil had a total mean soil seed density of 1932 seeds/m^2. In goat droppings, almost 37% of the seeds were still alive [42]. As a result, many germinate, and growth is quick thanks to the animal dung.

Other elements that aid in its invasion include a high capacity for coppicing and a strong dispersal system. After being burned or trimmed, the plants vigorously re-sprout, and within two to three months, they have once again formed a thicket. Livestock, camels, and goats all contribute significantly to the dispersal of *P. juliflora* seeds via their excrement [42]. These animals transport the seeds to various locations. The distribution of seeds to various regions is also greatly aided by rivers and waterways. *P. juliflora* has a strong invasion pattern in wetlands, along highways, and in irrigation canals. This shows that *P. juliflora* may grow well in both sites with surface runoff water for seed dispersal and locations with access to water. This may possibly be the cause of P. juliflora's invasion over the majority of the region along the Awash River in the rift valley.

The species has impacts on other plant species that are allelopathic and allelochemical in addition to the aforementioned traits [47, 48]. Under the *P. juliflora* canopy, the number of annual plants substantially decreased [48]. Under field conditions, the plant has little to no self-allelopathic (auto-inhibitory) action [49]. This process, when combined with dry circumstances, can prevent competition from existing between species. *P. juliflora* maintains its capacity to suffocate other plants and prevent seedlings from germination beneath it as it grows [37, 50]. *P. juliflora* can quickly establish a plant-only presence on bare land. It has been discovered that cyanogenic glycoside is harmful to animals like cattle [51]. The sharp thorns and unappealing leaves deter most animals from browsing the plant itself, this, in turn, relieves pressure on the species and promotes its expansion.

Table 1. *Rate of Invasion from different LU/LC between 1986 and 2001 (ha).*

LU/LC list	Total area invaded	Invasion rate per year
Rangeland	1.1	0.1
Open bushland	728.7	48.6
Acacia woodland	434.3	29.0
Bare land	138.1	9.2
Water	0.2	0.0
Cultivated land*	1444.8	96.3
Shrub land*	882.0	58.8

*= land-use/land cover that showed the highest invasion rate in extent
Source: [52] *Spatial and Temporal Analysis of Prosopis juliflora (Swarz) DC Invasion in Amibara Woreda of the Afar NRS* (Doctoral dissertation, MSc Thesis, AAU. Retrieved from http://etd. aau. edu. et/handle/123456789/786).

During the dry season, these animals consume *P. juliflora* pods along with other nearby kinds of forage. According to [53] the number of seeds recovered from 1 kg of droppings following consumptive excretion by cattle, camels, goats, and donkeys ranged between 760 and 2833, which could be a source of the infestation and a means of diffusion for other land-use/land cover. From November to the end of January, these animals traveled to cotton fields to consume cotton residue in the study region, particularly in the state farm area around Melka Werer and Melka Sedi in the western and central part of the study area in the Awash River basin. The aforementioned fact may have been more of a motivating factor for *P. juliflora's* dynamic proliferation in the cultivated land than any other land use or land cover in the research area.

Above all, earlier research showed that *P. juliflora* possesses a variety of biological traits that facilitate its quick spread to new locations. According to [53] the development of many little, hard seeds capable of surviving passage through animal digestive systems, penetrating the soil to create soil seed banks, and remaining viable until there are favorable conditions for germination; enticing and rewarding pods for animals, contains juicy and delicious mesocarp for long-distance dissemination; accumulation of dormant but long-lived viable seed reserves to serve as a source of regeneration generation of a variety of seeds, only a few of which germinate soon after dispersal while others remain inactive; this makes it a formidable rival invader when paired with its reproduction through sexual means All of these features combine to make Prosopis a potent noxious invader.

Table 2. *Rate of Invasion from different LU/LC between 2001 and 2007 (ha).*

LU\LC list	Total area invaded	Rate of invasion per year
Rangeland	579.1	38.6
Open bushland	1731.6	115.4
Acacia woodland*	1888.2	125.9
Bare land	1551.7	103.4
Water	35.4	2.4
Cultivated land	1649.5	110.0
Shrub land*	2741.7	182.8

*= land-use/land cover that showed the highest invasion rate in extent
Source: [52] *Spatial and Temporal Analysis of Prosopis juliflora (Swarz) DC Invasion in Amibara Woreda of the Afar NRS* (Doctoral dissertation, MSc Thesis, AAU. Retrieved from http://etd. aau. edu. et/handle/123456789/786).

