UNLOCKING THE ECONOMIC POTENTIALS OF PROSOPIS IN THE FACE OF CHANGING CLIMATE

Proceedings of the 2nd National Prosopis Management Workshop

At Soi Safari Lodge, Lake Baringo 18th - 23rd May 2015

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Participants who attended the 2nd National Prosopis Management Workshop

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FOREWORD

The 2nd National Prosopis Management Workshop was organized by Kenya Forestry Research Institute (KEFRI) in collaboration with Kenya Forest Service (KFS) with financial support from Food and Agriculture Organization (FAO), GIZ, and Cummins Company Limited. The theme of the workshop was 'Unlocking the Economic Potentials of Prosopis in the Face of Changing Climate'.

Prosopis juliflora ('Mathenge') is now a common tree in northern and coastal counties of Kenya. The 'Mathenge' debate has continued to dominate many discussions in the country in the recent years due to adverse press publicity, and its conflict of interest status perceived by some as an asset, and by others as a burden and a threat.

Prosopis juliflora was introduced to mitigate the impacts of recurrent droughts in the drylands. The tree still remains the most suited species in many arid and semi-arid zones of the world. However in some areas, the species has becomes invasive. The most important factor that has enabled Prosopis to be invasive is the absence of utilization pressures and related processing technologies. Other factors that have enhanced its invasiveness in Kenya include; complete lack of its management, prolific seed production with no local natural enemies, long seed viability period, high germination rate, effective dispersal mechanisms, rapid maturation to seed producing stage, and strong vegetative growth.

In the last five years, the Government of Kenya in collaboration with development partners has played a valuable role in identifying and overcoming constraints to development of Prosopis tree as a resource. This workshop was convened to share results of these initiatives. For example, detailed resource mapping and inventory has been carried out in Baringo, Garissa and Tana River counties. Results have shown that *Prosopis juliflora* constitutes about 50% of the vegetation along the flood plains of River Tana Basin with standing biomass in excess of 4 million tonnes. This is a significant level of invasion that requires urgent intervention measures to safeguard against total elimination of other indigenous vegetation. Conversion of Prosopis biomass to charcoal as part of management interventions would accrue Ksh 9 billion to be shared as revenue by the two county governments of Garissa and Tana River, with significant resources also going to communities as a sustainable source of livelihood.

Prosopis trees like any other tree in the forest have the potential of climate change mitigation through carbon sequestration. In this way carbon sequestration becomes one of the major services that trees and forests provide as an alternative source of sustainable income to communities as internationally recognized and adopted by United Nations Framework Convention on Climate Change (UNFCCC). However, there exists a challenge on methods of estimating carbon stock in forestry.

A novel approach and techniques to estimate biomass and carbon stocks on areas invaded by *Prosopis juliflora* in Kenya has been developed and shared in this report. With knowledge that forest destruction contributes about 20% of carbon emissions globally into the atmosphere estimated at over 5.8 Gt CO_2 annually, there is therefore need to identify practices and measures that will ultimately reduce these emissions gradually to allowable limits. In Kenya, charcoal is produced using earth kilns, masonry kilns and metal kilns. These methods can be used in producing charcoal from Prosopis by rural communities.

National and international investors have also been given a role to play in management and utilization of *Prosopis juliflora* as a resource in the energy sector. The tree is a hard wood with high calorific values and therefore makes excellent high energy chips for industrial production of electricity through gasification or production of high pressure steam as is being undertaken by Cummins Company in Baringo County. The intention is to promote organized sustained large scale harvesting of *Prosopis juliflora* biomass over wide areas in such a manner that allows: zoning of invasions; development of intensive management and harvesting plans; and standard plantation felling cycles. It is envisaged that continuous demand for Prosopis wood as a raw material would lead to significant reduction of plant densities to manageable levels in invaded areas. Appropriate rules and regulations are however required to guide the long term harvesting and land rehabilitation programmes in these Prosopis invaded areas.

Lastly, I acknowledge all those who were involved in; preparation of the workshop, production of this proceeding, and all the participants who made the Second National Prosopis Management Workshop a success.

Joshua K. Cheboiwo (PhD)
Director-Kenya Forestry Research Institute

ACKNOWLEDGEMENT

The 2nd National Prosopis Management Workshop under the theme "Unlocking the Economic Potentials of Prosopis in the Face of Changing Climate" was organized by a committee with co-chairs from Kenya Forestry Institute (KEFRI) and Kenya Forest Service (KFS) – the organizers thank the KEFRI and KFS Boards of Management, the Directors and staff of these institutions.

Support from; GoK through KEFRI/KFS, FAO, GIZ, and Cummins Company is appreciated.

The organizers also appreciate support by the County Governments who were represented in the workshop due to invasion of Prosopis in their counties specifically County Executive Committee (CEC) members in-charge of Forestry/ Environment for counties of Garissa, Tana River Turkana and the host county, Baringo.

The initiatives being taken by the Ministry and key partners in the environment sector towards developing effective management and control of the invasive Prosopis species through utilization was noteworthy. The Ministry has piloted production and sale of Prosopis charcoal from Baringo, Garissa and Tana River Counties as part of the management strategy for Prosopis in Kenya with very encouraging results.

