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How do East African Communities Cope with the Impacts of Prosopis juliflora (Mesquite) Invasion? A Review

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Abstract
Prosopis juliflora is an evergreen invasive plant native to South America, the Caribbean, and Central America. The plant is well adapted to harsh environmental conditions. As a result, it has spread to most arid and semi-arid areas of the world causing both positive and negative impacts. This study reviewed the adaptation/coping strategies adopted by East African communities as a result of the invasion by the plant. The review results showed that East African communities cope by using the plant for human food and animal feed, leasing the infested land, renting land from uninvaded areas, clearing the plant from farming, grazing land, waterways, paths and homesteads, and using it as fuel in form of firewood and charcoal among others. The communities living in the infested areas now almost entirely depend on the plant for livelihood. Some of the employed adaptations/ coping strategies were found to be inadequate and to have negative environmental impacts. In order to enhance the adaptations/ coping strategies, we recommend commercialization of the plant's seed for animal feed and human food production, sensitization of the communities on the medicinal use of the plant and that programs to manage the plant should take into account the adaptations the communities have developed over time to avoid negative impacts on the communities' livelihoods.
Keywords: *Prosopis juliflora*; Coping strategies; East Africa; Invasion; Pod

1. Introduction

Prosopis juliflora (hereafter referred to as *P. juliflora*) is an evergreen plant native to South America, the Caribbean, and Central America (Swallow & Mwangi, 2008) and is well adapted to harsh environmental conditions (Mendes, 1986). In Africa, the plant has invaded some 4 million hectares of land resulting in reduction of underground water reserves, reduction of food and fodder, loss of biodiversity (Witt, 2010). The plant found its way to various East African countries at various times (Aboud et al., 2005; Broun and Massey, 1929) through intentional introduction with the intent of obtaining positive benefits including ameliorating the prevailing ecological conditions such as combating desertification, stabilizing sand dunes, addressing the concerns of deforestation and providing wood for fuel (Nawata, 2012; Swallow & Mwangi, 2008; Babiker, 2006). This is due to the ability of the plant to survive and do well in hot, salty and water scarce environments (Maundu et al., 2009; Nawata, 2012; Babiker, 2006) conditions that are prevalent in East Africa.

P. juliflora spreads at an alarming rate in the East African region majorly in Kenya, Sudan and Ethiopia where the plant has been declared noxious ((Lusweti et al.; El & Ahmed, 1986; MoARD, 2005). The rapid spread of the plant to new areas where it was not originally planted has been due to the following causes: (1) animal dispersal as the trees produce small seeds which are able to go through the animal digestive system without being digested so they are easily spread by the animal movements, (2) the seeds remain viable for long periods of time ensuring their survival during harsh conditions, (3) the plant is able to sprout upon damage and the coppice grows fast, (4) the plant's seed-containing pods are fleshy and have sweet mesocarps making the pods attractive to the animals (Shiferaw et al., 2004) hence enhancing dispersal by animals, and (5) the seeds can be dispersed by water through flooding (Rettberg, 2014) among others.

The plant has indeed brought with it benefits as were anticipated during its introduction. The benefits notwithstanding, *P. juliflora* has turned out to be of serious socio-economic and ecological concern. The concerns include injuries (and sometimes death) to both animals and humans, significant reduction of fodder, reduction of biodiversity of indigenous plant species, blockage of water ways/ paths thus constraining water from reaching the intended farms, forms hideouts for criminals, snakes and mosquitoes thus increased malaria cases, reduction/loss of agricultural lands thus curtailing crop farming, increasing communal conflicts (Maundu et al., 2009; Muturi et al., 2013; Rettberg, 2014; Swallow & Mwangi, 2008)

Because of these concerns, this paper sought to review the coping strategies that the local communities in the *P. juliflora* infested areas have adopted as coping and adaptation mechanisms in order to survive the aforementioned negative effects. The coping strategies are crucial since studies indicate hard and costly to eradicate the plant due to the enormous capital required for such a project (Spate Irrigation Network, 2014), the

plant's fast growing coppices and regeneration ability (Ayanu, 2014) especially in developing countries where funds are limiting.