The dynamics of land use/land cover revealed that the shrub land was the most affected by *P. juliflora* invasion during the research period. This could be attributed to animals moving from one land use to another after feeding on *P. juliflora* pods. Shrub land, together with native trees present in open bushland and Acacia woodland, has been identified as the most likely foraging environment for camels in this Woreda [52].

Table 3. *Total LU/LC in Amibara Changed to Invaded land (ha), 1986-2001.*

Status	Area (ha)	Area (%)
Changed to invaded	3,629.2	1.1
Unchanged	342,822	98.8

Table 4. *Total LU/LC in Amibara Changed to Invaded land (ha), 2001-2007.*

Status	Area (ha)	Area (%)
Changed to invade	11,578.7	3.4
Unchanged	328,621	96.6

Source: [52] *Spatial and Temporal Analysis of Prosopis juliflora (Swarz) DC Invasion in Amibara Woreda of the Afar NRS* (Doctoral dissertation, MSc Thesis, AAU. Retrieved from http://etd. aau. edu. et/handle/123456789/786).

2.2. Impacts on Plant Biodiversity

Many findings have found that the loss of biodiversity caused by the invasion of *P. juliflora* is massive in all over the globe [50, 54, 55]. *P. juliflora* can inhibit grass growth and biodiversity by delaying seed germination and lowering plant growth in terms of roots, shoots, leaf area, stem diameter, and plant height [32]. By taking into account both resources and the natural environment, it also reduces biodiversity [32]. According to [56] from Ethiopia's Allideghi Grassland, the *P. juliflora* seed occupies new surroundings and frequently replaces native plant species, causing major biodiversity harm. In India, it is estimated that *P. juliflora* reduces species richness by 63 percent as compared to open fields [57]. Kahi, H., and Ngugi, R. [58] discovered that the cover of understory herbaceous plant species was 27 percent lower in plots invaded by *P. juliflora* than in open regions. According to [59] an increase in *P. juliflora* invasion causes a rapid loss in the abundance and diversity of species in the ecosystem. Similarly, the species lowered overall biodiversity in arid and semiarid locations by decreasing abundance and spread, and, more importantly, by shifting the ecosystem function from rangeland to *P. juliflora* thicket [1].

Prosopis juliflora has harmed local farmlands and pasturelands. It acts as a physical barrier to seedlings of other plant species, making establishment extremely difficult. Because its branches are many, dense, and have evergreen leaves, sunlight does not reach the ground, and plants under the canopy of *P. juliflora* do not receive adequate sunlight for photosynthesis. Plants under the canopy of *Prosopis juliflora* may die as a result of this [16].

Chaturvedi *et al* [60] indicated the water use efficiency of *P. juliflora* to be 710 kg H_2O/ kg dry matter. With other species, 345 kg H_2O/ kg dry matter was estimated for *P. chilensis* [61]. This high level of water use efficiency is related to the high evaporation rate of their leaves. This makes the water table lower and unable to be reached by the roots of native plant species and results in the displacement of the native species with *P. juliflora* takes place.

P. juliflora also produces allelochemical chemicals in the soil, which may alter the native species' physiology and mutualistic relationships [16, 62]. This could help *P. juliflora* outcompete native plant species.

2.2.1. Shade Impacts of Prosopis juliflora on Native Plant Species

Under a canopy of non-indigenous invaders, the number of seedlings of native species has been reduced [63]. This is because more open stands are being converted to closed-canopy systems, which are accompanied by low light, increased humidity, lower temperatures, and other environmental and biological changes [64]. This climatic adjustment reduces the area's population size and species composition.

