Working Paper

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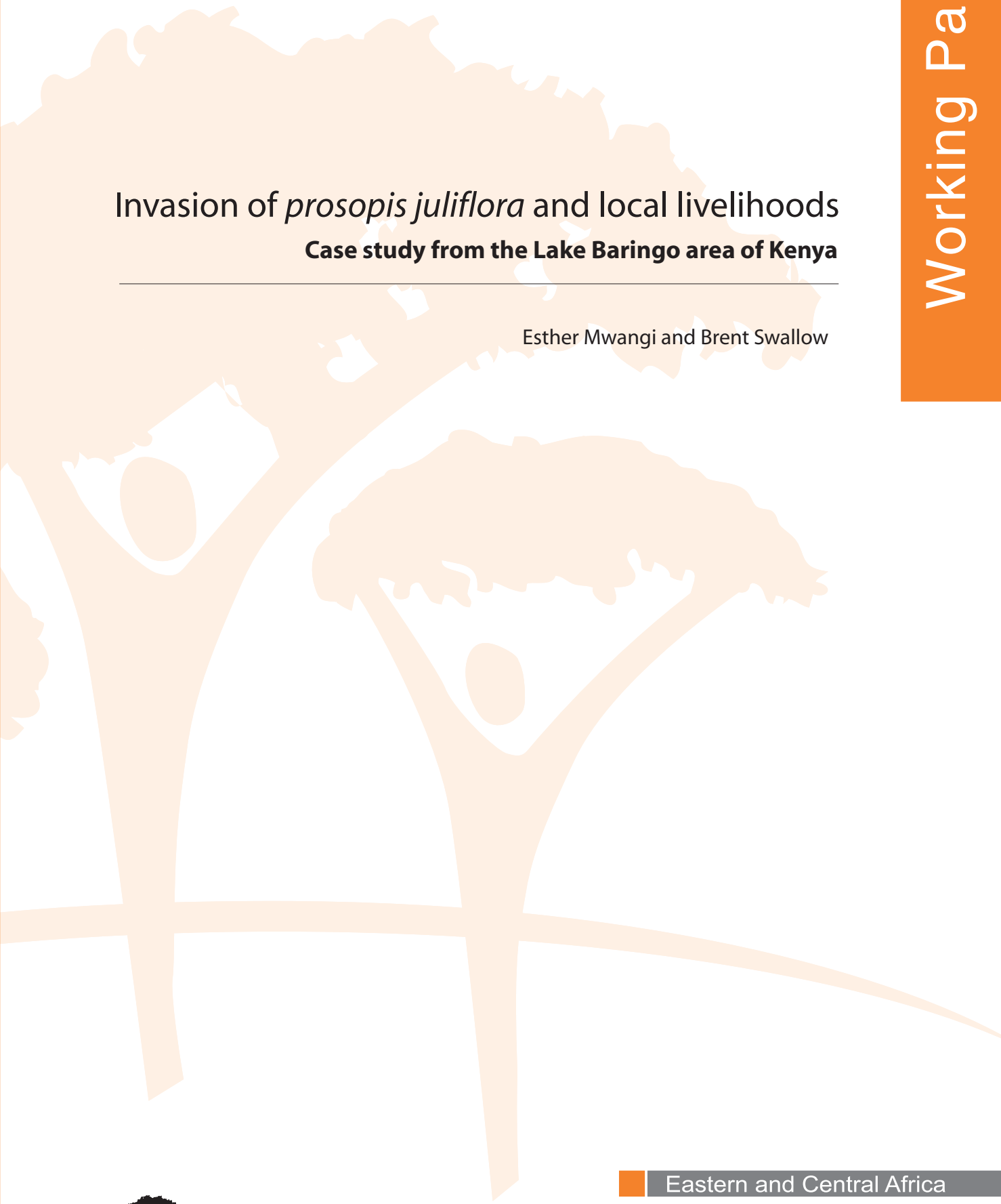
Case study from the Lake Baringo area of Kenya

Esther Mwangi and Brent Swallow



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Abstract

This paper presents an assessment of the livelihood effects, costs of control, and local perceptions of the invasive tree, *Prosopis juliflora*, on rural residents in the Lake Baringo area of Kenya. Global concern about deforestation caused by fuelwood shortages, prompted introduction of *Prosopis juliflora* to the Lake Baringo area in the early 1980s. *Prosopis juliflora* is in IUCN's new list of 100 world's worst invasive alien species. The *Prosopis juliflora* invasion in the study area has recently attracted national attention and contradictory responses from responsible agencies. Unlike some other parts of the world where it has been introduced, *Prosopis juliflora* potential benefits have not been captured and few people in the Lake Baringo area realize net benefits from the widespread presence of the tree. Strong local support for eradication and replacement appears to be well justified. Sustainable utilization may require considerable investment in the development of new commercial enterprises.

Keywords

Prosopis julifora, alien invasive species, livelihood effects, local perceptions

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Contents

Introduction

Prosopis juliflora (Sw.) DC is an evergreen tree native to South America, Central America and the Caribbean. In the United States, it is well known as mesquite.[1] It is fast growing, nitrogen-fixing and tolerant to arid conditions and saline soils. Under the right conditions, *Prosopis juliflora* can produce a variety of valuable goods and services: construction materials, charcoal, soil conservation and rehabilitation of degraded and saline soils. Concern about deforestation, desertification and fuelwood shortages in the late 1970s and early 1980s prompted a wave of projects that introduced *Prosopis juliflora* and other hardy tree species to new environments across the world. *Prosopis juliflora* has survived where other tree species have failed and in many cases become a major nuisance. *Prosopis juliflora* has invaded, and continues to invade, millions of hectares of rangeland in South Africa, East Africa, Australia and coastal Asia (Pasiecznik, 1999). In 2004 it was rated one of the world's top 100 least wanted species (Invasive Species Specialist Group of the IUCN, 2004).

This paper summarizes results of a study on *Prosopis juliflora* and rural livelihoods undertaken in the Lake Baringo area of Kenya in 2004. The study was motivated by the magnitude of the *Prosopis juliflora* invasion in the local area, the level of public and government concern about that invasion, and the general nature of the problem across East Africa. Given experience from India, where poor women in arid and semi-arid areas benefit disproportionately from the sale of *Prosopis juliflora* fuelwood and charcoal, 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 can be turned into a significant resource for the local population. In India, for example, it is well documented that poor rural women in arid and semi-arid areas benefit disproportionately from selling charcoal and fuelwood made from *Prosopis juliflora*. The field work for this study of livelihoods and institutions was undertaken in conjunction with a parallel ecological study of the *Prosopis juliflora* invasion and its impacts (Andersson, 2005).

[1] Pasiecznick et al. (2001) note that it is difficult to distinguish *Prosophis juliflora* from a closely related species, *Prosopis 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 *Prosopis juliflora* but acknowledges the taxonomic confusion between the two species.

This study focuses on the impacts of *Prosopis juliflora* and the distribution of these impacts on local communities in two administrative locations of Baringo district, in Kenya's drylands. *Prosopis juliflora* was among tree species introduced to the area about twenty years ago. The study documents the history of that introduction, establishes how *Prosopis juliflora* affects the livelihoods of individuals in the area, and how these effects are distributed across different categories of individuals in society such as men, women, pastoralists and smallholder mixed farmers. It determines the factors that structure individual and group responses to the proliferation of *Prosopis juliflora*. It also establishes the kinds of interventions local communities envision for its control / management and what their role would be in such interventions.

The study addressed the following questions:

1. What are the institutional pathways of *Prosopis* introduction in Baringo, and more generally in Kenya?
2. What are the costs and benefits to local communities of living with *Prosopis*? 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 *Prosopis*?
4. What are feasible solutions to the *Prosopis* problem in Baringo? Which agents, or combination of agents, may take responsibility for the various aspects of proposed solutions?

Prior to addressing these specific questions, the next section of this paper presents a general review of factors that shape people's perceptions and incentives to manage potentially invasive species.

Factors shaping perceptions of alien invasive species

Binggeli (2001) and Pasiecznik et al (2001) propose that people's perceptions of invasive species depend upon whether their economic needs are met by the species. In the Indian province of Rajasthan, for example, local people's perceptions of *Prosopis juliflora* were favorable during the early stages of its introduction. At that time, it was welcomed as a field boundary marker and helped avert a significant fuel wood shortage. Peoples' perceptions changed later as the negative effects of the invasion – colonization of agricultural land, its sharp thorns, suppression of grasses and crops -- became more pronounced.

Income/wealth levels and dominant livelihood strategies/occupations are also important determinants of how individuals perceive invasive species (Pasiecznik et al, 2001). In India, the more affluent who can afford bottled gas for cooking, for instance, view *Prosopis juliflora* negatively, while the rural poor who cannot afford bottled gas value it as a fodder and fuel tree. Similarly, ranchers and pastoralists whose main livelihood strategy is livestock keeping view it negatively because it invades valuable pastures. Poor farmers, on the other hand, acknowledge its benefits for fuel and fodder. In an aggressive program to revegetate India's saline lands with *Prosopis juliflora*, small, marginal farmers, landless laborers and women (who used to walk long distances to collect firewood and forage) emerged as the prime beneficiaries.

Veitch and Clout (2001) suggest other factors that influence people's perceptions of an invasive species. These 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; and the media's portrayal and the costs of managing the species.

From these examples, it seems that people's perceptions are fundamentally shaped by the way their daily lives interface with the species and how it affects their livelihoods and local economies. An economically beneficial species will more likely be favored in as far as the costs of managing it do not exceed the discernible benefits. However, calculations of benefit and cost will vary across a population. The livelihoods strategies that individuals pursue, their wealth levels and their gender are central factors shaping how they relate to and value an invasive species.

While an understanding of perceptions may provide valuable insights into individual and group valuation of invasive species, it provides no indication of how these valuations motivate some form of action response. What determines individual and group responses to the problem or threat of invasion? In the absence of substantive empirical work on human responses to species invasions, the literature on institutions provides broad insights into what factors may motivate individuals or groups to engage in action that would mitigate the threat of exotic species invasions. Institutions are the set of rules and constraints that govern behavioral relations among individuals and groups (Nabli and Nugent, 1989). They may be formal such as markets or informal such as cultural norms and conventions.

At the level of the individual, it is generally recognized that private property rights serve to create substantial incentives for investment in resource management. Under this institutional arrangement, individuals who invest their time, effort and money are able to reap benefits of their investment for themselves. Following this argument, individual owners of property will be more likely to engage in *Prosopis* mitigation or control activities because they will be assured of capturing the gains of their investments. However, accounts of invasive species management elsewhere in the world suggest that private property rights may be neither necessary nor sufficient to check the spread of invasive species. Although the United States has a well-developed system of private property rights for land ownership, the spread of invasive species across property boundaries continues to be a major concern.

In situations where individual actions are interdependent and related such as in the use of commonly held resources, incentive structures are even less likely to lead to efficient outcomes. The collective action problem (Olson, 1965) is that self-interested individuals will have incentive to free ride on others who provide for the public good. Each of these individuals will want to overuse the resource, leading eventually to its depletion or degradation. Thus, where land is held under common property arrangements, management responses to invasive species require cooperation among affected individuals (Perrings et al, 2002).

Theories of collective action provide insights into what motivates individuals to coordinate their activities to solve collective problems. While structural attributes such as group size, heterogeneity, etc have been found to enhance or depress group performance, a fundamental issue is an individuals' cost of contributing relative to the expected benefits. People are unlikely to be willing to undertake expensive actions that provide no noticeable benefits. On the other hand, when individual benefits are expected to be greater than costs, people are more likely to act. Institutional design is one way to overcome collective failures and to ensure that individuals capture gains from investments in joint resources.

By communicating and cooperating, individuals are able to devise a system of governance to regulate the use of the resource (Ostrom, 1990). This includes definition of rules, monitoring of behavior, and the enforcement of rules. Consequently, if individuals 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 the collective action problem and undertake effective control. Other institutional arrangements, including customs, social conventions and traditions, may also induce

cooperative solutions and help to overcome collective difficulties and achieve efficiency in the use of shared resources.

Government policies also shape responses to invasive species (Perrings et al 2002). Government policies may create incentives or disincentives that affect how people utilize invasive species and the extent of utilization. Government tree planting schemes, such as those common in the late 1970s and early 1980s created incentives that did not consider the possible 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 (and profitable) use of *Prosopis juliflora* products, which may effectively contribute to controlling its rapid spread.

This brief account on perceptions and responses leads this study to anticipate the following:

1. The livelihood strategies pursued by individuals will influence the distribution of costs and benefits of living with *Prosopis* among actors in society. Pastoralists and farmers will incur higher costs due to pasture depletion and farmland clearing. People pursuing livelihood strategies such as trading of *Prosopis* products will accrue greater benefits.
2. Women, who are heavily dependent on *Prosopis* for fuelwood, will likely enjoy greater benefits from *Prosopis* than men.
3. The distribution of these costs and benefits will likely influence the perceptions of individuals. Those who incur higher benefits relative to costs will more likely to favor the invasive species, while those whose costs are higher than benefits will strongly disfavor the species.
4. In the absence of joint community rules for management / control of *Prosopis*, it is unlikely that individuals will invest in controlling and/or eradicating *Prosopis* in the communal grazing lands.
5. Individuals will more likely invest in the control, management and/or eradication of *Prosopis* in their own private land.

Prosopis juliflora as an economic resource

Pasiecznik et al (2001) and Pasiecznik (1999) provide a comprehensive account of the generic uses of *Prosopis juliflora*. *Prosopis* plays a leading role in the afforestation of arid lands. Their capability of growing on degraded land under arid conditions has made them especially suitable for this purpose. Being a multipurpose tree, *prosopis* fits very well into

dryland agroforestry systems, controlling soil erosion, stabilizing sand dunes, improving soil fertility, reducing soil salinity, providing fuel energy resources, supplying feed and forage for grazing animals, furnishing construction timber and furniture wood, supplementing food for humans, and promoting honey production.

Prosopis juliflora produces good quality fuel of high quality calorific value, which burns well even when freshly cut. It also produces high quality charcoal and its heartwood is strong and durable. It branches are widely used as fencing posts, while its pods which are high in protein and sugars may be important fodder for livestock, and / or food for humans. However, the pods have been reported to result in facial contortions, impacted rumen and constipation among livestock. These ill effects may sometimes result in death. *Prosopis juliflora* has also been used to shelter agricultural crops from wind and to reduce the movement of soil and sand. Its leaves contain various chemicals known to affect palability to livestock, but also suppress the germination and growth of crops, weeds and other trees.

