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SOCIO-ECOLOGICAL IMPACTS OF INVASIVE ALIEN CACTUS (OPUNTIA) IN THE RANGELANDS OF NAROK COUNTY, KENYA

Githae, E.W. [*] **and Magana, A. M.**
[1] Faculty of Science, Engineering and Technology, Chuka University, P. O. Box 109-60400, Chuka, Kenya
***Correspondence:** Tel. +254 725 286095, **E-mail:** *egithaeh@gmail.com; egithae@chuka.ac.ke*

ABSTRACT

Many cactus species have been introduced in the Kenyan rangelands and their subsequent spread have had devastating effects on the ecosystem services. Opuntia stricta is the most widespread and forms dense impenetrable thickets that negatively impact on rangeland livelihoods and resources. This study assessed the impact of O. stricta on rural livelihoods and their environment in Narok County. Data was collected using household surveys, key informant interviews and transect-walks. Results indicate that communities in the region are well aware of Opuntia invasion in the area, which has increased rapidly over the recent past and spreading to various ecosystems. The cause of spread was attributed to planting the species for various purposes, garden throw-outs and floods. More than 70% of the respondents perceived the species as undesirable with negative impacts only. The impacts include denied access to natural resources, reduced productivity and increased threat to livestock and human health. Pasture lands, farmlands and degraded lands were the most invaded areas. Chopping was the preferred method of management but was combined with other mechanical and chemical methods in order to be more effective. Appropriate interventions are suggested to mitigate the negative impacts and improve rural livelihoods and their environment.

Keywords: Cactus; invasive species; rangelands; rural livelihoods, Narok County

INTRODUCTION

Invasive alien species (IAS) are regarded as one of the largest threats to global ecosystems and biodiversity. They are characterized by high ecological adaptability, high competitive ability and efficient reproduction and dispersal mechanisms. In a new environment, such species prosper in the absence of predators or parasites that would keep their relative abundance in check (Boy and Witt, 2013). Besides, they are able to occupy vacant niches or take advantage of ecologically stressed or disturbed environments with the capability of changing resource availability (Gordon, 1998). These in turn may increase the competitive advantage of the IAS, which may be better adapted to the new conditions and thus be able to dominate large areas. In the rangelands, impacts of IAS are mostly related to livestock production and include livestock deaths, reduced forage, interference with grazing practices, increased costs of management and reduced livestock yields (DiTomaso, 2000). They may also impact wildlife habitat and forage, deplete soil and water resources and reduce plant and animal diversity. Besides, effects on rural livelihoods are linked to extra cost of management, reduced ecosystem productivity, increased threat to health and reduced utilities from natural resources (Haile, 2008). However, little work has been undertaken at the local level to explore these impacts, which should form a knowledge base for policy interventions.

In Kenya, more than 80% of the country is arid and semi-arid lands (ASALs) - the rangelands where constraining environmental conditions provide limited options for sustainable land use other than livestock rearing. They contribute significantly to livestock production and wildlife conservation. However, a large number of cactus species have been introduced and their subsequent establishment and spread have had devastating effects on rangeland quality and quantity (Strum *et al.*, 2015). One of the genera, Opuntia Mill (Prickly pear), native to America, is a worldwide invasive species that has invaded in many countries including Australia, Europe and many African countries

(Novoa *et al.,* 2015). The species is a perennial, spiny shrub that produces large number of seeds which are dispersed by myriads of animals over long distances (Foxcroft *et al.,* 2011). Besides sexual reproduction, the species form dense thickets through vegetative reproduction that hinder the growth of potential competitors (Foxcroft *et al.,* 2011). In addition, the species undergoes phenotypic plasticity and genetic differentiation that enable it to adapt to different environments (Novoa *et al.,* 2015). Such trait facilitates its spreading and colonization in new areas.

