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Critical Review Of *Prosopis Juliflora* Species In Turkana County, Kenya: Current Status For Informed Policy Decision And Management Of The Species

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Abstract: ***Prosopis juliflora is among one of the world's most invasive alien species that is widely spreading in Kenya natural grazing lands due to its adaptive physiological characteristics. The species came from south Africa with the intention of benefiting the people living in the Arid and Semi-Arid Lands (ASAL), which ironically resulted in more harm than good. Turkana and Baringo are heavily hit counties whose people are suffering from the continuous expansion of land under Prosopis. Their speedy growth, development and colonization of an area are driven by the climate, existence of large herds of livestock, government policies and topography. To completely eradicate the species from agricultural land, it calls for an integrated approach that will bring together mechanical, chemical and biological methods of controlling Prosopis. To that extent, the Kenya government should enact appropriate policies governing its spread and detach Prosopis invested land from gazette government forest.***

Keywords: ASALs, Policies, Integrated Approaches, Prosopis and Turkana County

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I. PROSOPIS SPECIES AND THEIR ORIGIN

Prosopis is a xerophyte belonging to the genus of flowering plants in the family of Fabaceae species and are native to many nations (Patnaik et al., 2017; Hussain et al., 2020). The generic names were instigated from the Greek language and later adopted in Latin, which means 'burdock' (Rasanen & Lindstrom, 2003; Nabhan, 2018). There are more than 45 different species of prosopis found grown in subtropical and tropical regions of Africa, America and South & Western Asia (Zachariades et al., 2011). The dominant species are *Prosopis glandulosa*, *P. laevigata*, *P. Velutina* common in South America and Mexico (Pasiecznik et al., 2004), *P. abbreviate*, *P. alba*, *P. chilensis*, *P. juliflora*, *P. pallida*, *P. strombulifera*, *P. calidenia* common in Neotropics, Argentina, Bolivia and Paraguay, Brazil (Pasiecznik et al., 2004), P. Africana common in Nigeria (Ataguba et al., 2015; Dau & Chenge, 2016), *P. cineraria*, *P. farcta*, *P. koelziana* extending from India to the Arabian Penisnsula (Baibout et al., 2022; Hughes et al., 2022).

The species are deep rooted and thrives well in arid sandy soils (Singh, 2022). The mature Prosopis have hard, dense and durable wood as well as pods (fruits) high in sugar (Wakie et al., 2016; Nabhan, 2018). The presence of sugar in the species has been associated with the wide spread of malaria in prosopis invested areas as the trees enhance the transmission of mosquito's plasmodium (Muller et al., 2017). Prosopis species have also been found to contain tannin, 5-hydroxytryptamine, tryptamine, apigenin, l-arabinose, isorhamnetin-3-diglucoside and quercetin (Prabha et al., 2014; Afifi et al., 2018; Singh & Pareek, 2023) . Some species like *P. africana* and *P. velutina* are known for gum production (Pasiecznik et al., 2004; Wakie et al., 2012). *P. Juliflora* mainly produce two products namely 5-HTP and tryptamine (Prabha et al., 2014; Sharifi-Rad et al., 2019)).

Prosopis juliflora, also known as Mathenge tree in Kenya, is a native of Mexico, Carribian and South America which is invasive (Pasiecznik et al., 2001; Masakha, 2013; Ilukor et al., 2014; Okumu, 2019). The trees can grow to a height of 12 meters and drunk diameter of 1.2 meters (Hughes et al., 2022).

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The tree has deciduous, light green leaves with about 12 to 20 leaflets (Pasiecznik, 2001; Shaheen et al., 2020). The pods that result from fragrant golden yellow flowers are about 30cm long, with each pod containing a maximum of 30 seeds (Maundu et al., 2019; Pasiecznik, 2001; Hughes et al., 2022). The seeds are mostly propagated by animals (mostly camels, cattle and sheep) who feed on them spread through droppings (Masakha,2013; Okumu, 2019; Singh, 2022). The species contains thorns in pairs at the nodes while its roots are able to grow to a depth of 53m in search of water (Gallaher & Merlin, 2010).

