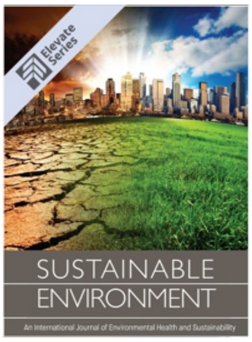

Taylor & Francis
Taylor & Francis Group

Sustainable Environment

An international journal of environmental health and sustainability

ISSN: 2765-8511 (Online) Journal homepage: www.tandfonline.com/journals/oaes21

Prosopis juliflora (sw.) DC in the drylands: A review of invasion, impacts and management in Eastern Africa

Josephat Mungoche, Oliver Vivian Wasonga, Davis Ikiror, Haron Akala, Charles Gachuiri & George Gitau

To cite this article: Josephat Mungoche, Oliver Vivian Wasonga, Davis Ikiror, Haron Akala, Charles Gachuiri & George Gitau (2025) *Prosopis juliflora* (sw.) DC in the drylands: A review of invasion, impacts and management in Eastern Africa, Sustainable Environment, 11:1, 2521946, DOI: 10.1080/27658511.2025.2521946

To link to this article: https://doi.org/10.1080/27658511.2025.2521946

Published online: 23 Jun 2025.

Elevate Series

SUSTAINABLE ENVIRONMENT
2025, VOL. 11, NO. 1, 2521946
https://doi.org/10.1080/27658511.2025.2521946

ENVIRONMENTAL RESOURCE MANAGEMENT | REVIEW ARTICLE

OPEN ACCESS Check for updates

Prosopis juliflora (sw.) DC in the drylands: A review of invasion, impacts and management in Eastern Africa

Josephat Mungoche [a], Oliver Vivian Wasonga [a], Davis Ikiror [b], Haron Akala [a], Charles Gachuiri [c] and George Gitau [d]

[a]Department of Land Resource Management and Agricultural Technology, Faculty of Agriculture, University of Nairobi, Kangemi, Kenya; [b]Vétérinaires Sans Frontières Suisse (VSF-Suisse), Nairobi, Kenya; [c]Department of Animal Production, Faculty of Veterinary Medicine, University of Nairobi, Kangemi, Kenya; [d]Department of Clinical Studies, Faculty of Veterinary Medicine, University of Nairobi, Kangemi, Kenya

ABSTRACT

Prosopis juliflora is a native tree species of Central and Southern America. Since its introduction in eastern Africa, *P. juliflora* has invaded most of the drylands with far-reaching negative effects on people's livelihoods and the environment, amid several benefits derived from its use. This systematic literature review aimed to provide empirical evidence from existing studies on the extent of spread, impacts, management options and lessons learned in Eastern Africa. This study utilized results from 52 studies in Eastern Africa selected through a multi-step screening process. Key findings reveal that *P. juliflora* has occupied significant swathes of land, disrupting native ecosystems, encroaching on water resources and causing socio-economic hardships, but has at the same time provided utilization opportunities for various purposes. In Ethiopia, *P. juliflora* occupies 12% of the land surface, and close to 550,000 hectares in Somaliland, while in Kenya, its spread has increased more than 200-fold since the 1980s. In Eastern Africa, its management strategies involve mechanical, biological, reseeding after removal and utilization approaches, with emphasis on community involvement and economic utilization. Tanzania and Uganda also promote mechanical removal, reseeding after removal and utilization, emphasizing community involvement and preventative measures. Key lessons across eastern Africa include the effectiveness of integrated approaches combining mechanical, chemical and biological methods with economic utilization; the critical role of community involvement and the importance of continuous monitoring of the rate of spread of *P. juliflora*.

ARTICLE HISTORY
Received 26 August 2024
Accepted 15 June 2025

KEYWORDS
Invasive plants; Prosopis; spread; impact; control; management; utilization

Introduction

In the recent past, biological invasion has been on the rise (Pasiecznik, 2022), particularly the invasive plant species that have become a major concern in the rangeland ecosystems. The invasions have been recognized as a worldwide challenge with negative impacts on the environment, biodiversity and livelihoods (Shackleton et al., 2019). According to Linders et al. (2019), invasive plant species pose a substantial threat through reduced land productivity resulting in food insecurity, compromised adaptive capacities of pastoralists, livestock diseases, loss of livelihoods, and loss of native plant species. The loss of vital rangeland habitats, in particular, is associated with the deterioration of vegetation value and soil quality. The decreasing capacity of the rangelands to adequately nourish livestock (Arjjumend, 2018; Blache et al., 2016; Oba, 2012), which are the main livelihood assets of pastoralists, results in a reduced ability of pastoralists to meet their basic needs, besides associated contribution to conflicts over scarce resources, and other negative impacts on the wellbeing of communities. As indicated by Hughes et al. (2022) P. juliflora within belongs to the Neltuma clade, a group largely composed of invasive species, suggesting a higher invasive potential within this lineage.

According to the Global Invasive Database Witt et al. (2018), there are close to 210 invasive plant species in Eastern Africa. The distribution of these alien plant species in each country is as follows; Kenya (49), Tanzania (48), Uganda (33), Somalia (11) and the rest are spread in the other Eastern African countries (Shackleton et al., 2019). The most prevalent alien plant species in the region is *P. juliflora* locally known as 'Mathenge' in Kenya. *P. juliflora* has been listed among 100 of the 'Global' worst invasive plant species because of its huge impacts on pasturelands, agriculture and livelihoods, particularly for pastoralist communities globally. The species has been reported to cause threats to animal and human lives in Somalia, Kenya, Djibouti, Eritrea, Tanzania, Rwanda, Sudan and Ethiopia.

CONTACT Josephat Mungoche murungajosephat@gmail.com Department of Land Resource Management and Agricultural Technology, Faculty of Agriculture, University of Nairobi, P.O. Box 29053, Kangemi 00625, Kenya

Prosopis juliflora, a native of South America, Central America and the Caribbean, is a fast-growing, leguminous and drought-tolerant tree species, locally known as *Mathenge*, after the extension officer associated with its introduction in Kenya (Pasiecznik, 2022). *P. juliflora* blooms year-round with yellow flowers (Batista et al., 2002). Its fruit takes the form of pods, initially green in their immature state but transforming to yellow upon maturity. These pods have a high sugar content and are appetizing to livestock when fully ripe. A mature *P. juliflora* tree has the potential to yield 40 kg of pods annually, containing approximately 60,000 seeds (Alban et al., 2002, Nair et al., 2021). Due to its rapid growth, resilience to drought and salt, and ability to regenerate from cuttings, *P. juliflora* has effectively colonized extensive areas of arid lands in Kenya.

The plant was introduced to Africa for various reasons, including rehabilitating degraded lands, reducing soil erosion and providing shade, fodder, honey, charcoal, timber and fuel (Van Klinken, Hoffmann, Zimmermann, & Roberts, 2009). The earliest *P. juliflora* was introduced in Africa as follows: Senegal in 1822, Sudan in 1917, Kenya in 1948 and later Ethiopia and South Africa in the 1970s and 1980s (Sintayehu et al., 2020). In all these cases, the species was introduced to address fuel wood shortage and combat land degradation in arid and semi-arid areas. *Prosopis juliflora* species is found in 129 countries around the world in hot arid and semi-arid areas, but in many places where they were introduced, they have become invasive (Shackleton et al., 2014). This is due to their ability to produce many seeds that remain viable for decades, their fast growth rates, their ability to regenerate even after damage, and their efficient use of surface and groundwater through their deep root systems. *P. juliflora* withstands extreme weather conditions, such as high temperatures and low rainfall, and is not limited by alkaline, saline, or infertile soils (Hosseini Nasr et al., 2012).

During the 1980s, *P. juliflora* became a popular choice for dryland afforestation and soil control programs in Kenya. The local communities discovered that the tree withstands constant cutting in arid areas and began to embrace it, contributing to its spread (Maundu et al., 2009). Compared to other invasive species, *P. juliflora* rapidly spreads in arid areas, therefore drawing the attention of policymakers, development agencies, scientists and the public, particularly due to its impacts on the environment and local communities (Akwee, 2023; Hussain et al., 2021; Mwangi & Swallow, 2005). Despite its benefits, *P. juliflora* also caused concern due to its negative impacts, which include injury from its thorn to people and animals, wearing and loss of teeth and diarrhea when consumed by livestock, displacement of important fodder species, and encroachment of paths, dwellings, water sources, farm fields, grazing/browsing areas, and serving as hideouts for criminals and habitat for snakes (Huho & Omar, 2020; Maundu et al., 2009; Tuwei et al., 2019).

Because *P. juliflora* has both beneficial and harmful traits, its complete eradication may not be the best solution (Wakie et al., 2016). The chemical and mechanical methods used for its eradication are expensive, labor-intensive and often ineffective (Eschen et al., 2021; Hussain et al., 2021; Tuwei et al., 2019). Therefore, utilization of the species for income generation remains the best approach, as recommended by various studies (Tuwei et al., 2019; Wakie et al., 2016). This method is promoted because it creates new opportunities for generating income while contributing positively to the control and management of the invasive *Prosopis* trees (Shackleton et al., 2014).

The management of *P. juliflora* species is a challenge because there is inadequate information and understanding of the important characteristics of these invasive species (Khan et al., 2022; Sivakumar et al., 2018). To reduce plants' negative effects and increase their benefits, it is essential to comprehend their dynamics. Since only 13% of nations with naturalized and invasive *P. juliflora* have thorough occurrence records, we must increase our understanding of *P. juliflora* distribution and population levels in drylands where they have been introduced (Shackleton et al., 2014) to guide decisions on the species management. There is a need for empirical data on the spread, impacts, management, utilization of *P. juliflora* and lessons learned from its management efforts in Eastern Africa to develop effective management strategies for the species. The generalized management and control efforts in the region have yielded relatively little success, and, therefore, the need for area-specific intervention strategies in the region. This systematic literature review presents the spatial distribution, ecological and socio-economic impacts of Prosopis, its, control and management, as well as lessons learned and associated knowledge gaps in Eastern Africa.

Methodology

Literature search

In developing an effective search strategy, the framework developed by Kable et al. (2012) was utilized. This framework is a valuable tool for documenting the search strategy used in a systematic review and helps researchers consider all necessary aspects for finding relevant literature. In this systematic review, the relevant publications were identified using titles, abstracts and keywords before subjecting them to an exclusion/inclusion criterion. The review focused on the publications that entailed the extent of invasion/spread, impacts, management and associated lessons learned. The literature that did not meet this eligibility criteria was excluded. In addition, the identified articles were excluded from the review if their full text was unavailable or unpublished.

A data extraction form was created to enable the extraction of relevant information from each article and its categorization. Using the form, each article was screened for pertinent information, eliminating the need to read the entire paper. The information collected from the selected literature included the title, authors, year of publication, country, journal, type of study and key findings related to spread, impacts, management and lessons learned from respective countries. The retrieved data were analyzed to address the primary objectives of the review. The search resulted in a selection of 52 studies from various eastern Africa countries that were included in this review (Figure 1). Many of the included studies, such as retrospective, observational and cohort studies, were conducted using databases or data collected from previous studies.

Search terms and databases

The literature review utilized the Web of Science, Google Scholar, Science Direct, 'CAB Direct', 'Agricola', 'Scopus' and JSTOR, which are widely used multi-disciplinary research platforms that are linked to a vast array of peer-reviewed journals and are regularly updated. Systematic searches were performed from February 2024 to April 2024, adhering to PRISMA guidelines (Figure 1). Many search terms were discarded after test batches revealed they did not yield any new or relevant results. The final search terms used were: *P. juliflora*, the extent of *P. juliflora* cover in Eastern Africa, lessons learned on *P. juliflora* management, and 'spatial' or cover or area and distribution or trend or spread or extent, and ecological impact or socio-economic impacts or livelihoods impacts and management strategies or control strategies or utilization and species or plants.