Research undertaken by KEFRI, KARI, University of Nairobi, the Ministry of Agriculture and Livestock Development, and local communities have focused on the use of Prosopis pods as cost effective ingredient in the formulation of commercial livestock feeds. These efforts are commended.

The role of the Private Sector, CBOs, private sector, is also appreciated. Cummins Company hosted in Baringo County is the first investor to pilot production of electricity from Prosopis biomass in Kenya. We thank them for hosting participants for a visit to the Company during the workshop. The Charcoal Producers Associations (CPA) in Baringo also hosted the participants for a visit during the workshop.

The Government of Kenya is facilitating the entire process and monitoring the new developments as the new frontiers of scientific knowledge and innovation surrounding Prosopis as a resource become a reality in Kenya.

In conclusion, keynote speakers, sponsors and all other partners who supported this workshop in different ways are acknowledged.

Appreciation to the following: Paul Tuwei, Gabriel Muturi, James Ndufa, Simon Choge, Josephine Wanjiku, and Charles Koech who edited these Proceedings of the Second National Prosopis Workshop.

TABLE OF CONTENTS

CHAPTER 1
1.0 INTRODUCTION

1.1 Workshop Objectives

Objectives of the workshop were:

1. To review progress on the recommendations made in the First National Prosopis Workshop of October 2003
2. Presentations on various research findings and development trends on Prosopis management and utilization
3. To propose recommendations on utilization and sustainable management of Prosopis

1.2 Expected Output

1. Workshop proceedings
2. Recommendations on utilization and sustainable management of Prosopis in the drylands
3. Future areas for research and development in Prosopis

1.3 Participants, Resource Persons and Facilitators

Participants of the workshop comprised a wide range of stakeholders (Table 1) including;

- Community Based Organizations (CBOs)
- Charcoal Producers Associations (CPAs)
- County Executives in charge of Environment
- Forest Managers
- Researchers
- Universities
- Government Ministries
- Development Partners

Table 1: List of Organizations that Participated in the 2nd National Prosopis Management Workshop

No	Organizations	Particulars	Total
1	Kenya Forestry Research Institute (KEFRI)	Resource persons and facilitators	11
		Secretariat and support staff	6
2	County Governments	County Executive Committee (CEC) member in charge of Forestry/ Environment	9
		Support staff	2
3	Cummins	Resource person	1
4	Charcoal Producers Associations (CPAs)	Charcoal producer organizations from Baringo, Tana River, Turkana and Garissa counties	4
5	German Agency for International Cooperation (GIZ)	Representatives	2
6	Ministry of Agriculture and Livestock Development	Representatives	2
7	Civil Societies	CBO/NGO representatives working in forestry related fields	14
8	Food and Agriculture Organization (FAO)	Representatives	2
9	University of Nairobi	Resource person	1
10	Ministry of Devolution	Representative	1
11	Kenya Wildlife Service (KWS)	Representative	1
12	Kenya Forest Service (KFS) Field Offices	Ecosystem Conservators	9
		Head of Conservancy, Mau	1
13	Kenya Forest Service (KFS) Headquarters	Resource persons and facilitators	4
		Secretariat and support staff	4
14	Media		4
15	Community Members		2
	Total		**80**

1.4 Official Opening

1.4.1 Introductory remarks from the chair: Dr Clement Ngoriareng

On behalf of organizers, I welcome all the participants to the 2nd National Prosopis Management Workshop and particularly welcome our chief guests for the day. A quick glance at the attendance records, I have observed from the attendance records with utmost appreciation that the workshop is well attended. I have been informed that the participants comprise a wide range of stakeholders including;

- Community Based Organizations (CBOs)
- Charcoal Producers Associations (CPAs)
- County Executives in charge of environment
- Forest managers
- Researchers
- Universities
- Government Ministries
- International organizations
- Farmers representatives

While preparing for this workshop, the organizers developed a concept and shared with various organizations requesting for their support. However, only two organizations responded to this call and we therefore extend our appreciation for their quick response. Finally, may I call upon the County Executive in-charge of Environment and Natural Resources in Baringo County to welcome the participants and guests to the County.

1.4.2 Welcome remarks by County Executive, Environment, Natural Resources, Energy and Mining, Baringo County - Hon Caroline Lentupuru-Tenges

I am honoured and humbled to welcome all participants on behalf of His Excellency the Governor of Baringo County, Mr. Benjamin Cheboi. I want to assure all the participants of their safety during the workshop period.

Lake Baringo is an active tourist circuit with a variety of many types wildlife including; birds, mammals and reptiles. Key among these are hippos and crocodiles which could pose a threat during the day, therefore take precaution especially in the evenings *Prosopis juliflora* is a challenge in Baringo County and several other counties represented here due to its invasiveness. I therefore hope that by end of this workshop the participants will have made appropriate recommendations to alleviate this menace.

I take this opportunity once again to welcome you all to Baringo County and to wish you a successful workshop.

1.4.3 Remarks by Director, Kenya Forestry Research Institute (KEFRI) - Dr Ben Chikamai

Ladies and gentlemen

May I also take this opportunity to welcome you to the second National Workshop on Prosopis Management. The first National Workshop on Prosopis was held here about 12 years ago; at that time, there were more challenges than answers. Since the first workshop, a lot in terms of both research and development has taken place through GoK (KEFRI / KFS) and development partners (FAO).