Opuntia stricta Haworth (hereafter Opuntia) is the most widespread and among the top 100 of the world's worst invasive alien species (Lowe *et al.,* 2000). It is reported as a well established IAS in Australia, Spain and South Africa (Foxcroft *et al.,* 2004). Two varieties are recognized: O. stricta var. stricta (Haworth) and O. stricta var. dillenii. Opuntia stricta var. stricta is the most common abundant in Kenya and the one identified in this study. The species has little benefits and the most problematic in terms of impeding mobility, reducing fodder availability and impacting negatively to human and livestock health (Shackleton *et al.,* 2017). In Kenya, the species was introduced in 1940s as an ornamental plant but has successfully invaded the ASAL regions where it has negatively impacted natural resources and livelihoods. The species form dense impenetrable thickets and has continued to disperse in other habitats including national parks, wetlands, croplands and forest edges (Strum *et al.,* 2015). The alarming rate at which the species is proliferating poses a considerable threat to the well-being of livelihoods and this is expected to increase as the effects of climate change become widespread. Assessing factors that facilitate the establishment and spread of the species is therefore essential for successful management and restoration of these ecosystems. Furthermore, understanding community perception of Opuntia in the rangelands is required for sustainable management in the context of changing environmental conditions (Rai *et al.,* 2012). When this is done at a local level it can support the establishment of a knowledge base that can contribute to monitoring programmes. This assessment is important especially in areas where information on impacts is scarce and can justify the need for further research in management interventions (Shackleton *et al.,* 2017). This study was carried out in Narok County that exemplifies communities in ASALs that are dependent on livestock for their livelihood. However, the occurrence of frequent droughts and presence of invasive species contributes to range resource shortages leading to intense competition for the available resources. Although the presence of Opuntia is well recognized in this region, research on its impacts to the livelihoods and their environment is limited. This study therefore assessed communities' perceptions of the species to be integrated in management interventions in order to mitigate the negative impacts and improve rural livelihoods.

METHODOLOGY

Study area

This study was carried out in Narok County situated in the south-west part of Kenya along the Great Rift Valley at -1° 04' 59.99" S and 35° 52' 0.12" E (Fig. 1). It covers an area of 17,944 sq km and has a population of 850,920 (Narok County, 2017). The area was purposively selected based on the species distribution range. The area is classified as an ASAL with most households relying on livestock and natural resources for survival. The County has an average annual rainfall of 500 mm (lowlands) to 1800 mm (highlands), which is highly variable with recurrent droughts and floods. Temperatures are high throughout the year (ranging from 12° C to 40° C) with the rates of evaporation being twice the annual rainfall. Vegetation is dominated by grasslands with scattered trees and shrubs. Key contributions to the economy are in the tourism sector through the Maasai Mara national park and the agricultural sector through livestock farming (Narok County, 2017). Land ownership is under group ranches with an increasing trend towards subdivision into individual holdings. During the last few decades, the area has experienced great land use change due to increasing human population, which has decreased the native vegetation cover and given a leeway for invasive alien plants.

Figure 1: Location of Narok County in Kenya

Data collection and analysis

This study was carried out in three main stages. The first stage involved a formal household survey using a semi-structured questionnaire. The second stage consisted of in-depth discussions with key informants while the third stage involved transect-walks across the landscape. The questions included in the questionnaire were informed by literature findings from previous studies conducted in similar settings (Haile, 2008; Shackleton *et al.,* 2017). A pilot baseline survey to pre-test the questionnaire was carried out in one of the villages. The area was then clustered into two clusters based on the constituencies (North and South). Each cluster was then stratified into wards (6 in the South and 25 in the North). The wards were randomly sampled where three were selected in the South and ten in the North giving a total of 13 wards. In each ward, households were randomly selected and the questionnaire administered to the representative of each household. A total of 195 households were successfully sampled. The type of data collected involved: (i) demographics characteristics (ii) perceptions of introduction and impacts (iii) state and rate of invasion, and (iv) management practices and interventions required. Secondary data from various sources were also used as additional sources of information. Data collected was coded, cleaned and analyzed using MS Excel and the Statistical Package for Social Sciences (SPSS) version 20. The data was analyzed by use of descriptive statistics and results presented in form of graphs and tables.

RESULTS AND DISCUSSION

Demographic characteristics

A total of 195 homesteads were surveyed. Out of these, 54% of the heads were men (Table 1). These are the decision makers and the most influential in a rural setting. On the other hand, a relatively higher number of the heads were women (46%). They were more vulnerable to the negative impacts of Opuntia than men since they are the primary users of forest resources and should therefore be considered in decisions related to managing IAS. In terms of age and literacy level, 48% of the respondents were middle-aged (31-50 years) and 32% were well educated to tertiary level. They had adopted modern way of life and demonstrated the ability to understand knowledge and skills of managing Opuntia. But with the indigenous culture, 28% opted for non-formal education, which transfers indigenous knowledge from one generation to another. This system of education is highly enriching and cheaper to implement in their culture and its flexibility is maintained over time to be able to respond to changing needs (Krätli, 2001). While designing frameworks to support efforts to control and mitigate the impact of IAS, this system is fundamental in order to cater for the needs of the indigenous communities. Although livestock played many roles in the lifestyle of the communities, only 8% of the respondents engaged in pure pastoralism. This is because many pastoralists had settled in response to various factors such as increasing drought and famine, privatization of land and loss

of common property resources. This led to diversification of livelihoods into farming, agro-pastoralism and trade in order to enhance income and food security. Without appropriate sustainable measures, this mode of diversification can provide an opportunity for invasion and can result in permanent changes in ecosystem structure and function (Strum *et al.*, 2015).