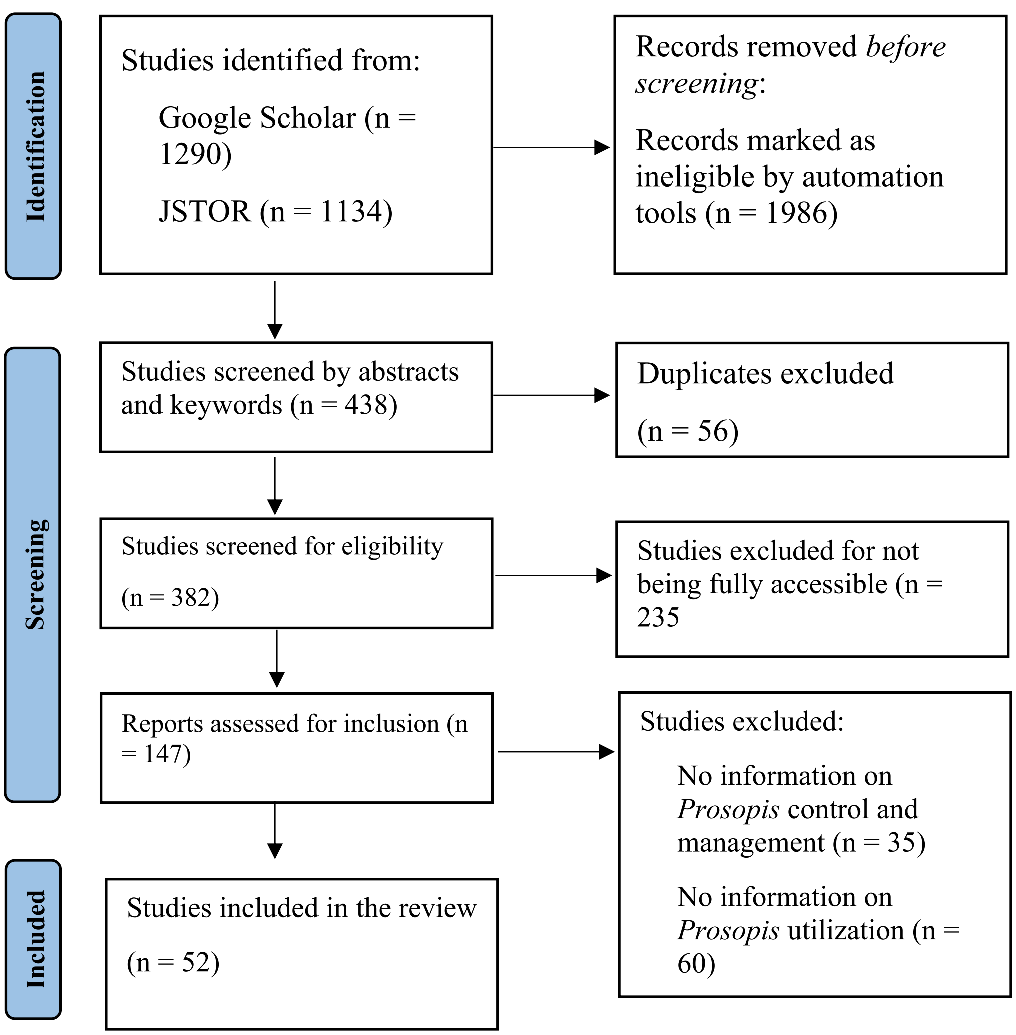

Figure 1. Identification and screening process for studies for inclusion in the systematic literature review.

Table 1. Inclusion and exclusion criteria for the systematic literature review

Inclusion criteria	Exclusion criteria
Studies about *P. juliflora* as an invasive species	Studies about invasive that did not specify the names of the plants
Peer-reviewed journal articles, conference papers, theses and dissertations	Editorials, opinion pieces and non-peer-reviewed articles
Studies focusing on the spread, ecological and socio-economic impacts and management strategies of *P. juliflora*	Studies not addressing the spread, impacts, or management of *P. juliflora.*
Studies providing empirical data, statistical analyses, or strong qualitative assessments on the effects of *P. juliflora* on the livelihoods of people.	Studies lacking empirical data or strong methodological approaches
English publications on *P. juliflora*	Non-English publications *P. juliflora*
Studies published from 2000–2024	Studies published before 2000
Studies conducted in Eastern Africa (Kenya, Ethiopia, Somalia, Sudan, South Sudan, Eritrea, Djibouti, Tanzania, Uganda)	Studies in regions outside Eastern Africa

Search criteria and query

A multistep process was followed to compile all the relevant publications (Figure 1). The empirical studies that fulfilled a set of criteria were picked for further analysis. The criteria included: a) papers published between 2000 and 2024; b) studies conducted within eastern Africa; c) publications on management and control of *P. juliflora;* d) studies on the spatial distribution of *P. juliflora*; e) studies on ecological, social, environmental and economic impacts of *P. juliflora.*

Eligibility criteria

An eligibility criterion was applied to ensure the inclusion of relevant studies and to prevent the exclusion of any study without it being assessed. Studies were included for review only if they met one or more of the exclusion criteria (Table 1). The search was confined to peer-reviewed journals, as these sources provide validated knowledge and reliable estimates of accepted topics and methodologies. The time frame for the studies selected for this review was 2000 to 2024 to capture both past and recent research on *P. juliflora*. However, due to the scarcity of research on some topics, studies from 2000 were included. The search terms were limited to the title, abstract, and keywords of the articles.

Summary of key findings for thematic areas

Hotspots of P. juliflora *in Eastern Africa*

The alien plant species invasion has posed serious challenges to biosecurity in Eastern Africa (Sileshi et al., 2019). This has compromised the provision of ecosystem services as well as adversely affected the livelihoods of people, particularly in rangelands where pastoralism is the primary source of livelihood (Bogale & Tolossa, 2021). *P. juliflora* is spread in eastern Africa countries such as Kenya, Ethiopia, Somalia, Eritrea, Sudan, Djibouti and Uganda (Figure 2). The species thrives in environments with annual average rainfall ranging from 150 mm to 1,000 mm and can tolerate high temperatures and saline soils. The invasion of *P. juliflora* is exacerbated by changes in land use, the emergence of new propagules, and globalization (Carboni et al., 2018). *The species* has spread from its original sites, where it was introduced, invading the surrounding areas along livestock and wildlife corridors, river courses and infrastructural developments, which have acted as major dispersal pathways (Mbaabu, 2023). The disturbances of habitats attributed to land use changes have resulted in an increased dispersal of *P. juliflora* in many parts of Eastern Africa. The plant covers extensive areas along riverbanks, roadsides and grazing lands, displacing native vegetation and altering ecosystems.

The initial documented introduction of *P. juliflora* and *Prosopis pallida* to Kenya occurred in 1973 for the rehabilitation of quarries near the coastal city of Mombasa with seeds sourced from Brazil and Hawaii (Jama & Zeila, 2005). Subsequently, in the early 1980s, *P. juliflora* was introduced to the Lake Baringo area as part of the Fuelwood Afforestation Extension Project (Lenachuru, 2003). In Kenya, *P. juliflora* is predominantly found in Baringo, Tana River, Garissa, Marsabit and Turkana counties. In Baringo County alone, *P. juliflora* is estimated to cover about 18% of the land area Mwangi and Swallow (2008). The species made its initial entry into Bura, Tana River County in 1983 when a forester employed by Kenya's National Irrigation Board (NIB) established a pilot plantation of 10 hectares near Bura town. The primary goals of this project were to engage local communities in tree-planting for firewood and restoration of degraded land. The seeds utilized for the introduction of *P. juliflora* in Bura were procured from a commercial tree seed supplier based in the Netherlands (Zeila et al., 2004). The species has since spread to neighboring Garissa County. Flooding has contributed to further invasion of the species through seed dispersal

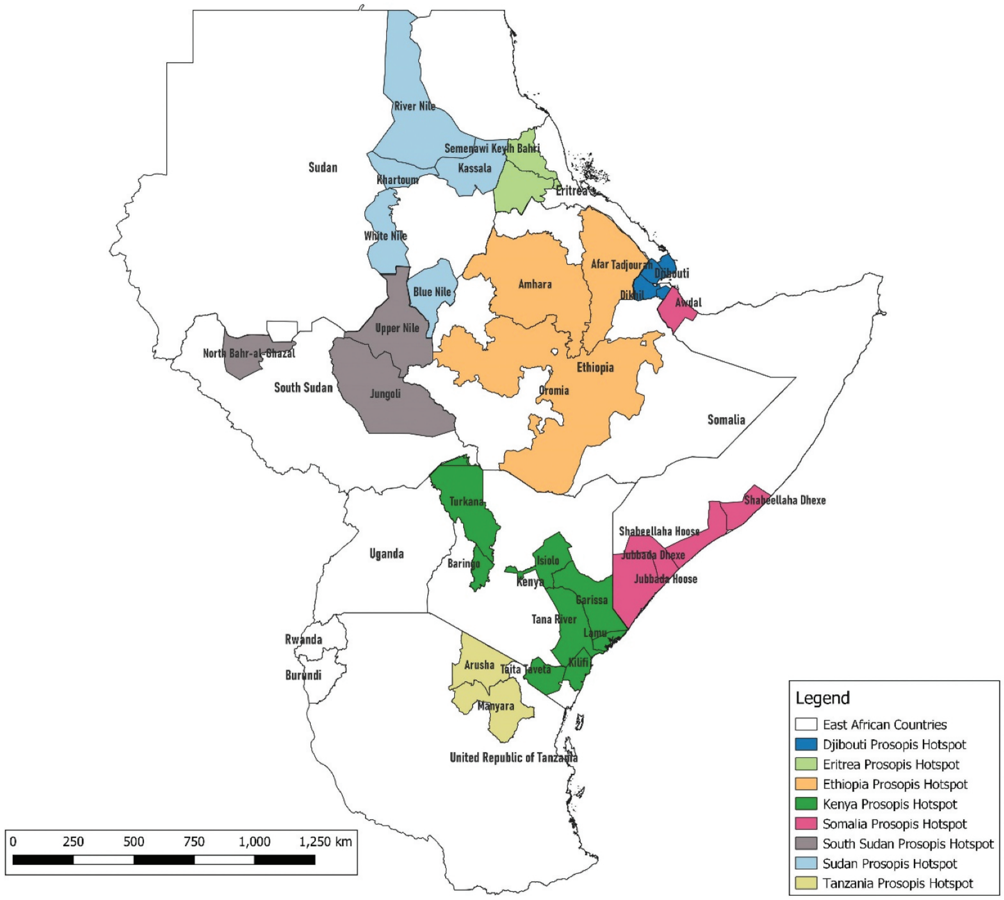

Figure 2. Hotspots of Prosopis juliflora in Eastern Africa (Source: Author).

to other areas along the Ewaso Nyiro River in Isiolo County of Kenya. However, livestock and wildlife are considered the main dispersal agents of *P. juliflora* through the process of endozoochory whenever they feed on the pods. The changes in the animal (both domestic and wild ungulates) movement patterns due to shifts in seasonality and prolonged droughts have also escalated the dispersal of the *P. juliflora* seeds through dung in Kenyan rangelands including Isiolo County, Kenya. Due to an increase in infrastructural development, nomadic pastoralism, prolonged droughts, and climate change, there is increased invasion of *P. juliflora* in Kenyan rangelands particularly, Isiolo County. The dispersal of *P. juliflora* is through the movement of livestock across the grazing sites. The concentration of people within a settlement site also exacerbates the spread *of P. juliflora* due to the presence of waterpoints for domestic and livestock use.

In Ethiopia, *Prosopis juliflora* was introduced in the 1970s to combat desertification and provide fuelwood (Berhanu & Tesfaye, 2006), and the species has since spread extensively due to favorable climatic conditions (Boy, 2005). It covers approximately 12% of the land in Ethiopia, significantly affecting the livelihoods of people in the Afar and Somali regions (Shiferaw et al., 2019). The species has spread rapidly and encroached on the pastures, leading to diminishing grazing lands in the affected regions. It is estimated to cover approximately 1.2 million hectares, constituting about 3 (Shiferaw et al., 2019) – 5% (FAO, 2020) of Ethiopia's total land area. It has invaded rangelands, agricultural fields and water points, posing a threat to food security and biodiversity. In Somalia, *P. juliflora* covers around 550,000 hectares, particularly in Somaliland. The species was introduced for similar reasons as in other eastern African countries but has since spread, affecting both agricultural and pastoral lands (Kamiri et al., 2024).