Empirical studies conducted in Sudan indicate that wind speed inside a five-year-old *Prosopis juliflora* plantation was reduced by an average 14 %, while potential evaporation was reduced by 22%. There was also considerable improvement in soil texture and soil organic matter under the tree canopy, with soils under the canopy having higher total nitrogen and available phosphorus, and lower soil pH than soils in the adjacent open field (El Fadl, 1997). Similar studies in the Njemps flats of Kenya's Baringo district reveal that standing biomass of understory plant species were five times lower under the *P. juliflora* canopy (Kahi, 2003). Plant cover was also lower under *P. juliflora* than in the open areas. Organic carbon and total nitrogen concentrations in soils under *P. juliflora* were 13% and 45% higher than in the open areas. An evaluation of the comparative performance of *Prosopis juliflora* against other tree species such as *Albizia lebbec*, *Azadirachta indica*, *Dalbergia sissoo*, *Morus indica*, *Populus deltoids*, *Syzigium cuminii* and S*yzigium fructicosum* found that *Prosopis juliflora* seedlings had the highest survival rate, height gain, girth growth and the highest primary biomass production.

The importance of *Prosopis* as a dryland resource is illustrated in India where it is considered a valuable tree species of the desert ecosystem, particularly in the arid zone of the northwestern Gujarat state. There, it constitutes a large percentage of vegetative cover, producing about 25 to 30 tons of biomass/ha/year at a short rotation age of 4 to 5 years (Varshney, 1996). It also has a tremendous potential for pod production. Between 1990 and

1995, the Gujarat Agricultural University, collected about 2000 metric tons of pods, generating about 100,000 man-days of labor.

During the same period the university collected, processed and marketed about 300 metric tons of honey, which generated about a half million man-days of labor, an important source of employment and income for local people. In addition, the Gujarat Agricultural university manufactures charcoal from *Prosopis juliflora* for the government of Gujarat. Between 1990-1995, it manufactured about 300,000 bags of charcoal and generated about 300,000 man-days of labor demand.

In Mexico, Argentina, and Brazil, *Prosopis* pods are an important source of animal feed (Felker and Moss, 1996). In Peru, pods of especially sweet varieties are used for human food. *Prosopis juliflora* pods are a valuable low cost fodder in the semi-arid areas of northeastern Brazil (de Barros et al, 1988), where it partly offsets fodder scarcity during the dry season. To prevent undesired *Prosopis juliflora* propagation in pastures or subsistence farming lands, animals are fed on ground pods, either alone or combined with other fodder, so that the seeds are totally destroyed and plants do not proliferate through seeds embedded in animal droppings (Ribaski, 1988). Results of feeding trials indicate that rations for goats, sheep, beef cattle and dairy cattle can give very good weight gains and/or milk production when about 60% of the diet consists of ground *Prosopis* pods (Abdelgabbar, 1986). Suitable amendments such as urea, cottonseed meal or molasses must be included in the feed. In central Mexico, rural cooperatives that have organized for the storage and processing of mesquite pods have increased the cash incomes of rural farmers and provided a local source of nutritious livestock feed (Silbert, 1996). A study on the costs and returns for *Prosopis juliflora* plantings in the semi-arid northeast of Brazil indicate *Prosopis juliflora* planting is competitive with other short-cycle crops traditional in the semi-arid region (de Sousa Rosado, 1988). The economic yield is higher than that for mascar bean, corn and arboreal cotton.

The remarkable economic and physiological characteristics of *Prosopis juliflora* make it a prime contributor to the development of many arid regions, especially if its invasive habit is controlled and the thorns that limit its widespread acceptance are controlled. Efforts are underway in different parts of the world to moderate these unwanted attributes. New erect *Prosopis* clones with small thorns and high production of highly palatable human pods have been identified in Peruvian field trials (Felker, 2002). These have had exceptional

performance in field trials in Haiti, Cape Verde and India. India's mesquite improvement program is involved in the large-scale collection of seeds of superior mesquite trees, both within the country and abroad (Singh, 1996).

Prosopis juliflora as an alien invader

Invading *Prosopis* tends to form dense, impenetrable thickets, associated with unfavorable impacts on human economic activities. Millions of hectares of rangeland have already been invaded, and the process is still occurring in South Africa, Australia and coastal Asia (Pasiecznik, 1999). Invasion has already occurred in northern Sudan where the Gash Delta of the Atbara River has been almost completely taken over by *Prosopis juliflora* (Catterson, 2003). In the Awash basin of Ethiopia, it is aggressively invading pastoral areas in the Middle and Upper Awash Valley, and Eastern Harerge. It is one of the three top priority invasive species in Ethiopia and has been declared a noxious weed. Sudan has passed a law to eradicate it (Sudan Update, 1997).

Land use changes, competitive ecological advantages, and climate change are key factors thought to influence the probability of invasion (Pasiecznik et al, 2001). In Australia and South Africa, for instance, *Prosopis* invasions followed periods of high rainfall when conditions for germination and establishment were particularly favourable. In northern India, *Prosopis juliflora* is a pioneer species that rapidly colonizes denuded / abandoned ravines. Invasions into riverine areas and degraded rangelands of Africa, Asia and Australia have resulted in high-density populations. Whatever the trigger for invasion, the principal factor in this process is the rapid and prolific seeding of mature *Prosopis* plants (Zimmerman, 1991). Seed production is estimated at 630,000 to 980,000 seeds per mature tree per year (Harding, 1988; Felker, 1979). Those seeds are most likely to germinate when the sugary pods are consumed by domestic livestock, the seeds scoured while passing through the animals' digestive tract, and the scoured seeds dropped into moist feces (Felker, 2003).

In the Sudan, invading *Prosopis* is reported to depress the growth and survival of indigenous vegetation around it. Some farmers in the area of Kassala claim to have lost their farmlands to *Prosopis*, others complain that not only is it costly to clear but it also destroys agricultural crops, while others are wary of *Prosopis* thorns which are harmful both to farm workers and their machinery. Additionaly, it said to consume underground water, threatening the Beisha oasis in western Sudan (Sudan Update, 1997). Herders claim that the plant's pods bring about some animal diseases. In Ethiopia, the aggressive invasion in pastoral areas is displacing

native trees, forming impenetrable thickets and reducing grazing potential. Agricultural lands and protected areas such as the Awash National Park are threatened.

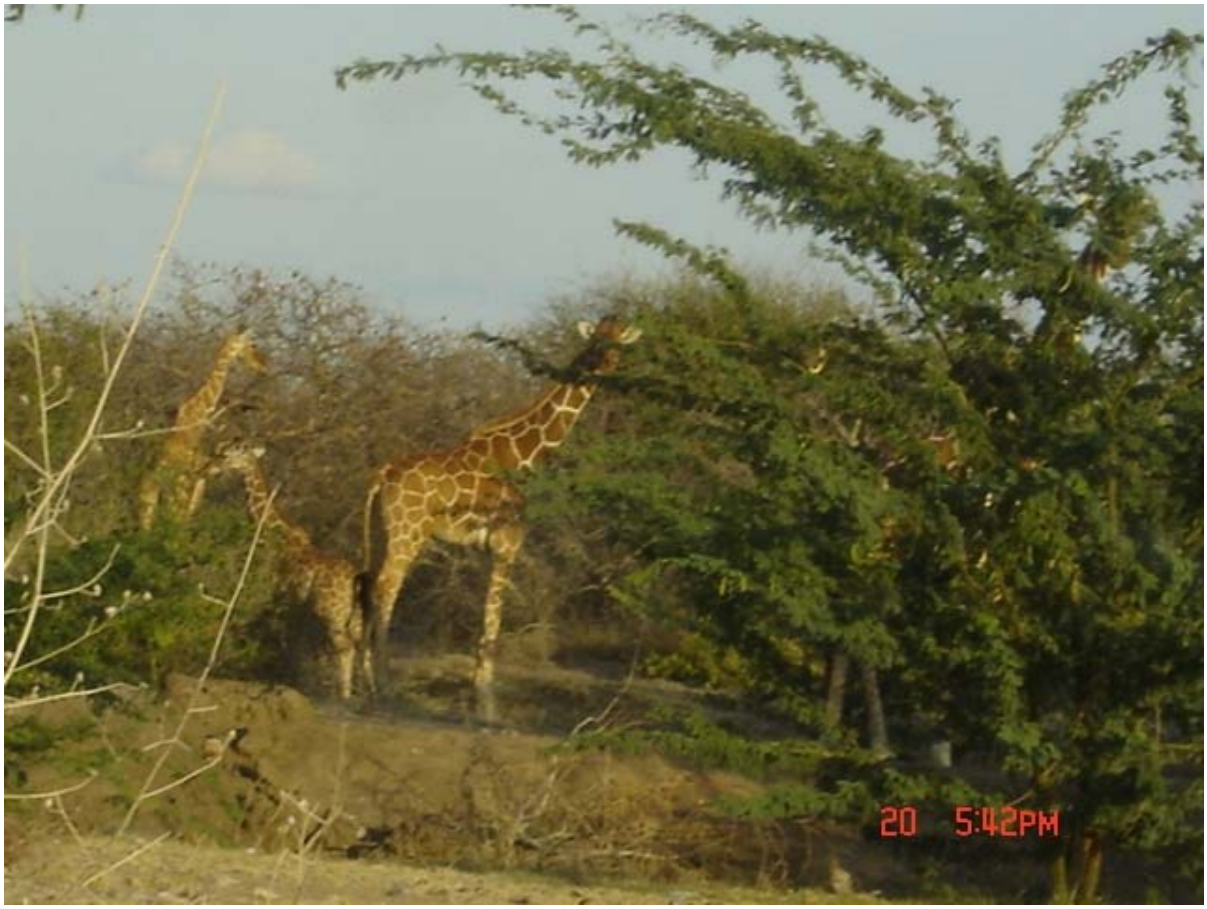


Photo: Aike G./Zeila A.

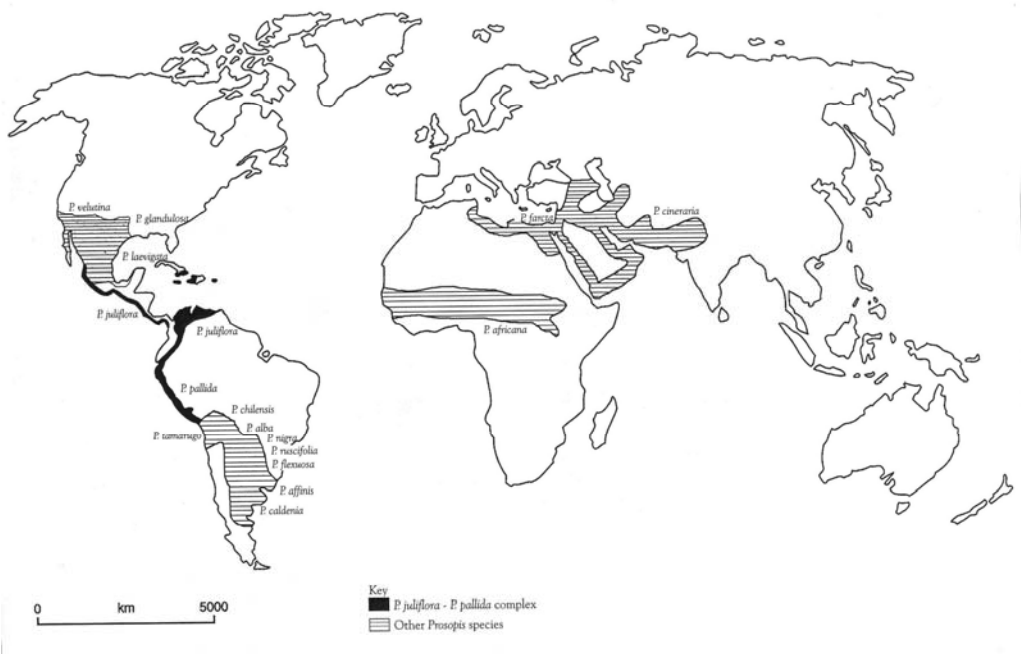
In South Africa, it is estimated that *Prosopis spp.* reduce mean annual run off by about 481 million cubic meters across the country (Impson et al, 1999).

For over fifty years, ranchers in south-western USA and Argentina tried a range of techniques to eradicate or control *Prosopis* (Pasiecznik, 1999). Despite the high costs of eradication, a cost effective program is yet to be found. South Africa and Australia are experimenting with biological control methods, using seed-eating beetles. Because eradication efforts have been neither cost-effective nor technically successful, it seems the best option might be to adapt land use to its management and use. Reduction in stocking rates can encourage good grass cover, which may prevent seedling establishment. Existing dense stands may be thinned and/or pruned, cut stumps treated, and fuelwood, charcoal and timber products harvested from existing stands (Pasiecznik, 1999).

Early introductions into Africa

The native range of the *P.juliflora-pallida* complex covers a broad geographical region in the Americas, from latitudes 22-25 degrees north to 18-20 degrees south (Figure 3). Countries in this range include Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, Ecuador,Peru and the Caribbean and Galapagos islands.

