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Impacts of Prosopis Juliflora on Land Use and Ecology of Salabani Location, Marigat District, Baringo County, Kenya

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Abstract
Invasive alien plants dominate ecosystems and are a growing threat to the delivery of ecosystem services. The ecological adaptation of invasive species over native plant species affects land use and structure of vegetation. This study therefore examined the impacts of *Prosopis juliflora* on land use and ecology of Salabani Location in Marigat District, Baringo County in Kenya. Satellite imageries of 1998 and 2012 were used to establish various land use classes, determine rate of spread of Prosopis and its impact on other land use. The study established that in 1998, *P. juliflora* had only covered 2,906 ha which is 4.2 % of land cover. However by 2012 it had spread very fast to 8,555ha representing 68.1% annual increment. Invasion of prosopis has reduced grazing land by 40.3%, acacia woodlots by 89.8%, and forest cover by 57.1%. The plant has invaded all land use types and in general 61.8% of Salabani Location has been lost to *P. juliflora* invasion. The invasion of *P. juliflora* has changed the structure of the ecology in Salabani location since the weed is allelopathic and coppices heavily. *P. juliflora* is now a threat to the ecosystem of Lake Bogoria Nature Reserve a Ramsar site. The study recommends that the government of Kenya should facilitate commercial production of charcoal from the plant, encourage and facilitate utilization of other products from the plant like steam energy, animal fodder, wax and medicinal value. The study concludes that the plant is spreading very fast and is becoming a threat to the ecosystem of Salabani besides other ecological benefits. This raises concern to the community and stakeholders alike hence need to manage the spread.
Keywords: Invasion, *Prosopis juliflora*, land use, Ecology

Introduction

Concern about deforestation, desertification and fuel wood shortages in the late 1970s and early 1980s prompted a wave of projects that introduced *P. juliflora* and other hardy tree species across the world. *P. juliflora* has survived where other tree species have failed and in many cases become a major nuisance. *P. juliflora* continues to invade millions of hectares of rangeland in South Africa, East Africa, Australia and coastal Asia (Pasiecznik *et. al*., 2001). In 2004 it was rated one of the world's top 100 least wanted species (IUCN, 2004). Affected countries have devoted increasing amounts of time and funds to control invasion with limited success.

Prosopis juliflora was introduced in Kenya in 1973 in Bamburi, Mombasa District, Tana River District, and Turkana District. Later in 1983, the plant was introduced in Marigat in Baringo District during the Baringo Fuel Wood Afforestation Extension Project by the World Bank, FAO and Government of Kenya. The purpose was to mitigate desertification and fuel wood shortages in the ASALs (Pimentel *et. al*., 2000). The plant was preferred due to its resilience, drought tolerance, fast growth, source of fodder and fuel wood (Meyerhoff, 1991). It was easily imported into Kenya due to the poor phytosanitary regulations and enforcement policies of the 1960s to 1980s. Further planting of the tree was stopped in the early 1990s when the weedy characteristics of the plant were noticed (Choge *et. al.*, 2002). In 2007, the affected communities in Marigat District sot compensation from the Kenya Government for introducing what they termed a 'dryland demon'. The purpose of this study therefore was to provide a clear understanding of the impacts of *P. juliflora,* on land use and ecology of Salabani Location in Baringo County of Kenya.

Methodology

The study compared satellite imageries of 1998 and 2012 to establish various land use classes, determine rate of spread of Prosopis and its impact on other land use classes. Density of Prosopis was determined by counting the number of coppices per stool in each type of land use. Ecological impacts were determined through observation and interviewing key informant groups.

Study Area

Salabani Location lies between longitude $0^0$45'N, $0^0$30'N and latitude 35^0 45'E, $36^0$0'E. It is located about 15 km from Endao bridge junction along Marigat - Kambi Samaki road in the Ilchamus (Njemps) plains between Lake

Baringo and Lake Bogoria. The local community relies mainly on pastoralism. Salabani experiences severe soil erosion due to poor vegetation cover and poor soil structure (GoK, 2002). Soils are mainly clay loams with alluvial deposits derived from tertiary / quaternary volcanic and pyroclastic rock sediments that have been weathered and eroded from the Tugen highlands. The soils contain high levels of phosphorous, potassium, calcium and magnesium and low levels of nitrogen and carbon. The soils range from acidic to slightly alkaline (GoK, 2002).