2. Literature search, Methods and Selection criteria

The study aimed at reviewing the coping strategies to *P. juliflora* invasion and associated impacts in East African region encompassing Ethiopia, Kenya, Uganda, Tanzania, Rwanda, Burundi, Sudan and South Sudan. The search extensively relied on Web of Science and Google Scholar which has a wider scope of journals. Google Search engine was also used to capture relevant grey literature, however, this (grey literature) constituted a smaller portion of all the literature cited. Further, manual search from the references of identified articles or grey literature was used. The search included but not limited to combinations of the following key words: 'Kenya*', 'Prosopis*', 'juliflora*', 'Tanzania*', 'Ethiopia*', 'Rwanda*', 'Burundi*', 'Uganda*', 'Sudan*', 'effects*', 'coping strategy (ies)*', 'adaptation*', 'impacts*', 'mesquite*'.

The abstracts of the articles were then scanned for relevance and the relevant articles selected for review. The search was limited to literature reported in English without regard to time frame.

3. Results and Discussion

The search did not yield any results for Tanzania, Uganda, Rwanda and Burundi. The reason for the apparent absence of studies on *P. juliflora* in these countries could be due to limitation by language used for search (English) and little infestation by the plant thus no major impact that 'warranted' studies. This may also be the possible reason why Tanzania and Uganda have not declared the plant as noxious as did Kenya, Ethiopia and Sudan (El & Ahmed, 1986; MoARD, 2005; Lusweti et al).

The study found out that the major adaptation/coping strategies employed by the communities in affected areas of East Africa include the use of the plant for human food and animal feed, leasing the infested land, renting land from uninvaded areas, clearing the plant from farming land, grazing land, waterways, paths and homesteads, and using it as fuel in form of firewood and charcoal among others. These are discussed in this paper. The review also found out that the plant infests mainly the arid and semi- arid areas of East Africa.

The communities in *P. juliflora* invaded areas have diversified their sources of livelihood in various ways; sale and use of the plant as fuel (charcoal and firewood) and as poles in constructing houses (Ilukor et al., 2016; Maundu et al., 2009; Rettberg, 2014; Swallow & Mwangi, 2008). Because most of the areas infested by *P. juliflora* are majorly dry with few or no woody trees for use as fuel, *P. juliflora* presents a reliable source of wood fuel owing to its fast coppicing and regeneration ability (Ayanu, 2014). Ilukor et al., (2016) in their study in Afar, Ethiopia found out that of all the income derived from the ecosystem goods and services, about half (46%) was contributed by *P. juliflora*. This exploitation can be viewed to provide relief to the ever decreasing indigenous forests as they were the only source of wood for charcoal production and other uses before *P. juliflora* was introduced. Hence these communities derive their livelihood from the sale of charcoal, firewood and poles. Similar observations were made in a pastoralist community in Kenya in which the communities' farms could no longer be used for growing crops and/ or to support animals since the main livestock feed, that is grass, acacia and herbaceous plants had been dislodged by *P. juliflora* forcing the people to almost entirely rely on the plant for livelihood (Maundu et al., 2009). In addition, the communities engage in other businesses (apart from trade on products of *P. juliflora).* This is in response to the reduced fodder (as a result of *P. juliflora* invasion) for the cattle which had been the communities' source of income (Rettberg, 2014). These changes may have the effect of disorienting the community as they have to adjust to different ways of living or livelihood especially if the disturbed means of livelihood forms part of their culture.

The use of *P. Juliflora* however can be a good way of reducing the rate of deforestation more so to the ecologically significant indigenous trees. Charcoal burning as a coping mechanism could be used to control its spread and the control can be more effective if the stumps are uprooted (Wakie, Evangelista, & Laituri, 2012) and used as firewood or used in making charcoal.