The species was introduced in Sudan in the early twentieth century for dune stabilization and fuelwood (Mudoi, 2022). It now occupies large areas in the eastern and central regions, including Kassala and Gedaref States. The species has also spread to South Sudan, where it impacts the livelihoods of people along the Nile and Sobat river basins (Khider et al., 2011; Wakie et al., 2016). In Eritrea and Djibouti, *P. juliflora* was introduced in the 1980s and 1990s for afforestation and combating desertification. It has since invaded extensive areas, particularly in the coastal and arid regions, affecting local biodiversity and water resources (Gianvenuti et al., 2018).

In Tanzania, *P. juliflora* is found mainly in the semi-arid regions of the northern and central parts of the country. Introduced for agroforestry and land rehabilitation, the species now affects both agricultural lands and natural ecosystems, leading to conflicts over land use due to the shrinking of productive lands (Bukombe et al., 2021). *Prosopis juliflora* was introduced to Uganda in the early 1970s by the Food and Agriculture Organization (FAO) as part of efforts to combat desertification and soil erosion (Obonyoa et al., 2017). The species was promoted for its drought tolerance, ability to stabilize soils, and potential to provide fuelwood and fodder in arid and semi-arid regions. Initially, it was planted in areas like Karamoja in northeastern Uganda, where it was expected to address environmental degradation and meet community needs. However, over time, it became invasive, leading to challenges in managing its spread and mitigating its negative ecological and socio-economic impacts. It poses a potential threat to native vegetation and agricultural productivity in the semi-arid regions of Karamoja and other northern areas (Wakie et al., 2016).

Impacts of **P. juliflora** *in Eastern Africa*

Prosopis juliflora has both negative and positive impacts on the environment, people's well-being and economic dynamics at various temporal and spatial scales (Mudoi, 2022). The negative effects can be classified into competition for resources (water, light, space and nutrients); physical obstructions; health effects (livestock poisoning, physical injury, human and animal disease vectors); depletion of water sources (deep root acquisition of water) and allelopathic suppression. The positive impacts include control of erosion, biological nitrogen fixation, provision of habitat for wildlife (cover and nesting platform for birds), source of nectar/pollen and pumping of nutrients from subsoils for crop production.

In most Eastern African rangelands, including Isiolo County, the negative impacts of *P. juliflora* outweigh its positive attributes. The species invasion has resulted in changes in the natural rangeland ecosystems and caused huge negative impacts on the livelihoods of pastoralists and agro-pastoralists inhabiting the arid and semi-arid rangelands. The socio-economic impacts of *P. juliflora* in Kenya's rangelands range from tens of millions to billions of dollars annually with massive ecological impacts (Kamiri et al., 2024). Studies have reported that the *P. juliflora* invasion has resulted in a decline in livestock numbers leading to decreased income from pastoralism in Kenya's rangelands in the last 10 years (Eschen et al., 2021; Mbaabu, 2023; Mohamed & Mbataru, 2021). The cost of managing the species has also been reported to be too high, for instance, in South Africa, it is estimated that the country uses USD 35.5 million annually on the management and control of *P. juliflora* (Kamiri et al., 2024).

Despite the highlighted negative impacts of *P. juliflora*, the species has many economic benefits such as the provision of timber, fuel, feed for livestock and acting as a windbreak (Ravhuhali et al., 2021). For instance, in Isiolo County of Kenya, the plant is widely used for charcoal production which is utilized locally in homes as well as sold to earn extra income. It is also used for making fencing poles in most parts of Kenyan rangelands including Isiolo County. In some regions such as Baringo County, Kenya, *P. juliflora* pods have been used to make flour for human consumption as well as for livestock feds from the seed pods (Koech, 2010; Maundu et al., 2009; Odero, 2015). This has generated income and reduced the spread and invasion by the removal of viable seeds. *P. juliflora also* increases the availability of soil K, Mg, Ca, soil P and total N as well as contributing to biological nitrogen fixation and addition of organic C to the soil through leaf litter fall. However, there are still research gaps on the effects of *P. juliflora* on soil improvement for potential future land uses.

Ecological impacts of **P. juliflora**

A study conducted in Kenya's semi-arid rangelands reported a 27% decline in the herbaceous plants covered under *P. juliflora* within a year (Choge et al., 2022). *P. juliflora* invasion also leads to the loss of useful C4 rangeland grass species such as *Cenchrus ciliaris Eragrostis* spp., Cynodon spp., *Chrysopogon* spp., *Hyparrhenia* spp, *Setaria* spp (Kamiri et al., 2024). The invasive *P. juliflora* has allelopathic properties and the leachates adversely affect the growth of other plant species as well as inhibiting seedling growth and germination (Bibi et al., 2023; de Brito Damasceno et al., 2020; Khan & Shaukat, 2006).

Studies by Gitau (2020) and Witt et al. (2018) have indicated that the species out-compete the native plant species in Kenyan rangelands as it depletes the water and nutrient resources. The thorns have been reported to cause injuries to livestock and people (Hussain et al., 2020; Patnaik et al., 2017). In Merti, Isiolo County of Kenya, it has been reported that there are several cases of death of donkeys after prolonged consumption of *P. juliflora*. Similar cases have been reported in Somaliland and Ethiopia, where *P. juliflora* was attributed to Denervation atrophy disease in livestock (Awale & Sugule, 2006; Balcha, 2022). The *P. juliflora* invasion has also resulted in a shortage of livestock feed resources in Kenyan rangelands (Huho & Omar, 2020; Mwangi & Swallow, 2008).

Evidence in Eastern Africa shows that *P. juliflora* significantly alters invaded ecosystems. It leads to a decline in native species and depletes natural water springs (Tadros et al., 2020). Its evergreen nature contributes to continuous water consumption throughout the year (Shiferaw et al., 2023). In Kenya, it has displaced crucial forage species and native flora like *Cyperus* species in wetlands, reducing biodiversity and altering habitat structures (Masakha & Wegulo, 2015). In Ethiopia's Afar region, it has replaced native grass and forage species such as *Cynodon dactylon*, *Cenchrus ciliaris*, *Chrysopogon plumulosus* and *Brachiaria ramosa*, disrupting local wildlife (W. Shiferaw et al., 2021; Wakie et al., 2016). Despite these negative impacts, *P. juliflora* has been reported to improve soil physicochemical properties, stabilize soil and sequester carbon, offering some ecological benefits (Jama & Zeila, 2005; Shiferaw et al., 2021; Shitanda et al., 2013).

Riverine forests are facing increasing invasion by *P. juliflora*, posing a threat to indigenous species. The evergreen nature of *P. juliflora* contributes to its continuous water consumption throughout the year, with even higher water usage during dry seasons compared to rainy seasons. Consequently, unless the spread of *P. juliflora* is curbed and its density reduced in established areas, it is poised to have severe repercussions on the sustainable livelihoods of Eastern Africa (Shiferaw et al., 2021).

Clement et al. (2020) revealed that the invasion of *P. juliflora* of the riverine ecosystem of Turkana County, Kenya, has resulted in a reduction in the population of native forage species such as *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*, thereby jeopardizing the socio-economic livelihoods of the local communities. Across both riverine and non-riverine in Karamoja, Afar region, Lake Baringo, Awash river basin, Nile and Tana river sites, *P. juliflora* emerged as the most prevalent and dominant plant species (Anders Granström, 2005; Mworia et al., 2011; Shiferaw et al., 2021). Its invasive characteristics have contributed to a decrease in plant species richness and diversity along the riverine in Eastern Africa.

According to Masakha and Wegulo (2015), *P. juliflora* has displaced *Cyperus* species, which previously served as natural filters for water entering the Lakes Baringo and Bogoria. Unlike Cyperus, *P. juliflora* lacks the water filtration capabilities of this ecotone species it has replaced, potentially impacting the water quality of both lakes. Additionally, the proliferation of *P. juliflora* has outcompeted species that traditionally provided vegetables and fruits that were relied upon during drought seasons.

A study carried out by W. Shiferaw et al. (2021) in the Afar region of Ethiopia revealed that a mature *P. juliflora* consumes a substantial amount of water, ranging from 3.1 to 3.3 billion cubic meters annually, translating to about half of the amount of water received from rainfall in the areas it has invaded. Wakie et al. (2016) reported that wild animals, especially herbivores, have migrated to other areas and their numbers have declined due to the replacement of native grass and forage species by *P. juliflora*in Afar of Ethiopia. In Eastern Africa, *P. juliflora* has also adversely affected native flora by invading grasslands, shrublands and woodlands since it grows rapidly, quickly fills available space, forms dense thickets and prevents the growth of nearby native plants (Kamiri et al., 2024).

According to Shitanda et al. (2013), *P. juliflora* affects soil chemical properties, with areas beneath the canopies of *P. juliflora*, having a reduction in salinity and alkalinity compared to adjacent open areas. In addition, the abundance of organic matter in the soil attributed to the accumulation of fallen leaves, and nitrogen fixation properties due to its symbiotic bacteria in the roots has been reported to contribute to high levels of total nitrogen (Kahi et al., 2009). Shiferaw et al. (2021) observed that invasion of *P. juliflora* positively influences the physicochemical properties of the soil, therefore making the soils suitable for crop and forage production upon restoration). In arid regions where land is left exposed, *P. juliflora* species is used to mitigate desertification and manage soil erosion (Jama & Zeila, 2005). Additionally, the tree offers other beneficial services such as providing shade, stabilizing soil and sequestering carbon.

Socio-economic impacts of Prosopis in Eastern Africa

With its fruit-bearing cycle, it is feasible to collect large quantities of pods from forest areas and roadsides. These pods are utilized safely as a cost-effective feed resource by substituting expensive forages like corn and bran. The pods of *P. juliflora* are also processed to reduce their sugar content and utilized to produce commercial human food products (Shitanda et al., 2013).

Flowers of *P. juliflora* are a valuable source of pollen and nectar, attracting native pollinators, especially bees, which makes it suitable for apiculture (Jama & Zeila, 2005; Kuwait & Nepal, 2019). The plant's ability to flower throughout the year and produce plenty of pollen grains and sugar-rich nectar is highly beneficial for beekeeping and honey production (Kishoin et al., 2024). The honey from *P. juliflora* flowers is of high quality, with a pleasant taste and aroma (Pasiecznik, 2022; Walter & Armstrong, 2014). The honey and its products in Garissa are sold to generate additional household income (Mohamed & Mbataru, 2021).

As reported by Felker (2009), the exudate gums from the trunk and branches of *P. juliflora* are utilized in various industries, including food, pharmaceuticals, chemicals and manufacturing. The gum creates an adhesive mucilage and serves as an emulsifying agent in confectionery and for repairing pottery. The pharmacological properties are attributed to the presence of flavonoids, phenolic compounds, alkaloids and other secondary metabolites (Ukande et al., 2019). Therefore, the plant plays an important role in maintaining human health and well-being. The benefits associated with the utilization of *P. juliflora* include the provision of various ecosystem services, contribution to household incomes, increased adaptive capacity through nature-based solutions, and therefore enhanced resilience against climate change (Table 2).

Management strategies of P. juliflora

The management and control strategies for *P. juliflora* include chemical, mechanical and biological approaches aimed at reducing its spread and density (Kamiri et al., 2024). Mechanical control methods, such as hand pulling, cutting, digging, or uprooting, are common but costly (Maundu et al., 2009). In Kenya, the management of *P. juliflora* involves a combination of mechanical, biological and utilization strategies. The mechanical control methods include manual uprooting, cutting and clearing using machinery, although these methods are labor-intensive and costly, with estimates reaching approximately USD2125 per hectare (Maundu et al., 2009). Despite their effectiveness in the short-term, these methods require repeated efforts to maintain control over the invasive species (Table 3). Studies on biological control agents, such as seed-feeding beetles in Sudan like *Algarobius prosopis* and *Steraspis speciosa*, have shown promise in reducing seed viability and managing Prosopis populations (Khider et al., 2011). Utilization strategies play a significant role in the management of P. *juliflora*, particularly through its conversion into charcoal and other wood products. This not only helps control the spread of the species but also provides economic benefits to local communities. Charcoal production, in particular, has been encouraged as a viable solution, turning a problematic species into a valuable resource (Mwangi & Swallow, 2008).