Table 1: Demographic characteristic of respondents

Parameter	Frequency of responses (n=195)	Percentage (%)
Gender		
Male	105	54
Female	90	46
Age group		
20-30	35	18
31-40	51	26
41-50	43	22
51-60	35	18
61-70	27	14
71-80	4	2
Level of Education		
Primary	23	12
Secondary	55	28
Tertiary	62	32
Non-formal	55	28
Livelihood strategy		
Agro-pastoralism	35	18
Pastoralism	16	8
Farming	23	12
Trade	20	10
Agro-pastoralism and trade	43	22
Pastoralism and trade	23	12
Farming and trade	35	18

Knowledge of Opuntia

The communities were well aware of the presence of Opuntia in the landscape with the invasions increasing rapidly over the last 10 years. The awareness of the IAS increases with its abundance as it becomes a nuisance and a significant hindrance to local livelihood activities and options (Shakleton *et al.*, 2006). The current invasion after many years of introduction is as a response to recent changes in land use primarily settling of pastoralists with subsequent land degradation (Strum *et al.*, 2015). On the other hand, all respondents were not aware that Opuntia was an alien species because it had been present in the landscape for decades. Lack of awareness and information on IAS is a common problem to their managing and it makes it harder to promote consistent decision-making by different stakeholders. Regulatory frameworks alone can therefore not solve problems related to IAS and they need to be complemented by non-regulatory efforts particularly education and awareness-raising campaigns (Clare *et al.*, 2000). More than 50% of the respondents said that Opuntia invasion had increased with time and the thickets were scattered all over the landscape. The worse affected areas were abandoned and hosted impenetrable bushes that acted as habitats of various pests and parasites. They attributed the causes of spread to using the plant as a hedge and ornamental, garden throw-outs, floods and climate change. More than 70% believed that the rapid spread was facilitated by people, livestock and baboons. These vectors are reported to spread Opuntia over long distances (Strum *et al.*, 2015). Deliberate planting through ornamental trade and garden throw-outs are a major

cause of Opuntia invasion (Hodkinson and Thompson, 1994). However, ornamental trade continues within the region and should therefore be regulated and monitored to prevent further spread and future invasions. Some respondents perceived the spread as caused by flash floods since new plants emerged immediately after the floods. Flooding facilitates dispersal, removes some biological barriers and modifies the environments for potential invasion (Parendes and Jones, 2000).

Effects of Opuntia on local livelihoods

Various responses were received on the impacts of Opuntia invasion. More that 70% of the respondents perceived the species as undesirable species with negative impacts only while the rest perceived it as having both positive and negative impacts. The different perceptions on the benefits and harmful effects of IAS are very important in any decision-making process (Rai *et al.,* 2012). This is because they vary with various factors such as the duration impacts on their livelihoods with majority reporting denied access to land (Fig. 2). This had a negative impact on pasture by displacing nutritious indigenous fodder plants. Food crops were also

African nightshade, spider plant and pumpkins. This contributed to food insecurity hence increasing vulnerability of these livelihoods. Another negative impact mentioned was injury to livestock and human. It was reported that in some cases death occurred when livestock developed a condition known as pear mouth that prevented the animals from feeding. Eating Opuntia can also result in infected lesions in the digestive tracts of animals leading to poor health or even death (Merrill *et al.,* 1980). Furthermore, Shackleton et al. (2007) of the presence of invasive plants in the landscape and household characteristics. Nevertheless, Opuntia was mainly used as a natural fence due to its impenetrable spiny thickets. Its cultivation as a natural barrier can help in rehabilitation of degraded areas as well as improvement of agro-ecological benefits. On the other hand, once the hedge is established, it becomes difficult to control since cladodes immediately root when they fall on the ground and the hedge becomes progressively thicker. Only a few respondents (8%) used the species as food (fruits) and medicinal while none used the species as a source of fodder. This indicates that although the species is appreciated for both direct and indirect uses by many livelihoods (Shackleton *et al.,* 2007), Opuntia is still hardly utilized in this region due to the present of spines and glochids that cause injuries to both human and animals. All respondents mentioned a multiple of negative