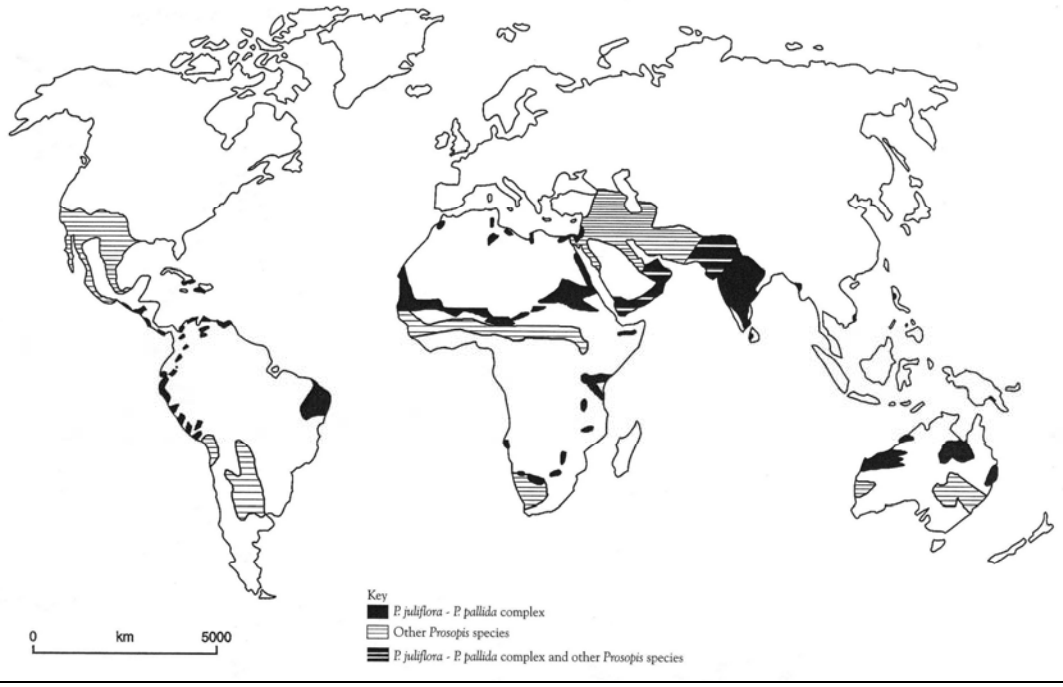
Map 1: Native range of *Prosopis* spp



Source: Pasiecznik et al 2001

In Africa, *Prosopis* was introduced in 25 countries spanning all regions of the continent, including Morocco, Algeria, Tunisia, Libya, Egypt in North Africa, Cape Verde, Senegal, Gambia, Mauritania, Mali, Burkina Faso, Niger, and Chad in the Sahel region of Western Africa, Ghana and Guinea-Bissau and Nigeria in West Africa, Sudan, Ethiopia, Eritrea, Kenya, Tanzania in the East and Horn of Africa, and in Namibia, Zimbabwe, South Africa and Reunion in Southern Africa. The current global distribution of *Prosopis* spp is illustrated in Map 2 below.

Map 2: Current distribution of Prosopis spp



Source: Pasiecznik et al, 2001

While records indicate that the earliest introductions to Africa may have been in Senegal, South Africa, and Egypt in the early to late 19th century, earlier introductions may have occurred (Pasiecznick et al, 2001). Unfortunately, the introductions into Sahelian Africa and the Indian subcontinent were from trees with non-palatable pods (Alban et al, 2002). Introductions into other parts of Africa remain unclear. In East Africa in particular, the exact origins of *Prosopis* spp. remain uncertain. *Prosopis juliflora* may have come in via livestock from Sudan, southern Africa or by traders from India or southern Africa.

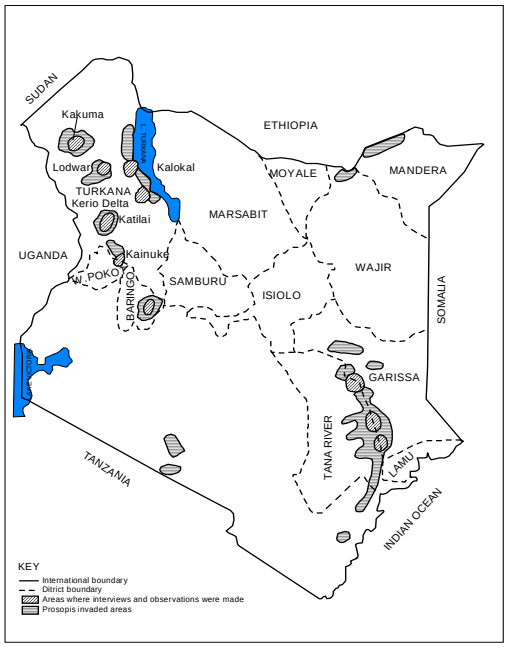
In the Sudan, Jackson (1960 cited in Gabar 1988) reported *Prosopis juliflora* introduction from Egypt and South Africa in 1917. *Prosopis* plants were grown in experimental plantations in Khartoum in 1928 and 1938, where they were found to thrive best on sand dune crests, eroded slopes and sandy soils. Following this, *Prosopis juliflora* became popular in arid area afforestation schemes, with subsequent introductions of different species (Abdelbari, 1986).

Introductions to Kenya

The first documented introductions of *Prosopis juliflora* and *Prosopis pallida* to Kenya was in 1973 for the rehabilitation of quarries near the coastal city of Mombasa, with seed sourced

from Brazil and Hawaii (Johansson, 1985 cited in Choge et al, 2002). The same species were introduced into the semi-arid districts of Baringo, Tana River and Turkana districts in the early 1980s with the intention of ensuring self-sufficiency in wood products, making the environment habitable and safeguarding the existing natural vegetation from over-exploitation by the rising human populations (Choge et al, 2002). These introductions were uncoordinated and seeds sourced from commercial suppliers without reference to origin or quality. A report by the Kenya Forestry Research Institute and Forestry Department (Choge et al, 2002) shows pockets of large-scale colonization across the semi-arid areas of Kenya, with large-scale invasions indicated in the Tana River area of eastern Kenya and in the Lake Tana and Pokot areas in northwestern region of the country (Map 3).

Map 3: Location of *Prosopis juliflora* invasions across Kenya

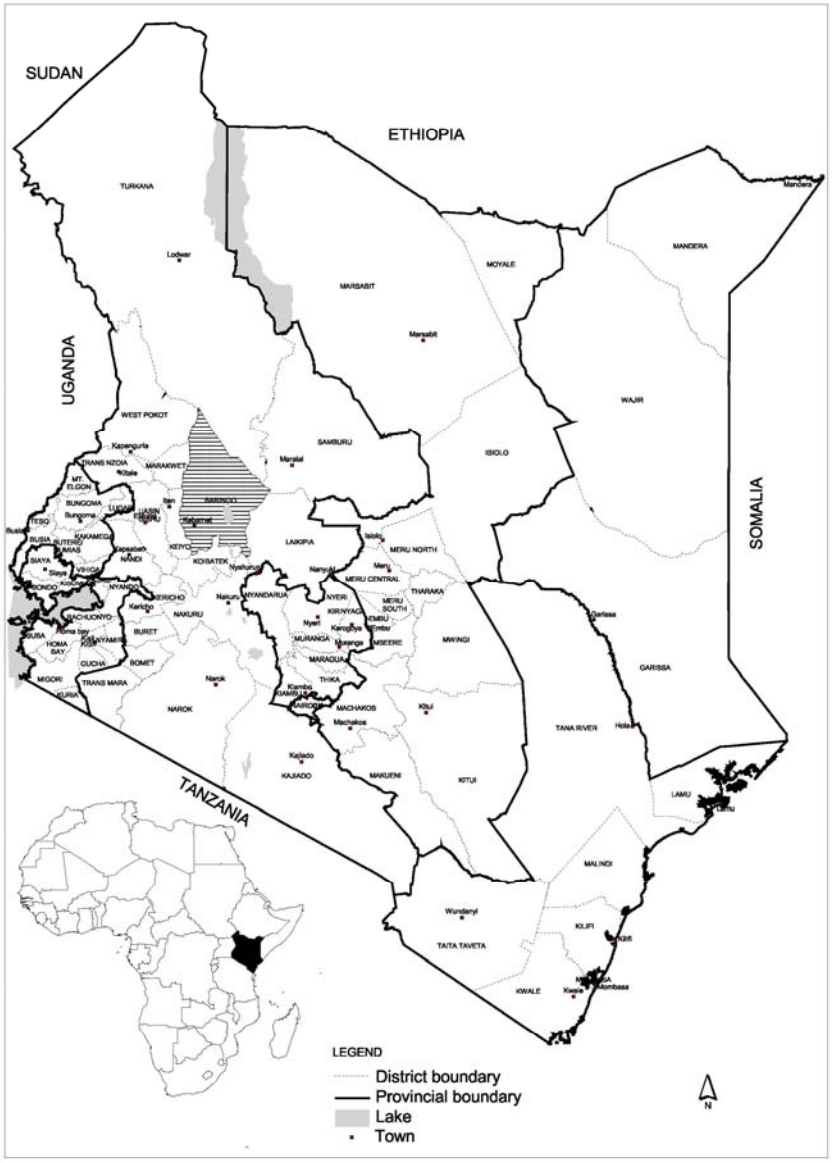


Source: Choge et al., 2002

Study Site

In 2004, the authors conducted a study of benefits, costs and perceptions of *Prosopis juliflora* in Ng'ambo and Loboi, which are administrative locations in Baringo District. The Ng'ambo site now has a high density of *Prosopis juliflora*, Loboi a much lower density. Map 4 shows the location of Baringo district within the East African country of Kenya.

Map 4: Location of Baringo District, Kenya



Source: Choge et al., 2002

Within Baringo district, the *Prosopis juliflora* invasion is largely confined to Marigat Division, which covers an area of 1,276 km2. Marigat is located about 100 kilometers from Nakuru town. The site is located in a 900 square kilometer area between latitudes $0^0$20'N and $0^0$44'N and longitudes $35^0$57'E and $36^0$12'E (FAO, 1992).

The area, mainly rangeland, has flat lands and scarp elevations between 1,000 and 3,000 meters above sea level. The study site includes Lake Baringo and Lake Bogoria, two smaller lakes in the Rift Valley system of lakes that bisect Kenya from northeast to southwest. Lake

Baringo (130 km^2) is a fresh water lake, while Lake Bogoria (34 km^2) is a salt-water lake that is globally renowned for its high population of migratory birds. The catchment area for the lakes includes escarpments, steep hillside areas, rolling hills leading down to the lakes and small flatlands near the lakes.

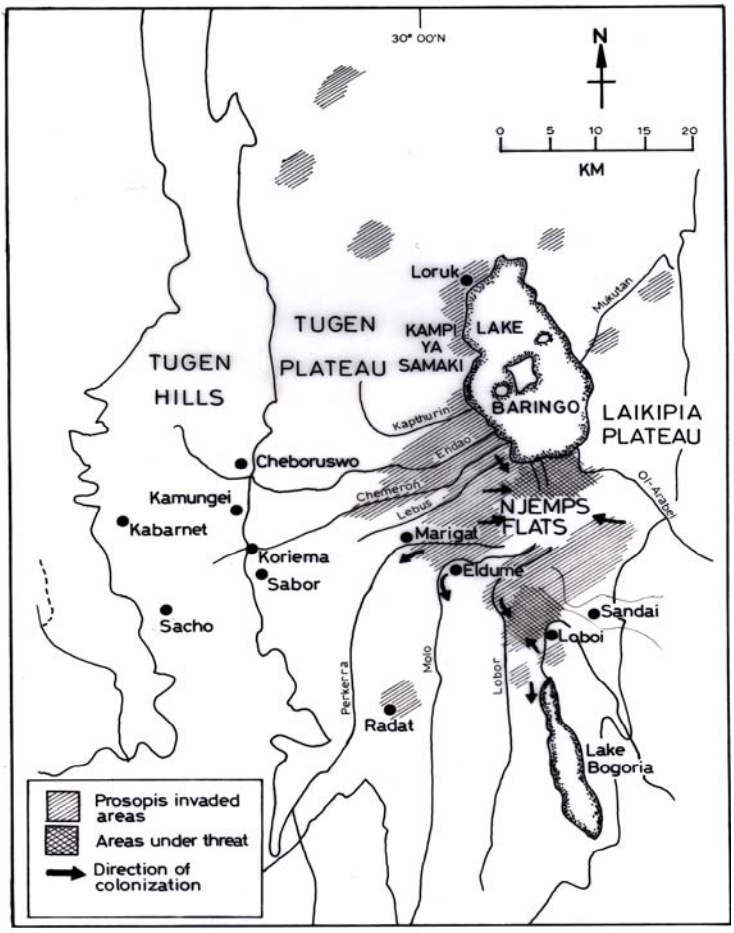
Photo: Aike G./Zeila A.

The administrative locations of Loboi and Ng'ambo were selected for a household-level study of benefits, costs and institutions affecting the control of *Prosopis juliflora*. According to the expert opinion of local residents, government officials and NGOs based in Baringo, these two areas represent a density gradient from very high densities of *Prosopis juliflora* in the Ng'ambo areas where the initial planting sites were, through to Loboi on the northern edge of Lake Bogoria, with moderately dense stands of *Prosopis juliflora*. The Loboi area is at the edge of Lake Bogoria National Reserve where there are individual trees of *Prosopis juliflora*. In each of these two locations, villages with the densest stands of *Prosopis juliflora* were selected for sampling with the guidance of local residents, government officials and NGO workers. In Ng'ambo location, the four villages of Masai, Chemonke, Keperr, and Nairrag-Enkare were selected. In Loboi location, two villages, Tingtinyon and Kapronguno, as well as the Loboi trading center area, were chosen.

The study area is hot and dry throughout most of the year. Rainfall is highly variable, both annually and interannually. Average annual rainfall is 650 mm with weak bimodal peaks recorded from March- May and June-August. Temperatures vary from 30^{o}C to 35^{o}C and can rise to 37^{o}C in some months. The monthly mean maximum temperature is usually 30^{o}C; with the mean minimum varying from 16- 18^{o}C. Vegetation in the area is comprised of Acacia trees (mainly *A. tortilis)* in association with *Boscia* spp and *Balanites aegyptiae* and bushes of *Salvadora persica*. The ground is generally bare springing up with ephemeral herbs when it rains. This sparse vegetation gradually gives way to bush savanna grassland towards the uplands in the eastern, western and southern extremities of the area. Vegetation becomes more sparse towards the north of the area.

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 uplands. They contain high levels of P, K, Ca and Mg and low levels of N and C. They range from acidic to slightly alkaline. While the soils are generally fertile, high evapotranspiration rates and low, variable rainfall, create water scarcities that limit intensive agricultural use. Irrigation practiced on Ministry of Agriculture demonstration plots yields a wide range of products including maize, tomatoes, onions and watermelons (Andersson, 2005).

Map 5: Status of *Prosopis* spp. invasion in Baringo



Source: Choge et al., 2002

Human population density in the study site is relatively low by Kenyan standards, about 21 persons per square kilometre, with a total population of 26,985 people in Marigat division according to the 1999 census. Ng'ambo location has 4,060 people, while Loboi location has a total population of 1,251. The people of Ng'ambo and Loboi locations belong to two main ethnic groups, the Il Chamus and the Tugen. The Il Chamus (also known as Njemps), are a Maa-speaking group, who inhabit the lowlands around Lake Baringo. The Tugen are a Kalenjin-speaking group who occupy the Loboi area.

