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Article

Prosopis juliflora Invasion and Rural Livelihoods in the Lake Baringo Area of Kenya

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Abstract

Global concern about deforestation caused by fuelwood shortages prompted the introduction of *Prosopis juliflora* to many tropical areas in the 1970s and 1980s. *P. juliflora* is a hardy nitrogen-fixing tree that is now recognised as one of the world's most invasive alien species. The introduction and subsequent invasion of *P. juliflora* in the Lake Baringo area of Kenya has attracted national media attention and contradictory responses from responsible agencies. This paper presents an assessment of the livelihood effects, costs of control and local perceptions on *P. juliflora* of rural residents in the Lake Baringo area. Unlike some other parts of the world where it had been introduced, few of the potential benefits of *P. juliflora* have been captured and very few people realise the net benefits in places where the invasion is most advanced. Strong local support for eradication and replacement appears to be well justified. Sustainable utilisation will require considerable investment and institutional innovation.

Keywords: *Prosopis julifora*, alien invasive species, livelihood effects, Lake Baringo, Lake Bogoria, distributional effects, Kenya, mesquite

INTRODUCTION

PROSOPIS JULIFLORA (SW.) DC is an evergreen tree native to South America, Central America and the Caribbean. In the United States of America, it is well known as mesquite.[1] It is fast growing, nitrogen-fixing, and tolerant to arid conditions and saline soils. In some circumstances, *P. juliflora* can provide a variety of valuable goods and services: fuelwood, charcoal, animal feed, construction materials, soil conservation and rehabilitation of degraded and saline soils (Pasiecznik 1999; Pasiecznik *et al.* 2001). In the drylands of India, *P. juliflora* is considered one of the most valuable tree species (Pasiecznik *et al*. 2001).

Concern about deforestation, desertification and fuelwood shortages in the 1970s and 1980s prompted a wave of projects that introduced *P. juliflora* and other hardy tree species to new environments across the world. *P. juliflora* has survived where other tree species have failed and in many cases become a major nuisance. Invading *P. juliflora* forms dense, impenetrable thickets. Millions of hectares of rangeland have been invaded and the invasion process is continuing in South Africa, Australia, coastal Asia (Pasiecznik 1999) and Eastern Africa (Sudan Update 1997; Catterson 2003). Land use changes, competitive ecological advantages and climate change are thought to be key factors influencing the probability of invasion (Pasiecznik *et al.* 2001). *P. juliflora* has been rated as one of the world's 100 least wanted species (Lowe *et al*. 2000).

This paper summarises the results of a study on *P. juliflora* and rural livelihoods undertaken in the Lake Baringo area of Kenya in 2004. The study was motivated by the magnitude of the *P. juliflora* invasion in the area, the level of public and government concern about the invasion, and the magnitude of the problem across East Africa. This case study was informed by a review of experiences in India, where poor women in arid and semi-arid areas benefit disproportionately from the sale of *P. juliflora* fuelwood and charcoal (Saxena 1997; Tewari *et al*. 2000). Based on that experience, the research began with two presumptions: first, that the invasion resulted in clear winners and losers among the local population and second that the invasion could be turned into a significant resource for the local population.

This paper focuses on the impacts of *P. juliflora* and the distribution of these impacts on local communities in two administrative locations of Baringo district where *P. juliflora* was introduced about 20 years ago. The paper addresses the following questions:

1. What were the institutional pathways of *P. juliflora* introduction in Baringo, and more generally in Kenya?
2. What are the costs and benefits to local communities of living with *P. juliflora*? How are these costs and benefits distributed across society?
3. What factors, in addition to costs and benefits, shape individuals' and group perceptions and responses to *P. juliflora*?
4. What appear to be feasible solutions to the *P. juliflora* problem in Baringo?

Few studies have considered the differential socio-economic impacts of invasive species. By disaggregating 'community', this account provides insights into the way that different groups of individuals are affected. This study also emphasises the institutional factors that influence individual and group responses to the threat of invasion.

BACKGROUND AND HYPOTHESES

Binggeli (2001) and Pasiecznik *et al*. (2001) propose that people's perceptions of invasive species depend upon whether and how their economic needs are met by the species. For example, in the Indian state of Rajasthan, local people's perceptions of *P. juliflora* were favourable during the early stages of its introduction when it was welcomed as a field boundary marker and supplier of fuelwood. These perceptions changed later as the negative effects of the invasion—colonisation of agricultural land, its sharp thorns, suppression of grasses and crops—became more pronounced.

Income/wealth levels and dominant livelihood strategies are also important determinants of how individuals perceive invasive species (Pasiecznik *et al*. 2001). In India again, the more affluent who use bottled gas for cooking, tend to view *P. juliflora* negatively, while the rural poor who cannot afford bottled gas value the tree for fuel and fodder production. Similarly, ranchers and pastoralists whose main livelihood strategy is keeping livestock view it negatively because it invades pastures (Saxena 1997).

Other factors influencing people's perceptions of invasive species include: how damaging the species is to property and/or natural ecosystems (e.g. weeds in a crop, insects eating a crop, destruction of native trees); whether or not the species is physically appealing; the opinions of powerful, charismatic and influential individuals; the media's portrayal of the species; and the costs of managing the species (Veitch & Clout 2001).