It is important to highlight that Propsopis is an invasive species but if well managed presents a wide range of opportunities. Various enterprises can, and have been developed from Prosopis including; charcoal, generation of electricity, animal feed, and wood carving. The Second National Workshop on Prosopis with the theme "Unlocking the economic potentials of *Prosopis* in the face of climate change" aims at taking stock of achievement made since the First National Workshop was held.

I appreciate the support from; GoK through KEFRI/KFS, FAO, GIZ, and Cummins Company and all the organizers led by Dr. Gabriel Muturi and Dr. Clement Ngoriareng.

With these few remarks I wish all participants a fruitful workshop.

1.4.4 Remarks by Ag. Director, Kenya Forest Service (KFS) - Mr Emilio Mugo

I am happy to join the Chief Guest during the opening of the second National Prosopis Management Workshop.

I wish to note that, shortcomings associated with Prosopis species throughout the country have been attributed to the Kenya Forest Service: I recall during the recent court proceedings where a goat was presented as an exhibit supposedly suffering from effects of Prosopis and the government was blamed, particularly the KFS.

In the past before introduction of Prosopis in Baringo County, Euphorbia was originally the dominant species. Then in the late 1980's, *Prosopis juliflora* was introduced with the sole purpose of increasing tree cover in the region. In essence, tree cover increased and the dust storms were reduced tremendously but with several challenges that emerged including invasiveness of the species.

My colleague, the Director KEFRI, Dr Chikamai has listed several challenges associated with Prosopis species. However, I wish to note that this tree provides opportunity for development of many products. I am pleased to note that that this workshop aims among other things to look at marketing of these products from Prosopis species and consequently inform Government of the potentials provided by the species.

Thank you

1.4.5 Remarks by Executive GIZ representative - Dr Ute Schneiderat

It is my pleasure to join all the guests and participants during this second National Prosopis Management Workshop. I was here during the First National Workshop on Prosopis in the year 2003 and I am keen to follow the presentations and deliberations particularly on the past achievements and progress to date.

One year ago I came to Kenya and decided to work in Turkana County. I later went for a conference in Ethiopia and learnt a lot about the infestation of Prosopis in the upper region of Kenya.

For GIZ this meeting presents a good opportunity to share; experiences, business plans and concepts, lessons learnt, and need for educating communities on how to make use of Prosopis species.

I am also looking for partnerships, concepts, and business plans from various stakeholders. With me I am also joined by 6 other persons from Turkana County to participate in the workshop.

I conclude by noting that I am not fluent in English and therefore speaking in Swahili will be a bigger challenge.
Finally, it is my pleasure to be part of this workshop and thank you very much indeed.

1.4.6 Remarks by Food and Agriculture Organisation (FAO) representative to Kenya - Mr. Robert Allport

I wish to note that the FAO has been associated with the introduction of Prosopis into the country where the organization was enjoined in a court case against the Government of Kenya.

However, going by the recent sentiments by charcoal entrepreneurs in Nairobi there is positive attitude towards charcoal from Prosopis. However, I note that this may not be the case at the county level as the species remains invasive.

In my opinion, large scale commercialization of Prosopis is not possible due to the following reasons; inconsistent supply of the wood, poor harvesting methods and poor logistics to markets. It is only therefore, when the above issues are addressed that the species could be exploited on commercial basis.

Thank you and I am happy to be part of this workshop.

1.4.7 Speech by Principal Secretary, Ministry of Environment Water and Natural Resources, Dr Richard Lesiyampe

The Director, Kenya Forestry Research Institute (KEFRI)
The Director, Kenya Forest Service (KFS)
Food and Agriculture Organization (FAO) representative to Kenya
GIZ Representative
The Representatives of the County Governments
The Representatives of the affected communities
Distinguished Delegates,
Ladies and Gentlemen,

It gives me great pleasure to be with you today to preside over the official opening of the 2nd National Workshop on Management of Prosopis Species in Kenya. The Conference brings together scientists and officers from Kenya Forestry Research Institute (KEFRI), Kenya Forest Service (KFS), Universities, Government Ministries, County Governments, International organizations as well as community representatives and international stakeholders to share their research findings and experiences on management and utilizaton of invasive Prosopis trees.

It is gratifying to note the active participation of officials from various County Governments and community representatives alongside Community Based Organization's (CBOs) in this forum. The turnout is in response to rising concerns about the country's many serious environmental challenges that require urgent applications of Science, Technology and Innovation to overcome. This meeting therefore is a rare opportunity to initiate a joint and collective responsibility to ensure that Kenya's environment is sustainably managed now and in the future.

I note with satisfaction that the theme of this worshop **"Unlocking the economic potentials of *Prosopis* in the face of a changing climate"** is appropriate and consistent with the Kenya Government's development strategy blueprints that include the Vision 2030, the Constitution of Kenya 2010, and the National Climate Change Response Strategy. These documents provide elaborate pathways towards enhanced livelihoods of the Kenyan people and mankind in the rest of the world.