In Ethiopia, *P. juliflora* has negatively impacted pastoral communities in the Afar region by reducing the availability of grazing land and water resources. Its invasion leads to the loss of livestock and increased vulnerability of local communities to food insecurity and poverty (Berhanu & Tesfaye, 2006). Despite these challenges, the species provides fuelwood and charcoal, which are crucial for household energy needs (Wakie et al., 2016). In Somalia, it has been reported that *P. juliflora* thorns harm livestock, while its dense thickets impede movement and access to water sources. Its invasion has exacerbated food insecurity and conflicts over land use (Alvarez et al., 2017). However, the species is used as fuelwood and provides charcoal, which is a source of income for local communities (Wakie et al., 2016).

In Sudan and South Sudan, *P. juliflora has* displaced native vegetation and reduced the availability of grazing land, leading to conflicts over resources, particularly in pastoral areas. Despite its negative impacts, the species provides fuelwood and construction material, contributing to local economies (Khider et al., 2011). In Eritrea and Djibouti, *P. juliflora* reduces native plant diversity by up to 80% in heavily invaded areas and depletes water resources by consuming approximately 25–30% more groundwater than native vegetation, while its dense thickets obstruct access to rivers and wells, exacerbating biodiversity loss and water scarcity. Its thickets impede movement and access to agricultural lands, leading to conflicts over access to critical land resources. However, it provides fuelwood and charcoal, which are vital for household energy needs (Gianvenuti et al., 2018).

In the Ng'ambo region of Tanzania, *P. juliflora* has encroached on agricultural lands and natural ecosystems, thereby intensifying competition over resources that eventually results in conflicts. Its invasion has increased food insecurity and reduced income for pastoralists. However, the species provides affordable wood for construction and fuel, supporting local economies (Bukombe et al., 2021). In the Karamoja region of Uganda, *P. juliflora* poses a potential threat to native vegetation and agricultural productivity. Its invasion leads to conflicts over land use and increased food insecurity in semi-arid regions (Wakie et al., 2016).

Relevant findings by country

Most of the studies on the management of *P. juliflora* in Eastern Africa have been predominantly conducted in Kenya and Ethiopia. The distribution of the reviewed publications on Prosopis management, spatial distribution, utilization and impacts in Eastern Africa shows

Table 2. Impacts of *Prosopis juliflora* (Adopted from Pasiecznik (2022); Lenachuru (2003); Berhanu and Tesfaye (2006); Clement et al. (2020); Huho and Omar (2020); Hussain et al. (2021); and Mbaabu (2023))

Impact Category		Impact Description	Impact outcome	Impact Mechanism
Ecological impacts	Competition	Competition for water and nutrients, results in reduced soil moisture and depletion of natural water springs.	Reduced native biodiversity Negatively impacts agriculture	Competition by monopolizing resources
	Biodiversity Loss	Reduction in the population of native forage species, decrease in plant species richness and diversity.	Reduced native biodiversity Threat to loss of native species	Competition by monopolizing resources
	Impact on water	Evergreen nature causes continuous water consumption throughout the year, with higher usage during dry seasons.	Modification of hydrology, Reduced native biodiversity	Competition by monopolizing resources
	Interaction with Other Species	Migration and decline in herbivore populations due to replacement of native grass and forage species	Threat to/loss of native species negatively impacts animal health	Competition by monopolizing resources
	Soil Composition	Positive changes: Reduction in salinity and alkalinity, Increased organic matter and nitrogen levels due to leaf litter. Negative changes: Alteration of soil nutrient pools	Soil accretion	Rapid growth and colonization of invaded areas
	Desertification/Soil erosion	Helps combat desertification by stabilizing soil, and preventing soil degradation	Soil accretion	Rapid/faster growth and spread
Economic Impacts	Pods for Animal Feed	Pods are used as a cost-effective feed resource, reducing feed costs for livestock.	Enhanced livelihoods through increased food production and income	Nutritious livestock feeds
	Human Food Production	Pods processed into flour or syrup for human consumption	Enhanced livelihoods through increased food production and income	Increased food sources
	Timber and Construction Material	Increased supply of high-quality wood for fuel, posts, timber, and poles	Enhanced livelihoods through income generation	Improved infrastructure
	Charcoal production	High-quality charcoal production, providing affordable cooking fuel	Enhanced livelihoods through income generation	Improved income
		Creation of employment opportunities through harvesting and collecting wood for bio-energy plants such as the one in Marigat, Baringo	Enhanced livelihoods through increased food production and income	
	Apiculture	Supports apiculture, through the provision of nectar for honey-making	Additional household income	Improved income
	Medicinal Uses	Traditional remedies for various ailments are attributed to the presence of beneficial compounds.	Improved health and wellbeing of people	Improved family health and wellbeing
	Gum and Tannin	Used in food, pharmaceuticals, and other industries.	Improved health and wellbeing of people	Improved Nutrition outcomes for people
Social Impacts	Health Impacts	Thorns cause harm to humans, potentially leading to hospitalization Increased risk of malaria due to the creation of mosquito breeding grounds.	Negatively impacts human health.	Produces spines and thorns
	Obstruction of Activities	Obstruction of roads, paths and reduction of visibility Hindering socio-cultural activities	Transportation disruption, Reduced amenity values	Rapid growth, Produces spines and thorns

Table 3. Management strategies for controlling Prosopis juliflora in Eastern Africa (Adopted from (Wakie et al., 2016); Ukande et al. (2019); Choge et al. (2022); Pasiecznik (2022); Mohamed and Mbataru (2021) and Kamiri et al. (2024))

Strategy Goal	Specific aim	Biophysical needs	Resource Requirements	Organizational needs
Mechanical Control	Use of machinery to remove trees and stumps.	Dry or moderately moist soil	Tractors, root ploughs, heavy chains	High level of management input, and maintenance of machinery.
Chemical Control	Use herbicides to reduce the growth and development of *P. juliflora*.	Trees with woody stems	Systemic herbicides, aerial application systems	Monitoring and regulation of herbicide use.
Biological Control	Introduce predators or pathogens to control reproduction and reduce the seed population.	Suitable habitat for biological agents	Identification and introduction of specific insects	Long-term monitoring, and collaboration with research institutions
Control through Utilization	Utilize cleared wood for charcoal or fuel wood. Use cleared land for pasture or crops. Manufacture pod-flour for animal feed and human food.	Suitable conditions for harvesting	Processing facilities, market access, training	Market development, community engagement

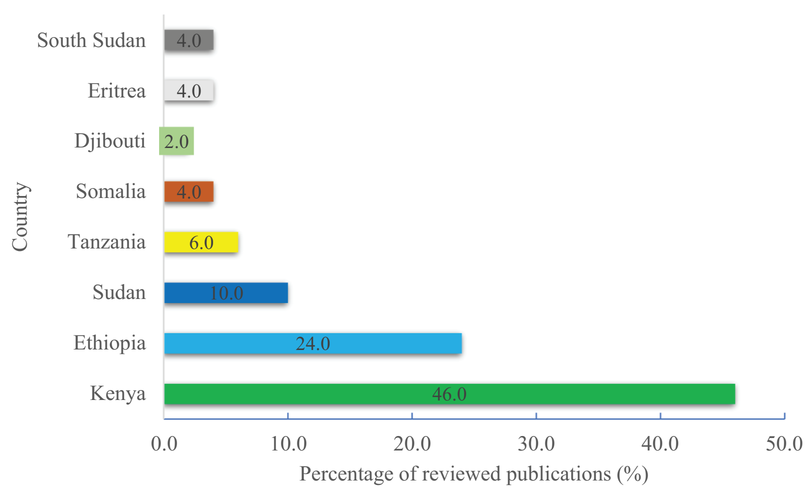

Figure 3. Distribution of publications on the management of *P. juliflora* by Eastern African countries.

Kenya leading with 46% of the papers, followed by Ethiopia (24%), Sudan (10%), Somalia (4%), Tanzania (6%), Eritrea (4%), South Sudan (4%) and Djibouti (2%) (Figure 3; Table 2). This indicates a strong research presence and a likely higher priority in addressing *P. juliflora*-related challenges in Ethiopia and Kenya. The higher number of studies in Kenya is attributed to, among others, the severity of the *P. juliflora invasion* and impacts in the country, the magnitude of interest and concern about *P. juliflora* in the Country, and presumably the urgency to understand its impacts to inform the management strategies and policy relative to Ethiopia.

The disparity in the intensity of research on Prosopis between the two countries suggests that while the invasion of *P. juliflora* is a concern in both Kenya, the problem is probably either more severe or more prioritized in Kenya. This may reflect differences in environmental conditions, the scale of *P. juliflora* invasion, the impact on the environment and communities, and availability or resource allocation to research and management efforts.

Management of P. juliflora *in Eastern Africa*

The studies on Prosopis management strategies reveal a balanced use of different methods to address the complex challenge posed by the invasive species. Its control through utilization, which is the most common strategy, emphasizes turning a problem into an economic opportunity (Choge & Muthike, 2014; Kamiri et al., 2024; Mohamed & Mbataru, 2021; Mwangi & Swallow, 2008; Patnaik et al., 2017; Wakie et al., 2016). Chemical control offers a quick and effective reduction of Prosopis spread but comes with environmental and safety concerns (Choge et al., 2022; Degefu et al., 2022; Ilukor et al., 2016; R. D. van Klinken, Hoffmann, Zimmermann, Roberts, & Muniappan, 2009; Wakie et al., 2016). Mechanical control provides immediate physical removal but is resource-intensive (Balcha, 2022; Shanwad et al., 2015; Wakie et al., 2016). These strategies represent a comprehensive approach to managing *P. juliflora*, reflecting both the urgency of the problem and the diverse conditions under which different methods may be applied effectively.

The 27 cited studies in this review, highlight three primary approaches of *P. juliflora* management: utilization, mechanical control, chemical control, restoration and biological control. Each strategy reflects different methods and philosophies for addressing the spread and the impacts of the species. The utilization approach emerged as the predominant management strategy, accounting for 55.6% of the reviewed studies (Figure 4). A study by Mwangi and Swallow (2008) emphasized the potential of *P. juliflora* as a source of economic benefits to local communities through the provision of fuelwood, charcoal and fodder. According to Sirmah (2018), the use of *P. juliflora* pods as livestock feed in Baringo Kenya highlights the nutritional benefits of the species and its potential to reduce grazing pressure on native forage species. According to N. M. Pasiecznik et al. (2001), *P. juliflora* pods can be processed into flour for human consumption, providing an alternative food source during times of scarcity. Choge et al. (2007) more economic opportunities presented by *P. juliflora*, including its provision of materials for furniture making and construction, thus creating employment opportunities among local communities.

Mechanical methods were reported in 22.2% of the reviewed studies, highlighting the reliance on physical removal techniques such as cutting and uprooting (Figure 4; Table 4). These methods are often employed in conjunction with other strategies to ensure more effective control of *P. juliflora* populations. Findings of the study by Shackleton et al. (2014) suggested that mechanical removal could be effective in the short-term, but might require continuous effort and monitoring to prevent regrowth. In Ethiopia, Mehari (2015) established that repeated cutting and manual removal could significantly reduce *P. juliflora* density, although it was found to be labor-intensive. In another study by Kassahun et al. (2008), it was reported that mechanical removal in Ethiopia led to significant reductions in *P. juliflora* cover, but also emphasized the importance of follow-up treatments to prevent reinvasion. Wakie et al. (2012) observed the need for combining mechanical methods with other strategies to enhance long-term effectiveness, which aligns with the current review's findings, showing the predominance of mechanical methods, in combination with other approaches to enhance efficacy.