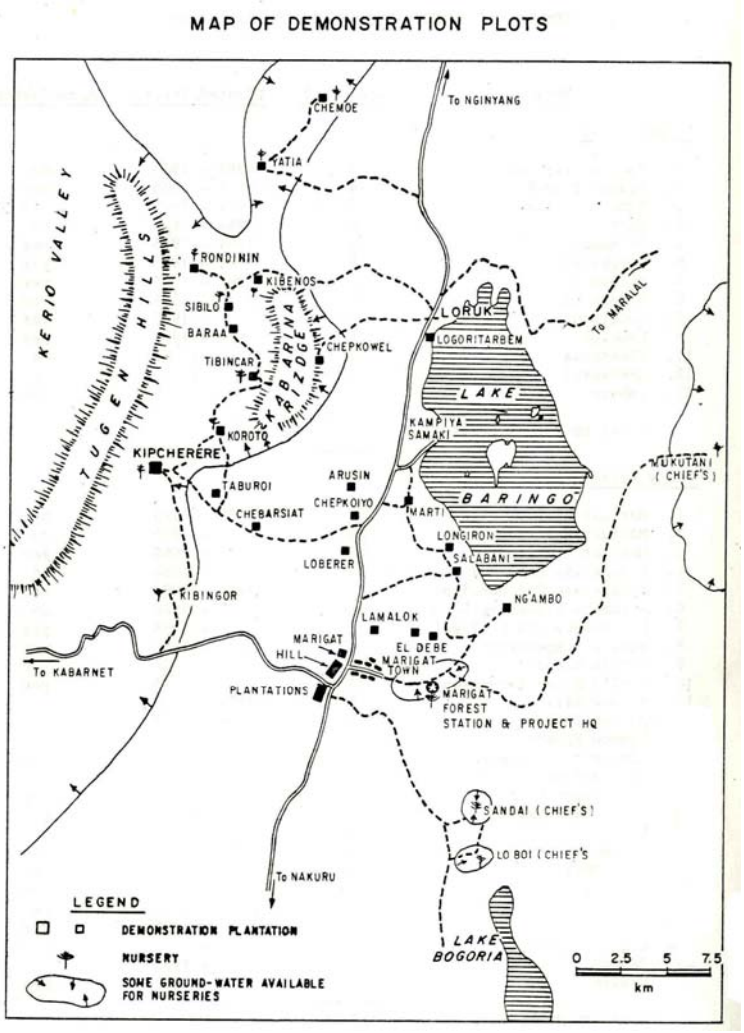
A range of formal government organizations, non-governmental organizations and traditional institutions are active in Baringo District. In Marigat Division there is a heavy presence of government administration, including line ministries such as Agriculture, Livestock and Marketing, Environment, Health, etc. The Rehabilitation of Arid Environments (RAE) Trust is a non-governmental organization that has been active in range rehabilitation and reseeding in various parts of the Division for more than 20 years. In order to stimulate an interest in the

commercialization of *Prosopis juliflora* products, RAE Trust recently purchased *Prosopis juliflora* poles from individuals in Ng'ambo location. The WorldWide Fund for Nature has undertaken a community-based wetland management programme in the Lake Bogoria area for the past five years.

Traditional institutions such as elders' councils are active among the Il Chamus and Tugen ethnic groups, although the authority of these institutions has declined as government agencies and statutory law have taken over the functions of land allocation and conflict resolution that previously were prime activities of the traditional councils. Most land in Baringo District currently held under the communal tenure regime of the Group Ranch, an institution established via the Land (Group Representatives) Act of the 1960s. There are nine group ranches in the Lake Baringo area. As in some other parts of Kenya, there are moves toward individualization of these group ranches. At present, three of the group ranches are in the process of sub-division, while two others have formally requested sub-division.

The main sources of cash income in the area are sales of livestock, fishing in Lake Baringo, and sales of honey. Data from the 1997 Welfare Monitoring Survey indicates a poverty rate of 37% in Baringo District, the lowest of any district in Rift Valley Province. The Il Chamus people are mainly livestock keepers who practice some rainfed agriculture and irrigated agriculture. Some Il Chamus people also fish in Lake Baringo. The Tugen people are more mixed crop-livestock producers. The main land use in the area 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 designated for habitat and species conservation. Local and international tourism generates revenue for local administration in these areas.

Map 5: Map showing the location of study sites



Source: FAO, 1992

Research methods

The following methods were used to collect information: review of literature, semi-structured interviews, and unstructured interviews. Data were analyzed using simple statistical procedures and used in simple quantitative analyses of the individual benefits and costs of *Prosopis juliflora*.

Review of literature and archival material

Project assessment reports, workshop presentations and correspondence were reviewed in order to establish the institutional/organizational pathways of *P. juliflora*'s introduction, follow up strategies, and challenges faced by relevant implementing agencies.

Semi- structured interviews

A semi-structured interview was administered to individuals who were selected to ensure representation of different gender, age, occupation, and wealth categories. The questionnaire for that interview is contained in Appendix I. In Ng'ambo location, a random group of individuals, cutting across gender and wealth for each of the four selected villages of Masai, Chemonke, Keper and Nairrag-Enkare were selected from the list of residents maintained by the location chief. Not all individuals were available for interviewing: some had moved to other sites due to *Prosopis* invasion and / or displacement by floods, while others on the list actually lived and worked in urban centres. In these cases, neighboring households to those randomly selected were interviewed. In the Loboi villages, the chief's list proved to be unreliable due to the scattered nature of settlement. An attempt was made to interview as many households as possible within the limited resources of the project. In each household sampled, the male head and his first wife were interviewed. Female-headed households were included in the interview. A total of 30 questions were asked about the following:

1. Who introduced the species, when and whether the individual was involved in the introduction;
2. Whether the species density had increased or decreased, where and why
3. The general effects of this increase on other plant species, particularly grasses and forbs that form the undergrowth;
4. The most important products harvested from *Prosopis*, quantities harvested, whether for subsistence and/or sale. If sale, where sold, at how much;
5. Constraints faced in the harvest and/or sale of products;

6. Knowledge of alternative uses from those mentioned, and whether interested in alternative uses for the species and reasons why;
7. A list of the nature of problems faced regarding the species, and a quantification of the effects of these problems;
8. Whether management, control or regeneration of the species was undertaken and where this has been done, the costs of these activities, and whether done individually or by groups;
9. The kinds of interventions they would like regarding the species and who would implement the intervention.

In Ng'ambo area 65 individuals were interviewed, 36 male and 28 female, in the four villages of Chemonke, Keper, Masai and Nairrag-Enkare. The individuals ranged in age from 16 to 65. The majority (55.7%) identified themselves as farmers; about 15% identified themselves as both farmers and herders; 8.2% as herders alone, 8.2% as traders/business persons, and the rest were students, civil servants or teachers. Most (52%) were educated to the upper primary level i.e standards 6-8, while a large proportion (22%) had not gone to school. About 19% went to secondary school, while 8% went to lower primary.

In the Loboi area a total of 48 individuals were interviewed in two villages of Tingtinyon and Kapronguno, as well as a handful of people from the Loboi Trading Center. There were 23 males interviewed and 25 female. Four assistants in Ng'ambo and three assistants in Loboi assisted administration of interviews. Fieldwork was conducted over a 3-week period in March of 2004.

Unstructured interviews

Unstructured interviews were conducted with key informants selected from government agencies, local and district government administration, NGOs and community based organizations to find out their respective roles in the specie's introduction, management, control and use. These interviews were also intended to find out desired interventions and the role of respective agencies in this initiative, as well as to verify any allegations from the individual interviews within the selected communities.

Individuals interviewed were from the Ministry of Agriculture, Kenya Agricultural Research Institute, Worldwide Fund for Nature (WWF), Lake Bogoria National Reserve, World Vision International, RAE Community Trust, and district officers such as chiefs and the district development officer. The list of names and organizations is presented in Appendix II and the question guide is presented in Appendix III.

Data analysis

The value of direct costs and benefits was estimated in Kenya shillings for products harvested for direct use (both subsistence and trade) as well as for direct losses associated with *Prosopis* invasion. At the time of the study, the average exchange rate was approximately 1US$ = 75 Kenya Shillings.

Calculating benefits

Benefits were estimated from individuals' responses to a question that sought to find out the quantities of various products harvested from *Prosopis* and whether those products were was used for home use, sale or both. Quantities harvested, whether they were for sale or home use or sale, were used to estimate total value derived from those products. Prices were averaged for respondents in each location who gave Kenya shilling values, and these prices used to calculate the value of both home consumed and marketed products. For example in the case of firewood, even though most individuals mentioned that they harvested firewood chiefly for subsistence, they did indicate the number of backloads they collected per week. Because a backload of firewood sold at an average of Ksh 50 in Ng'ambo (or Ksh 30 in Loboi), the value of this quantity for an entire year was determined, as firewood collection is a yearlong activity. Depending on the quantity of item harvested, and the frequency of harvest in each year, a total benefit to each individual for each product for an entire year was calculated.

The unit of harvest and frequency of harvest varied with the type of product harvested. In the case of fencing and construction poles, for example, individuals indicated the number of poles/posts harvested each year. In the case of honey, they indicated the quantity in kilograms harvested, how many times per year. For charcoal, the total number of bags harvested; for pods, the number of sacks harvested each season; and for ropes, the total number of bundles harvested. In the case of *Prosopis* pods, however, most individuals could not estimate the amount of pods consumed by his/her livestock, primarily goats. A few were able to estimate the quantities or *Prosopis* pods harvested, in terms of sacks, for an entire dry season, from January to April. Such quantities were used to extrapolate to those who were unable to estimate pod consumption.

Table 1: Average costs of products generated from Prosopis Juliflora in the two study sites

Harvested Item	Ng'ambo (costs in KShs)	Loboi (costs in KShs)
Construction poles	13sh per pole	15sh per pole
Fencing poles	15sh per pole	15sh per pole
Fuelwood	50sh per backload	30sh per bundle
Honey	100sh per kilogram	75sh per kilogram
Charcoal	170sh per sack	150sh per sack
Pods	10sh per sack	Not indicated
Ropes	24sh per bundle	Not harvested

Source: Authors' analysis of survey data

Calculating costs

Individuals' responses to other questions on the questionnaire was used to quantify losses in Kenya shillings from *Prosopis* invasion and the labor costs of clearing / managing / controlling *Prosopis* from individuals' fields and homesteads. The cost of human labor in *Prosopis* management (i.e. uprooting whole plant, uprooting seedlings, cutting, burning, pruning, clearing undergrowth) was provided in Ng'ambo. In Loboi, very few individuals undertook any form of management and labor costs were not clearly specified, consequently, labor costs from Ng'ambo were applied in Loboi. In Ng'ambo, the average cost of labor was 50Ksh per day. Each working day was roughly 6 hours long, with each working week comprised of 6 days. These figures were used to estimate total cost of labor for each management activity where the number of laborers and the amount of time spent on each activity was provided.

Some individuals only provided the amount of money they spent uprooting an acre. If they did not provide the total number of acres cleared, then only the absolute figure he/she mentioned was taken as a cost. Other individuals indicated that they enlisted the help of family or friends, but did not provide a quantitative estimate of the number of persons involved. In these cases, it was assumed that four individuals were involved in the control operation. In cases where individuals paid for labor by providing local brew instead of cash, conversations with experts indicated that the cost of beer brewed would tally very well with the cost of labor, this being a more convenient mode of payment for some individuals at certain times. Where rotational labor groups were used for management activities, labor costs were also calculated using the average cost of 50 Ksh / day / individual.

In order to calculate the cost of livestock deaths allegedly via *Prosopis*, local agricultural officers from their annual agricultural reports provided three-year average figures for costs of these items at Marigat central market. For the past three years, a healthy cow sold at Ksh 8,000 and an unhealthy cow for Ksh 4,500 at the Marigat market. The average of these figures, Ksh 6,250, was used to calculate the cost of each cattle death. Sheep and goats were over the past three years were sold at Ksh 1,100 for healthy animals and Ksh 650 for unhealthy animals. Thus, an average price of Ksh 875 was used to calculate the cost of each sheep or goat death. Over the same past three years, a 90kg bag of maize fluctuated between Ksh 700 and 1,100, with an average of about Ksh 800, while bean prices fluctuated between Ksh 2,700 and 3,000 for a 90 kg bag.

Statistical analysis

Data analysis relies primarily on the use of simple descriptive statistics such as percentages and averages. Chi-square analysis is also employed to analyze whether variation in the social categories of gender, age, education, occupation and village residence influenced how *Prosopis* is used. The association between each of these social categories and the different uses such as fuelwood, construction/fencing poles, honey production, pods for fodder, ropes, etc was examined. Analysis of variance was conducted to help determine the variation in the distribution of the costs and benefits of *Prosopis* management across the social direct benefits of *Prosopis julifora.*

Findings

Narrative of prosopis juliflora in Baringo

Prosopis juliflora was introduced into Baringo district through the efforts of the "Fuelwood/afforestation extension in Baringo" project, a joint FAO/Government of Kenya initiative. This project originated from prior consultations that identified Baringo district 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 1983-85 and phase II from 1987-90, with a brief interruption in 1987 when FAO temporarily withdrew project management support.

The project's objectives were to:

1. Establish demonstration plantations incorporating trials of tree species and development techniques suitable for arid and semi-arid conditions;
2. Demonstrate integrated land use practices incorporating fuelwood production as an important component as well as management practices for community forestry;
3. Support and strengthen forestry extension activities in the Baringo district;
4. Evaluate the effects and impact of the government afforestation and extension scheme and suggest necessary modifications/improvements;
5. Provide other assistance as necessary to Kenya's Forest Department.

The project operated under the Ministry of Environment and Natural Resources, Forestry Department, coordinated by the Chief Conservator of Forests and the Provincial Forest Officer (Rift Valley) as the national project director. The project engaged in diverse activities including the establishment of demonstration plantations, recruitment of nomadic pastoralists and agro pastoralists into individual tree planting; trainings of beneficiaries; provision of employment to pastoral communities mainly through 'food for work basis,' and the establishment of a central seedling nursery and 19 smaller nurseries.

While the project became operational in February 1982, plantings were conducted in 1983 and 1984. Both were drought years with annual rainfall totals of only about 200mm, just 31% of the long-term annual average. Plots were established by local communities through food aid assistance from the World Food Program, which ensured continued field operations during the drought years when over 1000 local men and women were employed on food for work basis. Land acquisition for tree planting was through a lengthy negotiation between project staff and the pastoralist communities, who were initially apprehensive of committing their land for such ventures due to the fear that the Forestry Department might one day gazette such land, rendering it inaccessible to the traditional owners (Kariuki, 1993).