Ladies and Gentlemen,
Forests comprise very old, very valuable habitats, and their protection is a serious responsibility for all of us. If our generation allows the loss of this habitat, the future of our children is affected forever. It is not an easy task to ensure consistent sustainability of our forests and woodland habitats and, wishing alone will not make them so.

The Government of Kenya through the Ministry of Environment, Water and Natural Resources considers this as a great responsibility. We recognize that forests and woodlands are part of our heritage and have enormous potential for this country.

We therefore want to share with you some of the plans we have in the Ministry. These plans are helping us to determine how to take up this challenge directly because if we do not, the very precious forest resources of our country will be lost. These grand strategic plans are enshrined in three major development blueprints that were launched a few years ago namely: Kenya Vision 2030; the Constitution of Kenya, 2010; and the National Climate Change Response Strategy.

As you are aware, Environment has been identified as one of the key sectors of the social pillar of the Vision 2030 that aims to transform Kenya into a newly industrializing middle income nation. Kenya aims to be a nation that has a clean, secure, and sustainable environment by 2030, with several targets that include increasing the forest cover. In this regard, the Ministry is glad to note that the forest cover now stands at about 6.99% and that we are confident of soon achieving the internationally recommended target of 10%. In the same vein Prosopis, which is the reason we are here, contributes to forest cover despite its negative effects. It is for this reason that, Vision 2030 has recognized the Prosopis invasion challenges and recommended its management through utilization.

The New Constitution underlines that every person has the right to a clean and healthy environment, which includes the right to have the environment protected for the benefit of present and future generations through legislative and other measures. On the other hand, the State shall;

- Ensure sustainable exploitation, utilization, management, and conservation of the environment and natural resources, and ensure equitable sharing of the accruing benefits;
- Work to achieve and maintain a tree cover of at least ten per cent of the land area of Kenya;
- Protect and enhance intellectual property in, and indigenous knowledge of, biodiversity and the genetic resources of the communities;

- Encourage public participation in management, protection, and conservation of the environment;
- Protect genetic resources and biological diversity;
- Establish systems of environmental impact assessment, environmental audit and monitoring of the environment;
- Eliminate processes and activities that are likely to endanger the environment;
- Utilize the environment and natural resources for the benefit of the people of Kenya.

Every person has a duty to cooperate with State organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources.

Climate Change Strategy and REDD+

The evidence of climate change in Kenya is unmistakable. The same is true for other countries in Africa and indeed, the rest of the world. Temperatures have risen throughout the country. Rainfalls have also become irregular and more unpredictable, and when it rains, downpour is more intense.

Ladies and Gentlemen,

Extreme and harsh weather is now a norm in Kenya particularly in the recent decades, and this is expected to get worse over time if intervention measures are not put in place in good time. These changing climatic patterns are increasingly being manifested through adverse impacts on Kenya's socio-economic sectors. Moreover, current projections indicate that such impacts will only worsen in the future if the world does not implement measures that result in deep cuts in anthropogenic Green House Gas (GHG) emissions, which are responsible for climate change.

Kenya's ability to cope with the impacts of climate change is compounded by many factors including poverty, weak institutions, poor infrastructure, inadequate information, poor access to financial resources, armed conflicts due to a scramble for diminishing natural resources and low management capabilities among others.

It is estimated that every year, Kenya loses about 54,000 hectares of forest through deforestation, degradation, land use change activities, and logging, a situation that presents serious challenges to the national desire of increasing quality forest cover.

In response to this, the Government of Kenya launched the National Climate Change Response Strategy (NCCRS) whose primary focus is ensuring that adaptation and mitigation measures are integrated in all government planning, budgeting and development objectives. It aims at promoting collaborative and joint actions with all stakeholders (development partners, private sector, civil society, NGOs, faith-based organizations, etc) in tackling the impacts of climate change.

The most vulnerable sectors of the economy:- agriculture, water, energy, forestry, rangelands, health, social and physical infrastructure are prioritized for quick and immediate action, and relevant programmes are already being rolled out.

Recent efforts to reverse the adverse trends in forestry sector by the Government have focused on facilitating the private sector, development partners, local communities, and civil society to conserve and restore degraded forest areas throughout the country. This comprises; the state forest areas, farmlands, and in the drylands.

The water catchment forests, popularly referred to as water towers, have received close attention due to their significance in soil, water and bio-diversity conservation in addition to amelioration of regional climatic conditions.

The vision of the NCCRS is for a prosperous and climate change resilient Kenya, whereas the Mission of the Strategy is to strengthen nationwide focused actions by ensuring commitment and engagement of all stakeholders towards adapting to and mitigating against climate change.

Besides the broad NCCRS process, the Government is in the process of addressing the challenges faced specifically within the forestry and other natural resource management sectors in Kenya through Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme.

The programme is looking into the drivers and underlying causes of deforestation and degradation, as well as promoting sustainable forest management for improved livelihoods. In addition, the Ministry has invested in developing technologies for quantifying carbon emissions through the "System for Land Based Emission Estimation in Kenya (SLEEK) project where KEFRI and KFS are major players.