2.2.2. Allelopathic Effects of Prosopis juliflora

Depending on the dose and the organism impacted, Allelopathic outcomes can take both forms beneficial and negative. Allelopathy refers to the active and passive impacts of substances discharged into the environment on other species. It is the biochemical change of the donor's (*P. juliflora*) environment to improve its survival and reproduction [67]. The chemicals released suppress (rarely encourage) the germination and growth of nearby plants. Aside from that, they impede nutrient absorption and dry matter accumulation in target species shoots and roots [67].

Allelochemicals disrupt many different cellular processes in target organisms, including membrane permeability [68] ion uptake [69] photosynthesis and the respiratory chain [70] enzymatic activity [71] and cell division inhibition [72].

P. juliflora leaves contain a variety of compounds, including tannins, flavonoids, steroids, hydrocarbons, waxes, and alkaloids [16]. These are recognized to alter cattle palatability, but they also affect the germination and growth of *P. juliflora*, crops, weeds, and other trees [16]. These substances have a direct impact on plant germination and growth. The plant growth inhibitory alkaloids 3'-oxo-juliprosopine and secojuliprosopine were identified from *P. juliflora* leaf extract [73].

In general, the longer the two species coexisted, the less allelopathy affected their interaction. New species compositions, rapid successional changes, and foreign species introduced can all have a significant allelopathic influence [65].

Allelopathic chemicals can be released or evacuated from a tree by a variety of mechanisms, including evaporation into the air or from the soil surface, erosion or leaching from the tree surface, exudates from roots, and release from decaying dead organic materials. Allelochemicals can be found in high amounts in seeds, fruits, buds, and pollen. These defensive materials can protect reproductive resources from harm and degradation. Allelopathic substances can be produced and concentrated by leaves, buds, and phloem tissues to reduce harm and consumption. Allelopathic materials can help you live longer in a harsh environment [67].

Species with high allelopathic interference components frequently change the surrounding soils enough to act as a shield against other allelopathic species. Some allelopathic species coexist because each successfully controls its influence on the environment while protecting itself from the allelopathic components of others. Environments with high levels of allelopathic interference are stressful for both conveyors (allelopathic plants) and receivers (native plants) [66]. Water stress may have boosted allelopathic chemical production in trees, and chemical exudation may have risen due to increased root surface area. It is one component of the entire stress that trees must undergo to thrive.

2.2.3. Impacts on Human and Animal Health

According to significant research, *P. juliflora* is known to physically harm humans and animals, sometimes fatally [3, 4]. The most important impact of *P. juliflora* on human health is caused by its thorns, which cause itching, sores on hands and legs, lameness, and possibly the need for amputation of hands and legs due to infection. Its thorns may result in blindness and eye injury [74]. Greater inflammation results from *P. juliflora* thorn piercing an animal's eye or skin than would be anticipated from the physical harm. A wound caused by a thorn from this species does not heal rapidly, even with thorough medical care. Wax products could irritate [75]. The P. juliflora's thorns have caused serious injuries to the residents, who are angry at the plant's quick colonization of the area. Kids that eat *P. juliflora* pods experience impaction and constipation [76].

Burning wood in a fireplace can potentially cause dermatitis [77]. People are also being sprayed by lions and hyenas that nest and hide in the *P. juliflora* thicket, which has been related to an increase in malaria infections in the invaded areas [1, 3, 76].

Losses due to lack of access to water, disease, and death of livestock as a result of ingesting *P. juliflora* pods and being pierced by the sharp and sturdy thorns are just a few of the negative effects. Other negative effects include the complete loss of pasture and rangelands for both domestic and wild ruminants. Despite the fact that Prosopis seed pods are edible for livestock, it is believed that goats, cattle, and camels are hazardous due to the chemical content. Sheep and goats can perish from a high-pod diet because it permanently damages their capacity to digest cellulose [77, 78]. Due to the high tannin content, cattle can die if they consume large amounts of *P. juliflora* leaves over an extended period of time [36]. According to [74] thorns can kill cattle, camels, and donkeys by infecting their eyes and hooves. Berhanu, A., and Tesfaye, G. [1] discovered that long-term ingestion of the pod results in the mortality of cattle. Stomach poisoning by the pod may result in a lifelong impairment of the ability to digest cellulose, possibly due to the pod's high sugar content, which depresses rumen bacterial cellulose activity and eventually kills the animal [1]. Additionally, it has been noted that excessive seed accumulation after feeding results in the death of goats and camels [79]. Because of this, care should be used while giving the pods to domestic animals.