The literature on institutions (e.g. North 1990) provides general insights into how people's perceptions of an invasive species motivate individual and collective responses to an invasion. It is generally recognised that private property rights create substantial incentives for individual investment in resource management. Individual land owners will be more likely to engage in *P. juliflora* mitigation or control on their own land since they are more assured of capturing the gains of their investments (Pimentel *et al*. 2000). Where land is held under common property arrangements, management responses to invasive species will depend upon whether the group is able to mobilise cooperation among its members (Perrings *et al*. 2002). Thus if the individuals who are jointly affected by the rapid proliferation of an invasive species on their shared land are able to design and enforce appropriate rules for its management, then they are much more likely to be able to overcome collective action problems and undertake effective control (Ostrom 1990). In the Baringo area, grazing land is governed as a common resource, while crop land is managed by individual families.

Government policies also shape responses to invasive species (Perrings *et al*. 2002). Government tree planting schemes often create incentives that did not consider the costs that invasive species may later impose on society. Similarly, government policy may constrain the range of possible profitable uses of an invasive species. In Kenya for example, restrictions on charcoal transportation and sale may discourage more intense use of *P. juliflora* products (Bailis *et al*. 2006).

This background information led this study to anticipate the following:

1. The livelihood strategies pursued by individuals will influence the distribution of costs and benefits of living with *P. juliflora* among actors in society. Pastoralists and farmers would incur higher costs due to pasture depletion and land clearing. People pursuing livelihood strategies such as trading of *P. juliflora* products would accrue greater benefits.
2. Women, who are heavily dependent on *P. juliflora* for fuelwood, will accrue greater benefits from *P. juliflora* than men.
3. The distribution of these costs and benefits will in all likelihood influence the perceptions of individuals. Those who incur higher benefits relative to costs will favour the continued presence of the species, while those who incur costs higher than benefits will not favour the species.
4. In the absence of joint community rules for management/control of *P. juliflora*, it is unlikely that individuals will invest in controlling and/or eradicating *P. juliflora* in communal grazing lands.
5. Individuals will be more likely invest in the control, management and/or eradication of *P. juliflora* on their own private land.

MATERIALS AND METHODS

The Study Sites

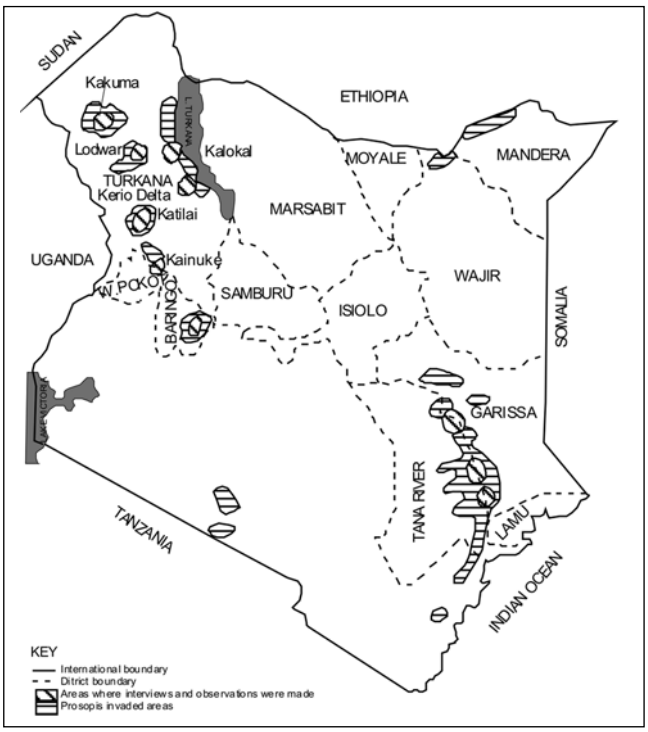
P. juliflora was first introduced in the coastal areas of Kenya in 1973 with seed from Brazil and Hawaii (Choge *et al*. 2002). In the early 1980s it was introduced in the semi-arid districts of Baringo, Tana River and Turkana in order to promote energy self-sufficiency and environmental stabilisation (Choge *et al*. 2002). Today, these three areas show large pockets of *P. juliflora* colonisation and invasion (Figure 1).

The study site is located in a 900 sq km area between latitudes 0º20'N and 0º44'N and longitudes 35º57'E and 36º12'E (FAO 1992). The study area, mainly rangeland, has flat lands and scarp elevations between 1000–3000 m above sea level. The study area includes Lake Baringo and Lake Bogoria, two lakes in the Rift Valley system. Lake Baringo (130 sq km) is a freshwater lake, while Lake Bogoria (34 sq km) is a salt water lake that is globally renowned for supporting a large population of migratory birds (Figure 2). Average annual rainfall is 650 mm and temperatures vary from 30°C to 35°C. Native vegetation comprises Acacia trees (mainly *Acacia tortilis*) in association with *Boscia* spp. and *Balanites aegyptiae*, and bushes of *Salvadora persica* (Andersson 2005).

Human population density in both locations is relatively low, about 20 persons per sq km. The main sources of cash income are from sale of livestock and honey, and fishing in Lake Baringo. The main land use is livestock grazing, combined with some crop agriculture around homestead sites and some irrigated agriculture near Lake Baringo. Lake Bogoria National Reserve and areas around Lake Baringo are reserved for habitat and species conservation, with local and international tourism generating some revenue. Most lands in Baringo district are held under the communal tenure regime of the Group Ranch, an institution established in the 1960s.