These lowlands receive 600 mm of rainfall annually which is bimodal, low, erratic and unreliable. Long rains start from March to July while short rains between September and November. The mean annual maximum temperature lies between 25°C and 30°C and minimum temperatures from 16–18°C (GoK, 2002). The hottest months range from January to March. The flood plains lie between agro-ecological zone IV and V. The ASAL vegetation is characterized by *P. juliflora* and Acacia woodlots (mainly *A. tortilis*) in association with *Boscia* spp., *Balanites aegyptica* and bushes of *Salvadora persica*. High evapo-transpiration rates and low variable rainfall create water scarcities that limit intensive agricultural land use (GoK, 2002). The population density is relatively low 21 persons per square kilometer, with a total population of 40,985 people in Marigat division and 2000 households in Salabani.

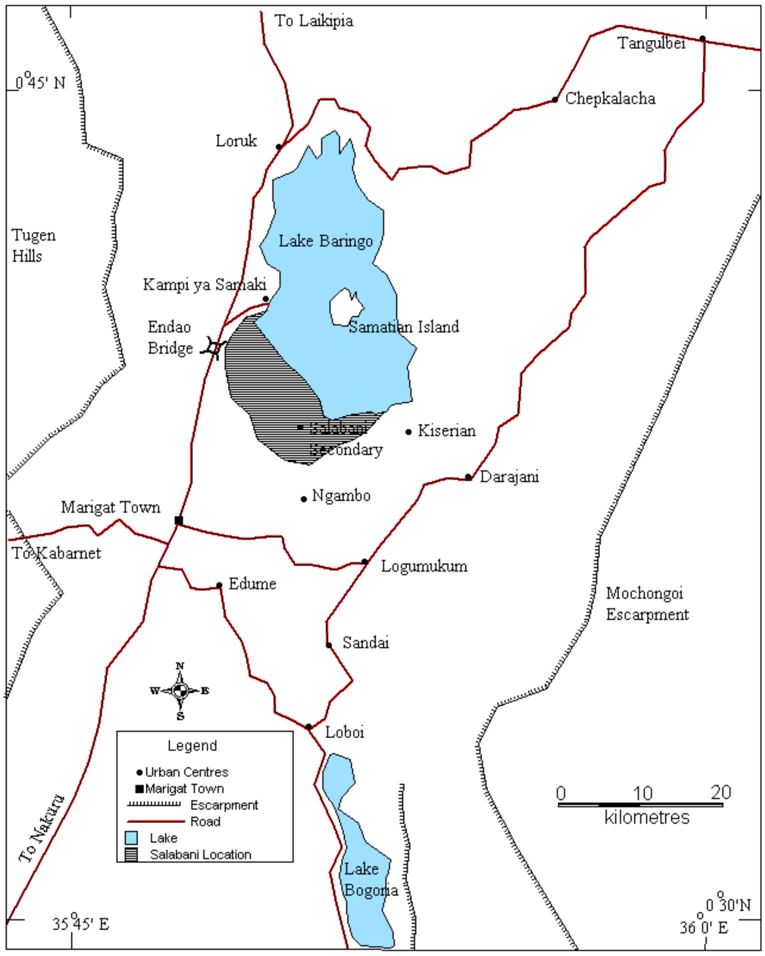


Figure 1: Map of Salabani Location, Kenya
Source: Moi University, Geography Department 2012

Data Analysis
Data was analyzed using descriptive statistics. Data on density of Prosopis in various classes was analyzed using one way ANOVA and a change detection matrix used to analyze impacts of Prosopis on other land use classes.

RESULTS AND DISCUSSIONS

Table 1: Land use changes between 1998 and 2012

	1998		2005		2012	
Land cover	**Area (ha)**	**% cover**	**Area ha)**	**% cover**	**Area (ha)**	**% cover**
P. juliflora	2906	4.2	4986	7.3	8555	12.4
Forest	16572	24.1	11572	16.8	7101	10.3
Shrub land	17556	25.5	31555	45.9	56704	69
Agricultural land	440	0.6	1940	2.8	3845	5.5
Acacia	13,045	19.0	4164	6.1	1328	1.9
Grazing land	12749	18.5	8656	12.6	7609	11
Settlements	5479	8.0	5874	8.5	6297	9.1
Total	68747		68747		68747	