P. juliflora causes camels to become ill, and eating its thick seed pods causes cow teeth to fall out, reducing their ability to graze. Camel intake of *P. juliflora* leaves causes flatulence, diarrhea, and even constipation, while the thorns of *P. juliflora* are harmful to animals [80]. Furthermore, *P. juliflora* invasion raised health risks due to increased predator exposure, limited access to water supplies, and the emergence of novel lethal animal diseases such as "Harmaku" produced by cytotoxins destroying the neurons of inebriated animals [81].

2.2.4. Agricultural and Pasture Production Effects

Rangeland regions have been damaged and forage grass productivity has significantly diminished as a result of the potentially severe *P. juliflora* invasion [10, 11] In areas where it has spread, it has destroyed natural pasture, uprooted indigenous trees, and left pastoralists with fewer and poorer quality rangeland locations [12]. The abundance of fodder/feed on grazing grounds is negatively correlated with the growth in *P. juliflora* invasion, according to [32, 82]. Research indicates that encroached grazing grounds reduce herbage productivity [83-84].

The invasion of *P. juliflora* rangelands resulted in a lack of grazing land for animals, resulting in a significant fall in livestock numbers and output [74]. *P. juliflora* is a particularly aggressive invader that has turned grasslands into woodlands and forests. It causes the extinction of both domestic and wild ruminants by displacing natural vegetation and taking over rangelands [85]. It is mostly because to decreased carrying capacity of the land *P. juliflora* trees displace attractive grasses that we're unable to compete for light, nutrients, and water [86].

Source; *P. juliflora* invading the range land, Allidegie Plain [52].

Figure 1. *P. juliflora invading the range land, Allidegie Plain.*

Invasions of *P. juliflora* also compete with agriculture and reduce its yield [87]. The plant's invasion causes the farm's acreage to shrink, and P. juliflora's roots make it challenging to plow land [32]. A research in the Oromia region's Fentale woreda, East Showa zone, found that crop yield has decreased since P. juliflora's invasion of the area [88]. Similar to [89] who discovered that *P. juliflora* had a negative impact on crop output due to competition for agricultural land, time wasted clearing, and labor cost increases, *P. juliflora* is a weed that affects both high and medium infestation areas.

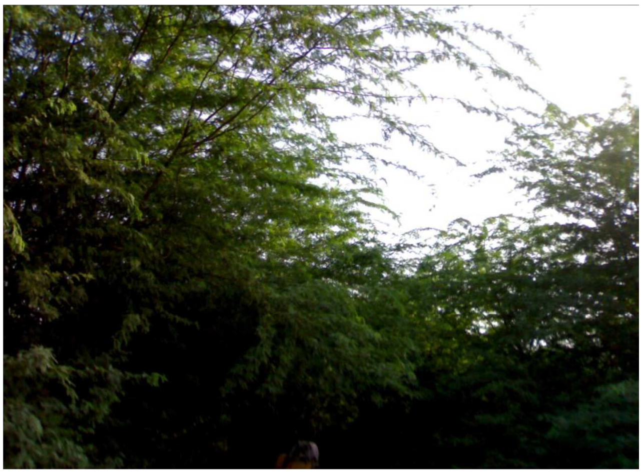

Figure 2. *P. juliflora invading the cultivated land, more than 12m in height at Ambash.*

Source: [52] Spatial and Temporal Analysis of *Prosopis juliflora* (Swarz) DC Invasion in Amibara Woreda of the Afar NRS (Doctoral dissertation, MSc Thesis, AAU. Retrieved from http://etd. aau. edu. et/handle/123456789/786).

2.2.5. Effect on the Production of Animals

Recent studies by [90, 91] discovered a negative correlation between the rate of *P. juliflora* invasion and cattle output. The loss of dry season grazing grounds by *P. juliflora* plants has resulted in a significant decrease in cattle production and productivity. The number of all pleasant native pasture species has decreased [36, 92]. For cattle, sheep, goats, and camels, respectively, the total amount of milk lost by *P. juliflora* pasture issues for a particular lactating period is 10, 1, 5, and 4 liters. Additionally, for cattle, sheep, goats, and camels, respectively, the overall weight loss associated with *P. juliflora* pasture issues per animal is 15, 3, 3, and 8 kg per year [93]. Similar to this, [88] found that *P. juliflora* had a negative impact on cattle productivity because of things like its encroachment on grazing pastures and physical harm to the animals [94].