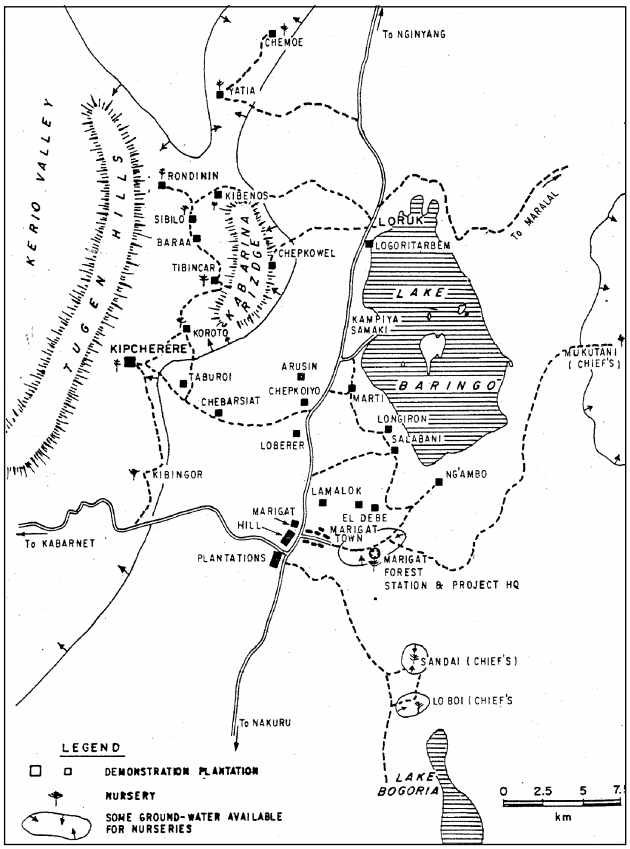
This study focused on the administrative locations of Ng'ambo and Loboi as they represent a gradient from very high densities of *P. juliflora* in Ng'ambo near Lake Baringo, through to Loboi on the northern edge of Lake Bogoria, where there are less dense stands of *P. juliflora*. In each location, villages with the most dense stands of *P. juliflora* were selected for sampling with the guidance of local residents, government officials and non-governmental organisation (NGO) workers. In Ng'ambo, the four villages of Masai, Chemonke, Keperr and Nairrag-Enkare were selected. In Loboi, two villages, Tingtinyon and Kapronguno, as well as the Loboi trading centre area were chosen. The people of Ng'ambo are of the Il Chamus ethnic group (a Maa-speaking group who are also known as the Njemps), while the people of Loboi are of the Tugen ethnic group, a Kalenjin-speaking group.

Figure 1
Location of* P. juliflora *invasions across Kenya



Source: Choge *et al.* 2002

Figure 2
Location of demonstration and study sites in the Baringo area



Source: FAO 1992

Data Collection

Data were collected through a review of published and grey literature, key informant interviews and a semi-structured survey of residents in the Ng'ambo and Loboi areas. A random sample of individuals was selected from a list of residents provided by the location chief. Not all individuals were available for interviewing: some had moved to other sites due to *P. juliflora* invasion and/or displacement by floods, while others actually lived and worked in urban centres. Neighbouring households were chosen to substitute for those who were missing. In male-headed households, the male head and his first wife were interviewed, while in female-headed households only the female head was interviewed. A semi-structured survey with a total of thirty questions was administered. In Ng'ambo sixty-five individuals were interviewed, thirty-seven men and twenty-eight women, while in Loboi, forty-eight individuals were interviewed, twenty-three men and twenty-five women.

Data Analysis

The values of direct costs and benefits were estimated in Kenyan shillings (KES) for products harvested for direct use (both subsistence and trade) as well as for direct losses associated with the *P. juliflora* invasion. When the field work was done in early 2004, the average exchange rate was approximately 1 USD=75 KES.

Benefits were estimated from individuals' responses to questions regarding the quantities of various products harvested from *P. juliflora* and whether those products were used domestically, were sold or both. Quantities harvested, whether for sale or home use, were used to estimate total value derived from those products. Prices were averaged for respondents who provided that information in each location, and those prices used to calculate the value of both home consumed and marketed products for all households. Prices of the seven main *P. juliflora* products in Ng'ambo and Loboi are given in Table 1.

Individuals' responses to other questions were used to quantify losses from *P. juliflora* invasion and the labour costs of clearing, managing or controlling *P. juliflora* on individuals' fields and homesteads. The average cost of labour in Ng'ambo (50 KES per day) was assumed to hold in both locations and was used to value all labour inputs, including labour provided through labour groups and alternative payment arrangements such as local brew.

Three year average prices paid at the Marigat central market, as reported by the local agricultural officers in their annual reports, were used to calculate the cost of livestock deaths attributed to the *P. juliflora* invasion. The average price for a healthy cow was KES 8000, while the average for an unhealthy cow was KES 4500. The simple mean of KES 6250 was used to calculate the cost of each cattle death. The average price of sheep and goats was KES 1100 for healthy animals and KES 650 for unhealthy animals. Thus, an average price of KES 875 was used to calculate the cost of each sheep or goat death.