The National Prosopis Workshop

Ladies and Gentlemen,

I am informed that this workshop follows successful pilot research and development agenda developed during the first national workshop held at the same venue about 12 years ago.This workshop therefore seeks to review progress on five key recommendations made in the first workshop and chart the way forward for Prosopis research and development (R & D) for the next decade. Recommendations made in the first workshop were:

1. To develop technologies for effective management of the species;
2. To maximize utilization of various Prosopis products and develop their markets;
3. To involve local communities in management and utilization of the species;
4. To investigate integrated control measures and;
5. To promote utilization of Prosopis by removing policy and legislative barriers.

I take note of the bold initiatives being taken by the Ministry and key partners in the environment sector towards developing an effective management and control of the invasive Prosopis species through utilization. This would, presumably, contribute significantly to the country's economy as the affected communities adopt new technologies and innovative approaches that have been developed and tested in the last ten years.

My Ministry has piloted production and sale of Prosopis charcoal from Baringo, Garissa and Tana River counties as part of the management strategy for Prosopis in Kenya with very encouraging results. Although supervision of these activities remains an outstanding challenge, the Prosopis based charcoal is transforming lives of pastoral communities.

For example, for Baringo County in general and Marigat Sub-county in particular, monthly incomes in excess of Ksh 10 million accrue regularly to the communities from sale of Prosopis charcoal. The full potential in Garissa, Tana River and Turkana counties whose combined Prosopis biomass is over 50 times that of Baringo remains largely untapped.

Baringo County is hosting the first investor to pilot the production of electricity from Prosopis biomass in Kenya. Production of 4 MW of power into the national grid has been planned to launch this month (May 2015) and gradually increased to 10 MW if the level of biomass is permitting.

Ladies and Gentlemen,

The Government of Kenya is facilitating the entire process and monitoring the new developments as the new frontiers of scientific knowledge and innovation surrounding Prosopis as a resource become a reality in Kenya. Similar Prosopis based power generation investments are being planned for Garissa, Tana River and Turkana counties, thus making Prosopis a new green crop in Kenya. Besides production of charcoal and electricity from Prosopis trees, efforts made by KEFRI, KARI, University of Nairobi, the Ministry of Agriculture and Livestock Development and local communities have focused on the use of Prosopis pods as cost effective ingredient in formulation of commercial livestock feeds.

In addition, focus is also placed on self-sufficiency in local supply of feed resources by communities in ASALs where feed scarcity is a major constraint to livestock production during drought crises. Opportunities for proper management and control through commercial use of Prosopis to support livelihoods and to maintain environmental integrity are enormous.

It is the goal of this workshop therefore to review progress on recommendations made in the first workshop, and chart the way forward for Prosopis research and development for the next decade. I wish to take this opportunity to thank all the Development Partners who have continued to provide support to the environmental sector in Kenya. As a Ministry, we will continue to have elaborate mechanisms to ensure that the resources provided are efficiently utilized and fully accounted for. Your partnership in extending the knowledge barriers on management, control and utilization of Prosopis trees in particular is highly appreciated.

In conclusion, I wish to thank the KEFRI and KFS Boards of Management, the Directors and staff of these institutions, County Governments, CBOs, Communities and the organizers of the 2nd National Workshop on Management of Prosopis, Keynote speakers, Sponsors and all other partners who have supported this Conference in different ways.

It is now my pleasure to declare the 2nd KEFRI/KFS National Workshop on Management of Prosopis officially open.

Thank you.

CHAPTER 2
2.0 RECOMMENDATIONS OF THE FIRST NATIONAL PROSOPIS WORKSHOP OF OCTOBER 2003

The following are the recommendations of the First National Prosopis Workshop held in October 2003 (Table 2).

Table 2: Key Recommendations of the First National Prosopis Workshop

No.	Issue	Specific Recommendations
1	Policy and legislation issues	1. Review and strengthen existing legislation on alien species 2. Enhance land adjudication 3. Promote appropriate land use practices 4. Enhance environmental management through education and awareness 5. Promote utilization, value addition, certification of products 6. Conserve cultural values of affected communities 7. Restore, promote and conserve biodiversity in affected areas
2	Management issues	1. Enhance the role of Prosopis in environmental protection 2. Reduce negative effects (through utilization, breeding, bio-control, etc) 3. Add value to products to maximize benefits (feeds, honey, charcoal) 4. Introduce silviculture techniques 5. Capacity building of communities, technical personnel 6. Information dissemination and sharing (tours, demonstrations)
3	Utilization aspects	Develop various utilization options for Prosopis among them 1. Major current uses (a) Fuelwood (b) Charcoal (c) Posts and poles 2. Potential wood uses (a) Wood carving industry (b) Flooring parquettes (c) Furniture (d) Fibre boards (e) Paper industry (f) Timber