Source: DRSRS, 2012

Table 2: Change detection matrix between 1998 and 2012

Land Use		2012 Land use (Km^2)							
		Prosopis	**Forest**	**Shrub**	**Agr**	**Acacia**	**Grazing**	**Settlement**	**Total**
1998 Land use Km^2	**Prosopis**	66							71.6
	Forest	-49.2	-57.1						-79.4
	Shrub	11.4	-64.3	69					26.8
	Agr	16.3	-187.9	327.5	-88.5				496.8
	Acacia	-19.1	125.6	-55.4	-70.0	-89.8			-76.2
	Grazing	-42.9	10.4	-10.3	-19.4	-22.8	-40.3		-97.1
	Settlement	-49.9	-39.9	21.0	-27.9	-11.6	-12.5	7.2	-62.6
	Total	-61.8	-186.3	362.5	205.8	-124.2	-52.8	7.2	279.9

Satellite images of 1998 and 2012 showed that there were seven types of land use classes in Salabani Location. The land use classes identified were: *P. juliflora* cover, grazing land, acacia woodland, shrub land, settlement areas, forest cover mainly riverine forests and agricultural land (plate.1). The estimated total land area in Salabani Location is 68,747 ha. From these images it was observed that by 1998 *P. juliflora* had only covered an area of 2,906 ha. This represents only 4.2 % of the total land cover which is small as compared to the public outcry by the local community. In Australia *P. juliflora* is estimated to have covered 800,000 ha (Pasiecznik et.al. 2001). The satellite images of 1998 showed that the land use cover under forest was 24.1% of the total land area (16, 572 ha), shrub land cover 25.5% (17,556 ha), agricultural land 0.6% (440 ha), acacia woodlots 19% (13,045ha), grazing land 18.5% (12,749 ha) and area under settlement 8% (5,479 ha) (Table 1). Hence by 1998 forests, shrub land and acacia woodlots represented 68.6% of total land use cover in Salabani Location.

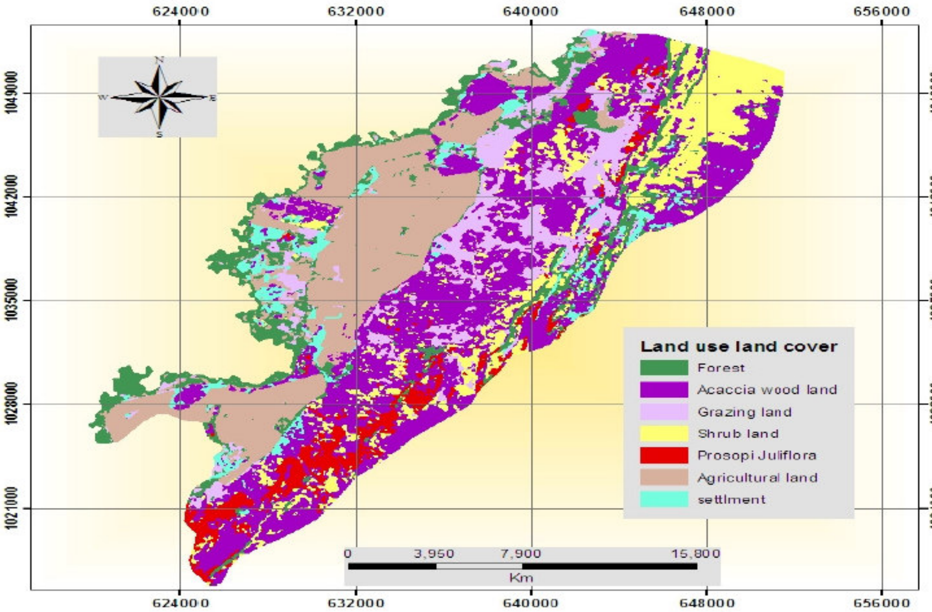


Plate 1: Satellite Imagery of the land use/ land cover map of the study area in 1998

Source: DRSRS, 1998

However, by 2012, a span of 14 years, *P. juliflora* had spread to an area covering 8,555 ha representing