affected by the invasion; the most affected being indigenous vegetables that depended on Opuntia for support. They included amaranthus, stingingnettle,

reported that the potential costs associated with Opuntia invasion in the rangelands are based on reduced grazing land, replacement of native forage species as well as negative impact to health. Other impacts mentioned were denied access to native trees for various purposes (Table 2). This implies that infestation of invasive plants influences availability of products by reducing the abundance of native plant species, which in turn affect the ecosystem services (Rai *et al.,* 2012).

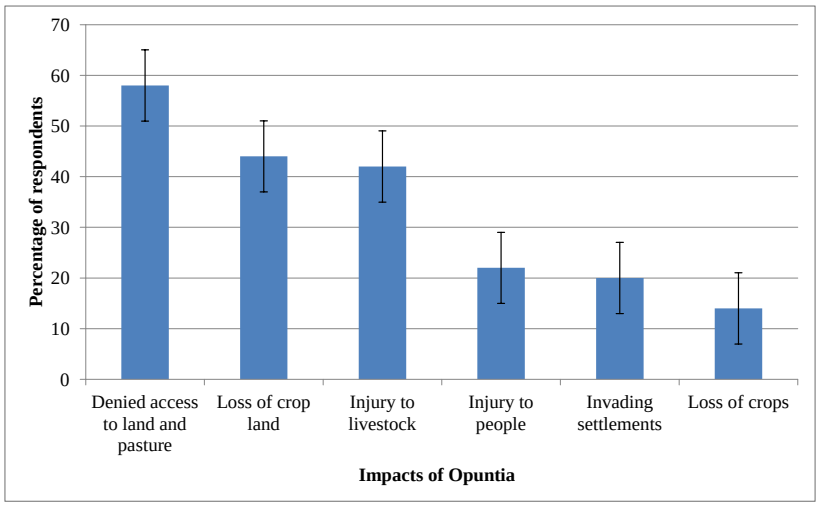

Figure 2: Negative impacts of Opuntia on the rural livelihoods of Narok County

Table 2: Plant species threatened by Opuntia invasion and their local uses

	Name	Uses	References
1.	*Acacia drepanolobium Sjostedt*	Charcoal production, firewood, food, medicine, forage, bee forage live fence.	Maundu and Tengnäs, 2005; Okello *et al.,* 2001
2.	*Rhus natalensis Krauss*	Medicinal value, charcoal production, wood and firewood, forage, shade, dye and tooth brush.	Maundu and Tengnäs, 2005
3.	*Euphorbia candelabrum Kotschy*	Natural fence, firewood, beehive, bee forage, shade, ornamental, medicine, furniture and musical instruments.	Maundu and Tengnäs, 2005; Smith *et al.,* 1996
4.	*Balanites aegyptiaca (L.) Del*	Medicinal, charcoal, wood, oil, forage, poles, edible fruits, vegetable, bee forage, resin, gum and live fence.	Maundu and Tengnäs, 2005
5.	*Grewia tenax (Forssk.) Fiori*	Medicinal, edible fruits, firewood, poles, tool handles, forage, shade, fibre and curving.	Martins *et al.,* 2008, Nep and Conway, 2010
6.	*Cordia sinensis Lam.*	Medicinal, edible fruits, gum, timber and forage.	Maundu and Tengnäs, 2005; Warfa et al. 1990

Areas most invaded

Pasture and farm lands were the most invaded areas despite being the most important for livelihoods in the region (Fig. 3). Since livestock do not graze around the cactus for fear of injury, a buffer strip around each cactus is created, which is equivalent to twice the area covered by the cactus plant (Taylor and Whitson, 1999). In addition, about 35% of forage is lost if a pasture producing 450 kg of forage per acre per year develops a 20% cactus infestation. In many African countries, forage losses to unpalatable invasive plants have reduced rangeland capacities three-fold (Boy and Witt, 2015). In addition, invasive weeds alone are responsible for reducing overall crop yields by not less than 25% with extreme cases of more than 75% (Boy and Witt, 2015). Degraded areas were also mentioned to be highly invaded. Factors contributing directly to such degradation include intensive grazing, land clearance for agriculture and drought. Many IAS are colonizing species that benefit from the reduced competition that follows habitat degradation (Clare *et al.,* 2000). Opuntia in particular invades areas that have experienced large land-cover transformations especially in woodlands and bush lands located near urban areas (Vila *et al.,* 2003). However, at the ecosystem level, invasive alien plants modify community structure and composition and therefore their eradication may open niches for establishment of other undesirable plants unless restoration practices are incorporated (Masters and Sheley, 2001). Restoration of natural herb layer and tree cover might stop the spread of Opuntia by reversing the degradation that facilitated its expansion in the first place (Strum *et al.,* 2015).