No.	Issue	Specific Recommendations
		3. Potential non-wood uses (a) Livestock feeds (b) Human food (c) Honey (d) Soil conservation (e) Gums and resins (f) Tannin extraction
4	Marketing strategies for products	1. Awareness creation (demonstrations, etc) 2. Exchange visits (South Africa, Americas, India) 3. Research on diversification on uses 4. Improved policy environment (products and marketing, certification
5	Socio-economic and cultural issues	1. Carry out PRA on impacts 2. Plan and implement intervention measures 3. Enhance income generation activities at household levels 4. Conflict resolutions on shared resources 5. Land tenure issues addressed as motivation to manage Prosopis 6. Effective community involvement at all stages is required
6	Research issues	1. Utilization aspects (a) Mapping and inventory of the existing biomass (b) Commercialization of products (c) Diversification of products (d) Market research (local and off-shore) (e) Community empowerment (f) Certification of products 2. Cultural and socio-economic issues (a) Cultural and socio-economic constraints (b) Identification of effective entry points for communities (c) Diversification of alternative sources of income from Prosopis
7	Co-ordination, Monitoring and Evaluation	Formation of a national task force on Prosopis management with mandate to; (a) Establish best approaches to implement the recommendations of the National Workshop, and; (b) Develop a project proposal to test the best technologies for managing and controlling further spread of Prosopis in Kenya

CHAPTER 3

3.0 PRESENTATIONS

I. Estimation of Prosopis Biomass in Kenya: Development and Use of Allometric Equations and Application of Remote Sensing

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Kenya Forestry Research Institute (KEFRI), P. O. Box 20412, 00200 - Nairobi, Kenya

Development and Use of Allometric Equations

Estimates of biomass for various forest and woodland situations are used in: determining primary productivity of ecosystems; and quantifying energy pathways product yields from harvest activities. Determination of biomass provides important biological information useful in estimating wood production, net primary productivity, in CO_2 dynamics and the greenhouse effect. Accurate estimates of stand biomass are important for the determination sustainable harvesting levels in forest ecosystems and woodlands.

In planning and developing policy for the management of the Prosopis invasion it is important to have easily applicable tools for estimating Prosopis biomass. Traditional forest inventory techniques were developed for highlands forests and are aimed at industrial needs only. For Prosopis products such as fuel wood and charcoal other biomass inventory methods are required.

To address this gap, work was therefore undertaken to:

- Develop equations for estimating single tree biomass yield of *Prosopis juliflora* and for estimation of productivity per hectare
- Estimate *P. juliflora* standing biomass by fitting developed biomass equations and complementing the information using remote sensing data
- Evaluate suitability of various tree parameters (height, D_{30} and DBH) as variables for biomass estimation in naturally established Prosopis stands

The Diameter at Breast Height (DBH) structure for Prosopis stands along the Turkwel was evaluated using sixteen intensive sample plots at Nadapal and Katilu. Nadapal was selected for allometric models development. Trees were sampled to cover diameter distribution of the species. Two more sites i.e. Marigat and Bura were selected for validation of the developed models

Forty five Prosopis stems of 2.5-18.0 cm diameter range from 30 trees were sampled at Nadapal along the Turkwel riverine forest for development of biomass and volume prediction equations for naturally established stands. The trees were assessed for height, diameters (DBH and D_{30}), crown diameter and depth, and number of stems/tree.

Trees were felled at 10 cm stump height and separated into respective multiple stems. Each stem weighed separately and added up to determine whole tree fresh weight.

Volume was determined using water displacement while dry weight was determined through oven-drying of collected samples at 105°C until a constant weight was achieved. Linear and power models were evaluated for volume and biomass prediction through regression analysis of measured tree parameters vs dry and fresh weight and volume.

Validation of models conducted at two sites in Marigat and Bura, revealed strong significant correlations between predicted and measured tree biomass and volumes, suggesting effectiveness of the models in biomass prediction across sites.

A choice can be made between use of D_{30} and DBH in biomass and volume estimation, depending on stand characteristics, because the difference between models prediction outputs were insignificant between the two diameters. The following allometric formulas are recommended for estimation of respective Prosopis resources:

(a) Ln (Fresh weight (kg)) = $0.292D_{30} + 0.59$ ($R^2 = 0.94$),

(b) Ln(Dry weight (kg)) = $0.2933D_{30} – 0.03$ ($R^2 = 0.92$),

(c) Ln(Volume (m^3)*1000) = $0.3025D_{30} + 0.32$ ($R^2 = 0.92$).

Application of Remote Sensing in Estimation of Prosopis Biomass in Garissa and Tana River

The conventional method of biomass assessment relies heavily on field measurements. However this approach is time consuming, labour intensive, and difficult to implement in remote areas. Remote sensing approach, in combination with ground -truthing data, was used in mapping the spatial distribution of Prosopis spp. Images acquired by Landsat 8 and Landsat 5 were used in mapping the extent of *Prosopis juliflora* distribution along River Tana. To determine amount of Prosopis resource in Garissa and Tana River satellite-based mapping used at the initial stage to provide an indicative estimate of the potential occurrence and distribution. Results of GB inventory was used to calculate estimates up to per hectare basis and thereafter combined with satellite-based mapping to provide large area estimates.

A total of 27 plots of 0.1 ha were selected. All trees in each plot were assessed for the following parameters: Height, DBH (1.3 m above ground), Diameter at 30 cm above ground (D_{30}) and crown width. For multi-stemmed Prosopis trees, all the stems were assessed for DBH and D_{30} in addition to other parameters listed.

Determination of plot biomass was done by;

(a) Determining the study area from satellite based map by delineating the blocks,

(b) Obtaining detailed plot biomass data using field-sampling procedures and developed equations. The plots were then combined with other plot totals for individual blocks, and average values and precision estimates calculated,

(c) The area data from (A) were combined with averages from (B) to yield estimates (e.g. total biomass) of individual blocks and the whole population as estimated from satellite mapping, and

(d) Biomass density was calculated from biomass/ha by first estimating biomass of the inventoried plots and then "expanding" this value to take into account biomass of the other aboveground components.