Chemical control was highlighted 11.1% of the studies, with an emphasis on the application of herbicides to manage *P. juliflora* (Figure 4). This method is often considered when mechanical methods are insufficient or impractical. Zeila (2011) noted that herbicides could be effective in reducing *P. juliflora* density but need careful consideration of environmental impacts and the potential development of herbicide resistance. Balcha (2022) observed that specific herbicides could effectively control *P. juliflora* in northern Ethiopia despite the obvious concerns about the cost of application and potential environmental consequences. According to a study by Degefu et al. (2022) in Ethiopia, the efficacy of different herbicides in controlling *P. juliflora* and the importance of applying them at the correct growth stages showed effectiveness in the management of the plant. Linders et al. (2019) emphasized the role of integrated chemical management, combining herbicide application with mechanical removal to enhance overall control efficiency. The moderate representation of chemical control in the reviewed literature reflects the cost and

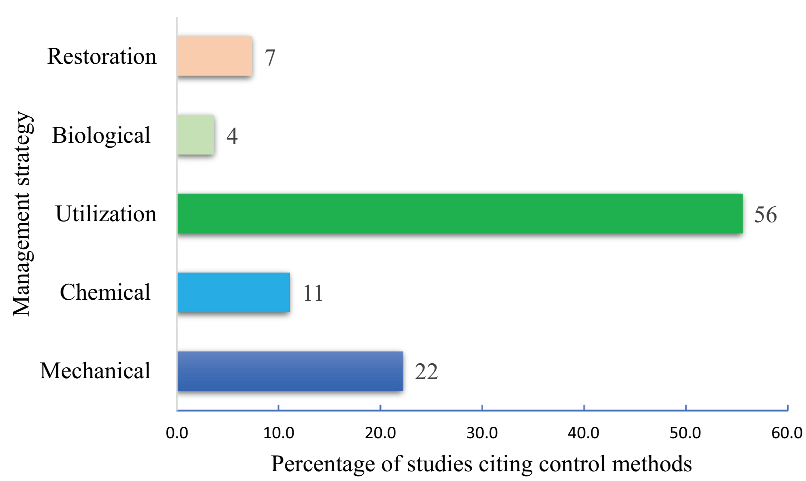

Figure 4. Management strategies of *P. juliflora* in the reported studies ($n = 27$ studies).

Table 4. Selected studies for each thematic area addressed in the review

Thematic Area	Key Findings	References
Spread and Spatial Distribution	*P. juliflora* was introduced in Kenya in 1973 for the rehabilitation of quarries near the coastal city of Mombasa from where it spread to other parts of the coastal region.	(Jama & Zeila, 2005)
	It was introduced to Lake Baringo, Kenya in the early 1980s area as part of the Fuelwood Afforestation Extension Project.	(Lenachuru, 2003)
	Initial entry into Tana River County, Kenya was in 1983 when a forester established a pilot plantation.	(Zeila et al., 2004),
	P. juliflora has occupied 12% of land in Ethiopia, close to 550,000 ha of land in Somaliland, and increased more than 200-fold in Kenyan rangelands between 1980 and 2017.	(Kamiri et al., 2024)
	The spread of *P. juliflora* is attributed to the expansion of agriculture, climate change, increased travel and trade, and massive development of road and irrigation systems in East Africa.	(Boy, 2005)
Ecological Impacts	*P. juliflora* has resulted in a decline in native species and the depletion of natural water springs.	(Tadros et al., 2020),
	The evergreen nature of *P. juliflora* contributes to its continuous water consumption throughout the year.	(W. Shiferaw et al., 2021)
	It has resulted in a reduction in the population of crucial forage species.	(Clement et al., 2020)
	It has displaced Cyperus species which previously served as natural filters for water entering Lake Baringo and Lake Bogoria in Kenya.	(Masakha & Wegulo, 2015)
	In Afar, Ethiopia, wild animals have been displaced due to the replacement of native grass and forage species by *P. juliflora*.	(Wakie et al., 2016)
	P. juliflora reduces the salinity and alkalinity of soil.	(Shitanda et al., 2013)
	P. juliflora positively influenced the physicochemical properties of the soil.	(W. Shiferaw et al., 2021)
	The trees provide shade for plants, stabilize soil, and sequester carbon.	(Jama & Zeila, 2005)
	The species out-compete the native plant species in Kenyan rangelands by depleting the water and nutrient resources.	(Gitau, 2020) (Witt et al., 2018).
	Herbaceous plants growing under *P. juliflora* have declined by 27% compared to non-invaded areas within a year.	(Choge et al., 2022)
	The positive impacts of *P. juliflora* include control of erosion, biological Nitrogen fixation, provision of nesting platforms for birds and habitats of other wildlife, and source of nectar/pollen.	(Mudoi, 2022)
Social impacts	*P. juliflora* thorns cause harm to humans.	(Maundu et al., 2009)
	It has spread across most of the Afar region of Ethiopia in areas previously used for traditional Afar sports hence hindering sports and dance activities in all the villages.	(Wakie et al. 2016)
	It has encroached on paths, dwellings, water sources, farms, and pastureland, restricting movement and other activities.	(Maundu et al., 2009)
	P. juliflora thickets create breeding grounds for mosquitoes, leading to a rise in malaria cases.	(Mwangi & Swallow, 2005)
	Its invasion leads to severe food insecurity and potentially triggers tribal conflicts over the remaining pastures and farmlands.	(Admasu, 2008)
	In Tanzania, it has led to the reduction of grazing areas, competition for pasture and water, and both interethnic and intra-ethnic conflicts.	(Bukombe et al., 2021)
	In Baringo, Kenya, it has displaced people forcing them to seek new settlements and sometimes lease land for cultivation.	(Mwangi & Swallow, 2005)
Economic Impacts	*P. juliflora* invasion has resulted in a decline in livestock numbers leading to decreased income for pastoralists in Kenyan rangelands.	(Eschen et al., 2021)
	P. juliflora provides affordable wood that is used for construction or fencing poles.	(Huho & Omar, 2020)
	It provides fuelwood or wood for charcoal production	(Tuwei et al., 2019)
	Charcoal from *P. juliflora* provides an opportunity to supply affordable cooking fuel.	(Koech et al., 2020) (Tabe- Ojong, 2023),
	It is a valuable forage for livestock.	(Ruiz-Nieto et al., 2020)
	Pods are utilized as a cost-effective feed resource by substituting expensive feedstuff like corn and bran.	(Sawal et al., 2004)
	Pods are processed to reduce their sugar content and then utilized as commercial human food products.	(Shitanda et al., 2013)
	P. juliflora flowers are a valuable source of pollen and nectar which makes them suitable for apiculture	(Jama & Zeila, 2005)
	It's ability to flower throughout the year and produce plenty of pollen grains and sugar-rich nectar is highly beneficial for beekeeping and honey production.	(Kishoin et al., 2024)
	P. juliflora honey is of high quality, with a pleasant taste and aroma.	(Pasiecznik, 2022; Walter & Armstrong, 2014)
	The honey and its products are sold to generate additional household income.	(Mohamed & Mbataru, 2021)
	The exudate gums from the trunk and branches of *P. juliflora* are utilized in various industries, including food, pharmaceuticals, chemicals, and manufacturing.	(Felker, 2009)
	The pharmacological properties of *P. juliflora* play an important role in maintaining human health and well-being.	(Ukande et al., 2019)
Control Strategies	The primary control strategies of *P. juliflora* involve chemical, mechanical, and biological approaches aimed at reducing stand densities.	(Kamiri et al., 2024)
	Mechanical control entails removing *P. juliflora* using machinery or manual methods such as hand pulling, cutting, digging, or uprooting.	(Shitanda et al., 2013)
	In Ethiopia, mechanical control of *P. juliflora* has been attempted using bulldozers and human labor.	(Network, 2014)
	In Kenya, mechanical clearing of one-hectare costs about USD 2125/ha.	(Maundu et al., 2009)
	In Ethiopia, slashing and burning young *P. juliflora* was effective in controlling and preventing spread in recently infested semi-arid areas but ineffective in humid environments.	(Berhanu & Tesfaye, 2006)
	In Baringo County, Kenya, 90% of affected farmers favor complete eradication through mechanical uprooting of *P. juliflora* and replacing it with less invasive and thornless shrubs.	(Mwangi & Swallow, 2005).
	Chemical control methods are unsuitable for low-input agricultural systems in Eastern Africa due to high costs and the required technical skills.	(Haregeweyn et al., 2013)
	In Sudan, two beetle species, *Alagarobius Prosopis* (family Brucidae) and *Steraspis speciosa* (family Buprestidae), are used for control of *P. juliflora.*	(Khider et al., 2011)

(*Continued*)

Table 4. (Continued).

Thematic Area	Key Findings	References
Management Strategies	*P. juliflora* is managed through containment at specific sites or isolating infested areas to slow the spread from the center of occurrence.	(Mbaabu, 2023)
	Fencing is done to restrict animal movement which prevents seed dispersal by animals.	(Alvarez et al., 2017)
	In Ethiopia, *P. juliflora* is controlled through the utilization of charcoal production.	(Wakie et al., 2016)
	In Djibouti, *P. juliflora* provides cooking energy to the Ali-Addeh and Holl Holl refugee camps, and this helps control its spread.	(Gianvenuti et al., 2018)

environmental concerns and therefore need for integrated management approaches.

Biological control methods were the least mentioned in the reviewed literature, with only 3.7% of the studies focusing on the approach (Figure 4; Table 4). This might be due to the complexity and unpredictability of biological control agents. van Wilgen et al. (2012) highlighted challenges in identifying and establishing biological control agents for invasive species, emphasizing the need for rigorous pre-release testing to ensure specificity, prevent non-target effects, and predict ecological outcomes, along with long-term monitoring to evaluate impacts and refine strategies. Witt and Luke (2017) investigated the potential of utilizing natural enemies of *P. juliflora* in Kenya but indicated that more research was needed to identify effective biocontrol agents. Additionally, Tessema (2012) explored the potential of fungal pathogens as biological control agents for *P. juliflora* in Ethiopia, although further research has been recommended to confirm their efficacy. Adhikary (2021) discussed the use of seed-feeding bruchid beetles as a potential biocontrol method, highlighting the need for rigorous evaluation before widespread application.

The restoration approach, which was reported in 7.4% of the reviewed studies, aims at rehabilitating areas invaded by *P. juliflora* (Figure 4; Table 4). This often involves the removal of *P. juliflora* and replanting native vegetation to restore ecological balance. Shiferaw et al. (2004) highlighted the challenges of restoring ecosystems impacted by *P. juliflora* while emphasizing the importance of native species re-establishment. Githae and Mutiga (2021), in their study conducted in Kenya, found that integrating community involvement in restoration efforts led to more sustainable outcomes. A study by Wainaina et al. (2021) also found that participatory restoration projects involving local communities significantly improve the success rates of rehabilitation efforts. Eschen, Bekele, Jumanne, Kibet, Makale, Mbwambo, Megersa, et al. (2023) in their study conducted in Eastern Africa, demonstrated the effectiveness of combining mechanical removal with the replanting of native grasses to restore degraded rangelands.

Research gaps on P. juliflora *management in Eastern Africa*

Table 5 highlights critical research gaps concerning the management, impacts and dissemination of information about *Prosopis juliflora*. The species poses significant environmental, social and economic challenges, yet there are notable deficiencies in research and practical frameworks needed for its effective control. The identified gaps underline the urgent need for comprehensive studies, policy formulation and integrated management approaches to mitigate the adverse effects of *P. juliflora* in the Eastern African landscape.