RESULTS

Introduction of *P. juliflora* in Baringo District

P. juliflora was introduced into Baringo district through the efforts of the 'Fuelwood/Afforestation Extension in Baringo' project, a joint initiative of the Food and Agriculture Organization (FAO) and the Government of Kenya. This project originated from prior consultations that identified Baringo as an area needing rehabilitation from over-grazing and over-exploitation of its semi-arid woodlands (FAO 1985). The Baringo Fuelwood/ Afforestation Extension project became operational in February 1982. It was implemented in two phases, phase I from 1983 to 1985 and phase II from 1987 to 1990.

The project operated under the Forestry Department of the Ministry of Environment and Natural Resources, co-ordinated by the chief conservator of forests and the provincial forest officer. Its activities included the establishment of demonstration plantations, recruitment of nomadic pastoralists and agropastoralists into individual tree planting, training of beneficiaries, provision of employment to pastoral communities through 'food for work', and the establishment of a central seedling nursery and nineteen smaller nurseries.

Plantings were conducted in 1983 and 1984 on plots established by local communities through food aid assistance from the World Food Programme, employing over 1000 local men and women. These plots were identified after a lengthy negotiation between project staff and the pastoralist communities. Communities were initially apprehensive of committing their land in the fear that the Forestry Department might gazette the land as state forest land, rendering it inaccessible to the traditional owners (Kariuki 1993).

By the end of the first phase, the project had established twelve extension nurseries, with a total potential annual output of 620,000 seedlings. Demonstration plan-

Table 1
Average costs of products generated from* P. juliflora *in the two study sites

Harvested Item	Ng'ambo	Loboi
Construction poles	13 KES per pole	15 KES per pole
Fencing poles	15 KES per pole	15 KES per pole
Fuelwood	50 KES per backload	30 KES per bundle
Honey	100 KES per kg	75 KES per kg
Charcoal	170 KES per sack	150 KES per sack
Pods	10 KES per sack	Not indicated
Ropes	24 KES per bundle	Not harvested

Source: Authors' analysis of survey data

tations of 246 ha had been established on thirty-six sites around the area, fourteen in the Il Chamus area and twenty-two in the Tugen plateau (FAO 1985). *P. juliflora* was planted in all but six of the Tugen sites. Twenty-eight tree species were tested, eighteen indigenous and ten exotic, that were known to be hardy, drought resistant and fast growing (Ndegwa 1987).

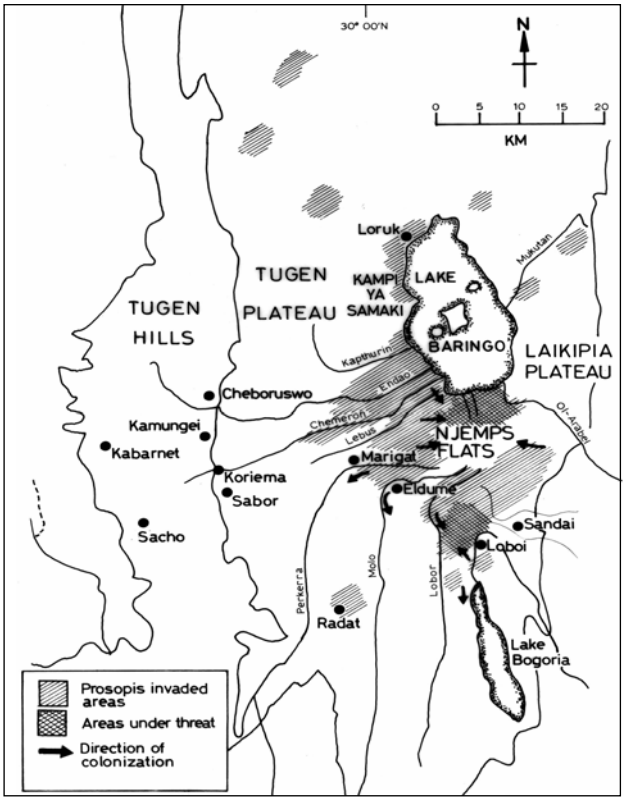
Following a favourable appraisal of the first phase, the project was extended for a further 3 years. When the project ended in 1990, a total of 740 ha of demonstration plantations had been established (Kariuki 1993). The project was to hand over the demonstration plots to community groups within 18 months of establishment. Communities however declined to take over the management of the plantations for several reasons. One reason was that people were unwilling to commit their limited financial and labour resources to tree husbandry where a market for fuelwood did not exist (Kariuki 1993). Another reason was that the project did not work out a benefit appropriation mechanism at the project design stage. The Group Ranch land tenure arrangement was introduced to the area at the same time as the tree planting project, creating uncertainty regarding land ownership and control between the Tugen and Il Chamus peoples. Group Ranch committees had not yet crystallised and did not enjoy the same authority as traditional leadership structures (Kariuki 1993).

