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This publication is part of a series of briefs describing findings from the EU-funded Governing Multifunctional Landscapes Sustainable Woodfuel project, which aims to contribute to knowledge, options and engagement for more sustainable woodfuel value chains across Sub-Saharan Africa.

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Key lessons

- Originally introduced to dryland areas in Kenya as a solution to deforestation and fuelwood shortages, the shrub *Prosopis juliflora* has become highly invasive, displacing native plants, and negatively impacting both biodiversity and livelihoods.

- Efforts to control *Prosopis* include, among others, using it to produce sustainable charcoal, which can both fill a major bioenergy gap and clear land for agriculture.

- However, limited knowledge and a lack of proper equipment for pruning have prevented communities from realizing the full economic potential of *Prosopis*.

- In Baringo County, CIFOR-ICRAF and partners took an integrated approach to sustainable charcoal production using *Prosopis*, through participatory mapping and ‘training of trainers’ on sustainable harvesting and the use of improved kilns.

- Results show that using *Prosopis* for charcoal production is sustainable in three ways: it is abundant, it can be regenerated through selective pruning, and it produces high-quality charcoal more efficiently than other woody species.

- This brief describes these results and offers recommendations for the use of invasive species for charcoal production.

Introduction

The invasive *Prosopis juliflora* shrub and its potential for charcoal production

*Prosopis juliflora* (hereafter *Prosopis*), also known as mesquite or ‘mathenge’ in Kenya, is among the world’s 100 worst invasive species (Lowe et al. 2000). In Kenya, it was planted between the mid-1970s and the 1980s in dryland areas to halt desertification, control deforestation and alleviate fuelwood shortages (Pasiecznik et al. 2006). The introduction of *Prosopis*, which has biochemical properties that negatively affect neighbouring plants, has resulted into the loss of biodiversity both above and below ground (Maundu et al. 2009; Kaur et al. 2012; Vilà and Hulme 2017). It also affects other ecosystem services, such as water cycles (Gallaher and Merlin 2010, Dzikiti et al. 2013), and has cut off livelihood opportunities through its displacement of native plants (Maundu et al. 2009; Al-Humaid and Warrag 1998). The shrubs provide breeding habitats for mosquitoes, their thorns cause injuries to humans and livestock, and their sugary pods can harm livestock’s teeth when consumed in large quantities (Njenga 2019). With its dense, impenetrable thickets that protect it from animals, *Prosopis* has survived where other tree species have failed. It has also become highly invasive, branching very close to the ground, inhibiting the seedling establishment of other tree species and grasses (Pasiecznik et al. 2001; Singh 2008; Eckert et al. 2020).

In Baringo county, *Prosopis* was first introduced in Ng’ambo and Loboi locations. Initially, 20 sites of approximately 250 ha were planted with *Prosopis* (Anderson, 2005). The plant has since spread to other areas including, Salabani, Ilng’arua, Ilchamus, Kiserian, Rugus, Kapkuikui, Loboi and Sandai locations, and Endao, Perkerra and Yatoi sublocations (Little 2019). Scaling the planting of *Prosopis* was stopped in early 1990s once its invasive characteristics were discovered (Choge et al. 2002). Unfortunately, the community lost 18,792 ha of cropland, grassland, and woodland to *Prosopis* between 1986 and 2016 (Mbaabu et al. 2019).
Without intentional management practices such as biological control, chemical treatment, uprooting and clearcutting, and use of *Prosopis*, the shrubs will continue to colonize new areas and become the dominant vegetation. To stop this trend, the invasive species can be turned into a resource. For example, the species is being used for sustainable charcoal, fodder, poles, honey, and fuelwood initiatives supported by the Kenya Forestry Research Institute (KEFRI) and other stakeholders in Kenya (Tuwei et al. 2019). The potential for charcoal production is huge, as there are an estimated 40 million tonnes of utilizable *Prosopis* biomass across Baringo, Turkana, Samburu, Tana River, Garissa, Kajiado and Taita Taveta counties – this could fill the country’s 55% charcoal deficit (MENR 2013). Further management and use of *Prosopis* could open land for agriculture, allow the recovery of indigenous plant species, and reduce human and animal injuries (Mwangi and Swallow 2008). When well controlled, the species can provide timber and non-timber products such as firewood, charcoal, pods, fodder, and ecosystem services such as soil erosion control and improvement of soil fertility (Pasiecznik et al. 2001; Wise et al. 2012).