12.4% of the total land cover (Table 1). This implies that *P. juliflora* is spreading fast at a rate of 403 ha per year or 68.1% per annum. This rate of spread is very fast an indicator of the invasiveness of *P. juliflora*. This is in agreement with findings of studies carried out in Gasha delta Northern Sudan (Pasciecznik etal. 2001) Beisha Oasis in Western Sudan where underground water was threatened with invasion (Laxen 2007). In Ethiopia Prosopis has been declared an obnoxious and invasive species (Catterson 2003). It may be observed from the satellite image of 2012 (Plate 2) and the change detection matrix (table 2) that forest cover had declined from an initial cover of 16,572 ha in 1998 to 7101 ha in 2012; this represents a decline rate of 57.1% which implies that the riverine forests are being lost to *P. juliflora* invasion at a fast rate. Similarly acacia woodlots declined from an initial land cover of 13,045 ha in 1998 to a megre 1328 ha in 2012, which indicates a dramatic decline rate of 89.8%. This dramatic decline in acacia woodlots could be attributed to the ecological advantage of *P. juliflora* as it has allelopathic effects inhibiting growth of other species around it (Baumer 1990, Hulme 2012). Grazing land also declined from 12,749 ha in 1998 to 7609 ha in 2012, which represents a decline rate of 40.3%. Both livestock and wild animals feed on the pods from *P. juliflora* but are unable to digest the seeds which are only scarified and past through the nutrient rich dung which are spread in the grazing fields hence livestock act as dispersal agents. Floods run off and rivers wash the seeds downstream spreading the seeds further. The observed decline in acacia woodlots and pastureland is a serious concern to the respondents as it has serious implications to their pastoral way of live. They depend on beekeeping from acacia woodlots, firewood from acacia woodlots and pasture for their livestock. These findings are in agreement with Lenacuru (2006) who observed that uncontrolled cutting down of *P. juliflora* could have encouraged the invasion of the plant through coppicing. El Fadl (1997) also found out that Prosopis was threatening pastureland in Kassala region in Sudan.

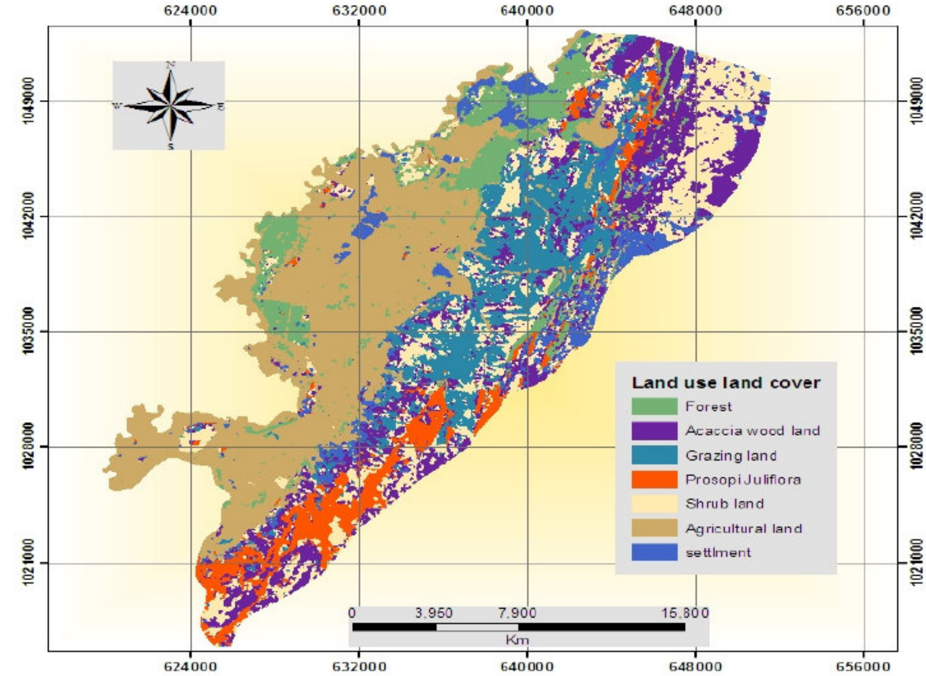
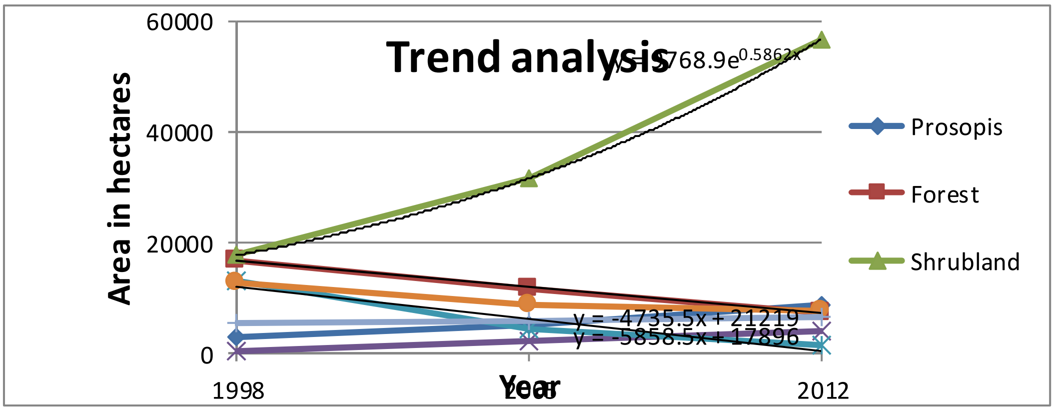