Local Perceptions of *P. juliflora*

Local people perceive that there has been a rapid increase in the density of *P. juliflora* over the last 5–10 years, both in communal grazing areas and on individually controlled homesteads and cultivated fields. The increase of *P. juliflora* on individual land was attributed to difficulties in controlling the spread of the trees and dispersal of seed by both livestock and water. There was a great increase in *P. juliflora* density on communal land because there were no organised control efforts. Livestock were identified as an important dispersal agent for *P. juliflora* seeds because they eat the seed pods and drop the seeds with their manure. The communal grazing fields are located around the shores of Lake Baringo, where soil moisture is high, further enhancing the conditions for the growth and proliferation of *P. juliflora.*

For the first 10 years after its initial introduction, there were few problems associated with *P. juliflora* in Ng'ambo. At that time (mid-1990s), *P. juliflora* was considered to be somewhat scarce and was largely confined to the demonstration plots. Individuals appreciated it as a fuelwood source and for its environmental services of reducing erosion and dust storms, providing shade and reducing ambient temperatures. However, 15 years later, when this study was done, *P. juliflora* had invaded many new areas, apparently stifling other fodder species and forcing livestock to be fed almost exclusively on *P. juliflora* pods. Key informants with long knowledge of the area estimate that about 75 per cent of the Ng'ambo area is currently subject to *P. juliflora* invasion, directly affecting about 10,000 people (Figure 3).

Figure 3
Status of* Prosopis *spp. invasion in Baringo



Source: Choge *et al*. 2002

Benefits and Costs of *P. juliflora*

The survey identified seven products of *P. juliflora* in both study sites: construction poles, fencing poles, fuelwood, pods, ropes, honey and charcoal. Charcoal is far less important than expected. There was variation between the sites: construction poles were mentioned most frequently in Ng'ambo, while fuelwood was mentioned most frequently in Loboi. Ropes were mentioned by 28 per cent of respondents at Ng'ambo, but only 2 per cent of respondents in Loboi. Honey was mentioned by 26 percent of respondents in Ng'ambo, but only percent 2 percent of respondents in Loboi (See Table 2).

All respondents indicated some use of *P. juliflora* products. Most users harvested *P. juliflora* products only for subsistence (fifty out of sixty-five respondents in Ng'ambo and thirty-three out of forty-eight in Loboi). In both Ng'ambo and Loboi, twenty-two individuals harvested products for both subsistence and sale. The following constraints hamper harvest of products:

- The branches have strong thorns, reputed to be poisonous, that make harvesting difficult.

- *P. juliflora* is very hard to cut and wears down simple cutting tools.
- There are few ready buyers.
- *P. juliflora* products are readily abundant throughout the area and most individuals access them directly for their own use.
- Transportation to more distant markets remains a key problem as many public vehicles avoid going to the area because of frequent tyre punctures due to *P. juliflora* thorns.
- The heavy wood makes it difficult to carry poles out of the area.

Contrary to expectations, the statistical analysis revealed few statistical relationships between individual attributes of age, gender, occupation, wealth level (number of cows, sheep and goats), education level or village with the products harvested. Women in Ng'ambo harvested significantly more fuelwood than did men (χ=7.64; α=0.006). Chemonke village, which holds the densest stands of *P. juliflora*, harvests more honey than any of the other villages (χ=8.573; α=0.036). All other statistical relationships were insignificant.

Table 2
P. juliflora *product use in the Ng'ambo and Loboi areas*

Product	% of respondents reporting use in	
	Ng'ambo (*n*=65)	Loboi (*n*=48)
Construction poles	94	40
Fencing poles	82	33
Fuelwood	72	58
Pods (for livestock fodder)	62	40
Ropes	28	2
Honey	26	2
Charcoal	5	6

Source: Authors' analysis of survey data

Table 3
Economic value of* P. juliflora *products per year for individuals in the Ng'ambo and Loboi areas

Product	Ng'ambo (*n*= 65)	Loboi (*n*=48)
	Average value (SD* of value) in KES	Average value (SD* of value) in KES
Construction poles	4982 (18,511)	86 (186)
Fencing poles	3618 (7826)	164 (406)
Fuelwood	5140 (4215)	9263 (26, 522)
Pods (for livestock fodder)	733 (1459)	15 (26)
Ropes	22 (58)	0 (0)
Honey	1297 (3761)	31 (216)
Charcoal	228 (1688)	53 (242)
Total for all seven products	16,020 (20, 364)	9612 (26,538)

*SD=Standard deviation
Source: Authors' analysis of survey and market data

Table 3 provides economic estimates of the benefits that individuals derive for each stated use in both Ng'ambo and Loboi areas. Individuals in the Ng'ambo area generated average benefits of KES 16,020 annually from the use of pods as livestock fodder, construction poles, fencing poles, honey, fuelwood, charcoal and ropes (average exchange rate of 75 KES=1USD). By far the most important product was fuelwood, with an average value of KES 5140 per individual. Fencing materials and honey harvesting were also important in Ng'ambo. In Loboi, the average annual value of *P. juliflora* products was KES 9612 per person. Fuelwood was again the most important benefit, with a mean annual value of KES 9263 per person.

Construction poles, fencing poles and fuelwood are available throughout the year. These products are harvested according to need, and may range from once a year for fencing poles, to once every 3 years for construction poles. On the other hand, people harvest fuelwood every day or several times per week throughout the year. Pods for livestock fodder are usually harvested in the dry season, from December to March. Honey harvesting is variable in timing, though it generally occurs in the periods following the onset of the long and short rains in April and October.

Problems Associated with *P. juliflora*

The problems that people associate with the *P. juliflora* invasion are listed in Table 4.