Leasing out invaded lands, renting unaffected lands and abandoning and or migrating from the *P. juliflora* invaded lands have also been adopted by the local communities to the cope with *P. juliflora* invasion (Rettberg, 2014). In Afar area of Ethiopia among the pastoralist community, Rettberg (2014) found out that the locals leased out the infested lands to non-local agricultural investors for farming. The previously invaded lands have the possibility of increasing agricultural production due to the ability of *P. juliflora* to fix nitrogen to the soil (Kahi et al., 2009). In leasing the land, the locals forgo their grazing priorities and derive financial benefits directly from the lease and from employment in the farms. In Kenya, some are forced to abandon/migrate to other areas or look for pastures far away from their homesteads that are as far as 40-50 km away (Maundu et al., 2009; Swallow & Mwangi, 2008). Swallow & Mwangi (2008) observed that communities rent land in areas that are not infested by the plant. The results of these human and animal movements often lead to human and wildlife conflicts (Rettberg, 2014; Swallow & Mwangi, 2008). Migration from and leasing of these invaded areas may be due to the thick thickets of *P. juliflora* and associated negative impacts beyond the ability of the local people to

manage. The likely scenario in these cases is increase in density and area invaded. Abandoning ancestral homes for other areas may also have negative cultural impacts to the communities since people have some cultural attachments to their ancestral lands. Financial costs are incurred especially in situations where the communities are forced to rent land.

Further, due to the dwindling livestock numbers as a result of inadequate fodder occasioned by the invasion of *P.juliflora*, communities sell their animals so as to obtain other food items which they can no longer produce as a result of the invasion (Ilukor et al., 2016). The plant is also considered to cause livestock ill health such as pods clogging the animals' gut, wearing away and loss of teeth, accumulation of fruit gums on the jaws of the animals, diarrhea and thorns causing injuries to the hooves (Maundu et al., 2009). In order to evade these animal health problems, the communities are forced to sell their sick livestock at significantly lower prices to avoid total losses (Swallow & Mwangi, 2008). This exposes these impoverished communities to risk of malnourishment and reduced capacity to bounce back in an event of a calamity hence continual dependence on relief.

Another mechanism employed is clearing *P. juliflora* from the infested areas. The farmlands or grazing fields or homesteads are cleared manually as a community or individually by uprooting, manual cutting, burning and pruning (Nawata, 2012; Swallow & Mwangi, 2008). This mechanism is however tedious owing to the fast regrowth of the plants' branches (Maundu et al., 2009; Nawata, 2012) requiring frequent clearing. Paths/roads and waterways (irrigation water channels and river channels) are also cleared using traditional tools such as machetes (Maundu et al., 2009). Blockage of paths/roads and waterways are caused by the overgrown branches of *P. juliflora* making people use longer routes or distances and causing flooding. However, in situations where land is owned communally as is the case in some areas in Kenya (Maundu et al., 2009), individual responsibility to manage the spread of the plant is lacking In addition, there is the use of less effective tools that may result in recolonization of the cleared areas. Further, there is significant loss of income as some locals incur additional costs in hiring labour to clear their farms (Swallow & Mwangi, 2008).

In addition, the communities in the region cope up with the challenges posed by *P. juliflora* by using parts of the plant as human food and animal feed (the pods) without undergoing processing such as crushing (Maundu et al., 2009; Nawata, 2012). The pods are sweet, nutritious and have low levels of tannins (Pasiecznik et al., 2001). The ripe dry pods *of P. juliflora* have been found to contain 12% crude protein, 15% crude sugar, high level of energy at 75% of Total Digestible Nutrients (TDN) with the seeds containing 31-37% protein (Sawal et al., 2004). Moreover, it has been established that mixing 20% of *P. juliflora* flour with animal feed is likely to reduce on production cost of animal feeds without compromising the quality of the feed (Girma et al., 2012) . These make it ideal to be used as animal feed especially during the droughts, a common phenomenon in the region. The crushed pods not only benefit the animals but also aid in reducing the dispersal of the seeds. However, most of the plant mass is not palatable and the pods need further processing especially crushing (by humans before giving to animals) to enhance digestibility (Sawal et al., 2004). The pods are also palatable to humans with Maundu et al. (2009) and Nawata (2012) indicating that the pods are eaten by the local people in Kenya and Sudan respectively. The government of Kenya in this regard started enhancing the adaptability of the affected communities by exploring the possibility of using *P. juliflora* flour as food (Choge et al., 2007). *P. juliflora* flour has been used in North American Desert of Sonoran as food (Simpson 1977) and in Brazil the pods have been used to produce a nutritious sweet syrup that is combined with other ingredients to make cakes and other edible products (Guilherme et al., 2007). This would therefore present the region with a good opportunity of benefitting from the plant and minimize the effects of the frequent droughts and famines in the East African region if it is commercialized.