Mapping of *Prosopis* spread and envisioning a future landscape

Despite several attempts to control the spread and further invasion of *Prosopis* in Baringo County, success has been elusive due to a lack of proper tools and equipment for pruning, low community-level commitment, and limited knowledge on how to tap into the economic potential of *Prosopis* and create incentives to manage it (Koech et al. 2020). Integrated approaches are needed to maximize the benefits and minimize the costs associated with *Prosopis* (Samuel et al. 2012). Multistakeholder engagement and bottom-up approaches are critical to ensuring that community visions are considered, as well as to mobilize the diverse skills and resources needed to overcome this challenge.

This brief describes activities undertaken by the Governing Multifunctional Landscapes Sustainable Woodfuel project, specifically an intervention prioritized during community action planning in Baringo. It documents community perceptions of the benefits and challenges of *Prosopis* invasion arising from community mapping of its spread, as well as a vision for an improved landscape through specific interventions. Also described are outcomes from a ‘training of trainers’ session on sustainable woodfuel, held in October 2019, during which charcoal producers and a primary school teacher learned sustainable harvesting techniques and were supported with a drum kiln, as well as equipment to improve wood-to-charcoal production in the traditional earth mound kiln.

The work was carried out in Baringo South sub-county (known as Marigat sub-county by the national government administration) by the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF), KEFRI, Adventist Development and Relief Agency (ADRA), Kenya Forestry Service (KFS), the County Government of Baringo, local authorities, and several charcoal producer associations.
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Potential benefits from Prosopis

The assessment of the spread and use of Prosopis was done during the above-mentioned ‘training of trainers’ course (Njenga et al. 2019). Participants included 11 women and 21 men comprising charcoal producers, a primary school teacher, five young male metal artisans and two officers from the Department of Agriculture and Livestock of the county government. Together, they identified and ranked 14 different benefits of Prosopis in Baringo (See table). Supply of charcoal, firewood and fencing materials were the top three benefits according to women, while men prioritized charcoal, fencing and poles. Charcoal was at the top for both men and women, while women also found supply of firewood to be a priority, as it is their responsibility to source it. While charcoal was mainly produced for commercial purposes and sold within and beyond the county, fencing and poles were mostly for local consumption.

### Prosopis products harvested by communities in Marigat subcounty

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Nature of function</th>
<th>Women (N=7)</th>
<th>Men (N=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score</td>
<td>Rank</td>
<td>Score</td>
</tr>
<tr>
<td>Charcoal</td>
<td>Woodfuel</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Firewood</td>
<td>Woodfuel</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Fencing</td>
<td>Timber</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>Shade</td>
<td>Timber</td>
<td>29</td>
<td>4</td>
</tr>
<tr>
<td>Poles</td>
<td>Timber</td>
<td>40</td>
<td>5</td>
</tr>
<tr>
<td>Roofing</td>
<td>Timber</td>
<td>56</td>
<td>6</td>
</tr>
<tr>
<td>Control of soil erosion</td>
<td>Ecosystem service</td>
<td>58</td>
<td>7</td>
</tr>
<tr>
<td>Furniture making</td>
<td>Timber</td>
<td>63</td>
<td>8</td>
</tr>
<tr>
<td>Improvement of soil fertility</td>
<td>Ecosystem service</td>
<td>70</td>
<td>9</td>
</tr>
<tr>
<td>Medicine (roots, leaves, bark)</td>
<td>Medicinal value</td>
<td>71</td>
<td>10</td>
</tr>
<tr>
<td>Animal feed</td>
<td>Food and feed</td>
<td>73</td>
<td>11</td>
</tr>
<tr>
<td>Windbreak</td>
<td>Ecosystem service</td>
<td>76</td>
<td>12</td>
</tr>
<tr>
<td>Poultice for wounds</td>
<td>Medicinal value</td>
<td>78</td>
<td>13</td>
</tr>
<tr>
<td>Food</td>
<td>Food and feed</td>
<td>81</td>
<td>14</td>
</tr>
</tbody>
</table>

*Score: 14–81 points; ranking from 1 to 14, where ‘1’ is the most important.*
Participatory mapping of the landscape

Outcomes from the participatory mapping of the landscape in Marigat sub-county – which has the highest density of *Prosopis* cover in Baringo county – showed that in the 1980s the area had only a few scattered Acacia trees along the rivers (First map).

Community members said that the mapped area was mostly used for grazing by pastoralists and some farming along rivers, but that there was no charcoal production. *Prosopis* was introduced in the area around 1983, with demonstration plots established in 1984. By 2018 *Prosopis* had colonized vast tracks of land in Marigat sub-county such as Ng’amo, Loboi and Ilchamus, among others, and had displaced grasslands and croplands (Second map).