In Ng'ambo, the most severe problems were reduction of pastures for livestock grazing, reduced farm lands and associated opportunities for cultivation, and damage to the teeth of goats. In Loboi, the incidence of malaria associated with the expansion of *P. juliflora* thickets was the most frequently mentioned problem. Disfigured jaws of goats was the second most frequently cited problem. In marked contrast to Ng'ambo, only 5 per cent of respondents indicated that *P. juliflora* was a problem constraining crop farming, while 13 per cent indicated problems of reduced pastures for livestock.

Livestock keepers explained that the invasion of communal grazing lands around Lake Baringo reduced pas-

Table 4
Problems associated with* P. juliflora *in the Ng'ambo and Loboi areas

Problem	% of respondents reporting problem in	
	Ng'ambo (*n*=65)	Loboi (*n*=48)
Disease-malaria	40	60
Dental condition in goats	59	55
Strong, poisonous thorns	30	40
Declining pastures	68	13
Reduced farm lands	60	5
Ground cracking	11	0
Drainage problems	8	0

Source: Authors' analysis of survey data

tures available for local livestock. Livestock are now more frequently taken to pastures 40–50 km away from Ng'ambo. In some of these areas, however, livestock from Ng'ambo are denied access to pastures by resident communities who fear spread of the *P. juliflora* problem to their grazing areas.

For the majority who describe themselves as farmers, the prolific expansion of *P. juliflora* is a major threat. Many cite the continuous and costly process of clearing as a constraint to their farming activities. Only those who can afford to pay for labour to clear *P. juliflora* are able to have land for cultivation. Some individuals, mainly from Chemonke village, claim to have been displaced from their original settlements/homes by *P. juliflora*. They have had to seek alternative settlement elsewhere, sometimes renting land in these new areas. Conflicts have arisen when the displaced seek alternative settlement sites.

The disfiguration of goats' jaws due to consuming the hard pods of *P. juliflora* and the tooth decay resulting from the pods' high sugar content was perceived to be a major problem. These dental problems impair the health of the goats and in some cases causes death due to starvation. Individuals are often forced to sell their animals before they die, yet such sales fetch poor prices.

The sharp, strong and poisonous thorns of *P. juliflora* were cited as a major problem. Thorns make it difficult for individuals to penetrate the dense thickets to harvest fuelwood. A case was reported of a woman losing her eye following *P. juliflora* thorns pricking her eye.

Respondents also cited effects on water resources and infrastructure. *P. juliflora* stands interfere with drainage, blocking watercourses and exacerbating the effects of flooding. *P. juliflora* has blocked key paths and roads used by both humans and livestock, requiring longer walking times to get to desired destinations. For example, while in the past it took 2 hours to walk to Loruk, it now takes between 6–8 hours. *P. juliflora* is also alleged to have displaced other important and useful native trees such as *Iltepesi* (*Acacia* spp.) and *Kalalia* (*Euphorbia* spp.).

About half the respondents in Ng'ambo location indicated having some form of conflict following the invasion of *P. juliflora*. These conflicts centred on access to resources due to displacement from homes and farms (52 per cent) and trespass of displaced people into others' territory (48 per cent). Individuals who have been unable to control the spread of *P. juliflora* invade other peoples' farmlands. People from Chemonke, where the *P. juliflora* invasion is most intense, have moved to the villages of Keper and Loropil.

Estimated Costs of *P. juliflora*

Data from the survey were combined with estimates of the value of livestock to estimate the costs associated with the combined effects of two of the problems listed above: dental problems and loss of pastures leading to death of cattle, sheep and goats. The results are presented in Table 5.

Minimum efforts to control the *P. juliflora* problem have been undertaken at the group level. In 2001, the local chief and elders of Ng'ambo location mobilised community members, including women and youth, to remove *P. juliflora* from communal areas in order to open land for cultivation. After clearing, a lottery system was to be applied to allocate the reclaimed land to households that participated in the operation. While the community successfully cleared *P. juliflora* from parts of the area, the project was disrupted by the onset of heavy rains. That year the river burst its banks and changed course, flooding the entire cleared area. The community control effort was abandoned and *P. juliflora* has since re-colonised the cleared area. No further group clearing had been undertaken until the time of this survey in 2004.

At the individual level, all individuals interviewed in the Ng'ambo area and most of those interviewed in Loboi had undertaken some form of control on land that is *de facto* considered to be their 'own,' i.e. the land around their homesteads and on farmlands allocated by the Group Ranch to their families. Interventions include uprooting seedlings and whole trees, cutting, burning and pruning.

Most individuals (fifty-two of sixty-five in Ng'ambo) uproot or cut *P. juliflora* trees on their crop fields, usually once a year during land preparation. This work is done by all family members and sometimes by casual labourers. The frequency of this activity varied from once a year (fourteen respondents), four times per year (ten respondents) and continuously through the year (ten respondents). Seventeen individuals prune the *P. juliflora* trees on their compounds.