The invasion of *P. juliflora* resulted in a scarcity of grazing places for cattle, resulting in a significant fall in animal numbers and output [74]. This is primarily due to *P. juliflora* encroachment on grazing land, which generates a lack of animal food [32]. By displacing ideal grasses that could not withstand the intensive competition for light, nutrients, and moisture, *P. juliflora* trees reduce the capacity of the land [86]. Additionally, it causes the destruction of natural pasture, the uprooting of indigenous trees, a decrease in stocking density, toxic cattle, and the growth of impenetrable thickets [74, 86]. The principal source of fodder for grazers like cattle, native grasses and other plant species have been greatly reduced in number and productivity [95]. Data from Ethiopia's Central Statistical Agency (CSA) were utilized by [96] to demonstrate that *P. juliflora* invasion issues caused the cow and camel populations in the Amibara zone, which was the study area, to decline at rates of 36% and 20%, respectively, between 1997 and 2011.

2.3. Control Methods of Prosopis julifora Invasion

Other *P. juliflora* management approaches, such as prevention and confinement, are rarely practical as management alternatives in locations where *P. juliflora* species have already spread over very vast areas. Control, in conjunction with restorative habitat management, may be the only effective approach at that point. A control program seeks to minimize the abundance and density of infestations while keeping the adverse effects of an invasion as low as feasible and within acceptable bounds [8]. Mechanical, chemical, and biological control mechanisms are the three main categories of control systems, and each is discussed in more detail below. Several studies have demonstrated that using a single management strategy will not control or diminish the invasion of *P. juliflora*. As a result, integrated techniques that combine more than one alternative are required to limit the spread of this weed [37, 97].

2.3.1. Techniques of Mechanical Control

Physical manipulation or uprooting of plants, which is usually accompanied with burning, are examples of mechanical control approaches [98]. Mechanical and manual control techniques entail the elimination of an infestation's invaders by hand or with tools, equipment, or machinery Alien plant invasions can be manually controlled by pulling, uprooting, hoeing, falling, or cutting back. Such approaches can be labor-consuming, but in areas where human labor is commonly accessible and reasonably priced, manual techniques is frequently both efficient and economical. Ring-debarking (girdling) might also be helpful, but only for getting rid of woody intruders of species that aren't coppicing.

The majority of manual control techniques also have the advantage of being entirely target-specific. However, because disturbed ground and soil erosion in cleared areas may encourage reinvasion, additional follow-up control operations and subsequent restoration efforts are frequently needed. Large-scale infestations are rarely entirely eradicated by manual control. The obvious drawback of mechanical treatments that use bulldozers, tractor-drawn plows, or other machinery to raze no target plant species as well as target plant species is that they are indiscriminate and may create conditions that are favorable for re-invasion. It is critical to keep clearing and uprooting newly developing saplings from farmlands, pasture grounds, and surrounding towns by hand. Mechanical control, such as chopping for charcoal and firewood, may be useful in lowering the impact on native plant species and the rate of invasion [99]. Cutting, however, will not help to eradicate *P. juliflora* in the area unless done some distance below ground due to its excellent coppicing capacity and a significant number of sprouts after cutting. The second most effective but labor-intensive mechanical control method involved digging up the plant to a depth of 10-15 cm before using the space for crop cultivation [100].

2.3.2. Regulation by Chemical

Chemical management methods, which involve the careful use of licensed herbicides, can improve the effectiveness of manual and mechanized clearing activities. Systemic herbicides applied to cut tree stumps or incisions created in the bark of trees or shrubs (known as frilling) will gradually kill the targeted trees or shrubs after spreading via the vascular tissue of treated invaders. Basal stem therapies and stem injections have the same effects. These applications are extremely targeted, with no detectable off-target impacts [8].