Lessons learnt and knowledge gaps in the management of P. juliflora *in Eastern Africa*

In Kenya, most research findings have emphasized the importance of community involvement and economic utilization (Mbaabu, 2023; Mwangi & Swallow, 2008). Effective management requires the active participation

Table 5. A summary of potential research areas and identified gaps during the review

Research areas	Gaps
Research outputs and Dissemination	• Inadequate capacity-building framework, community education, and awareness of *P. juliflora* management • Lack of an integration approach for bringing together the social, ecological, and economic attributes during management decisions.
Management of *P. juliflora*	• No clear empirical data on the on-farm resources needed in the management of *P. juliflora*. • No cost–benefit analysis to establish cost-effective control/management strategies. • *P. juliflora*. In Kenya and Ethiopia, there exist National Prosopis Strategies that need to be fully implemented. • No data/monitoring tool for the management and control of future *P. juliflora* spread and invasion.
Impacts of *P. juliflora*	• No empirical data on the environmental, social, and economic losses as a result of the *P. juliflora* invasion. • No risk analysis for the future spread and genetic evolution of the species.
Data on invasion pathways	• No data on site-specific causes of the spread and cover of *P. juliflora.* • Inadequate research across various ecosystems

Table 6. Specific requirements, objectives, methods, challenges, conditions and resources needed for Prosopis containment, eradication and utilization (Adopted from Kamiri et al. (2024); Maundu et al. (2009); Mudoi (2022); Pasiecznik (2022); Pasiecznik et al. (2014); Tabe-Ojong (2023); Wakie et al. (2016); Witt et al. (2018) and W. Shiferaw et al. (2021))

Specific Requirements for	Objective	Method	Challenges	Conditions	Resources needed
Containment of Prosopis Spread	Prevent or slow the spread.	Fencing of invaded areas, restricting animal movement, control measures at the periphery	High initial investments, knowledge of sedentary animal production, labor-intensive control of young plants	Wetlands with shallow groundwater, humid environments for early interventions, dry season for biomass burning	Capital for fencing, labor for clearing, knowledge-intensive livestock rearing
Eradication and Control of Prosopis	Complete removal or long-term reduction of the Prosopis population	Physical removal, chemical control, restorative habitat management	High labor costs, need for coordinated action, environmental impact of chemicals	Recently invaded sites, semi-arid regions, low livestock density areas	High labor, chemicals, machinery, coordinated community efforts
Utilization of Prosopis	Derive economic benefits from Prosopis-invaded land	Timber and firewood production, charcoal making, transforming pods into animal feed and human food	High management demands, restrictions on logging and sale of wood, lack of awareness of benefits, risk of slowing down eradication efforts	Requires older, well-established stands	Low initial investments for charcoal production, capital for pruning and processing, knowledge-sharing, education, and training, harmonized government policies

of local communities in monitoring and control efforts, ensuring that strategies are sustainable and adapted to local conditions. Empirical studies have encouraged the use of *P. juliflora* for economic purposes such as the production of charcoal and wood products, as well as the provision of financial incentives towards support control of the species (Khider et al., 2011; Mbaabu, 2023).

Most studies in Ethiopia highlight the need for integrated approaches and sustainable practices (Berhanu & Tesfaye, 2006). Combining mechanical removal with utilization strategies has proved to be more effective than relying on a single method of control (Wakie et al., 2016). Studies have emphasized the sustainable utilization of *P. juliflora*, such as charcoal production and animal feed to help control its spread while supporting local livelihoods (Shiferaw et al., 2019). On the other hand, studies in Somalia emphasize the importance of community engagement and economic incentives in ensuring effective and sustainable management of Prosopis (Alvarez et al., 2017). Involving local communities in removal and utilization efforts is crucial for the success of control measures. Providing economic benefits through the use of *P. juliflora* supports sustainable management and enhances the removal of the plant (Geesing et al., 2004). Studies in Sudan and South Sudan highlight the effectiveness of integrated management and local participation.

Lessons learned from Eritrea and Djibouti show the importance of community-based approaches and economic utilization. Involving local communities in management efforts ensures management by application of sustainable intervention. Studies from Tanzanian underscore the importance of integrating community engagement and economic benefits because effective management requires active participation from local communities to ensure sustainability and effectiveness (Kweka et al., 2023; Malila, 2021; Swai et al., 2024). Studies conducted in Uganda emphasize the need for preventative measures and community involvement. Early intervention and preventative measures are crucial for effective management of the spread of *P. juliflora* (Table 6)

Conclusion

The spread of *P. juliflora* in Eastern Africa is extensive, having been introduced in the 1970s and 1980s for projects such as quarry rehabilitation, afforestation, and fuelwood production. It now occupies vast areas, including 12% of Ethiopia's land, 550,000 hectares in Somaliland, and significant portions of Kenyan rangelands, where its presence has increased more than 200-fold since 1980. This proliferation is driven by agricultural expansion, climate change, and infrastructure development, emphasizing its aggressive spread across diverse landscapes.

The ecological impacts of *P. juliflora* are both positive and negative. Negatively, it suppresses native species, reduces herbaceous vegetation by up to 27%, displaces natural water filters, and contributes to the loss of wildlife habitats. On the positive side, it stabilizes soil, enhances soil nutrients through nitrogen fixation, and provides shade for plants. These contrasting effects highlight its role as both an ecological disruptor and a contributor to environmental services in certain contexts.

Socially, *P. juliflora* poses significant challenges to both animals and people. Its thorns harm humans, while its invasive spread restricts access to water, pasturelands, and traditional activity areas. It also displaces communities and exacerbates health issues, such as malaria, due to mosquito breeding in its thickets. Furthermore, it has disrupted traditional and cultural practices in Ethiopia and triggered resource-based conflicts in regions like Tanzania, amplifying its social ramifications.

Economically, *P. juliflora* offers a mix of opportunities and challenges. While it provides affordable wood, charcoal and high-quality honey, along with forage and gum for industrial applications, its invasion reduces grazing lands and livestock numbers, leading to income losses for pastoral communities. Its products, however, support livelihoods, showcasing its economic potential when managed sustainably.

Management of *P. juliflora* remains a significant challenge due to the high costs and technical demands of control strategies. Mechanical methods, though effective, are resource-intensive, while chemical control is often impractical in low-input systems. Biological approaches, such as using beetles, show potential but require further refinement. Utilization strategies, like charcoal production, containment through fencing and livestock feed formulation, provide promising avenues for mitigating its spread while deriving economic benefits. These management efforts underscore the importance of balancing eradication with sustainable utilization.

Acknowledgements

The Authors would like to acknowledge Swiss Governmental Bodies and Foundations for funding this work through VSF-Suisse "Project "Strengthening the drought resilience of (agro-)pastoral communities in Isiolo County (INNOPLA-Number 10343)" https://www.vsf-suisse.org/project/innopla/?lang=en.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Swiss Governmental Bodies and Foundations for funding this work through VSF-Suisse "Project "Strengthening the drought resilience of (agro-)pastoral communities in Isiolo County (INNOPLA-Number 10343)".

ORCID

Josephat Mungoche http://orcid.org/0009-0008-1748-5346

Authors contribution

Conceptualization of the review paper, Prof. O.V. Wasonga, Dr. Davis Ikiror; Original draft preparation and writing, Mr. Josephat Mungoche; Review and editing, Prof. Prof. O. V. Wasonga, Prof. Charles Gachuiri, Mr. Haron Akala, and Prof. George Gitau; Validation of content, Dr. Davis Ikiror. All authors have agreed to submit the review paper for publication.

Data availability statement

This review paper is based on the analysis of publicly available literature and data. All data supporting the findings of this study are derived from previously published studies, which are appropriately cited within the manuscript. No new datasets were generated or analyzed during the current study. The authors confirm that the data supporting the findings of this study are available within the article and/or its supplementary materials.

References

Adhikary, L. (2021). *Change in mesquite volatile organic compounds and associated response of a native node boring beetle after herbicide treatment* [Master's thesis]. New Mexico State University.

Admasu, D. (2008). *Invasive plants and food security: The case of Prosopis juliflora in the Afar region of Ethiopia*, pp.1–13, Farm-Africa, IUCN.

Akwee, P. E. (2023). *Impact of Prosopis juliflora to biodiversity and ecosystem services in Lake Turkana ecosystem in Turkana County, Kenya*. https://www.ijiras.com/2023/Vol_10-Issue_10/paper_10.pdf

Alban, L., Matorel, M., Romero, J., Grados, N., Cruz, G., & Felker, P. (2002). Cloning of elite, multipurpose trees of the Prosopis juliflora/pallida complex in Piura, Peru. *Agroforestry Systems*, *54*(3), 173–182. https://doi.org/10.1023/A:1016093106338

Alvarez, M., Leparmarai, P., Heller, G., & Becker, M. (2017). Recovery and germination of Prosopis juliflora (sw.) DC seeds after ingestion by goats and cattle. *Arid Land Research and Management*, *31*(1), 71–80. https://doi.org/10.1080/15324982.2016.1234521

Anders Granström. (2005). *Spread of the introduced tree species Prosopis juliflora (sw.) DC in the Lake Baringo area, Kenya*. https://core.ac.uk/download/pdf/211578713.pdf

Arjjumend, H. (2018). Review of pastoralists' resilience and adaptation to climate change: Can technology help pastoralists mitigate the risks? *International Journal of Bio-Resource & Stress Management*, *9*(1), 118–128. https://doi.org/10.23910/IJBSM/2018.9.1.1833a

Awale, A. I., & Sugule, A. J. (2006). *The proliferation of honey mesquite (Prosopis juliflora) in Somaliland. Opportunities and challenges case study; candle light for health, education and environment: Abu Dhabi, United Arab Emirates.*

https://agris.fao.org/search/en/providers/122621/records/64724fa453aa8c896305d41f

Balcha, L. D. (2022). Prosopis juliflora distribution, impacts, and control methods available in Ethiopia. *International Journal of Natural Resource Ecology and Management*, *7*, 132–144. https://doi.org/10.11648/j.ijnrem.20220703.12

Balcha, L. D. (2022). Prosopis juliflora distribution, impacts, and control methods available in Ethiopia. *Int J Nat Resour Ecol Manag*, *7*, 132–144.

Batista, A., Mustafa, A., McKinnon, J., & Kermasha, S. (2002). In situ ruminal and intestinal nutrient digestibilities of mesquite (Prosopis juliflora) pods. *Animal Feed Science and Technology*, *100*(1–2), 107–112. https://doi.org/10.1016/S0377-8401(02)00136-0

Berhanu, A., & Tesfaye, G. (2006). The Prosopis dilemma impacts dryland biodiversity and some controlling methods. *Journal of the Drylands*, *1*(2), 158–164.

Bibi, S., Bibi, A., Al-Ghouti, M. A., & Abu-Dieyeh, M. H. (2023). Allelopathic effects of the invasive Prosopis juliflora (sw.) DC. On native plants: Perspectives toward agrosystems. *Agronomy*, *13*(2), 590. https://doi.org/10.3390/agronomy13020590

Blache, D., Vercoe, P. E., Martin, G. B., & Revell, D. K. (2016). *Integrated and Innovative L*. https://doi.org/10.1007/978-3-319-47928-6_8

Bogale, G. A., & Tolossa, T. T. (2021). Climate change intensification impacts and challenges of invasive species and adaptation measures in Eastern Ethiopia. *Sustainable Environment*, *7*(1), 1875555. https://doi.org/10.1080/23311843.2021.1875555

Boy, G. (2005). How a multi-country 'war on weeds' project is helping an infested continent to stem the colonizing onslaught of invasive species. *Invasive Species*, *6975*.

Bukombe, J. K., Nkwabi, A. K., Mangewa, L. J., Sweke, E. A., Kavana, P. Y., Liseki, S. D., & Kija, H. H. (2021). Alien invasive species in Tanzania. *Invasive Alien Species: Observations and Issues from Around the World*, *1*, 263–290. https://doi.org/10.1002/9781119607045.ch9

Carboni, M., Gueguen, M., Barros, C., Georges, D., Boulangeat, I., Douzet, R., Dullinger, S., Klonner, G., van Kleunen, M., Essl, F., Bossdorf, O., Haeuser, E., Talluto, M. V., Moser, D., Block, S., Conti, L., Dullinger, I., Münkemüller, T., & Thuiller, W. (2018). Simulating plant invasion dynamics in mountain ecosystems under global change scenarios. *Global Change Biology*, *24*(1), e289–e302. https://doi.org/10.1111/gcb.13879

Choge, S. K., Pasiecznik, N. M., Harvey, M., Wright, J., Awan, S. Z., & Harris, P. J. C. (2007). *Prosopis* pods as human food, with special reference to Kenya. *Water Sa*, *33*(3), 419–424. https://doi.org/10.4314/wsa.v33i3.180613

Choge, S., Mbaabu, P. R., & Muturi, G. M. (2022). Management and control of the invasive Prosopis juliflora tree species in Africa with a focus on Kenya. In *Prosopis as a heat tolerant nitrogen fixing desert food legume* (pp. 67–81). Elsevier. https://doi.org/10.1016/B978-0-12-823320-7.00024-9

Choge, S., & Muthike, G. (2014). Experiences of managing Prosopis juliflora invasions by communities in Kenya: Challenges and opportunities. *Managing Prosopis Juliflora for Better (Agro-) Pastoral Livelihoods in the Horn of Africa*, 11, 93. https://wocatpedia.net/images/4/4b/052015_Proceedings_regional_conference_on_prosopis_juliflora,_Addis_Abeba.pdf#page=94

Clement, N. E., Humphrey, A., & John, O. (2020). Impacts of Prosopis juliflora on abundance and species diversity of forage species in Turkana County, Kenya. *Current Journal of Applied Science and Technology*, 112–125. https://doi.org/10.9734/cjast/2020/v39i3331026

de Brito Damasceno, G. A., Souto, A. L., da Silva, I. B., Roque, A. D. A., Ferrari, M., & Giordani, R. B. (2020). Prosopis juliflora: Phytochemical, toxicological, and allelochemicals. *Co-Evolution of Secondary Metabolites*, 521–541. https://link.springer.com/rwe/10.1007/978-3-319-96397-6_15

Degefu, M. A., Assen, M., Few, R., & Tebboth, M. (2022). Performance of management interventions to the impacts of Prosopis juliflora in arid and semiarid regions of the middle awash valley, Ethiopia. *Global Journal of Agricultural innovation, Research & Development*, *9*, 35–53. https://doi.org/10.15377/2409-9813.2022.09.4

Eschen, R., Bekele, K., Jumanne, Y., Kibet, S., Makale, F., Mbwambo, J. R., Megersa, B., Mijay, M., Moyo, F., Munishi, L., Mwihomeke, M., Nunda, W., Nyangito, M., Witt, A., & Schaffner, U. (2023). Experimental prosopis management practices and grassland restoration in three Eastern African countries. *CABI Agriculture and Bioscience*, *4*(1), 21. https://doi.org/10.1186/s43170-023-00163-5

Eschen, R., Bekele, K., Mbaabu, P. R., Kilawe, C. J., & Eckert, S. (2021). Prosopis juliflora management and grassland restoration in Baringo County, Kenya: Opportunities for soil carbon sequestration and local livelihoods. *Journal of Applied Ecology*, *58*(6), 1302–1313. https://doi.org/10.1111/1365-2664.13854

FAO. (2020). *Global forest resources assessment 2020*. Food and Agriculture Organization of the United Nations.