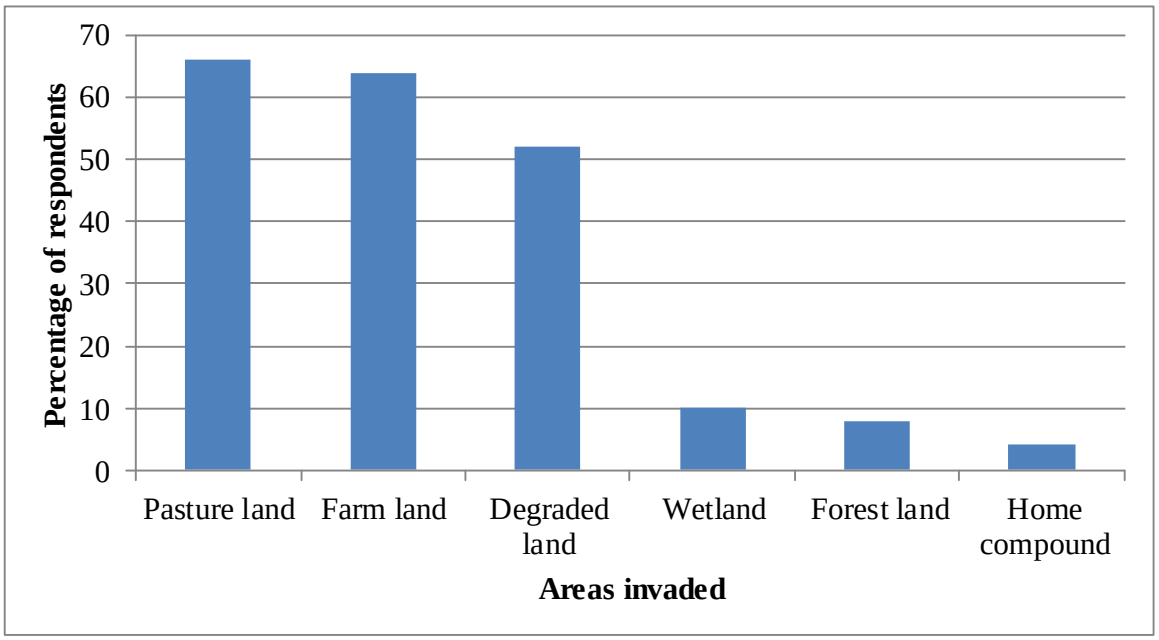

Figure 3: Areas invaded by Opuntia within the study site

Management practices and interventions

Chopping was the most preferred method of managing Opuntia but it was not very effective so it was combined with other methods such as burning and burying (Fig. 4). Mechanical and manual methods are preferred in managing invasion of woody species because they are target specific and economical (Rai *et al.*, 2012). However, they can be labour-intensive in large-scale infestations and the disturbed areas may encourage reinvasion (DiTomaso, 2000). Herbicides on the other hand improved the effectiveness of chopping. However, respondents said that the use of herbicides alone was ineffective because plants around Opuntia were eliminated but the cactus remained unaffected. Some respondents mixed different herbicides to increase efficacy but this was not successful either since the plant regenerated after some time. This is a major draw-back in the use of herbicides where populations are replenished from soil-stored seeds (Foxcroft *et al.*, 2004). Besides, herbicides are very expensive, do not provide long-term effects and can lead to replacement of sensitive species as well as resistance after continuous use (DiTomaso, 2000). It is critical to note that none of the respondents was aware of bio-control of Opuntia, which introduces host specific natural enemies of the pest. Bio-control of Opuntia is regarded as cost-effective with two natural enemies; Cactoblastis cactorum Berg. and Dactylopius opuntiae Costa. (Zimmermann and Moran, 1991). The latter was introduced in a pilot project in Laikipia, Kenya and has shown that bio-control is possible for this species (Dyck, 2017). However, bio-control species may become invasive and negatively impact non-targeted species (McLeod, 2004). Nonetheless, instead of relying on a single control method, successful management of invasive alien species requires an integrated approach that uses multiple control methods to prevent reinvasion and improve ecosystems.