II. INTRODUCTION AND SPREAD OF PROSOPIS TO KENYA

In Sub Sahara African countries including Kenya, about 40 species of Prosopis species have been reported. The widely known and mostly reported Prosopis species: *Prosopis juliflora, Prosopis chilensis and Prosopis pallida* with *Prosopis juliflora* being the most invasive (Catterson Thomas, 2003). In Africa, Prosopis was first reported in Senegal 1822, and then later to South Africa and Egypt in 1880 and 1900, respectively (Pasiecznik et al., 2001; Choge et al., 2007; Wudad & Abdulahi, 2021). In Kenya, the *P. juliflora* is an invasive species that was introduced in the arid and semi-arid areas (Zeila, 2011; Nadio, 2020). Countries like Hawaii and all states in Australia have branded *P. juliflora* a noxious weed.

P. juliflora was introduced in Kenya in the early 1970s in Mombasa to rehabilitate quarry and (Baringo region) in the 80s from South Africa as an initiative to combat desertification, provide firewood to community, shade, construction materials and fodder for the livestock (Pasiecznik et al., 2001; Choge et al., 2007; Tilahun et al., 2016; Mwania, 2017). This plant was introduced by the Government of Kenya under the stewardship of the National Irrigation Board (NIB), Kenya Forestry Research Institute (KEFRI) in collaboration with the government of Finland to restore the Njemps plain, right from Ngambo to Loboi then later covered the entire Marigat Subcounty (Kahi, 2004, Choge et al., 2007; Maundu et al., 2009; Oduor & Githiomi, 2013; Odhiambo, 2016). Indeed, it transformed the plain into a greener and densely tree-shielded landscape combating firewood & fodder shortage, soil erosion, and sandstorms (Oduor & Githiomi, 2013; Wakie et al., 2016; Singh, 2022).

The disguised blessing became a curse as the tree spread rapidly across the region, causing more harm than good (Choge et al., 2007). The rate of spread was alarming as the tree could cover about 500 – 1,300 hectares per year (Gichua, 2014). By 2009, *P. juliflora* had spread entirely in all arid and semi-arid areas of East Africa (Maundu et al., 2009), Kenya included (Fig 1).

In Kenya, *P. juliflora* can be found in the East and North East of the country, as well as in parts of the Rift Valley and the coastal region (Mwangi & Swallow, 2005; Maundu et al., 2009). Their growth and spread in arid and semi-arid areas is supported by waters from lakes and river systems like the Lake Baringo, Tana River and Turkwel rivers, thus posing a major threat to these water ecosystems (Maundu et al., 2009; Mworia et al., 2011; Nadio et al., 2020; Hussain et al., 2021).

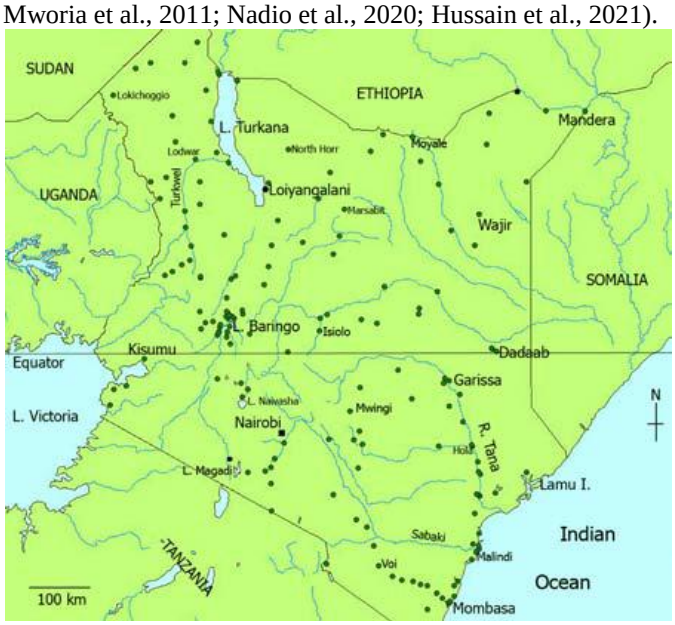


Figure 1: Distribution of Prosopis juliflora in Kenya in 2009; image source (Maundu et al., 2009)