Felker, P. (2009). *Unusual physiological properties of the arid-adapted tree legume Prosopis and their applications in developing countries. Perspectives in biophysical plant ecophysiology: A tribute to park S nobel*. Universidad Nacional Autónoma de México.

Geesing, D., Al-Khawlani, A., & Abba, M. L. (2004). Management of introduced Prosopis species: Can economic exploitation control an invasive species? *Unasylva*, *217*(55), 289–299. https://mediatum.ub.tum.de/doc/1304786/document.pdf

Gianvenuti, A., Farah, I., Yasmin, N., Jonckheere, I., & Xia, Z. (2018). *Using prosopis as an energy source for refugees and host communities in Djibouti, and controlling its rapid spread*. https://www.sidalc.net/search/Record/digfao-it-20.500.14283CA0163EN/Description

Gitau, A. N. (2020). *Influence of grazing management practices and topographic positions on vegetation attributes, soil organic carbon and greenhouse gas emissions in semi-arid rangelands of Laikipia County, Kenya*. http://erepository.uonbi.ac.ke/handle/11295/152933

Githae, E. W., & Mutiga, I. M. (2021). *Ecological restoration of pastoral landscapes in the drylands of East Africa*. http://repository.chuka.ac.ke/handle/chuka/15601

Haregeweyn, N., Tsunekawa, A., Tsubo, M., Meshesha, D., & Melkie, A. (2013). Analysis of the invasion rate, impacts and control measures of Prosopis juliflora: A case study of amibara district, eastern Ethiopia. *Environmental*

Monitoring and Assessment, *185*(9), 7527–7542. https://doi.org/10.1007/s10661-013-3117-3

Hosseini Nasr, S. M., Parsakhoo, A., Naghavi, H., & Kiani Savad Koohi, S. (2012). Effect of salt stress on germination and seedling growth of Prosopis juliflora (sw.). *New Forests*, *43*(1), 45–55. https://doi.org/10.1007/s11056-011-9265-9

Hughes, C. E., Ringelberg, J. J., Lewis, G. P., & Catalano, S. A. (2022). Disintegration of the genus Prosopis L. (Leguminosae, Caesalpinioideae, mimosoid clade). *PhytoKeys*, *205*, 147. https://doi.org/10.3897/phytokeys.205.75379

Huho, J. M., & Omar, M. H. (2020). Prosopis juliflora in asals of Kenya: A friend or a foe plant? *International Journal of Scientific & Research Publications (IJSRP)*, *10*(3), 9968. https://doi.org/10.29322/IJSRP.10.03.2020.p9968

Hussain, M. I., Shackleton, R., El-Keblawy, A., González, L., & Trigo, M. M. (2021). Impact of the invasive Prosopis juliflora on terrestrial ecosystems. In E. Lichtfouse (Ed.), *Sustainable agriculture reviews* (Vol. 52, pp. 223–278). Springer International Publishing. https://doi.org/10.1007/978-3-030-73245-5_7

Hussain, M. I., Shackleton, R. T., El-Keblawy, A., Del Mar Trigo Pérez, M., & González, L. (2020). Invasive mesquite (Prosopis juliflora), an allergy and health challenge. *Plants*, *9*(2), 141. https://doi.org/10.3390/plants9020141

Ilukor, J., Rettberg, S., Treydte, A., & Birner, R. (2016). To eradicate or not to eradicate? Recommendations on Prosopis juliflora management in Afar, Ethiopia, from an interdisciplinary perspective. *Pastoralism*, *6*(1), 14. https://doi.org/10.1186/s13570-016-0061-1

Jama, B., & Zeila, A. (2005). *Agroforestry in the drylands of eastern Africa: A call to action*. https://www.cabidigitallibrary.org/doi/full/10.5555/20063112690

Kable, A. K., Pich, J., & Maslin-Prothero, S. E. (2012). A structured approach to documenting a search strategy for publication: A 12-step guideline for authors. *Nurse Education Today*, *32*(8), 878–886. https://doi.org/10.1016/j.nedt.2012.02.022

Kahi, C. H., Ngugi, K., Mureithi, S. M., & Ng'ethe, J. C. (2009). The canopy effects of Prosopis juliflora (DC.) and acacia tortilis (Hayne) trees on herbaceous plants species and soil physico-chemical properties in jemps flats, Kenya. *Tropical and Subtropical Agroecosystems*, *10*(2009), 449.

Kamiri, H. W., Choge, S. K., & Becker, M. (2024). Management strategies of Prosopis juliflora in Eastern Africa: What works where? *Diversity*, *16*(4), 251. https://doi.org/10.3390/d16040251

Kassahun, A., Snyman, H. A., & Smit, G. N. (2008). Impact of rangeland degradation on the pastoral production systems, livelihoods, and perceptions of the Somali pastoralists in Eastern Ethiopia. *Journal of Arid Environments*, *72*(7), 1265–1281. https://doi.org/10.1016/j.jaridenv.2008.01.002

Khan, D., & Shaukat, S. S. (2006). Phytotoxic effect of Prosopis juliflora swSwartz. DC. Against some of its field associates and the cultivated species. *International Journal of Biology and Biotechnology*, *3*(2), 353–366.

Khan, R., Iqbal, I. M., Ullah, A., Ullah, Z., & Khan, S. M. (2022). Invasive alien species: An emerging challenge for the biodiversity. In M. Öztürk, S. M. Khan, V. Altay, R. Efe, D. Egamberdieva, & F. O. Khassanov (Eds.), *Biodiversity, conservation and sustainability in Asia* (pp. 459-471). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-73943-0_25

Khider, M. M., Al Abjar, Z. A., & Eltigani, A. (2011). Studies on ecology and biology of some insect pests of the mesquite trees, Prosopis Juliflora in Sudan. *Egyptian Journal of Biological Pest Control*, *21*(2).

Kishoin, V., Tumwesigye, W., Turyasingura, B., Wilber, W., Chavula, P., Gweyi-Onyango, J. P., Kader, S., Spalevic, V., Skataric, G., & Jaufer, L. (2024). The negative and positive impacts of Prosopis juliflora on the Kenyan and Ethiopian ecosystems: A review study. *Notulae Scientia Biologicae*, *16*(1), 11832. https://doi.org/10.55779/nsb16111832

Koech, G., Wanjira, E., Kirimi, M., Siko, I., Sola, P., Bourne, M., Muriuki, J., & Njenga, M. (2020). *Utilizing mathenge (Prosopis juliflora) for charcoal: The other side of an invasive species*. http://apps.worldagroforestry.org/downloads/Publications/PDFS/2020044.pdf

Koech, O. K., Kinuthia, R. N., Wahome, R. G., Choge, S. K. (2010). Effects of prosopis juliflora seedpod meal supplement on weight gain of weaner galla goats weight gain of weaner Galla goats in Kenya, *Res. J. Anim. Sci.* 4(2), 58–62.

Kuwait, M., & Nepal, O. (2019). Prosopis juliflora (Sw.) DC. *Bulletin OEPP/EPPO Bulletin*, *49*(2), 290–297.

Kweka, P. S., Munish, L., & Mbwambo, J. R. (2023). Study of socio-economic drivers and community perceptions on invasive alien plant Prosopis juliflora in northern Tanzania. *International Journal of Advances in Scientific Research and Engineering*, *09*(12), 12–27. https://doi.org/10.31695/IJASRE.2023.9.12.2

Lenachuru, C. (2003, October). Impacts of Prosopis species in Baringo district. *Proceedings of Workshop on Integrated Management of Prosopis Species in Kenya, Workshop Held at Soi Safari Club, Lake Baringo*, 1–2.

Linders, T. E. W., Schaffner, U., Eschen, R., Abebe, A., Choge, S. K., Nigatu, L., Mbaabu, P. R., Shiferaw, H., Allan, E., & Alpert, P. (2019). Direct and indirect effects of invasive species: Biodiversity loss is a major mechanism by which an invasive tree affects ecosystem functioning. *Journal of Ecology*, *107*(6), 2660–2672. https://doi.org/10.1111/1365-2745.13268

Malila, B. P. (2021). *Socio-economic and ecological implications of sustainable land management practices for controlling invasive alien species in Moshi rural and muheza districts, Tanzania* [Doctoral dissertation]. Sokoine University of Agriculture.

Masakha, E. J., & Wegulo, F. N. (2015). Socioeconomic impacts of Prosopis juliflora on the people of Salabani location, Marigat district, Baringo County in Kenya. *Natural Science Research*, *5*(19), 41–46. https://core.ac.uk/download/pdf/234656134.pdf

Maundu, P., Kibet, S., Morimoto, Y., Imbumi, M., & Adeka, R. (2009). Impact of Prosopis juliflora on Kenya's semi-arid and arid ecosystems and local livelihoods. *Biodiversity*, *10*(2–3), 33–50. https://doi.org/10.1080/14888386.2009.9712842

Mbaabu, P. R. (2023). *Prosopis juliflora invasion in Baringo, Kenya: Exploring its impacts on Lulc dynamics, Vachellia tortilis, selected ecosystem services, livelihoods and potential spread under climate change*. http://erepository.uonbi.ac.ke/handle/11295/164874

Mehari, Z. H. (2015). The invasion of Prosopis juliflora and Afar pastoral livelihoods in the middle awash area of

Ethiopia. *Ecological Processes*, *4*(1), 1–9. https://doi.org/10.1186/s13717-015-0039-8

Mohamed, E. H., & Mbataru, P. (2021). Socio-economic contribution of Prosopis juliflora on the livelihoods of local communities in Garissa County, Kenya. *Journal of International Business, Innovation and Strategic Management*, *5*(2), 1–17. https://www.jibism.org/core_files/index.php/JIBISM/article/view/149

Mudoi, S. M. K. (2022). *Mapping of the Prosopis-juliflora (mesquite) invasion and its effects on pastoralist livelihoods in the red sea state, Sudan-A remote sensing approach* [Master's thesis]. The University of Bergen. https://bora.uib.no/bora-xmlui/handle/11250/3013134

Mwangi, E., & Swallow, B. (2005). *Invasion of Prosopis juliflora and local livelihoods: A case study from the Lake Baringo area of Kenya* (Vol. 22). World Agroforestry Centre. https://oa.mg/work/10.5716/wp13657.pdf

Mwangi, E., & Swallow, B. (2008). Prosopis juliflora invasion and rural livelihoods in the Lake Baringo area of Kenya. *Conservation and Society*, *6*(2), 130–140. https://doi.org/10.4103/0972-4923.49207

Mworia, J. K., Kinyamario, J. I., Omari, J. K., & Wambua, J. K. (2011). Patterns of seed dispersal and establishment of the invader Prosopis juliflora in the upper floodplain of Tana River, Kenya. *African Journal of Range & Forage Science*, *28*(1), 35–41. https://doi.org/10.2989/10220119.2011.571402

Nair, P. R., Kumar, B. M., Nair, V. D., Nair, P. R., Kumar, B. M., & Nair, V. D. (2021). Multipurpose trees (MPTs) and other agroforestry species. *An Introduction to Agroforestry: Four Decades of Scientific Developments*, 281–351. https://doi.org/10.1007/978-3-030-75358-0_13

Network, S. I. (2014). *Controlling and/or using Prosopis juliflora in spate irrigation systems*. Practical Note.