Plate 2: Satellite Imagery of the land use/ land cover map of the study area in 2012

Source: DRSRS, 2012

However, shrub land increased from 17,556 ha in 1998 to 56,704 ha in 2012 which represents an increment of 69 % since *P. juliflora* is a shrub itself. Interestingly the area under agriculture increased from 440 ha in 1998 to 3845 ha in 2012 which represents an increment of 88.5 %. This could be attributed to the efforts by the community to open up more areas for farming and settlement as more NGOs and government agencies encourage maize farming in the area.

Figure 1: Trend analysis for land use changes between 1998 and 2012



From the trend analysis (figure 1) it may be observed that *P. juliflora* is invading at a linear function Y = 2824X - 166.6 whereas forests are declining at a linear function of Y = -4735X + 21219. Shrub land is increasing at a linear function of Y = 19574X – 3876 while Acacia woodlots are declining at a linear function of Y = -5858X + 17896

Table 3: Dynamics of *P. juliflora* invasion

Change in land use cover	**1998-2012 Area km²**	**Change in land use cover**	**1998-2012 Area km²**	**Net change Area km²**
Grazing land to *P. juliflora*	711	*P. juliflora* to grazing land	124	-587
Dense acacia to *P. juliflora*	109	*P. juliflora* to Dense acacia	76	-33
Shrub land to *P. juliflora*	12	*P. juliflora* to shrub land	125	113
Settlement to *P. juliflora*	51	*P. juliflora* to settlement	181	130
Forest to *P. juliflora*	354	*P. juliflora* to forest land	511	157
Agricultural land to *P. juliflora*	771	*P. juliflora* to agricultural land	995	224
TOTAL	2008		2012	

Source: DRSRS, 2012

Table 3 shows the dynamics of *P. juliflora* invasion and changes caused to other land use classes. The net change of grazing land lost to *P. juliflora* is 587 km² and acacia is 33 km² which affects the way of life of pastoralists. Overall, 61.8% of the entire land has been lost to *P. juliflora* invasion between 1998 and 2012. *P. juliflora* has invaded almost all land use types in the study area although the extent and severity of invasion varies from one land use type to another. The plant has highly encroached on Acacia woodlands. This is possibly because *P. juliflora* has allelopathic effects and coppices heavily from a single stem cut. Pastoral livelihoods rely a lot on Acacia woodlands for honey production, fodder and firewood hence this invasion has impacts which need mitigation. The results are consistent with findings of Lenacuru (2006) who observed that uncontrolled cutting down of *P. juliflora* could also have encouraged the invasion of the plant through coppicing. In areas where the invasion was intense, some of the local people have vacated their homesteads (Plate 1).

Plate 1: Invasion of *P. juliflora*

Source; Survey data, 2009

Prosopis density and land use classes

Density of *P. juliflora* was used to show distribution of the plant in various land use classes (Table 3). The number of coppices of *P. juliflora* determines the density of the plant per given area. It was determined that there were significant differences in the number of coppice in each of the land use classes (One-Way ANOVA P < 0.05). Coppicing was highest in settled areas followed by grazing land, but was least in the acacia woodlands. This could be attributed to cutting of stems to pave way to settlement and agriculture hence more coppicing. The mean number of coppices was 4.4 ± 0.15 which is almost similar to findings by Abiyot and Getachew (2006). Therefore, this suggests that stumping of *P. juliflora* increases the number of coppices per stool which then increases the density of *P. juliflora* per given area.