The densest thicket of Prosopis is currently found in Baringo, Taita-Taveta and Turkana Counties thus colonizing most of the grazing areas, ending up barring the growth of other plants (Koech et al., 2021; Choge et al., 2022). Arid and semi-arid areas account for 80% of the Kenya's land mass of which Prosopis have occupaid the entire 50% land mass (Maundu et al., 2009; Mbaabu et al., 2019). It is estimated that Prosopis has colonized over 1.5 million hectares of Kenya's land mass (Koech et al., 2020). In 2016, the Prosopis had occupied more than 18,500 hectares in Baringo county (Mbaabu et al., 2019; Eschen et al., 2021). In Turkana County, the Prosopis plant invaded many areas, among them Katilu, Letea, Lokangai, Songoti, Lotubai, Kalokol, Loriu, Naman, Kerio and Turkwell wards (Choge et al., 2007; Nadio et al., 2020). Currently, the county is leading in the area covered by Prosopis across the country, estimated to be about 3,300 square kilometers (Omungo, 2018; Mumina & Bourne, 2020). This has happened after the introduction of the species in 1979 by the Government of Kenya (GoK) alongside Norwegian Agency for Development Cooperation (NORAD) through a Rehabilitation Project by the Turkana district (Choge et al 2002; Nadio et al., 2020). The development agencies provided an avenue for the spread of the species up to the refugee camps in Kakuma and Lokichoggio since the trees could withstand constant cuttings (Maundu et al., 2009). The tree is now all over Turkana County and can be seen along the highways, right from Kainuk to Lokichogio.

Given the wide spread of Prosopis, rapid climate change effects and minimal efforts to control the plant, it may soon hit the heart of the Kenya economy, particularly crop lands, range lands and national parks and reserves. Thus, the government needs to provide technical know how and information on the control of the species, since manual removal of the species may be too expensive for the country.

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III. ECOLOGICAL DRIVERS OF PROSOPIS INVASION IN DRYLAND AREAS

History and satellite images (Fig. 2) show that Prosopis were dominant near water bodies and along the drainage lines/ riverine in the dry areas of Kenya (Mworia et al., 2011; Nadio et al., 2020; Hussain et al., 2021; Kihungu, 2022). Given the poor drainage systems of the dryland soils, there has been lots of surface runoff during heavy down pour aiding to the thriving of Prosopis (Karuku, 2018). For instance, seasonally flooded areas like Lotikipi aid in the dispersal of seeds and enhance the germination of Prosopis species (Maundu et al., 2009). During EL Nino rains in 1997, it was revealed that Prosopis inhabited Kenya's arid and semi-arid lands very quickly while getting favor from the high humidity and temperatures of the place (Opiyo, 2014; Becker et al., 2018). This was denoted by the outcry from the community members, immediately after the rains (Omungo, 2018).

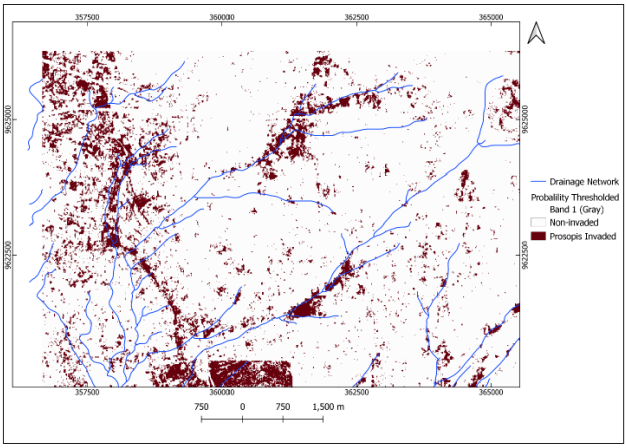


Figure 2: Drainage lines invaded by Prosopis in Taita Taveta County; Image source (Kihungu, 2022)