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The vision of the community is to manage *Prosopis* by harvesting mature stems for charcoal and other products such as poles, leaving other shrubs to grow. Another suggested intervention is the complete removal of some *Prosopis* plants to reduce the overall density and to create space for multi-purpose trees (e.g., fruit trees) and crops (Third map).
This shrub has affected livelihoods for farmers and pastoralists who need to find the money and resources to physically remove the shrubs. And it causes ecosystem management issues in areas where it grows very thick, preventing the free movement of livestock and wildlife.

Finding ways to control and manage this invasive species is a top priority for the county, but one that faces many challenges, as Ms. Kipkazi explains.

“There is a lack of resources to support Prosopis management activities, as well as a lack of awareness among communities about the importance of controlling Prosopis before it spreads and becomes too established,” she said. “There are also not enough staff who can offer extension services and training to community members.”

She also highlighted land tenure issues. As communally owned lands tend to have more Prosopis, it is a challenge to develop collective management plans to invest in controlling the plant, and to implement them across each community.

“At the county level, our main focus is to raise awareness among community members about the benefits of Prosopis management, and to show how they can transform their land through demonstration plots, where grass has returned to cleared areas,” said Ms. Kipkazi.

They also encourage sustainable charcoal production using Prosopis. “Continuous use of the plant through charcoal production can greatly reduce its spread,” she said. “Pruning the Prosopis shrub prevents them from taking over and limits seed production.”

“There has been good uptake of Prosopis as a source of charcoal, with producers using it even before the moratorium,” she added.
Overview of charcoal production using *Prosopis*

In 2018, the Government of Kenya imposed a moratorium on timber harvesting in all public and community forests to alleviate widespread drought. However, to control the spread of *Prosopis*, this invasive species was excluded from the ban on 20 December 2018. Prior to the ban, local communities in Baringo produced charcoal from indigenous species, mainly *Acacia lahi*, as it was thought to produce high-quality charcoal (Ndegwa et al. 2021).

Charcoal production using *Prosopis* is undertaken throughout the year. Activity peaks during the school holiday months of April, August and December, when students are available to contribute to the labour and parents need to raise school fees for the following term (Koech et al. 2020). All members of the household are involved in charcoal production, although roles are notably gendered. The main roles for men include felling trees, identifying suitable sites, setting up the kiln, stacking wood, managing the kiln, loading and unloading charcoal, marketing, and managing the income from charcoal sales. ‘Lighter’ activities such as pruning fallen trees, lighting and covering the kiln, harvesting, and sorting and packaging the charcoal are mainly carried out by women. Youth support their parents during school holidays until they are old enough to carry out production on their own.

Studies such as Singh (2008), recommend the use of *Prosopis* in short rotation energy programmes due to its fast growth, ability to grow new shoots after pruning, and ability to quickly regenerate biomass. Tewari et al. (2000) in India and Mehari (2015) in Ethiopia, established that *Prosopis* produces high-quality charcoal, and its wood does not spit, spark or emit much smoke. Studies indicate that in Kenya, *Prosopis* produces quality charcoal with a calorific value of 33 MJ/kg (Oduor and Githiomi 2013).
Training of trainers in Baringo

Before the training, stems were harvested from *Prosopis* trees and dried in the open air to reduce the moisture content to 20%. The training was then conducted in October 2019 through both classroom and community-level demonstrations to minimize transport and accommodation costs and to allow participants to continue attending to their livelihood activities. The total cost for the conference package was about USD 20 per participant per day for five days. In the classroom, trainees gained knowledge on sustainable woodfuel production technologies, which were later demonstrated in the field.

At the demonstration site, the wood was stacked tightly and carbonized using both the traditional earth mound kiln and improved earth mound kiln. Comparing the yields from the two kilns, the improved kiln produced as much as 50% more charcoal compared to the traditional kiln, with charcoal recovery rates of 22% and 15%, respectively (Njenga et al. forthcoming). Further, wood residues below 5 cm were cut to about 80 cm and carbonized using the drum kiln, with a recovery rate of 21%

Charcoal from *Prosopis* is targeted for both home use (10%) and for sale (90%). It is used in the home mainly during the rainy season for heating. Locally, small-scale food vendors and restaurants consume the bulk of the charcoal. The charcoal that is not consumed locally is sold to brokers, who aggregate it and sell to transporters for sale in towns such as Marigat, Kabarnet and Nakuru, as well as at external markets in Nairobi and Mombasa. The average price per bag ranges from between KES 400–450 (USD 3.60–4.50) at the producer level, and a kiln can produce 1–15 bags of charcoal, depending on the size of the kiln.