Tree species planted included leguminous species such as *Prosopis* spp., *Parkinsonia* spp., and *Cordia sinensis*, intended for fodder resources. Other hardy, drought resistant, fast growing species such as *Albizzia lebek, Cassia* spp., *Melia* spp., and *Eucalyptus* spp., were planted.

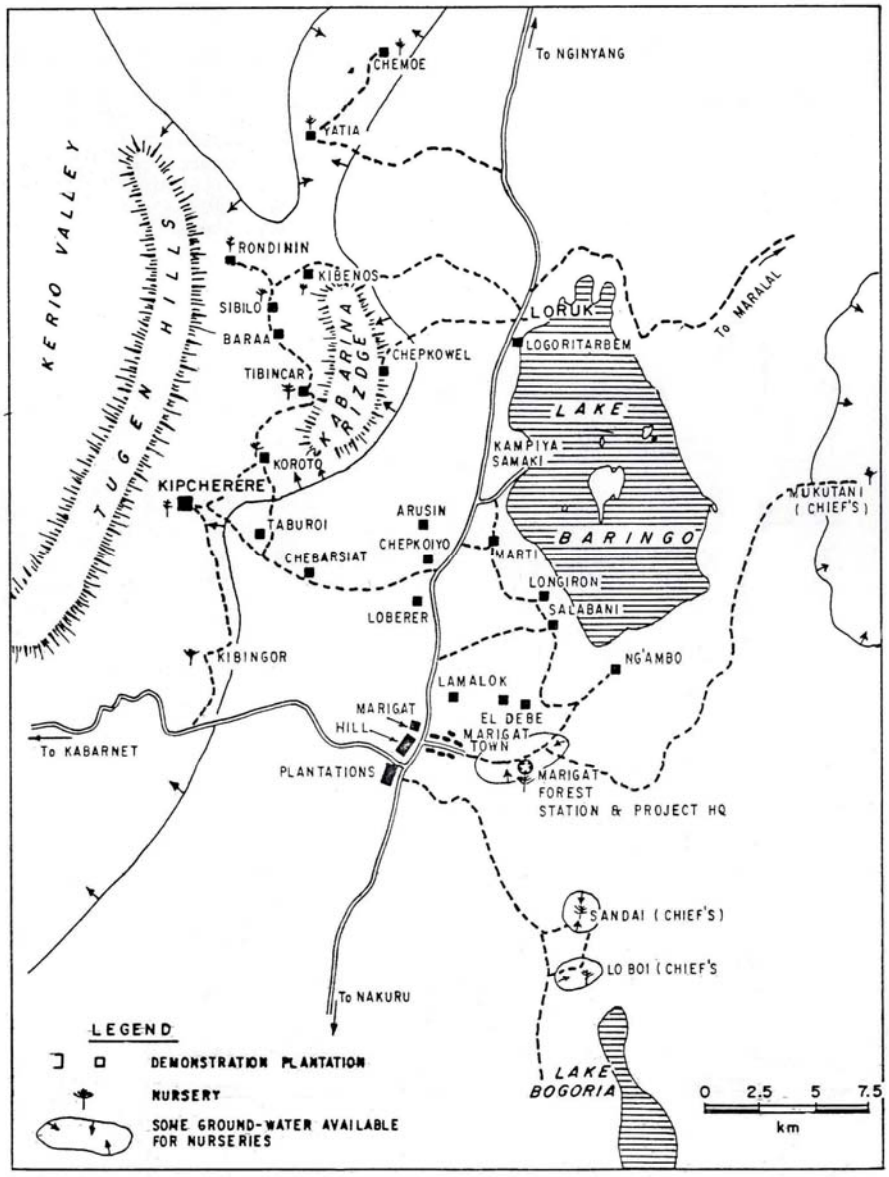
At the end of the first phase of the project, the project had established 12 extension nurseries, with a total potential annual output of 620,000 seedlings. 246 hectares of demonstration plantations had been established on 36 sites around the area (FAO, 1985), 14 in the Ilchamus area and 22 in the Tugen plateau. These demonstration plantations occupied a total of 246

hectares-140 hectares in the Il Chamus areas and 106 hectares in the Tugen areas. *Prosopis juliflora* was planted in all but six of the Tugen sites. During this period more than 60 tree species or provenances identified for fuelwood, fodder and fruit production were tried. Out of these 28 species, 18 were termed indigenous and 10 exotic (Ndegwa, 1988). *Prosopis juliflora* and *P. chilensis* were among the planted exotics.

Following a favourable appraisal of the first project phase by a tripartite (Kenya/Australia/FAO) review mission, the project was extended for a further three years from 1986-1988. Trees were planted in 19 more plots, covering 131.5 hectares. Most species planted at this time were exotics. For the Njemps flats in particular, emphasis was placed on four species: *Parkinsonia aculeata*, *Prosopis* spp., *Cordia sinensis*, and *Albizzia lebbek* (FAO, 1986). Emphasis was also placed on the integration of agroforestry tree species with sorghum, millet, cowpeas and green gram crops as a means of adding further value to the 1985 and 1986 demonstration plots.

Between April 1987 and March 1988 a further 22 plots were established on 166.5 hectares. *Prosopis* species were further recommended for farm-level extension, primarily on the Njemps flats. Most plots in the Njemps flats were fenced with barbed wire and protected by paid guards. In the Njemps flats, where pastoralism forms the main economic activity, tree planting outside the project demonstration plantations has been confined to mostly schools, with 60 individuals volunteering to intercrop trees with crops. By the end of the project in 1990, a total of 739.5 hectares of demonstration plantations had been established (Kariuki, 1993). The World Food Program's food-for-work agenda continued to provide most of the labor inputs to the project. Between 1983 and 1987, the cost of WFPs food rations was estimated at Kshs. 9 million.

MAP OF DEMONSTRATION PLOTS



It was the intention of the project to hand over the demonstration plots to the communities 18 months after establishment. Communities however declined to take over the management of the plantations for several reasons. Project beneficiaries were not ready or able to commit their meager financial, labor and other resources to the planting of trees where a market for fuelwood did not exist (Kariuki, 1993). Uncertainties in realization of tree benefits constituted a major disincentive for tree planting on communal land by individuals (FAO, 1992).

In addition, the project seems not to have worked out a benefit appropriation mechanism at the project design stage. Group ranches were introduced in the area at the same time creating some uncertainty regarding land ownership and control among and between the Tugen and Ilchamus pastoralists. Group ranch committees had not yet crystallized and did not enjoy the same authority as traditional leadership structures. Another challenge to the long-term sustainability of the project was its heavy reliance on the food for work programme of the World Food Program. By the end of the project food rations accounted for 34.7% of total project expenditure (Kariuki, 1993).

Perceptions of the invasion

It is now close to two decades since *Prosopis* spp were introduced in Baringo. Despite its stated benefits to both environment and economy, local communities are bitter about its negative impacts. The Ilchamus community, resident in the Ng'ambo area where the bulk of initial demonstration plots were established, are concerned about the magnitude of negative impacts associated with *Prosopis* prolific growth and establishment. On March 2nd 2004, the Il Chamus community, represented by a community-based organization, the Community Museums of Kenya, took their complaints before the National Environmental Management Authority's Public Complaints Committee. The PCC is an independent committee authorized under section 31 of the Environmental Management and Coordination Act of 1999 to investigate cases of environmental degradation as reported by the public (or even as gathered from other diverse sources) and to recommend appropriate action. It offers a simple avenue for conflict resolution without having to resort to the rigors of the court process.

Community Museums of Kenya presented a catalog of complaints to the Public Complaints Committee. Community Museums of Kenya leveled responsibility for the introductions against the Kenya Forestry Research Institute, whom they accused of having introduced the species in collaboration with the FAO. It was claimed that *Prosopis* caused soil erosion, resulting in flooding and siltation of Lake Baringo. Goats consuming *Prosopis* pods had problems with their teeth and produced bad tasting meat. The plant was alleged to lower the water table, leading to a drying up of swamps and ponds in a generally water scarce environment. Pollen from *Prosopis* is alleged to cause allergy and inflammation of the lungs, while the plants formed extensive thickets that choked other plants and threatened farming activities. They claimed that the introduction of *Prosopis* went against the provisions of the Noxious Weeds Act (Cap 325) of the Laws of Kenya. The local people were not involved in its introduction either. Community Museums of Kenya, on behalf of the Il Chamus community, demanded eradication of *Prosopis*. In the absence of sufficient information,

however, the PCC held against making a ruling until it visited the Ng'ambo area to verify the situation on the ground.

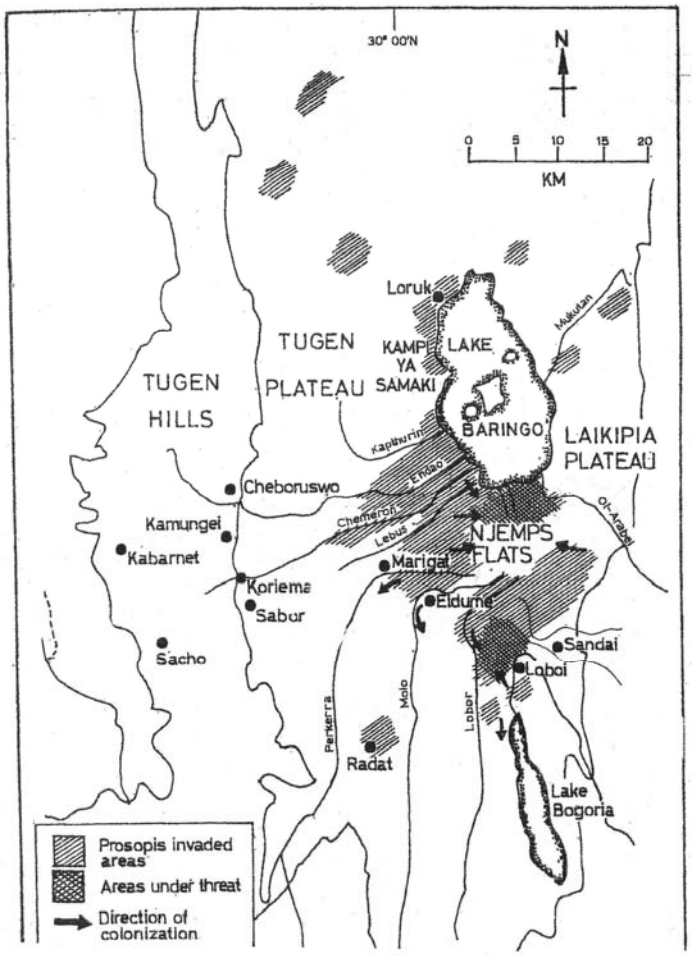
Prior to the Public hearing, the vices of *Prosopis juliflora* had captured the local print media's attention. In August of 2003, for example, *The East African Standard* featured the magnitude of threats posed by *Prosopis* to the Ilchamus community. It also featured, notwithout some embellishment, accusations and counter-accusations on *Prosopis* introduction that were flying between FAO, Community Museums of Kenya and the Ministry of Environment, Natural Resources and Wildlife. Yet another article made its way into the *Daily Nation* of November 13th 2003. This one from a local resident of Baringo, presumably from the Il Chamus community, who highlighted the species' strong thorns, its pods malformation of goats' dental structure, impenenetrable thickets that choke up important plants and destroy wetlands, and difficulties imposed on accessing Lake Baringo. More recently, the Director General of the National Environmental Management Authority added to the growing vilification of *Prosopis*. Concluding that *Prosopis* is "…a weed whose value is out-rated by the losses it poses." The director strongly advocated for its eradication by whatever means, chemical and/or manual. He stressed the need for urgent response (Michieka R. *East African Standard*, July 10th, 2004).

The public attention given to *Prosopis juliflora* invasion in Baringo has occurred against the backdrop of substantive efforts at understanding the *Prosopis juliflora* problem and its potential solutions, not only in Baringo but elsewhere in Kenya. Between October 2001 and January 2002, the Kenya Forestry Research Institute in collaboration with the Forest Department conducted an appraisal of the status and impacts of *Prosopis* invasion, its utilization by local communities, and the possibilities for commercial exploitation of its products by communities that have to live with it (Choge, et al, 2002).

Two years after the KEFRI/FD status inquiry, in October of 2003, KEFRI and Forest Department hosted a national workshop on the integrated management of *Prosopis* spp in Kenya (Choge and Chikamai, 2004). About 70 participants attended this workshop from a wide range of organizations and expertise, including local community leaders. Six technical papers on the status of *Prosopis* in different parts of Kenya were presented. An additional technical paper highlighted experiences of *Prosopis* utilization and management in other parts of the world. Working group discussions on policy, legislation, management, use, cultural and socio-economic issues, and research issues identified a framework for both short and long-term strategies for the integrated management of *Prosopis*. A cross-sectoral

Prosopis Task Force was established to provide advice to the government on ways of managing the *Prosopis* problem in the arid and semiarid lands of the country in an integrated and sustainable manner. The *Prosopis* task force would work through the larger National Task Force on the Environment.

Map 6: Areas invaded by Prosopis spp in Baringo District



Areas invaded by *Prosopis* spp and those under threat in Baringo District

Source: Choge et al, 2002

Local perceptions of Prosopis

Enquiry into the status of *Prosopis* over the last 5-10 years indicates a general increase in the tree's density, both on communal grazing areas and on individually controlled areas such as homesteads and cultivating fields. The increase of *Prosopis* on 'individual' land was attributed to several factors, including difficulties in controlling the spread of the trees and the dispersal of seed by both livestock and water. Only 3% of the respondents observed that the plant had declined on their land because of their continuous efforts to control it. On

community land, however, it was acknowledged that *Prosopis* density had increased tremendously primarily because there were no organized attempts at controlling its spread. Further, the tendency of livestock to graze and concentrate on the communal grazing fields transported the seeds there through their droppings. Soil fertility was enhanced by livestock droppings, creating good conditions for *Prosopis* growth. The communal grazing fields are located around the shores of Lake Baringo, where water is readily available, further enhancing the conditions for the growth and proliferation of *Prosopis.*

Ground cover of herbaceous species underneath *Prosopis juliflora* stands have decreased on both communal and individually controlled land. *Prosopis juliflora* roots and leaves are detrimental to the growth and establishment of other species. *Prosopis juliflora* stands are also thought to cast sufficient shade to suppress undergrowth establishment, while placing high demands on water and nutrient capacities of the soil. These deleterious effects of *Prosopis* on the development of undergrowth are more intense on the communal grazing grounds where the stands are denser.