People in Arid and semi-arid areas are pastoralists who are known for keeping large numbers of livestock (Huho & Omar, 2020, Mbaabu et al., 2020). Due to limited feeds the animals move from one point to the other. The sweet pods and leaves encourage the animals to feed on them and in the process, they disperse the seeds whenever they go through feces (Alvarez et al., 2017). Overgrazing has led to degraded grasslands (Doran et al., 1979; Witt & Luke, 2017; Eschen et al., 2021), thus creating a better environment for the invasive Prosopis species thus tumbling accessibility, abundance and quality of feeds (Kassahun et al., 2005; Linders et al., 2019). Prosopis are fast growing species with strong coppicing ability which enables it to colonize an area within the shortest time possible (Mbaabu et al., 2020).

Prosopis thrives well in all types of soils (Ng et al., 2018). The nature of the soils in the drylands have contributed, to a greater extent, to the Prosopis inversion (Throop & Archer, 2008; Eshete et al., 2020). Most of the soils are saline in nature due to high evaporation rates witnessed in the region, as well as highly alkaline in nature (Mwangi & Swallow 2005; Narain, 2008; Sharma & Singh, 2019). Prosopis, as opposed to legumes and other crops, can tolerate salinity levels of up to 32,000 mg/L NaCl (Velarde et al., 2003). Alternatively, they do well in soil with pH above 10 (Ewens et al., 2022). The nutrient-rich soils are said to support herbaceous vegetation like Prosopis (Kahi, 2004). Prosopis seed germination, survival and life expectancy can be positively impacted by high nutrient availability (Alvarez et al., 2017; de Souza Nascimento et al., 2020).

Prosopis can grow in areas receiving a wide range of rainfall ranging from 50mm to 1500mm per annum (El-Keblawy et al., 2015). During severe droughts, the tree remains green with all its leaves intact and can bear fruit (Shiferaw et al., 2004; Damasceno et al., 2017). High rainfall rates may render the soil ineffective as it becomes excessively humid and hinder Prosopis growth (Shiferaw et al., 2004). The plant adapts well in dry and hot areas with an average temperature of up 40^{o}C (El-Keblawy & Gairola, 2017; Hussain et al., 2020; Slate et al., 2020). Studies by Eschen et al., 2021 and Bogale & Tolossa 2021, shows that climate change may worsen the problem by increasing the invasion rates and extension of coverage areas due to changing rainfall patterns thus further decrease in fodder.

IV. MECHANICAL CONTROL AND INTEGRATED APPROACHES TO MANAGEMENT OF THE SPECIES

Mechanical methods are common practices used for controlling Prosopis, in both developed and developing nations (Wakie et al., 2016). This method can be financially costly when applied in a huge area, heavily invaded with Prosopis species. For instance, studies show that at one point South Africa used approximately \$2800 ha^{-1} to partially remove *P. juliflora* (Shackleton et al., 2014). Prosopis plants can be removed by using hands i.e., cutting, pulling, digging and mechanical uprooting (Tu et al., 2001; Shibru, 2015; Kool et al., 2019; Eschen et al., 2023). These methods are being used across Turkana County, especially Turkana west sub-county although monitoring and maintenance of the area has been a problem. Developed nations depend mostly on machines and have resolved more to bulldozer pulling, chain pulling, stick racking and blade ploughing (Vitelli & Pitt, 2006; Gallaher & Merlin, 2010; Northern Territory Government, 2015). On the other hand, spraying of species with hot salty water and smearing coal can be practiced. Farmers also use fires to burn plants to reduce their spread (Shanwad et al., 2015). Burning helps in vegetation reduction and killing of seeds that are on the Prosopis plant and those that have fallen on the ground (Campbell & Setter, 2002; DiTomaso et al., 2006; Eschen et al., 2023). There are major disadvantages associated with use of fire like killing of non-targeted plants species, wildfires risks and non-uniform destruction of species (Kool et al. 2019).