Income obtained from charcoal production is mainly used to buy inputs for crop and livestock production, as well as for school fees, buying goats, and as savings in village loan platforms. Although women in male-headed households have the economic capacity to buy goats from income obtained through the sale of charcoal, they do not have outright authority to sell the goats without seeking permission from their husbands.
Community-based outreach and scaling of *Prosopis* management and use for charcoal production

Follow up sessions to determine the impact of the training workshop were conducted on 31 July and 3 August 2020. Seventeen of the 24 trained charcoal producers were interviewed. Six of the graduates of the workshop in Ng’Ambo, referred to as ‘community trainers’, had reached other charcoal producers with the support of the area chief. One of the community trainers is a teacher at Sintan Primary school who trained primary school pupils in classes 6, 7 and 8 on *Prosopis* management and charcoal production using the improved kilns. The community trainers also established a demonstration plot on an area heavily invested by *Prosopis* at the Chief’s camp, where they provided hands-on training on *Prosopis* management and charcoal production using an improved earth mound kiln and a drum kiln. Details of these improved charcoal production technologies and related charcoal yields and emissions are discussed in the first brief in this series titled ‘Carbonization 2.0: How to produce more charcoal with less wood and emissions’ and in Njenga et al. (forthcoming).

Another five community trainers based in Ilchamus and six in Loboi went on to train other charcoal producers on the improved technologies through on-site charcoal production. They took advantage of visits by community members to their charcoal production site and farms to sensitize them on the importance of using efficient and improved charcoal production technologies, as well as on sound *Prosopis* management practices. The community trainers also reached out to community members in Loboi and Ilchamus through public meetings held by the area chief and at ‘cattle dips’ (i.e. to control parasites in livestock).

The improved earth mound kiln was preferred by charcoal producers, being selected by 17 of the 24 beneficiaries. Only five producers opted for the drum kiln, mostly women and youth who found it to be more convenient and efficient, requiring less labour and set-up time, less wood per batch, and yielding charcoal within 6–12 hours compared to up to 96 hours for earth mound kilns. The interviewed trainers reported to have reached a total of 359 charcoal producers between October 2019 and August 2020. However, these community learning activities were slowed when Lake Baringo and Lake Bogoria overflowed in 2020 causing flooding and displacement of target beneficiaries in Ng’ambo and Loboi, as well as from delays related to the Covid-19 pandemic.
Recommendations for scaling up

Harvesting wood from *Prosopis* for charcoal production is sustainable in three ways: first, the shrub is abundantly available as it has already invaded extensive areas of land in Baringo; second, *Prosopis* can regenerate its branches through selective pruning, resulting in a sustainable supply of woodfuel; and third, efficient preparation of the branches by reducing moisture up to 20% can increase the wood conversion rate, reducing wastage and boosting charcoal production. Combining proper wood production, harvesting, drying and stacking with the use of efficient carbonization technology such as improved earth mound kilns or drum kilns demonstrates a high potential for a sustainable charcoal production system. *Prosopis* produces high-quality charcoal with a calorific value of 33 MJ/kg (Oduor and Githiomi, 2013), and there are established markets for charcoal locally, in both neighbouring towns and in external markets such as Nairobi. Therefore, encouraging farmers to invest income from the sale of charcoal in community lending and loaning associations is likely to increase their returns, as they could then access loans to improve traditional earth mound kilns and acquire better equipment for wood harvesting. This would save labour and time that could be diverted to other livelihood activities such as beekeeping, crop cultivation and livestock keeping.

To help communities tap the huge potential of using invasive species for charcoal production, we offer the following recommendations:

1. Train charcoal producers on cost-effective innovations such as selective harvesting of branches, proper drying of wood, tight stacking of wood in the kiln to allow better air flow, and improved earth mound kilns with chimneys and breathers to increase the wood-to-charcoal conversion rate.

2. Mobilize charcoal producers to generate accessible financing options through the formation of village loan and savings groups, so that they have greater access to financing for the purchase of better harvesting and processing equipment, thereby leading to more efficient production, higher charcoal yields and more income to support other livelihoods and improve their lives.

3. Involve communities in context analysis and exercises to envision how their landscape could look, to foster joint responsibility towards a common goal and efforts to achieve that vision.

4. Build capacity among community champions on sustainable charcoal production using *Prosopis* through the training of trainers approach, to increase skills within the community, promote peer learning, and provide locally accessible extension services.

5. Integrate ‘management by use’ with other measures to reduce invasion by *Prosopis*, as recommended in the Kenya Bioenergy Strategy 2020–2027 (MoE 2020).
References


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