Further, the communities in the *P. juliflora* invaded areas have adapted by introducing beekeeping projects, using trimmed *P. juliflora* plant as fence and as shade during hot weather (Maundu et al., 2009; Nawata, 2012). Beekeeping is highly favored by *P. juliflora's* ability to flower all year round even during severe droughts (Junior, 1960) thus providing nectar for producing honey all year round. This enhances livelihood in the communities in invaded areas. The thorny nature of the plant makes it ideal for use as fence to keep away intruders thus improving security in these areas where cattle rustling are common.

The results show that only a few people in the communities use *P. juliflora* as medicine (Maundu et al., 2009) suggesting that the medicinal value of the plant is hardly known by the communities. Studies have shown that extracts of *P. juliflora* may be used as natural antioxidants, in cosmetic and pharmaceutical industries (Sirmah et al., 2008).

Some of the coping strategies employed however pose negative ecological impacts: In the process of clearing *P. juliflora* for the said uses, the indigenous trees considered to be of ecological importance are (illegally) cleared too (Ilukor et al., 2016). This exposes the environment to further degradation and contributes to loss of biodiversity in these areas. There is also water resource pollution by pesticides from the leased agricultural farms (Rettberg, 2014). The pesticides can reach the surface waters through surface runoffs hence endangering the aquatic life. Again, individuals who derive more benefits from the trade in *P. juliflora* products

such as charcoal are acting counter the efforts exerted to eradicate the plant (Ilukor et al., 2016) making the plants' management efforts futile.

Further research is needed to explore socially acceptable and ecologically sound ways of using the plant or parts of it such as the leaves whose benefits so far are limited especially for medicinal use.

Limitations of the study

This review was limited to studies reported in English thus there may be studies in French (Burundi and Rwanda) and Arabic (Sudan) that may have been missed. Also, the study screened the abstracts to evaluate the relevance of the articles for review consideration. And so the articles which touch on coping strategies but not included the strategies in the abstract may not have been considered

4. Conclusion future works

The coping strategies are to a large extent similar in the East African region with almost all the *P. juliflora* affected areas being arid/semi- arid pastoralist environments. There are diverse ways the communities have employed to cope with the impacts of *P. juliflora* invasion which include leasing the *P. juliflora* infested land, renting land from other areas, clearing the plant from farms, grazing land, waterways, paths and homesteads, using the plant for human food and animal feed and using it as fuel in form of firewood and charcoal. These adaptation/coping strategies to a large extent help in controlling the spread of this noxious plant while at the same time benefiting from its products. Among the adaptations/ coping strategies, the use of the plant's pods is the most appropriate in managing the spread of the plant especially that which involves crushing the seeds. Plans or programmes to eradicate this plant need to take into account the changes the local communities have made to adapt to impacts of the plant's invasion lest the communities' livelihoods be negatively impacted. Additionally, since it would be difficult and expensive to eradicate the plant, it is prudent to enhance the local communities' coping mechanisms by formulation of policies, research to come up with other beneficial ways of utilizing the plant, providing market to *P. juliflora* products or incentivizing the process and cost of preparing and delivering the products. Among the specific areas of venture by the Governments in the Eastern Africa region or concerned organizations would include milling and commercializing of *P. juliflora* seeds for use as animal feed upon establishing the seed stock and the seed production rate. Further, the communities should be assisted to identify alternative sources of plants of medicinal value to compensate for the indigenous medicinal plants which have been lost or are at risk of being displaced by *P. juliflora.*

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