Besides, the application of herbicides (chemical treatment) has shown tremendous results in the control of Prosopis (Sakthieswaran & Sophia, 2020; Balcha, 2022). The use of keroscene, glyphosate, diuron, paraquat, coaltar, 2,4-D amine and ester either in combination or individual chemicals have reduced both growth and development of Prosopis (Shanwad et al., 2015; Kaur et al., 2022). For efficient and effective results, the choice of chemical, application method, time and dosage are to be considered (Ansley et al., 2004; Vitelli & Pitt, 2006; Getachew et al., 2012; Shanwad et al.,

2015). The waxy layer on the outer part of Prosopis species, coupled with thick bark, small leaves and woody stems, may inhibit the penetration of chemicals, thus more analysis is required before arriving at the best combination or individual herbicide (Bovey, 2016; Nath et al., 2020;). Alternatively, some chemicals work well on the freshly cut stamp of mature prosopis which aid in killing the phloem and xylem prohibiting re-growth of the species (Kool & Nzumira, 2015).

Integrated control of Prosopis species can be done biologically through the introduction of seed feeding insects (Zachariades et al., 2011). Many studies have attributed the invasion of Prosopis to annual production of hefty numbers of seeds, thus a mechanism to destroy the seeds may be vital to prevent its growth and spread (Shiferaw et al., 2004; Shackleton et al. 2014). Bruchids especially, *Algarobius prosopis* (LeConte) and *Algarobius bottimeri* kingsolver have been found to destroy massive seeds in North America and South Africa (Zimmermann, 1991; Palmer et al., 2010; Zachariades et al., 2011; Cullen et al., 2012). These insect (beetles) species have also been seen effective in Australia alongside *Prosopidopsylla flava* -a sap-sucking psyllid that results in dieback, and *Evippe spp*.- a leaf-tying moth that results to defoliation (van Klinken et al.,, 2003; Gallaher & Merlin, 2012; Zachariades et al., 2011). There is also a need in have agents that can destroy the plant at its vegetative stage or those that can prevent pod setting and seed maturation (Kleinjan et al., 2021). An integrated approach that calls for a combination of either mechanical and biological or mechanical and chemical may work tremendously well. The use of three methods in combination may give better results in case the chemical used will have no adverse effects on the insects or organisms used.

V. CONCLUSIONS

There is evidence that Prosopis has taken over massive land in Turkana County. If proper measures are not taken, there is a possibility of the whole county being invaded, with Prosopis leading to downgraded livelihood among the communities. It also calls for combined efforts among different players working in government institutions, non-governmental organizations (NGOs) and private sectors. Prosopis invasion does not only touch on environmental matters but a wide spectrum of disciplines ranging from agriculture, survey, wildlife, forestry, livestock and climate change.

VI. RECOMMENDATIONS FOR POLICY MAKERS

There is great need for policy makers and researchers to disseminate scientific findings in *Prosopis juliflora* to the public and local communities affected by this invasive species.

The local communities living in the region need to be trained on growth and dependency on different sources of livestock feeds besides *Prosopis* to minimize spread via animals.

There must be a policy that controls the movement of animals; for instance, animals from heavily invaded areas are denied access in sparse or non-invaded areas. This may be achieved through demarcation and mapping out these regions.

For a long time, there was no policy guiding the management of Prosopis but as from 30th December 2008, the minister for agriculture in Gazette Notice no. 184 on the Suppression of Noxious Weeds Act (Cap. 325) published in the Kenya Gazette of 9th January, 2009 by government of Kenya (GoK, 2009), declared *Prosopies juliflora* as a noxious weed. The ban affected the Prosopis prone areas, as the communities could not use the species in what is referred as utility control. Thus, the government need to separate the invasive trees/ forest cover from other useful trees for informed decision making on their control. Additionally, the communities should be allowed to do massive falling of Prosopis for charcoal, poles on commercial purpose.

There is need of concerted efforts from all stakeholders including both levels of government (County government and National government), Non-governmental organizations (NGOs), research institutions, academia community, civil societies and the local community to address its control and management of the lands with *Prosopis* species. Therefore, this calls for appropriate policies, funded research to carry out demand driven action researches and strengthening capacity building.

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