Survey respondents answered questions related to the costs of these control activities. Some people responded in terms of money spent to hire labour, while others provided information about the amount of time spent in clearing and uprooting trees and seedlings. These time estimates were translated into labour costs through a

Table 5
Estimates of some of the in-kind economic costs of the* P. juliflora *invasion per year for individuals in the Ng'ambo and Loboi areas

	Ng'ambo (*n*=65)	Loboi (*n*=48)
Cost	Average value of loss per respondent (SD of value) in KES	Average value of loss per respondent (SD of value) in KES
Losses of goats	6529 (8931)	2133 (3962)
Losses of sheep	1400 (4390)	0 (0)
Losses of cattle	29,807 (100,321)	520 (2834)
Total livestock losses	37,736 (113,642)	2653 (6796)

Source: Authors' analysis of survey and market data

Table 6
Average annual individual benefits and losses due to* P. juliflora *for villages in the Ng'ambo and Loboi areas

	Average benefits (KES)	Average losses (KES)	Average net benefits (KES) (– indicates net loss)
Villages in Ng'ambo area	Analysis of variance F=0.771, P=0.515	Analysis of variance F=2.628, P=0.058	
Nairrag-Enkare (*n*=17)	13,539	20,794	–7,255
Masai (*n*=19)	21,750	22,763	–1,013
Chemonke (*n*=12)	11,647	109,802	–98,155
Keper (*n*=17)	15,179	20,544	–5,365
Villages in Loboi area	Analysis of variance F=0.680, P=0.512	Analysis of variance F=0.274, P=0.762	
Tingtinyon (*n*=20)	8456	2144	6312
Kapronguno (*n*=21)	13,758	3310	10,448
Loboi trade centre (*n*=7)	478	2143	–1665

Source: Authors' analysis of survey and market data

standard cost for casual labour of KES 50 per 6 hour day. The average annual cost for the sixty-five Ng'ambo respondents was KES 6232 (or USD 83), with a standard deviation of KES 1189, while the average annual cost for the forty-eight Loboi respondents was KES 1222 (USD 16), with a standard deviation of KES 684.

Combined Costs and Benefits at the Individual Level

By combining the analysis of the value of *P. juliflora* products, livestock losses and costs of control, we are able to generate a first estimate of the annual individual-level benefits and costs of *P. juliflora* for local households. The results presented in Table 6 show that losses due to livestock deaths and cost of control exceed benefits derived from sale and use of *P. juliflora* products in all villages in the Ng'ambo area where invasion is highest.

Individual benefits still exceed losses in two of the three villages studied in the Loboi area. In Ng'ambo, the highest losses were born by individuals who identified themselves as herders and/or farmers (differences with other groups were very large, although not statistically significant because of the high standard deviation). These results reflect the fact that the costs of clearing *P. juliflora* from farms are high and continuous. Herders seem to be hardest hit by the proliferation of *P. juliflora*, despite the potential benefits of *P. juliflora* as a dry season fodder.

It is important to emphasise, however, that Table 6 presents only a partial listing of costs and benefits. The costs of increased malaria incidence, loss of grazing territory, reduced crop production due to small field size or reduced crop production are not included.

Distribution by Gender

Table 7 presents an analysis of the distribution of benefits and costs by gender. On average, men in Ng'ambo accrue higher benefits (about 1.4 times higher) from *P. juliflora* than women, while also accruing much higher losses (about 3.4 times higher). The higher benefits result because men are more inclined to trade in *P. juliflora* products such as construction/fencing poles. Most women focus on harvesting fuelwood, primarily for subsistence. Women harvested statistically more fuelwood than men, and acknowledged that *P. juliflora* has greatly reduced their fuelwood burden. Men also reported higher losses than women, especially from livestock. Overall, the gender differentiated costs and benefits are not statistically significant.

In Loboi, however, though average losses are low, women tend to experience higher losses from *P. juliflora* than men. They also receive much greater benefits, almost seventeen times, than men (F=5.050; P=0.029). *P. juliflora* in Loboi is less widespread, the range of uses are limited mainly to firewood collection by women.

Further analysis of the distribution of benefits and costs between villages and occupations was also undertaken. One village in the Ng'ambo area, Chemonke, experiences the lowest benefits and highest costs of living with *P. juliflora*—close to five times the costs incurred by neighbouring villages (F=2.628; P=0.058). Chemonke village had the highest density and greatest invasion from *P. juliflora*, to the extent that many residents had abandoned their homesteads and moved to neighbouring areas such as Loropil. In Loboi, on the other hand, there is less variation in the magnitude of costs and benefits by village. In the Ng'ambo area, the highest losses are associated with individuals who identified themselves as herders and/or farmers. As indicated above, farmers bear high costs of clearing *P. juliflora* from their fields, while herders suffer from loss of grazing area and decline in animal health.

Local Perceptions of *P. juliflora* Control

Public operations for control of *P. juliflora* were under consideration at the time of this survey in early 2004. To in form those plans, we asked respondents questions

Table 7
Distribution of annual benefits and costs by gender

Area	Gender	Average benefits (KES)	Analysis of variance	Average losses (KES)	Analysis of variance
Ng'ambo	Male (*n*=37)	17427.317	F=1.11	55399.31	F=2.313
	Female (*n*=28)	12290.536	P=0.296	16375.00	P=0.133
Loboi	Male (*n*=23)	1001.513	F=5.050	1597.826	F=0.191
	Female (*n*=25)	17534.826	P=0.029	3625.000	P=0.191

Source: Authors' analysis of survey and market data

about the type of eradication or control operations they would prefer. In both study sites, about 85–90 per cent of respondents favoured complete eradication, through mechanical uprooting or application of chemicals, and replacement with other trees that would be less invasive and thornless. About 10–15 per cent of respondents wanted *P. juliflora* to remain because of the products that it generates.