Ten years ago, roughly 10 years after *Prosopis* introduction in Ng'ambo, there wasn't much of a problem with *Prosopis* because it had not spread to the extent it has today. At that time *Prosopis* was somewhat scarce and was largely confined to the demonstration plots where it was initially planted. Individuals appreciated it as a fuelwood source and its environmental services function of binding the soil, reducing erosion and dust storms, providing shade, and reducing ambient temperatures. Now the *Prosopis* invasion has spread virtually everywhere, stifling other fodder species and forcing livestock to be fed almost exclusively on *Prosopis.* Ex-chief Nabori, a local leader who was active in the species' introduction, estimates that about 75% of Ng'ambo area is currently subject to *Prosopis* invasion. Murray Roberts, who has been managing and running sustainable resource management programs in the area for over 20 years, observes that about 300 square kilometers around the area has been invaved, with about 10,000 people directly affected.

Benefits and costs *of prosopis juliflora*

Direct benefits

The survey identified the same seven products of *Prosopis juliflora* in both study sites: construction poles, fencing poles, fuelwood, pods, ropes, honey and charcoal. Charcoal was far less important than expected. The variation between the two sites was also unexpected.

Construction poles were mentioned most frequently in Ng'ambo, but fourth most frequently in Loboi. Ropes and honey were mentioned by 27% and 26% of respondents at Ng'ambo, but only 2% and 2% of respondents at Loboi (See Table 2).

Table 2: *Prosopis juliflora* product use in the Ng'ambo and Loboi areas

	Ng'ambo (n=65)		Loboi (n=48)	
Product	Number of respondents reporting use	Percent of respondents reporting use	Number of respondents reporting use	Percent of respondents reporting use
Construction Poles	61	93.8	10	40
Fencing Poles	53	81.5	16	33
Fuelwood	47	72.3	28	58
Pods (for livestock fodder)	40	61.5	19	40
Ropes	18	27.7	1	2
Honey	17	26.2	1	2
Charcoal	3	4.6	3	6

Source: authors' analysis of survey data

All respondents admitted to some use of *Prosopis juliflora* products. Most (50 out of 65 respondents in Ng'ambo and 33 out of 48 in Loboi) users harvested *Prosopis juliflora* products only for subsistence. In both Ng'ambo and Loboi, 22 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;
- *Prosopis juliflora* is very hard to cut and wears down simple cutting tools;
- Lack of ready buyers;
- *Prosopis 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 punctures due to *Prosopis juliflora* thorns; and
- For those who sell poles, the heavy weight of the wood is an additional constraint.

Contrary to expectations, the statistical analysis revealed few statistical relationships between individual attributes of age, gender, occupation, wealth level (number of cows and shoats), education level, or village with the products harvested (Table 3). A gender difference was found regarding harvesting of fuelwood. Women in Ng'ambo harvested significantly more fuelwood than men (chi=7.64; significance.006). Many of the women respondents acknowledged that *Prosopis* has greatly reduced their fuelwood burden. Because the distances to fuelwood sources are much shorter, more trips can be made with less effort.

Household fuelwood needs are now adequately met. An additional advantage is that *Prosopis* fuelwood burns well even when wet. Chemonke village, which holds the densest stands of *Prosopis*, appears to harvest honey more than the three other villages of Keper, Masai and Nairrag-Enkare (chi=8.573; significance 036).

Table 3: Statistical relationships between respondent characteristics and the value of prosopis products harvested

Attribute * Product	Chi-square value	Significance
Gender * Fencing poles	.026	.567
Gender * Construction poles	.068	.593
Gender * Fuelwood	7.464	.006
Gender * Pods	.234	.412
Gender * Ropes	.398	.362
Gender * Honey	.673	.298
Gender * Charcoal	.139	.595
Village * Fencing poles	.413	.937
Village * Construction poles	1.742	.628
Village * Fuelwood	.977	.807
Village * Pods	.538	.910
Village * Ropes	2.870	.412
Village * Honey	8.573	.036
Village * Charcoal	3.536	.316
Age * Fencing poles	3.818	.431
Age * Construction poles	.760	.944
Age * Fuelwood	3.045	.550
Age * Pods	7.576	.108
Age * Ropes	2.496	.645
Age * Honey	2.640	.620
Age * Charcoal	5.105	.277
Education * Fencing poles	.354	.950
Education * Construction poles	2.305	.512
Education * Fuelwood	1.574	.665
Education * Pods	1.585	.663
Education * Ropes	3.563	.313
Education * Honey	4.225	.238
Education * Charcoal	1.431	.698
Occupation * Fencing poles	10.821	.094
Occupation * Construction poles	2.71	.843
Occupation * Fuelwood	5.296	.506
Occupation * Pods	2.049	.915
Occupation * Ropes	4.481	.612
Occupation * Honey	7.350	.290
Occupation * Charcoal	6.028	.420

Source: authors' analysis of survey data

Table 4 provides economic estimates of the benefits that individuals derive for each stated use in both Ng'ambo and Loboi areas. All products are valued at the average market prices prevailing at the time of the study in early 2004. Individuals in Ng'ambo area generate average benefits of Ksh 16,019 annually from the use of pods as dry season livestock fodder, construction poles, fencing poles, honey, fuelwood, charcoal and ropes (average exchange rate in 2003-4 was 75 Ksh = 1 US$). By far the most important product is fuelwood, with an average value of Ksh 5,140 per individual. Fencing materials and honey harvesting are also important in Ng'ambo. In Loboi, the average annual value of *Prosopis juliflora* products was Ksh 9,613 per person. Fuelwood is the most important benefit, with a mean annual value of Ksh 9,263 per person. The economic benefits derived from other products are negligible in Loboi.

Table 4: Economic value of *prosopis juliflora* products for individuals in the Ng'ambo and Loboi areas

	Ng'ambo (n=65)		**Loboi (n=48)**	
Product	Average value (Ksh)	Standard deviation of value (Ksh)	Average value (Ksh)	Standard deviation of value (Ksh)
Construction Poles	4,982	18,511	86	186
Fencing Poles	3,618	7,826	164	406
Fuelwood	5,140	4,215	9,263	26,522
Pods (for livestock fodder)	733	1,459	15	26
Ropes	22	58	0	0
Honey	1,297	3,761	31	216
Charcoal	228	1,688	53	242
Total for all 7 products	16,019	20,364	9,612	26,538

Source: authors' analysis of survey and market data

Construction poles, fencing poles, and fuelwood are available all year round. The products are harvested according to the needs and may range from once a year for fencing poles, to once every three years for construction poles. Fuelwood harvesting is a daily activity, often 3-4 times a week for the entire year. Pods for livestock fodder are usually harvested in the dry season, from December to March. Honey harvesting is variable, though it generally occurs in the periods following the onset of the long and short rains in April and October.

Problems associated with *prosopis juliflora*

The problems associated with the *Prosopis* invasion varied considerably between Ngambo, where the invasion has been most severe, and Loboi, where the invasion is far less server. In Ngambo, respondents noted the most severe problems to be reduction of pastures for livestock grazing, reduced farm lands and associated opportunities for cultivation, and the

disfiguration of livestock gums (especially goats) and tooth decay, both of which result in deterioration of livestock health and sometimes death.

In Loboi, on the other hand, the incidence of malaria associated with the expansion of *Prosopis* thickets was the most frequently mentioned problem. Disfigured jaws were the second most frequently cited problems with up to 55% of the respondents. Even though about 70% of the individuals identify themselves as farmers, only about 5% of the respondents indicated that *Prosopis* is a problem in their pursuit of farming activities, while just about 12% admitted to *Prosopis* being a key factor in reducing available pastures for livestock (Table 5).

Table 5: Problems associated with *Prosopis juliflora* in the Ng'ambo and Loboi areas

	Ng'ambo (n=65)		Loboi (n=48)	
Problem	**Number of respondents reporting problem**	**Percent of respondents reporting problem**	**Number of respondents reporting problem**	**Percent of respondents reporting problem**
Disease-malaria	21	40	24	60
Dental condition in goats	31	59	22	55
Strong, poisonous thorns	16	30	16	40
Declining pastures	36	68	5	13
Reduced farm lands	32	60	2	5
Ground cracking	6	11		
Drainage problems	4	8		

Source: authors' analysis of survey data

The prolific growth and invasion of communal grazing lands that are located around the Lake Baringo is alleged to have reduced the amount of pastures available for local livestock. Because of its deep rooting system that consumes much moisture as well as shading under its thick canopies, *Prosopis juliflora* discourages grass growth and hence there is little or no grass for livestock. Livestock are now more frequently driven to pastures further afield such as Rugus, Loruk, and Kiserian and Sokotei that are about 30 km, 40Km, 18Km and 16 Km away from Ng'ambo area. They are also increasingly driven to Muchongoi on the Laikipia escarpment, about 50 Km away from the Ng'ambo/Marigat area. In some of these areas, however, livestock from Ng'ambo are denied pastures as resident communities fear that the *Prosopis* problem may be spread there as well. Because of increasing fodder shortage, two individuals have had to purchase hay to supplement their livestock's feeding. Women also complain that grass for thatching houses is harder to find now.

For the majority, who also happen to be farmers, the prolific expansion of *Prosopis* places a distinct threat to their farming activities. Many cite the continuous, and costly, process of clearing as an added set back to their farming activities. Only those who can afford to pay for labor to clear *Prosopis* are able to have land for cultivation. Some individuals, mainly from Chemonke viallge, claim to have been displaced from their original settlements/homes by *Prosopis*. They have had to seek alternative settlement elsewhere sometimes having to lease land for cultivation in these new areas. Conflicts may arise as the displaced seek alternative settlements.

The alleged disfiguration of goats' jaws due to the hard pods of *Prosopis* and the tooth decay resulting from the pods' high sugar content is a problem that is highly ranked by respondents. The hard seeds of *Prosopis* lodge between gums and teeth leading to inflammation; livestock jaws are eventually disfigured. These complications in livestock dentition, primarily among goats, result in declining livestock health and in some cases death due to starvation. Often individuals are forced to sell their livestock to avoid death, yet such sales fetch poor prices. The dense stands of invading *Prosopis* are a favored mosquito habitat, and the high incidence of malaria is associated with *Prosopis* invasion. These dense stands may sometimes harbor predators, which prey on young goats.

The sharp, strong and poisonous thorns of *Prosopis* were cited as a major problem. Thorns make it difficult for individuals to penetrate the dense thickets to harvest fuelwood. More commonly, thorns cause serious inflammation that may take a week to subside. In some cases, if left untreated infections may require amputation of limbs. There is a case of a woman losing her eye following *Prosopis* thorns pricking her eye.

Respondents also cited effects on water resources and infrastructure. Respondents alleged that the effect of *Prosopis juliflora* leaves dropping on water results in some form of pollution. It makes the water bitter. *Prosopis juliflora* stands interfere with drainage, blocking watercourses and exacerbating the periodic effects of flooding. Its extensive rooting system results in deep cracks in the ground, which pose particular risks for young goats. *Prosopis* has blocked key paths and roads used by both humans and livestock, requiring longer walking times to get to desired destinations. For example, while it used to take two hours to Loruk, it now takes about 6-8 hrs. One elderly man in a moment of frustration observed that he know has to walk with a *panga* at all times in order to clear his way of *Prosopis*. A large amount of labor is required to clear dense *Prosopis* thickets from existing paths/roads; currently labor is supplied for this purpose via the World Food Program's food

for work initiative. *Prosopis* is also alleged to have killed off other important and useful native trees such as *Iltepesi*, *Ilkiloriti*, *Ilwai*, *Kalalia* (Euphorbia spp.).

In Ngambo location, about half of the respondents admitted to having at least some form of conflict, though often resolved and resolvable, following the invasion of *Prosopis*. These conflicts centered on access to resources due to displacement from homes and farms (52%) and with trespass (48%). Individuals who have been unable to control the spread of *Prosopis* invade other peoples' farmlands. People from Chemonke, where the *Prosopis* invasion is most intense, have for example moved to Keper and to Loropil creating tensions among local families. Remaining available land is insufficient for expanding households.

According to local elder Charles Nabori, who was the local chief during the introduction of *Prosopis* in 1984, community members are now blaming their leaders for having facilitated *Prosopis* introductions on their land. As mentioned earlier, *Prosopis*-free areas are now disallowing livestock, particularly goats, from areas where the *Prosopis* invasion is most intense. Conflicts between Il Chamus and Pokots over access to pasture are on the rise especially at Rugus. In addition, one young woman mentioned that the warriors at Ng'ambo no longer allow her to cut grass in the grazing field for selling and for thatching houses because of the declining pastures.

Data from the survey was combined with estimates of the value of livestock to estimate the in-kind economic costs associated with the combined effects of two of these problems: dental problems and loss of pastures leading to death of cattle, sheep and goats. The results are presented in Table 6.

Table 6: Estimates of some of the in-kind economic costs of the *Prosopis juliflora* invasion for individuals in the Ng'ambo and Loboi areas

	Ng'ambo (n=65)		Loboi (n=48)	
Cost	**Average value of loss per respondent (Ksh per year)**	**Standard deviation of value (Ksh per year)**	**Average value of loss per respondent (Ksh per year)**	**Standard deviation of value (Ksh per year)**
Losses of goats	6,529	8,931	2,133	3,962
Losses of sheep	1,400	4,390	0	0
Losses of cattle	29,807	100,321	520	2,834
Total livestock losses	37,737	102,188	2,654	5,334

Source: authors' analysis of survey and market data

Controlling the invasion

Minimum efforts to control the *Prosopis juliflora* problem have been undertaken at the group level. In 2001, the local chief and elders of Ng'ambo location mobilized the community, including women and youth, to remove *Prosopis juliflora* from communal areas in order to open up land for cultivation. After clearing, a lottery system was to be applied to allocate the reclaimed land, with each household to receive a between 1 and 8 acres. While the community successfully cleared *Prosopis juliflora* from parts of the area, the project was disrupted by the onset of rains. That year the river happened to burst its banks and change course, flooding the entire cleared area. The effort was abandoned and *Prosopis juliflora* has since re-colonized the area.