Table 3: The mean number of coppices per stool in each land use/land cover types

Land use/land cover types	N	Minimum	Maximum	Mean ± SEM
Agricultural land	35	4	21	14.52 ± 4.21
Acacia woodland	44	3	13	9.11 ± 1.33
Shrub land	36	4	29	21.2 ± 4.55
Grazing land	42	5	25	23.5 ± 3.89
Settlement	39	4	42	37.9 ± 5.77
ANOVA				
F-value				18.55
P-value				0.004

Source: Survey Data, 2009

Ecological impacts

The invasion of this tree has been enhanced by the combined lack of knowledge on how the local people could best manage and use it, and presence of *P. juliflora* on communal lands where people have little or no responsibility to control its spread. The plant is now encroaching on Lake Bogoria nature reserve where it is a threat to ecology of the ecosystem which is a tourist attraction and a Ramsar site. Spread of the plant out-competes native plant species due to its allelopathic effect and competition for water through its deep rooting systems (Baumer, 1990, Coppen 1995). This might affect endemic species. It has replaced Cyperus species on Lakes Baringo and Bogoria which filter water entering the two Lakes yet Prosopis lacks the filtration effect of this ecotone species it replaces. This will have an effect on water quality in the two Lakes. These results are in agreement with findings of Pasiecznik et al. (2001) who found that Prosopis had replaced native species in Awash National Park and reduced grazing land. The plant has also outcompeted traditional vegetables and fruits which were used during drought seasons. These include *Amaranthus hybridus*, *Solanum incunum* and *Achyranthes aspera.* Equally native trees and Shrubs which have been replaced include *Lantana camara, Myosotis spp. Salvadora persica, Commelina benghalensis, Panicum maximum, Cynodon plectostachyus, Boscia spp. and Balanites aegyptiaca, Acacia spp. Sycamore spp.* and *Brussilica lowei.* These results are consistent with the findings of Baumer 1990, Huston (1993), Coppen (1995), Choge (2002) who noted that Prosopis leads to a loss of native plant species which alters vegetation structure and general ecology of dry lands. This is attributed to their ecological adaptation to survive arid environments. They have deep rooting systems, are allelopathic and coppice heavily when cut.

However the new habitat in Prosopis stands has encouraged fauna to flourish like tsetse flies and mosquitoes which unfortunately pose a health hazard. Mammals which have emerged include *Rhynchotragus kirki* (dikdik) and *Epomophorus wahlbergi* (bats) due to a new habitat. It has also offered protection to some animals against poachers, cattle rustling and protected farmers and their agricultural farms from marauding hippos and crocodiles from Lake Baringo. About 500 species of birds have been reported nesting in the area like parrots, bush shrikes, pelicans, and cormorants, hammer cops weaver, herons and Guinea fowls (Choge *et al*.2002).

Conclusions

In general 61.8% of Salabani Location has been lost to *P. juliflora* invasion between 1998 and 2012. The plant has invaded almost all land use types in the study area although the extent and severity of invasion varies with land use classes. The plant has highly encroached on Acacia woodlands and replaced native trees and shrub species. This is possibly because *P. juliflora* has allelopathic effects and coppices heavily from a single stem cut. The invasion has affected the way of live of pastoralists as it has reduced pasture land and acacia woodlots. Encroachment of *P. juliflora* is now becoming a threat to the ecology of Lake Bogoria Nature Reserve which is the third Ramsar site in Kenya. The rate of spread of *P. juliflora* raises concern to both the community and all stakeholders alike hence need to manage it.

Recommendations

The study recommends that the government of Kenya should undertake the following: enhance commercial utilization of the *P. juliflora* tree through: charcoal production, fast track the establishment of a plant to generate steam energy which has already been approved by NEMA. KWS and Baringo County government should uproot seedlings of *P. juliflora* which are encroaching into Lake Bogoria nature reserve before they spread further. The community should stop burning *P. juliflora* as it encourages re-sprouting from damaged stems, scarifies the dormant seeds and removes all valuable native plants from the ground. Moreover, it also releases carbon dioxide which contributes to global warming.

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