Most respondents indicated that individual households should be involved in clearing *P. juliflora* from their own fields, with government assistance. On public lands, about 60 per cent of respondents suggested that the Government of Kenya should conduct or lead eradication efforts. Forty per cent of people favoured a greater role for local communities, with some help from external actors, including the government and NGOs.

CONCLUSIONS

In the early 1980s, *P. juliflora*, along with several other hardy tree species, was introduced into the rangelands of Baringo. *P. juliflora* is now very well established in areas close to water sources and swamp lands; the same areas that are critical for dry season pasture and crop cultivation. Individuals in the Ng'ambo and Loboi areas, the sites of initial planting, are demanding its eradication, not least because its benefits are far outweighed by its undesirable properties. According to these communities, their primary livelihood options of farming and livestock keeping are threatened by the unchecked expansion of the invasive alien species.

Local residents in the Baringo area are demanding eradication of *P. juliflora* with an understanding that the tree generates both positive and negative effects on their livelihoods. Survey respondents report the following positive effects: production of poles for fences and home construction, greater availability of fuelwood, availability of pods which are used as livesetock fodder and as a snack for children, ropes made from bark, honey, and reduced dust storms. The negative effects include: invasion into crop fields and associated costs of clearing, invasion into grazing areas and associated loss of grazing territory for livestock, invasion into wetlands that reduces their value for watering and dry season grazing, invasion into the lakeshore areas making fishing more difficult, damage to the tyres of vehicles and bicycles, wearing out of cutting tools quickly due to the hard wood, consumption of seed pods that damage teeth of goats, sharp thorns that cause wounds to goats and cattle, and increased malaria incidence from having *P. juliflora* thickets close to homes.

Individuals' overall perceptions of *P. juliflora* are influenced by their assessment of present and future costs and benefits. The empirical results in this paper show considerable differences in the distribution of benefits and costs between areas, between people engaged in different occupations, and between men and women. Nonetheless, there is near unanimous support for eradication of the species from the area. Three explanations for this arose from the survey and the key informant interviews. First, it appears that people living in villages with relatively low *P. juliflora* density anticipate more intense invasions in the future, which will cause large increases in costs without corresponding increases in benefits. Second, the women who clearly benefit from greater supplies of fuelwood also bear high costs of clearing *P. juliflora* from their crop fields and gardens. Women may also be particularly concerned about the increase in the incidence of malaria that is being reported. Third, the more commercially oriented residents have not benefited greatly from the sale of *P. juliflora* products, while they have suffered considerably from lost grazing area and ill health of their livestock.

Actions in response to the invasion of *P. juliflora* have concentrated on control attempts on farms and homesteads, where individuals control land use and the benefits that their efforts generate. The jointly used communal grazing areas have seen very few control attempts, despite their importance for the livestock enterprises. So far, local authorities have been unable to mobilise significant control operations on their own.

Thus we conclude that perceptions of *P. juliflora* (and of invasive species more generally) by local communities are strongly influenced by how the beneficial effects of the species weigh against its costly characteristics. Institutions (property rights, customary authorities, formal policies) and the incentives that they produce limit the range and effectiveness of possible responses. Perhaps most importantly, government policy restrictions on the transportation and sale of charcoal severely limit the range of use options which may have potential to help in the control of *P. juliflora* stands. Though it is legal to buy, use and sell charcoal, it remains illegal to produce or transport it (Bailis *et al*. 2006).

Commercialisation of *P. juliflora* products has so far proven to be challenging in Kenya. While *P. juliflora* has potential for being manufactured into tools, floorboards and carvings, the economic potential of these enterprises is yet to be assessed. Charcoal is a highly problematic industry in Kenya, generating revenue of hundreds of millions of dollars from the arid and semi-arid areas, but subject to a wide array of taxation (legal and illegal), regulation and outright harassment (Bailis *et al*. 2006). Key informant interviews in the Lake Baringo area suggest that most people involved in the charcoal trade are young men from outside the local area. Few local people would proudly claim to be charcoal producers and sellers. Experience from elsewhere in Africa shows that a change in this situation is possible. Creating such a change in Kenya may require a package of new technologies (for wood harvest and efficient charcoal production), special labelling of the charcoal as being produced from *P. juliflora*, legitimate local organisations to manage production, sale and distribution of proceeds, and marketing arrangements that remove the formal and informal harassment and stigma attached to the product.

A key challenge for future control efforts will be strengthening the institutions that facilitate collective and individual action for rangeland management. By the time of this study in 2004, group ranch managers had been unable to organise effective control operations on grazing lands. There may be some possibilities for strengthening the group ranch leadership structures and to provide them with better information and technology for undertaking control through use. It might also be desirable for the group ranch to assign management responsibilities to small groups of livestock owners, who could be allowed to reserve cleared plots for dry season grazing.

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Note

1. Pasiecznik *et al*. (2001) note that it is difficult to distinguish *P. juliflora* from a closely related species, *P. pallida*. While both are distinct from most other *Prosopis* species, they closely resemble each other in flower, pod and leaf morphology. This study systematically refers to *P. juliflora* but acknowledges the taxonomic confusion between the two species.

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