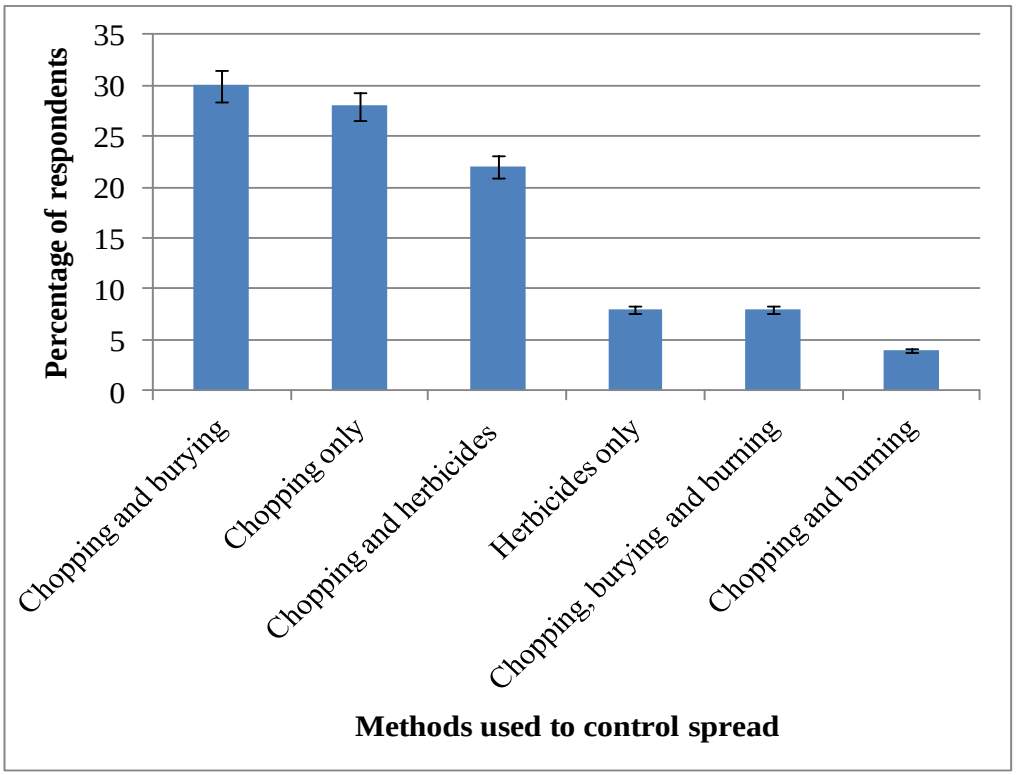

Figure 4: Combined methods used to control Opuntia invasion

The respondents proposed various interventions: (i) development of a strong and effective herbicide (41%), (ii) stop planting the species for any purpose (38%), (iii) create awareness on the spread (17%) and (iv) eradicate (4%). However, the best management method of rangeland invasive plant species is early identification, control and monitoring (DiTomaso, 2000). If this is not applicable, awareness creation on the pathways of invasion can be an effective means to prevent future spread. Eradication on the other hand completely eliminates the species from the site but this is difficult for plants with propagules that can survive under the soil for a long time e.g Opuntia.

CONCLUSION

Opuntia invasion has already caused serious social and ecological impacts in the southern rangelands of Kenya, where majority of the people depend on natural resources for survival. These problems include loss of agricultural and pasture lands, land degradation and harm to people and livestock. The most affected plants are indigenous vegetables and multipurpose tree species. Although various methods have been used in managing the species, they have posed various challenges in terms of practicality, expense and health. However, additional field research is required to validate some of the findings of this study.

Recommendations

It is important to provide support to the rural communities by creating awareness on the causes and pathways of invasion through various means such as trainings and awareness campaigns. New integrated management methods should also be developed that are practical, safe and cost effective. Nevertheless, since the use of Dactylopius opuntiae as a bio-control agent has been successful in the northern rangelands of Kenya, the same species can be introduced in the southern rangelands for successful management of the species within the region. Legislation on the status, introduction and use of Opuntia should also be addressed to prevent further invasions that can be out of control.

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