Prosopis is mainly found within the floodplains of the River Tana and constitutes about 50% of the total vegetation cover from Saka in NW Garissa to Nanigi in the SE of Garissa Town (Block A and B and Zones C and D) as shown in (Figure 1). The estimated Prosopis cover in the four areas is 18,993 hectares against 21,570 hectares of other vegetation.

Figure 1: Location of Blocks (Strata) A and B NW of Garissa (left) and Location of Blocks C,D and E SW of Garissa (right)

An analysis of estimated volume of Prosopis in the various zones is as shown in Table 1.

Table 1: Estimated total volume of Prosopis in the seven zones

Variable				
Prosopis Zone	**Prosopis Area (HA)**	**Estimated Total Fresh Weight (MT)**	**Estimated Total Dry Weight (MT)**	**Estimated Total Volume (M^3)**
A	6,288	1,135,647	614,644	1,046,143
B	4,900	829,098	431,874	747,059
C	2,856	145,221	68,371	123,505
D	4,949	624,090	313,063	550,349
E	20,914	1,664,267	834,848	1,467,620
Canal (Bura)	300	24,120	11,970	21,150
Bura-Hola Road	333	26,773	13,287	23,477
Total	**40,540**	**4,449,216 ±402,550**	**2,288,057 ±260,319**	**3,979,216 ±312,215**

II. A Synthesis of Ecological and Socio-economic Consequences of Land Rehabilitation with Prosopis Tree Species in Kenya

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Abstract

The devastating sahelian droughts of 1970's led to expansive loss of ground vegetation cover and both human and livestock mortality in sub-Sahara Africa. In Kenya, land rehabilitation aimed at increased ground vegetation cover was prioritized in drylands up to late 1980s. Exotic and indigenous species were screened for their land rehabilitation, fuelwood and fodder production potentials. *Prosopis chilensis* and *Prosopis juliflora* (both referred to as Prosopis hereafter) emerged as the most promising exotic Prosopis species and were extensively planted. Later, Prosopis species invaded the low lying riverine and wetland ecosystems due to extensive random seed dispersal by water, livestock and wildlife; leading to loss of pasture and farms. Following public agitation for Prosopis eradication in 1990's, ecological and socio-economic studies were conducted to ascertain the impacts and to guide policy formulation. This paper highlights major findings from the aforementioned studies. Ecological studies have revealed that Prosopis invasion manifests in the establishment of impenetrable thickets where tree density is higher and both herbaceous ground vegetation cover and biodiversity are lower than in the adjacent indigenous *Acacia tortilis* woodlands. Moreover, Prosopis allelopathy prevents the natural regeneration of *A. tortilis* leading to a gradual transformation of *A. tortilis* woodlands into Prosopis monocultures. Prosopis thinning and pruning trials have demonstrated potential optimization of trees and herbaceous species ground vegetation cover at an approximate spacing of 6m by 6m. After continuous capacity building of the affected communities by the Government of Kenya and other partners on Prosopis management and utilization, thinned wood is now commercially utilized as poles and for charcoal production. Use of Prosopis pods as raw materials for manufacture of livestock feeds and gasification of Prosopis biomass for electricity generation are also gaining prominence. This has changed the perception that Prosopis thickets are not nuisance but resources, if well managed. The change of perception is consistent government policy of Prosopis invasions management through utilization.

Keywords: Biodiversity, conservation, charcoal, *Prosopis chilensis* and *Prosopis juliflora*

1.0 Introduction

Drylands are globally important, as they occupy 41% of the world land surface. To a great extent, drylands are found in Africa and Asia (accounting for 32% of the global total), whereas the remainder is distributed over Australia, Europe, North America and South America (Kassas, 1995). According to Sombroek *et al*., (1982), drylands occupy 87% of the total land in Kenya. Of the Kenyan drylands, 46% are classified as very arid, 22% as arid, 15% as semi-arid and 5% as semi humid to semi-arid (Sombroek *et al*., 1982). In Kenya, drylands support 30% of human population, 70% of livestock and the bulk of wildlife that supports the tourism sector (GoK, 2007). Because of their largely untapped potential in the past, drylands are considered as a new frontier for national development in Kenya (GoK, 2012).

Pastoralism is the main economic activity in drylands, whereas agro-pastoralism is also practiced but has high incidents of crop failures (Darkoh, 1998; Speranza *et al.,* 2008, Eriksen and Lind, 2009). As livestock depends on the natural range resource and crop failure is frequent, then local communities rely more on natural resources for livelihoods than on crop production (Eriksen and Lind, 2009; Sietz *et al*., 2011). Overstocking and traditional land husbandry is the common practice that is often associated with land and range resource degradation (Darkoh, 1998). Resource degradation is further exacerbated by cyclic droughts that reduce biological productivity (Darkoh, 1998; UNEP, 2000; Dregne, 2002). Land degradation includes vegetation deterioration, soil erosion by wind and water, and salinization of water and soil. Because these environmental challenges are widespread (Darkoh, 1998; Dregne, 2002), the United Nations Convention to combat desertification was specifically dedicated to mitigate land degradation in drylands which is also referred to as desertification.