Cutting the stem at ground level and applying a suitable pesticide to the freshly cut stumps will kill larger trees and shrubs. Herbicides include Roundup, 2-4, D, Glenside Kerosene, and diesel fuel. It is usual practice to use herbicide foliar sprays, such as glyphosate, to reduce the seedlings of woody invaders. Herbicidal sprays offer a quick and efficient way of control with immediate effects when applied using portable "pack" sprayers. The risks of collateral damage and adverse effects on non-target species, which are always a risk with herbicides, can be decreased where chemical treatments can be given topically to specific plants. Many herbicides are non-selective in their activity; thus care must be taken while using them [8]. Herbicides licensed for use are effective against weeds, but chemical management calls for frequent, routine follow-up treatments [101]. In general, *P. juliflora* plants up to 5 cm in diameter and wet stems from the ground to 30 cm height can be efficiently controlled using Triclopyr + picloram @ 1 L/60 L diesel. *P. juliflora* can be controlled by cutting the stem close to the ground and treating it right away with triclopyr + picloram @ 1 L/60 L diesel. Triclopyr + picloram in a high volume (total spray), as Grazon DS Extra, can control *P. juliflora* seedlings and plants up to 1.5 m tall [102]. In their examination into the efficacy of herbicide application, [103]. found that Mera-71 @ 40 gm/ltr, followed by 2, 4-D @ 10 gm/ltr, was more effective than paraquat @ 30 ml/ltr and diuron @ 5 gm/ltr across all stem thickness sizes. The research also showed that Mera-71 and 2, 4-D work better together than they do separately to suppress *P. juliflora* growth. Paraquat and Diuron were approximately twice as effective when compared to Mera-71 (Glyphosate and 2, 4-D) [103].

2.3.3. Biological Regulation Methods

The most economical and reliable means of controlling massive infestations of invasive alien plant species, biological management (biocontrol), has gained popularity in many countries over the past few decades. The introduction of one or more highly specialized alien species that are physiologically designed to exclusively prey on or attack only plants of that species from the region where the invasive plant species naturally occurs is known as biocontrol [8].

In most situations, the introduced organisms are illnesses, mites, or insects that are particular to the host (mainly fungi). These are creatures that regulate plant development in their natural habitats. And it is in the absence of these natural adversaries that the plants can erupt into plenty and become invasive in their adopted environments, where they encounter no such foes. It is possible to introduce multiple control organism species, each designed to target a different aspect of the targeted invasive species. While biocontrol does not completely eradicate the alien plant invasion, it does lessen the competition that it has with local plant species, reducing its density and environmental impact and promoting the recovery of native vegetation [8].

P. juliflora reproduction is controlled by predators or infections. Sudanese researchers discovered predator insects that attack the leaves, causing the forest canopy to deteriorate. In Australia, four bug species have been introduced as biological control agents against mesquite: Evippe spp., Prosopidopsylla flava, Algarobius bottimeri, and Algarobius *Prosopis juliflora*. The larvae of these beetles devour mature mesquite seeds in pods on the ground and in trees (a leaf-tying moth that causes defoliation). Nonetheless, removing the tree is a time-consuming process [102].

The seed-feeding bruchids Algarobius bottimeri and A. Prosopis, the leaf-tying moth Evippe species, and the sapsucker Prosopidopsylla Flava have all been released in Australia [104, 105]. Two (A. Prosopis and Evippe species) have proliferated considerably, with the latter significantly affecting *P. juliflora* populations by decreasing long-term growth rates [105]. Australia has had better success with biological control than other countries, such South Africa, and the benefit-to-cost ratios are positive (0.5), with future estimates of rising [106]. To further strengthen control, more agents should be made available [104, 105].

2.3.4. Utilization Method

Traditional *P. juliflora* regulation approaches, particularly especially mechanical and chemical methods, have proven to be costly and ineffectual [107, 108]. As a result, measures aimed at minimizing expenses while maximizing economic advantages are being considered in many emerging countries. As a result, it might be claimed that using Prosopis is the greatest alternative for controlling the invasion of multiple invaded areas [10, 109]. Bekele, M., Girmay, Z. [109] coined this word to describe the economic exploitation of invasive species as a strategy of harnessing their economic potential for addressing basic human needs while also regulating their expansion and possibly destroying them. These usage policies are encouraged in developing countries because they provide new business options for the affected populations and significantly aid in the management and control of invasive species. The least preferred options in most developing nations are the more expensive biological and mechanical control techniques [28].