Oba, G. (2012). Harnessing pastoralists' indigenous knowledge for rangeland management: Three African case studies. *Pastoralism: Research, Policy and Practice*, *2*, 1–25. https://doi.org/10.1186/2041-7136-2-1

Obonyoa, C. O., Zhua, H., Hea, W., & Chinopfukutwaa, G. L. (2017). How do East African communities cope with the impacts of Prosopis juliflora (mesquite) invasion? A review, Vol.7, No.4. https://core.ac.uk/download/pdf/234664881.pdf

Odero, W. J. A. (2015). *Evaluation of inclusion levels of milled mature pods of Prosopis juliflora (Mathenge) in broiler finisher diets* [Doctoral dissertation]. Egerton University.

Pasiecznik, N. (2022). *Prosopis juliflora (mesquite) [Dataset]*. (43942). https://doi.org/10.1079/cabicompendium.43942

Pasiecznik, N. M., Felker, P., Harris, P. J., Harsh, L., Cruz, G., Tewari, J. C., & Maldonado, L. J. (2001). *The Prosopis juliflora-Prosopis pallida complex: A monograph* (Vol. 172). HDRA. https://gardenorganic-assets.s3.eu-west-2.amazonaws.com/documents/ProsopisMonographMainText.pdf

Patnaik, P., Abbasi, T., & Abbasi, S. A. (2017). Prosopis (Prosopis juliflora): Blessing and bane. *Tropical Ecology*, *58*(3), 455–483. https://www.cabidigitallibrary.org/doi/full/10.5555/20183161423

Ravhuhali, K. E., Mudau, H. S., Moyo, B., Hawu, O., & Msiza, N. H. (2021). Prosopis species—an invasive species and a potential source of browse for livestock in semi-arid areas of South Africa. *Sustainability*, *13*(13), 7369. https://doi.org/10.3390/su13137369

Ruiz-Nieto, J. E., Hernández-Ruiz, J., Hernández-Marín, J., Mendoza-Carrillo, J., Abraham-Juárez, M., Isiordia-Lachica, P. M., & Mireles-Arriaga, A. I. (2020). Mesquite (prosopis spp.) tree as a feed resource for animal growth. *Agroforestry Systems*, *94*(4), 1139–1149. https://doi.org/10.1007/s10457-020-00481-x

Sawal, R. K., Ratan, R., & Yadav, S. B. S. (2004). Mesquite (Prosopis juliflora) pods as a feed resource for livestock. A review. *Asian-Australasian Journal of Animal Sciences*, *17*(5), 719–725. https://doi.org/10.5713/ajas.2004.719

Shackleton, R. T., Le Maitre, D. C., Pasiecznik, N. M., & Richardson, D. M. (2014). Prosopis: A global assessment of the biogeography, benefits, impacts, and management of one of the world's worst woody invasive plant taxa. *AoB PLANTS*, *6*. https://doi.org/10.1093/aobpla/plu027

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

Shanwad, U. K., Chittapur, B. M., Honnalli, S. N., Shankergoud, I., & Gebremedhin, T. (2015). Management of Prosopis juliflora through chemicals: A case study in India. *Management*, *5*(23). https://core.ac.uk/download/pdf/234661818.pdf

Shiferaw, H., Alamirew, T., Dzikiti, S., Bewket, W., Zeleke, G., Teketay, D., & Schaffner, U. (2023). Water abstraction of invasive Prosopis juliflora and native senegalia senegal trees: A comparative study in the great rift valley area, Ethiopia. *Science of the Total Environment*, *862*, 160833. https://doi.org/10.1016/j.scitotenv.2022.160833

Shiferaw, H., Bewket, W., Alamirew, T., Zeleke, G., Teketay, D., Bekele, K., Eckert, S., & Eckert, S. (2019). Implications of land use/land cover dynamics and Prosopis invasion on ecosystem service values in Afar region, Ethiopia. *Science of the Total Environment*, *675*, 354–366. https://doi.org/10.1016/j.scitotenv.2019.04.220

Shiferaw, H., Teketay, D., Nemomissa, S., & Assefa, F. (2004). Some biological characteristics that foster the invasion of Prosopis juliflora (sw.) DC. At middle awash rift valley area, North-Eastern Ethiopia. *Journal of Arid Environments*, *58*(2), 135–154. https://doi.org/10.1016/j.jaridenv.2003.08.011

Shiferaw, W., Demissew, S., Bekele, T., Aynekulu, E., & Pitroff, W. (2021). Invasion of Prosopis juliflora and its effects on soil physicochemical properties in Afar region, Northeast Ethiopia. *International Soil and Water Conservation Research*, *9*(4), 631–638. https://doi.org/10.1016/j.iswcr.2021.04.003

Shitanda, D., Mukonyi, K., Kagiri, M., Gichua, M., & Simiyu, L. (2013). Properties of Prosopis juliflora and its potential uses in ASAL areas of Kenya. *Journal of Agriculture Science & Technology*, *15*(1), 15–27. https://www.ajol.info/index.php/jagst/article/view/112775

Sileshi, G. W., Gebeyehu, S., & Mafongoya, P. L. (2019). The threat of alien invasive insect and mite species to food security in Africa and the need for a continent-wide response. *Food Security*, *11*(4), 763–775. https://doi.org/10.1007/s12571-019-00930-1

Sintayehu, D. W., Egeru, A., Ng, W. T., & Cherenet, E. (2020). Regional dynamics in distribution of Prosopis juliflora under predicted climate change in Africa. *Tropical*

Ecology, *61*(4), 437–445. https://doi.org/10.1007/s42965-020-00101-w

Sirmah, P. K. (2018). *Are the pods and leaves of Prosopis juliflora growing in Baringo Kenya toxic to livestock? Chemical analysis perspectives*. http://ir-library.kabianga.ac.ke/handle/123456789/611

Sivakumar, K., Rawat, G. S., Ruchi Badola, B. S., & Kamalakannan, B. (2018). Study on ecological and socio-economic impact of invasive species, Prosopis juliflora and Lantana camara, and their removal from forest, common and fallow land of Tamil Nadu. *Technical Report, Wildlife Institute of India, Dehradun*. https://wii.gov.in/images/images/documents/publications/rr_2018_invasive_species_tamil_nadu.pdf

Swai, G., Sibuga, K. P., Kilawe, C. J., Kudsk, P., & Holst, N. (2024). *Effectiveness of control measures against Prosopis juliflora in Moshi and Simanjiro districts*.

Tabe- Ojong, M. P., Jr. (2023). Action against invasive species: Charcoal production, beekeeping, and Prosopis eradication in Kenya. *Ecological Economics*, *203*, 107614. https://doi.org/10.1016/j.ecolecon.2022.107614

Tadros, M. J., Al-Assaf, A., Othman, Y. A., Makhamreh, Z., & Taifour, H. (2020). Evaluating the effect of Prosopis juliflora, an alien invasive species, on land cover change using remote sensing approach. *Sustainability*, *12*(15), 5887. https://doi.org/10.3390/su12155887

Tessema, Y. A. (2012). Ecological and economic dimensions of the paradoxical invasive species juliflora and policy challenges in Ethiopia. *Journal of Economics & Sustainable Development*, *3*(8). https://core.ac.uk/download/pdf/234645666.pdf

Tuwei, P., Odera, E. C., Kiprop, J., & Wanjiku, J. (2019). Management of Prosopis juliflora invasion in Baringo County, Kenya through utilization. *Journal of Economics & Sustainable Development*, *10*(10). https://core.ac.uk/download/pdf/234649075.pdf

Ukande, M. D., Shaikh, S., Murthy, K., & Shete, R. (2019). Review on pharmacological potentials of Prosopis juliflora. *Journal of Drug Delivery and Therapeutics*, *9*(4–s), 755–760. https://doi.org/10.22270/jddt.v9i4-s.3372

Van Klinken, R. D., Hoffmann, J. H., Zimmermann, H. G., & Roberts, A. P. (2009). Prosopis species (Leguminosae). In R. Muniappan, G. V. P. Reddy, & A. Raman (Eds.), *Biological control of tropical weeds using arthropods* (1st ed. pp. 353–377). Cambridge University Press. https://doi.org/10.1017/CBO9780511576348.018

van Klinken, R. D., Hoffmann, J. H., Zimmermann, H. G., Roberts, A. P., & Muniappan, R. (2009). Prosopis species (Leguminosae). *Biological Control of Tropical Weeds Using Arthropods*, 353–377. https://books.google.co.ke/books?hl=en&lr=&id=CDECHl8qhsIC&oi=fnd&pg=PA353&dq=van+Klinken,+R.+D.,+Hoffmann,+J.+H.,+Zimmermann,+H.+G.,+Roberts,+A.+P.,+%26+Muniappan,+R.+(2009).+Prosopis+species+(Leguminosae).+Biological+Control+of+Tropical+Weeds+Using+Arthropods,+353%E2%80%93377.&ots=xRmzHAFCNx&sig=EGKNfEOh5PwCQf_Zh2jKbNQRaAw&redir_esc=y#v=onepage&q&f=false

van Wilgen, B. W., Forsyth, G. G., Le Maitre, D. C., Wannenburgh, A., Kotzé, J. D., van den Berg, E., & Henderson, L. (2012). An assessment of the effectiveness of a large, national-scale invasive alien plant control strategy in South Africa. *Biological Conservation*, *148*(1), 28–38. https://doi.org/10.1016/j.biocon.2011.12.035

Wainaina, P., Minang, P. A., Nzyoka, J., Duguma, L., Temu, E., & Manda, L. (2021). Incentives for landscape restoration: Lessons from Shinyanga, Tanzania. *Journal of Environmental Management*, *280*, 111831. https://doi.org/10.1016/j.jenvman.2020.111831

Wakie, T., Evangelista, P., & Laituri, M. (2012). Utilization assessment of Prosopis juliflora in Afar region, Ethiopia. *US forest service, USDA office of International programs, USAID pastoral livelihoods initiative II project (PLI II)*, 1–15. https://www2.nrel.colostate.edu/projects/csuethiopia/documents/NewsFeed_Wakie_Final.pdf

Wakie, T. T., Hoag, D., Evangelista, P. H., Luizza, M., & Laituri, M. (2016). Is control through utilization a cost-effective Prosopis juliflora management strategy? *Journal of Environmental Management*, *168*, 74–86. https://doi.org/10.1016/j.jenvman.2015.11.054

Walter, K. J., & Armstrong, K. V. (2014). Benefits, threats, and potential of Prosopis in South India. *Forests, Trees and Livelihoods*, *23*(4), 232–247. https://doi.org/10.1080/14728028.2014.919880

Witt, A., Beale, T., & Van Wilgen, B. W. (2018). An assessment of the distribution and potential ecological impacts of invasive alien plant species in eastern Africa. *Transactions of the Royal Society of South Africa*, *73*(3), 217–236. https://doi.org/10.1080/0035919X.2018.1529003

Witt, A., & Luke, Q. (2017). Guide to the naturalized and invasive plants of eastern Africa. CABI international. vi ±601. https://doi.org/10.1079/9781786392145.0000

Zeila, A. (2011). *Mapping and managing the spread of Prosopis Juliflora in Garissa County, Kenya* [Doctoral dissertation]. Kenyatta University. http://repository.embuni.ac.ke/handle/123456789/507

Zeila, A., Mwangi, E., & Swallew, B. (2004). *Prosopis juliflora: Boon or bane for dryland agroforestry*. The Prunus Tribune.