However, all individuals interviewed in the Ng'ambo area and most individuals in the Loboi area have undertaken some form of control intervention on land that is *de facto* considered to be their 'own,' that is 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 (52 of 65 in Ng'ambo) uproot or cut *Prosopis juliflora* trees on their crop fields, usually once a year during land preparation. This arduous work requires the joint efforts of family members and sometimes engaging the services of casual labourers. About 50 individuals claimed to uproot seedlings, mostly on their own land. The frequency of this activity varies quite considerably from only once a year (14 individuals) to four times per year (10 individuals). 10 respondents indicated that they uproot seedlings continuously through the year. Uprooting of seedlings is primarily conducted alone. 17 individuals prune *Prosopis 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 standard cost for casual labour of 50Ksh/6 hour day (average exchange rate in 2004/5 is US$1 = 75Ksh). Results are presented in monetary terms in Table 7. Overall, the average cost per respondent was Ksh 6,232 (or US$83) per year in Ng'ambo where the invasion is high and Ksh 1,222 (or US$16) per year in Loboi where the invasion has been less severe.

Table 7: Individual labour costs for managing/controlling Prosopis juliflora

	Ng'ambo (n=65)		Loboi (n=48)	
Cost	Average value (Ksh / year)	Standard deviation around mean (Ksh / year)	Average value (Ksh / year)	Standard deviation around mean (Ksh / year)
Cost of management /control on individual land	6,242	1,189	1,221	684

By combining the analysis of the value of *Prosopis juliflora* products, livestock losses and costs of control, we are able to generate a first estimate of the individual-level benefits and costs of *Prosopis juliflora* for local households. Table 8 summarizes the results.

Table 8: Average individual benefits and losses due to Prosopis juliflora for villages in the Ng'ambo and Loboi areas

Villages in Ng'ambo area	Average benefits (Kshs/year)	Analysis of variance (Kshs/year)	Average losses (Kshs/year)	Analysis of variance (Kshs/year)	Average net benefits (Kshs/year) (- indicates net loss)
Nairrag-Enkare (N=17)	13,539	F=.771 P=.515	20,794	F=2.628 P=.058	-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					
Tingtinyon (N=20)	8,456	F=.680 P=.512	2,144	F=.274 P=.762	6,312
Kapronguno (N=21)	13,758		3,310		10,448
Loboi Center (N=7)	478		2,143		-1,665

Source: Authors analysis of survey and market data

The results presented on Table 8 show that losses due to livestock death and cost of control exceed benefits derived from sale and use of *Prosopis juliflora* products in all villages in the Ng'ambo area; while the benefits exceed losses in two of the three villages studied in the Loboi area. In the Ng'ambo area, the highest losses are associated with individuals who identified themselves as herders and / or farmers (differences were very large, although not statistically significant). These results show that the costs of clearing *Prosopis juliflora* from farms are high and are incurred every year. Herders seem to be the hardest hit by the proliferation of *Prosopis juliflora*, in spite of the benefits of *Prosopis juliflora* as a valuable fodder during periods of scarcity.

It is important to emphasize, however, that Table 5 presents only 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 of benefits and costs by gender

Table 9 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 *Prosopis* 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 *Prosopis* products such as construction/fencing poles and because they more often than not harvest more *Prosopis* products than women do. Most women focus on harvesting fuelwood, primarily for subsistence. However, men also incur higher losses than women do because they consciously factor in the effects of livestock losses. More often than not, they are the ones who trade in livestock and are more attuned with the losses. However these gender differentiated costs and benefits are not statistically significant in Ng'ambo (F=1.11; p=.296).

In Loboi, however, though average losses are low, women tend to experience higher losses from *Prosopis* than men. They also receive much greater benefits, almost 17 times, than men (F=5.050; p=0.29). *Prosopis* in Loboi is less widespread, the range of uses are limited mainly to firewood consumption by women.

Table 9: Distribution of benefits and costs by gender

Area	Gender	Average Benefits (Kshs)	Analysis of variance	Average Losses (Kshs)	Analysis of variance
Ng'ambo	Male (N=36)	17427.317	F=1.11	55399.31	F=2.313
	Female (N=28)	12290.536	P=.296	16375.00	P=.133
Loboi	Male (N=23)	1001.513	F=5.050	1597.826	F=.191
	Female (N=25)	17534.826	P=.029	3625.000	P=.191

Distribution of benefits and costs across village areas

Table 10 presents an analysis of the distribution of benefits and costs across village areas. Quite clearly, Chemonke village in Ng'ambo experiences the lowest benefits and highest osts of living with *Prosopis*—close to 5 times the costs incurred by other neighboring villages (F=2.628; p=0.058). This is a statistically significant result that has a lot of empirical importance. Field observations and interviewee comments indicated that Chemonke village had the highest density and greatest invasion from *Prosopis*, to the extent that many residents had abandoned their homesteads for other neighboring areas such as Loropil.

The invasion of *Prosopis* in Chemonke is greatly enhanced by overspill/flooding when the Perkerra river changed its course. It may well be that the detrimental effects of *Prosopis* in Chemonke are magnified by periodic floods. The displacement of individuals from their home areas makes it less likely that they would also appreciate the benefits of *Prosopis*. In Loboi, on the other hand, there seems to be little variation in the magnitudes of costs and benefits by village (F=.512; p=.762). Note that these estimates do not include the many other costs associated with high invasion of prosopis.

Table 10: Distribution of benefits and costs across village areas

Village in Ng'ambo area	**Average Benefits (Kshs)**	**Analysis of variance**	**Average Losses (Kshs)**	**Analysis of variance**
Nairrag-Enkare (N=17)	13539.929		20794.117	
Masai (N=19)	21750.021		22763.157	
Chemonke (N=12)	11647.183	F=.771	109802.083	F=2.628
Keper (N=17)	15179.588	P=.515	20544.117	P=.058
Village in Loboi area				
Tingtinyon (N=20)	8456.540		2143.750	
Kapronguno (N=21)	13758.361		3309.523	
Loboi Center (N=7)	478.435	F=.680 P=.512	2142.857	F=.274 P=.762

Table 11: Distribution of benefits and costs across occupations

Occupation in Ng'ambo	**Average Benefits (Kshs)**	**Analysis of variance**	**Average Losses (Kshs)**	**Analysis of variance**
Student (N=3)	6718.133		10208.333	
Farmer (N=34)	20347.000		39386.029	
Business (N=5)	9721.560		14575.000	
Teacher (N=4)	15458.100		6437.500	
Civil Servant (N=1)	18744.000	F=.544 P=.773	25000.000	F= .498 P=.807
Herding (N=5)	14558.880		109675.000	
Farming & Herding (N=9)	9387.444		37666.666	
Occupation in Loboi				
Farmer (N=18)	909.152		1076.388	
Teacher (N=2)	2125.125		437.500	
Civil Servant (N=2)	239.000	F=1.247	.000	F=.905
Herding (N=2)	1217.500	P=.325	.000	P=.497
Farming & Herding (N=1)	458.750		5250.000	
Housewife (N=1)	3120.000		.000	

In the Ng'ambo area, the highest losses are associated with individuals who identified themselves as herders and/or farmers (Table 11). Although it is not a statistically significant result, it is worth elaborating these effects. The costs of clearing *Prosopis* from farms are extensive and accrue every first quarter of the year, prior to the long rains, during land preparation. Herders in their turn seem to be the hardest hit by the proliferation of *Prosopis* despite its benefits as a valuable fodder during periods of scarcity. *Prosopis* tends to stifle the growth of favored grasses and is much associated with a declining trend in pasture availability. Its proliferation especially in the communal grazing area where control efforts are minimal is particularly detrimental to the well being of livestock. *Prosopis* pods also allegedly result in the decline of animal health, with animals either dieing or being sold at low prices. Given these interrelated factors, it is not surprising that herders might on average experience higher losses relative to people to pursue other livelihood strategies. It is also worth noting that the effects of periodic droughts in the area may compound the *Prosopis* problem, and may be difficult to partition out livestock losses due to drought conditions.

In Loboi, the partitioning of benefits and losses across diverse occupations in an analysis of variance does not yield a statistically significant result and is less easily interpretable than in Ng'ambo. In general, the two teachers and one housewife interviewed seem to capture most of the *Prosopis* benefits. Similarly the one individual who claims to be both a farmer and a herder incurs the greatest amount of losses from *Prosopis*. This result may be an artifact of the small numbers of individuals in those categories. What is surprising though is that the two herders interviewed failed to register any losses.

Overall, both benefits and costs are much higher in Ng'ambo than in the Loboi area.
This is not surprising. More numerous and larger size of areas planted initially in Ng'ambo and the establishment and invasion of *Prosopis* is much higher in Ng'ambo than in Loboi. Periodic flooding in Ng'ambo may have enhanced stand growth. This does not mean that the Loboi area is not under threat, it is just that the stage of invasion may not be as advanced as in Ng'ambo but still important, particularly because of the presence of Lake Bogoria National Reserve, a world-renown biodiversity conservation area.

Local Perceptions of *prosopis juliflora* control

Public operations for control of *Prosopis juliflora* were under consideration at the time of this survey in early 2004. To inform those plans, we asked respondents questions about the type of eradication or control operations that they would prefer. In both study sites, about 85-90%

of the respondents favoured complete eradication of *Prosopis juliflora*, through mechanical uprooting or application of chemicals, and replacement with other trees that would be less invasive and thornless. Respondents also suggested that the thornless 'brother' of *Prosopis juliflora* be introduced and/or left out during eradication, as they do not consider it to be invasive. About 10-15% of respondents wanted *Prosopis juliflora* to remain because of its numerous benefits. Several remarks, as follows, capture the rationale for eradication;

> "destroy the existing (*Prosopis juliflora)* first then later learn new ways of using it but currently my children are in school and I rely on livestock to support their education…here is an enemy that is wiping out my livestock."-44-year-old male.
>
> "it should be totally eradicated despite of its benefits because it is occupying a big land and soon it will displace all of us."-32-year old female

Those supporting control argue as follows:

> "if I say we eradicate, I need firewood and shade.control its spread but not eradicate completely." -57 year-old male.

Most respondents indicated that individual households should be involved in clearing *Prosopis juliflora* from their own fields, but with government assistance. On public lands, about 60% of individuals suggested that the Government of Kenya should conduct or lead eradication efforts. Forty percent of people favour a greater role for local communities, with some help from external actors, including government and non-governmental organizations.

Conclusions

Twenty years ago *Prosopis juliflora*, among other tree species, was introduced into the rangelands of Baringo. It is now well established, and invaded, in the Baringo lowlands close to watercourses and swamplands that form critical dry season pastures and farmlands. Individuals in Ng'ambo and Loboi areas, the setting of initial planting sites, are demanding its eradication, not least because its benefits are being 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. The following is a summarized list of positive and negative effects of *Prosopis juliflora* on livelihoods in the Baringo area of Kenya.

Positive effects on livelihoods;

- Poles for fences, home construction and repair

- Availability of fuelwood and charcoal for subsistence and sale, reducing travel time for women and removal of other trees
- Pods for livestock fodder and as a snack for children
- Ropes made from bark
- Honey
- 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
- Invasion into wetlands that reduces their value for watering and dry-season grazing
- Invasion into the lakeshore area of lakes and wetlands, making fishing more difficult
- Damage to the tires of vehicles and bicycles
- Hard wood causes cutting tools to wear out quickly
- Consumption of the sweet pods causes damage to the teeth of goats
- Sharp thorns causes wounds to goats and cattle
- Increased malaria incidence associated with *Prosopis juliflora* thickets close to homes

Individuals' perceptions of the invasive *Prosopis* is influenced by their weighting of the costs against the benefits of living with *Prosopis*. This calculus is expressed in their overwhelming demand for eradication. However, in Loboi, there may be other factors beyond the benefit-cost calculus: even though individuals receive net benefits, they still demand that *Prosopis* be eradicated. The distribution of costs and benefits among actors suggest no specific burden or advantage to any specific individual or group of individuals as they pursue their dominant livelihood strategies. However, Chemonke village in Ng'ambo where *Prosopis* thickets are at their densest experiences the greatest cost burden. That area should be a priority for any intervention. The structure of product use in both Ng'ambo and Loboi indicates that women are the primary fuelwood users. Any future program must ensure continued access to fuelwood for women.

Actions in responses to *Prosopis juliflora*'s invasion have concentrated on control and/or eradication attempts in the *de facto* individually controlled farms and homesteads, where individuals also have control over the benefits generated by their efforts. The communal grazing areas that are jointly owned and used, have seen very limited attempts at checking the spread of the species. Yet this resource is crucial for sustaining the livestock enterprise. The effort designed to improve individual incentives to participate in the joint control of *Prosopis,* was undermined by the rapid proliferation of the species under enhanced growth conditions following a flooding episode. This collective effort had been mobilized by local

government administration with the promise of land allocation to each family. The authority of customary institutions has been inadequate to achieve this kind of community mobilization on its own. The abundance of *Prosopis juliflora* owing to its prolific seeding, rapid growth and multiple dispersal agents does not foster a need for imposing restrictions over its exploitation, which is the primary method by which customary authority achieves the management of scarce resources.

Thus perceptions of *Prosopis juliflora* (and of invasive species more generally) by local communities are strongly influenced by how the beneficial effects of the species weigh against the less favored and costly characteristics and impacts of the same species. However, what determines or influences how or whether these perceptions are translated into meaningful responses and actions? Institutions (property rights, customary authority) and the incentives that they produce amongst individuals may limit the range and effectiveness of possible responses in different arenas. Government policy restrictions on the transportation and sale of charcoal severely limit the range of use options, which may well have good potential to help in the reduction/control of *Prosopis* stands. Though it is legal to buy, use and sell charcoal, it remains illegal to produce and transport it. The proposed energy policy if enacted will ease the bottlenecks to production and distribution of charcoal. In the short term, however, special permits for transportation of charcoal and for its sale can be negotiated with the Provincial Administration and the Ministry of Trade and Industry. Whichever approach is used will have the effect of enlarging the institutional choice set for communities here.

The Kenya Forestry Research Institute and Forest Department, with support from FAO, are currently crafting an ambitious 20-month program for the control of *Prosopis* through management and use by local communities, starting in the Ng'ambo area of Baringo district. Our study informs this impending initiative, and others, in obvious ways. First, community desired solutions to the problem of invasion are strongly consistent with costs and benefits of living with the species, especially where information on alternatives may be limited. Second, the distribution of current benefits and costs is critical when considering solutions. Proposed solutions should not impose additional costs nor subtract existing benefits to whomever they accrue. Women for example, should be assured of continued access to adequate fuelwood resources. There is a danger that a shift to higher valued *Prosopis* commodities may crowd out lower income, though beneficial uses. Similarly, Chemonke village of Ng'ambo should see special effort to minimize the magnitude of costs associated with *Prosopis* invasion. Third institutions, land tenure arrangements in particular, will influence the willingness of individuals to invest their time and effort in management activities.