Current *P. juliflora* utilization and eradication techniques in Ethiopia include turning infested fields over to irrigated agriculture, making charcoal, and making flours [10, 92]. In the past, NGOs operating in Afar established cooperatives that manufactured and sold *P. juliflora* charcoal and flour made from its seed pods [92]. *P. juliflora* charcoal, farmed and manufactured in Afar, is now marketed and sold in major Ethiopian cities such as Addis Abeba and Mekelle [110]. Crushing and milling seed pods yield flour, which is used as animal feed.

In the right environmental situation, controlling the spread of *P. juliflora* can be a cost-effective management strategy, claim [111, 112]. The management of *P. juliflora*-infested sites for the production of charcoal and the conversion of *P. juliflora*-infested lands into irrigated agriculture are both commercially viable [111]. India-based research indicates that it is very profitable to produce charcoal from *P. juliflora* wood [112, 113]. To allow for the region's long-term growth of the charcoal business, it is also necessary to change the country's rules on charcoal (such as production and transportation, according to [110] which appear to be lacking.

Figure 3. *Women removing uprooted P. juliflora stumps from invaded lands for utilization in the A Source; [8] Prosopis juliflora utilization assessment in Ethiopia's Afar area.*

Another study found that by removing viable seeds, making flour from *P. juliflora* pods can also be used to stop new invasions. However, under Ethiopia's current management practices, the business was not commercially viable. Poor marketing strategies, expensive processing costs for pods (such as drying and crushing), and high initial investment costs are some of the causes [111]. For instance, combining *P. juliflora* flour with antiemetic medications, converting it into feed blocks, and marketing the final product as the best animal feed for worm control and cow production considerably raised the value of the ingredient in Kenya [113]. Ethiopian flour firms require study assistance, particularly on the nutritional qualities, chemical compositions, and toxicity levels of *P. juliflora* pods. Subsidies for flour producers should also be considered as a means of contributing to the control and eradication of this very invasive species.

3. Conclusion and Recommendations

3.1. Conclusion

Prosopis juliflora is the most common and harmful alien plant species in a variety of settings, including croplands, rangelands, roadsides, woodlands, watersheds, and other economically important ecosystems; there is also significant potential for species spread. The disadvantages and costs of *P. juliflora* for local livelihoods, rangeland health and biodiversity, and the national economy due to lower cow yield outweigh the benefits. The negative consequences on the environment and human livelihoods are fast-growing, and there is an urgent need to develop more effective management systems to substantially minimize negative impacts and increase benefits.

Through mechanical, chemical, and biological control measures, it is possible to remove this plant over time by making use of its potential beneficial benefits. This can be accomplished by offering job opportunities for job seekers that assure effective tree removal for various objectives. However, early government and non-governmental organization support are required for those groups to assure the effectiveness of eradication through usage.

3.2. Recommendations

To develop strategies for preventing further spread of this weed or achieving its eradication, a well-planned program should encourage participation from all stakeholders from the national to district level, including universities, research centers, individual researchers, government and non-governmental organizations, as well as the local traditional institutions;

Using integrated controlling techniques can have a beneficial synergistic effect. In this situation, a long-term and effective plan should be in place to convert the *P. juliflora*-occupied territory into cropland or another type of commercial setting;

Educating the public on P. juliflora's impact on agricultural productivity, human health, and the ecosystem, especially in pastoral and agro-pastoral areas. Accordingly, simple and affordable control mechanisms that may be implemented by these groups should be found in order to shorten their expected lifespan. All stakeholders should be able to understand the language in which research findings are conveyed;

There needs to be an extension service that can forge strong ties with the community and disseminate new technology and scientific discoveries in regional tongues. The use of local and national radio, television, newspapers, newsletters, brushers, and booklets can help with this extension service.

Competing Interest

The authors declare no competing interests.

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