Kenya is not the only country confronted with the problem of *Prosopis juliflora* invasion. There is considerable opportunity to learn from other countries where a *Prosopis juliflora* menace has been turned into a resource. In India, the Gujarat State Forest Development Corporation, the Gujarat Agricultural University, Anand, and the Vivekenand Research and Training Institute, Mandvi-Kachchh have developed programs for the collection, processing and marketing of various products from different parts of *Prosopis juliflora*, while providing employment to the rural poor. In the late 1990s, the Forestry Research Programme of the UK Department for International Development supported a project by the HDRA in the UK and CAZRI in India to collate information about the most common *Prosopis* species (www.hdra.org.uk/international_programme/ip_publications.htm). The three main conclusions of that effort are that *Prosopis juliflora* can be a very valuable resource for the drylands; that efforts to eradicate *Prosopis juliflora* are overly expensive and likely to be ineffective; and that *Prosopis juliflora* can be managed to be a very valuable source of commercial products and livelihoods in the drylands. Calculated learning and borrowing from India's efforts will not only increase the range of options for dealing with the *Prosopis* menace, but will also likely depress the costs of investment in basic research.

Commercialization of *Prosopis juliflora* products will be challenging anywhere in Kenya. While it is known that *Prosopis juliflora* also has potential for manufacture into tools, floorboards and carvings, the real economic potential of these enterprises is yet to be demonstrated. On the other hand, charcoal is 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. Key informant interviews in the Lake Baringo area suggest that most people involved in the charcoal trade are young men from outside of the local area. Few local people would proudly claim to be charcoal producers of sellers. Experience from elsewhere in Africa shows that a change in this situation is possible. This may require a package of new technologies (for wood harvest and efficient charcoal production), special labelling of the charcoal as being produced from *Prosopis juliflora*, legitimate local organizations to manage production, sale and distribution of proceeds, and marketing arrangements that remove the formal and informal harassment and stigma attached to the product.

This report represents a first. By disaggregating 'community', it provides greater insight into the way different individuals (of different genders, ages, occupations, wealth etc) are impacted. Policy responses can be tailored to accommodate these differential impacts. By linking to a more general explanation of human behavior, it reiterates the essential

institutional factors that influence individual and group responses to the threat of invasions. Few studies have considered institutional effects in the resolution of invasive species problems. This also links up with solutions and their longer-term feasibility.

Nevertheless, this exploratory study has its shortcomings too. Not the entire range of benefits and costs were taken into account. In some instances, it was indeed difficult if not impossible to separate out the effects of drought and flooding from the effects of *Prosopis juliflora* invasion. For example, how many livestock losses can be attributed to pasture declines due to regularly occurring droughts and how many due to pasture decline owing to *Prosopis* competition/exclusion and/or alellopathic effects? Of course, *Prosopis* invasion compounds the prior problem of droughts.

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APPENDICES

Appendix 1

Interview schedule for individuals

Date:	Name of respondent:
Male/Female:	Age/Age set:
Location:	Division:
Locality/Village:	Education Level:
Kiswahili:	

1. What is the local name of *Prosopis juliflora*?
2. Where is this species found within the area that you live?
    a. On own land
    b. On community land
    c. On government land
3. Name four places with highest density of *Prosopis* in descending order.
4. How did it come to be there? Was it planted? By whom? When? Why? Were you involved?
5. Please describe the habitat in which much of this species is found, and why you think this is so.
6. Has the density/cover of the species increased or decreased in the past 5-10 years? Give an estimate of the extent of increase or decrease.
7. Has the density/cover of the ground cover around *Prosopis juliflora* i.e. grasses and forbs increased or decreased in the past 5-10 years?
8. What are the most important products you harvest from this species? What aspect of your needs does it supply? When do you harvest? How much?
9. What constraints do you face in the harvest of products from this species?
10. What constraints do you face in the sale of products from this species?
11. Are there other ways that people might generate a livelihood through *Prosopis*?
12. Have you tried other ways of using this species?
13. What constraints have you faced in adopting these alternative uses?
14. Would you be interested in learning new/different ways of using this species? Why?
15. What are the most serious problems you are facing with this species today? Please quantify any losses.

16. What were the most serious problems you faced with this species 10 years ago? Please quantify any losses.
17. Did you report this problem to anyone?
    If yes, who did you report to, when and how did they help you?
18. Have you undertaken any management, control or regeneration activities with respect to this species?
19. Which type of activity and how frequently? Alone or with others-who are they? Where?
20. If activity is undertaken with others, please describe who they are.
21. If activity is undertaken with others, please describe how you organize yourselves. Who contributes what?
22. What are your main sources of income? How has the increase/decrease in *P. juliflora* affected this income? Please quantify.
23. Has the incidence of *P. juliflora* affected the availability of other resources that you have been using? How?
24. Has the proliferation/decline of *P. juliflora* caused any conflicts between you and others in the use of the above resources? Please explain.
25. Please describe the ways you traditionally control access to natural resources for example, access to water, to pasture and to tree products. Who has access, when and where? Does this include other communities? Who controls access?
26. Can we apply these methods to the use and management of *P. Juliflora*?
    If yes, how? If no, why not? What would be the main challenges?
27. Where do your livestock graze at different times of the year? Wet season/dry season. Name the places and for how long.
28. Please provide us with the numbers and types of livestock that you have. Are they all here or are some away? How many are away? Where and with whom?
29. What would you like to be done with regard to the *Prosopis* problem?
30. Who do you think should do it? Why?

APPENDIX II

List of Interviewees

Interviewees from Loboi area

Name	Area	Village
John Cheruyot	Loboi	Kapronguno
Kiprop Lokotos	Loboi	Kapronguno
Sammy Kibon	Loboi	Kapronguno
Elizabeth Kamuren	Loboi	Kapronguno
Elijah Kipteroi	Loboi	Kapronguno
Kurere Lokotos	Loboi	Kapronguno
Jackson Kibon	Loboi	Kapronguno
Harrison Komen	Loboi	Kapronguno
Tarkok Kertich	Loboi	Kapronguno
Frederick Kibon	Loboi	Kapronguno
Tarkok	Loboi	Kapronguno
Rosaline Yator	Loboi	Kapronguno
Tuiya Kipsarmat	Loboi	Kapronguno
Julia Kibon	Loboi	Kapronguno
Milka Kurere	Loboi	Kapronguno
Veronica Kurere	Loboi	Kapronguno
Pauline Sokome	Loboi	Kapronguno
Joseph Biwott	Loboi	Kapronguno
Francis Tiraito	Loboi	Kapronguno
Joseph Cherutich	Loboi	Kapronguno
Samwel Chelal	Loboi	Kapronguno
Susan Tuiya	Loboi	Kapronguno
Julius Langat	Loboi	Loboi Center
Judy Matere	Loboi	Loboi Center
Selina Chepsot	Loboi	Loboi Center
Grace Langat	Loboi	Loboi Center
Paul Kituro	Loboi	Sukutek
Silvester Kamuren	Loboi	Tingtingnyon
Kabon Leleito	Loboi	Tingtingnyon
Stanley Kabyegoi	Loboi	Tingtingnyon
Kertich arap Koech	Loboi	Tingtingnyon
Jeniffer Kipsang	Loboi	Tingtingnyon
Komen Kipsarmat	Loboi	Tingtingnyon
Joshua Karatu	Loboi	Tingtingnyon
Nickson Kimeli	Loboi	Tingtingnyon
William Kapyegoi	Loboi	Tingtingnyon
Tarkok Kibarar	Loboi	Tingtingnyon
Leah Ruto	Loboi	Tingtingnyon
Joseph Ruto	Loboi	Tingtingnyon
Rael Kiptoroi	Loboi	Tingtingnyon
Christine Tomno	Loboi	Tingtingnyon

Esther Bogoria	Loboi	Tingtingnyon
Magdaline Cheruiyot	Loboi	Tingtingnyon
John Cheruiyot	Loboi	Tingtingnyon
Angeline Kibon	Loboi	Tingtingyon
Tuyoi Kapyekoi	Loboi	Tingtingyon
Joseph Cherono	Loboi	Tingtingyon
Samwel Kibet	Loboi	Tingtingyon
Pricilla Karato	Loboi	Tingtingyon

Interviewees from Ng'ambo area

Name	**Area**	**Village**
Susan Taparakwei	Ng'ambo	Keper
Maurine Letangule	Ng'ambo	Keper
Parmery Lemerige	Ng'ambo	Keper
Gladys Nasieku	Ng'ambo	Keper
Mary Nasunguna	Ng'ambo	Keper
Ngoliton Tiren	Ng'ambo	Keper
Erickson Tirian	Ng'ambo	Keper
Adijah Kipir	Ng'ambo	Keper
Esther Parsalaach	Ng'ambo	Keper
Joseph Ole Nasieku	Ng'ambo	Keper
Elizabeth Nabori	Ng'ambo	Keper
Erickson Lebara	Ng'ambo	Keper
Lekideny Lekaitau	Ng'ambo	Keper
James Tauren Olesukuma	Ng'ambo	Keper
Jane Lendapana	Ng'ambo	Keper
Esther Lesamburi	Ng'ambo	Keper
Lekikenyi Tyson	Ng'ambo	Nairrag Enkare
Chamakany Sakayo	Ng'ambo	Nairrag Enkare
Jamlick Olerangal	Ng'ambo	Nairrag Enkare
Kenedy Lenkolyanga	Ng'ambo	Nairrag Enkare
Carori Sakei	Ng'ambo	Nairrag Enkare
Nancy Chamakany	Ng'ambo	Nairrag Enkare
Maxon Lesaaya	Ng'ambo	Nairrag Enkare
Esther Lendele	Ng'ambo	Nairrag Enkare
Charles Nabori	Ng'ambo	Nairrag Enkare
Nolkururu Chamakany	Ng'ambo	Nairrag Enkare
Alexson Nickson Lechamakany	Ng'ambo	Nairrag Enkare
Jackson Tiren	Ng'ambo	Nairrag Enkare
Esther Lemaalo	Ng'ambo	Nairrag Enkare
Christine Sunguna	Ng'ambo	Nairrag Enkare
Henry Lesamburi	Ng'ambo	Nairrag Enkare
Susan Kaitau	Ng'ambo	Nairrag Enkare
Benjamin Merige	Ng'ambo	Nairrag Enkare
Roseline Nabori	Ng'ambo	Nairrag Enkare

Julius Koyala	Ng'ambo	Chemonke
Nachaki Kateiya	Ng'ambo	Chemonke
Nixon Lowalan	Ng'ambo	Chemonke
Anna Koyala	Ng'ambo	Chemonke
Magdalena Kesaaya	Ng'ambo	Chemonke
Wilfred Koyala	Ng'ambo	Chemonke
John Sunguna	Ng'ambo	Chemonke
Helena Sunguna	Ng'ambo	Chemonke
Jackson Lenariasat	Ng'ambo	Chemonke
Nolkireyo Lekoyala	Ng'ambo	Chemonke
Lemokotani Kateiya	Ng'ambo	Chemonke
Mariyo Lewalan	Ng'ambo	Chemonke
Nonkishu Lerkeno	Ng'ambo	Masai
Rose Kisele	Ng'ambo	Masai
Lenkoosia Lekesio	Ng'ambo	Masai
Nangambo Lekeny	Ng'ambo	Masai
David Kusele	Ng'ambo	Masai
Jane Kusele	Ng'ambo	Masai
Gideon Parteneu	Ng'ambo	Masai
Sapania Sikamoi	Ng'ambo	Masai
Monica Lengosuranka	Ng'ambo	Masai
Kiramsoo Lengiyaa	Ng'ambo	Masai
Salome Sikamoi	Ng'ambo	Masai
Ngaime Lekesiso	Ng'ambo	Masai
Penina Parteneu	Ng'ambo	Masai
Hellen Sikamoi	Ng'ambo	Masai
Samson Nabori	Ng'ambo	Masai
Bernard Lengusuranga	Ng'ambo	Masai
Robinson ole Merige	Ng'ambo	Masai
Joseph Sompisha	Ng'ambo	Masai
Rispa Sikamoi	Ng'ambo	Masai
Richard Lengusuranka	Ng'ambo	Masai

List of Informants

Informant	**Position**
John Laku	Land Adjudication Officer, Baringo district
Joseph ole Nasieku	Chief, Ng'ambo location
Josephat Kipkemei Maina	Rural development officer, Ministry of Agriculture
David Korir	Clinician, Ministry of Health
Ezekiel Ayengwa	Clinician, Ministry of Health
Ibrahim Hassan	Clinician, Ministry of Health
Mark Tergat	Public health officer, Ministry of Health
Stephen Nyakundi	District Officer, Marigat Division
Juma Okati	District range officer, Baringo

Philemon Kemei	Agricultural officer, Ministry of Agriculture
Michael Chang'kwony	Area representative, Kenya Forestry Research Institute
Patrick Kariuki	Conservator, Forest Department (was project officer for FAO project in Baringo)
Fabian Musila	Coordinator, WWF Lake Bogoria conservation project at Loboi
Samson Kamung'oror	Attendant, Loboi tree nursery for FAO project

APPENDIX III

Unstructured informant survey and list of informants

1. When was *Prosopis juliflora* introduced? By who and for what purpose? Do you have any records of this? Please share with us.
2. Has there been any control and management related to this species?
   If yes, please describe who initiated it, when and what was done.
   If no, what are the reasons?
3. List the names and types of organizations that engage in activities related to *P. juliflora* (eg. Planting, other maintenance, harvesting, processing, producing, selling, enforcing).
4. Is there any coordination among these organizations? If yes, please describe. Do they make policy together, loan funds, exchange information, etc?
5. Are there currently conflicts between organizational policies and what the users would like in terms of the management of *P. juliflora*? Please explain.
6. Do any of the user groups have advantages over all other groups for harvesting *P. juliflora*? If yes, please describe.
7. Do harvesters from different user groups cooperate with each other? If yes, please describe.
8. Do conflicts among users affect the overall status of *P. juliflora*?
9. What do you think of community allegations on *Prosopis*?

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