Widespread introduction of drought tolerant multipurpose trees and shrubs has been an important tool to mitigate large-scale loss of ground vegetation cover in drylands. Trees from the genus Prosopis have been extensively introduced in many tropical drylands (Pasiecznik *et al*., 2001), because they meet the criteria of environmental stresses tolerance, fast growth, soil amelioration, fodder provision and fuelwood supply (Rosenschein *et al*., 1999; Pasiecznik *et al*., 2001; Gallaher and Merlin, 2010). In Kenya the introduced Prosopis species included *Prosopis chilensis* Stuntz., *Prosopis juliflora* (Sw.) D.C., *Prosopis cineraria* Druce, *Prosopis pallida* Kunth and *Prosopis tamarugo* Phil. (Barrow, 1980; Herlocker, Barrow and Paetkau, 1980; Maghembe *et al*., 1983). Unpublished data suggests that *Prosopis alba* Griseb., *Prosopis nigra* Hieron. and *Prosopis pubescens* Benth. were also introduced. From these efforts, *P. chilensis* and *P. juliflora* emerged as the most promising species (Barrow, 1980; Herlocker *et al*., 1980) and their seeds were freely exchanged across the country (Paetkau, 1980).

Although the history of Prosopis species introduction in Kenya has many gaps, extensive dryland rehabilitation with Prosopis species occurred after the prolonged Sudano-Sahelian drought of 1970's (Pasiecznik *et al*., 2001, Ngunjiri and Choge, 2004; Mwangi and Swallow, 2008). Like other woodland resources in drylands, Prosopis species were unmanaged. Subsequently, unprecedented natural seed dispersal by livestock, wildlife and water lead to their spread into the low lying riverine and wetland ecosystems (Mwangi and Swallow, 2008; Mworia *et al*., 2011). In drylands, riverine forests have higher floral biodiversity than the immediate vegetation (Stave *et al*., 2007) and are highly valued as seasonal pastures for the pastoral economy (Morgan, 1981; Timberlake, 1994). Therefore any threat to riverine forests poses a danger to the livelihood of the pastoral communities. In this review, we highlight the ecological consequences of Prosopis species invasion and the evolving socio-economic scenarios from the public outcry on invasion in 1990s to date.

2.0 Ecological impacts of Prosopis invasion in Turkwel

2.1 Overview of species invasiveness and habitats invasibility

The main factors that cause biological invasions relate to:
1) species invasiveness, and **2)** habitat invasibility). A species is classified invasive if it causes negative ecological and socio economic impacts outside its natural range (Pimentel, 2001; Mwangi and Swallow, 2008). Negative ecological impacts of invasive trees include biodiversity loss, reduction of ecosystem productivity and nutrient cycling. On the other hand, negative socio economic impacts may comprise the direct costs of managing invasive species or loss of environmental services provided by the habitat before invasion.

Often, invasion is associated with exotic species when they distort natural equilibrium of species previously found in the invaded environment (Lockwood *et al*., 2007). Allelopathy, evolution of competitive ability, enemy escape, propagules pressure and hybridization are amongst the widely acknowledged invasion hypotheses (Callaway and Ridenour, 2004; Schierenbeck and Ellstrand, 2009; van Kleunen *et. al*., 2010). Comparative studies between species' invasion traits in their native range and in their introduced environments have revealed evolution of superior invasive traits by varieties found in the introduced environments than those in the native range (e.g. Callaway *et al*., 2008; Inderjit *et al*., 2011). To a great extent, development of superior invasive traits is attributed to progressive natural selection of most adapted genotypes or genetic evolution of hybrids of formerly separated genotypes (Schierenbeck and Ellstrand, 2009) and polyploidy (te Beest *et al*., 2012).

Habitat invasibility is largely influenced by disturbance, empty niche, resource fluctuations and low biodiversity (Lockwood *et al*., 2007). In riverine forests, both natural and anthropogenic factors have contributed to habitat degradation and resource fluctuation (Hughes, 1990; Maingi and Marsh, 2006). In some cases riverine biodiversity is also naturally low (Wyant and Ellis, 1990; Stave *et al*., 2003). Therefore riverine forests are highly susceptible to invasions due resource fluctuations, disturbance and inherent low biodiversity.

2.2 Prosopis invasion mechanisms along the Turkwel riverine forest

Invasibility of Turkwel riverine forest and invasiveness of Prosopis species were studied to elucidate the main drivers of Prosopis invasion in riverine and wetlands ecosystems in Kenya (Muturi *et al*., 2010; Muturi, 2013; Muturi *et al*., 2013). Results of these studies are summarized below.

2.2.1 Drivers of ecosystem invasibility

Geographical Information System (GIS) techniques were used to assess vegetation change dynamics in Turkwel riverine forest between 1990 and 2007. In that study, Landsat Thematic Mapper satellite images covering the entire riverine forest were obtained for 1986, 1995, 2000, 2003 and 2006. These images were analysed to obtain Normalized Difference Vegetation Index (NDVI), which is the ratio of reflected spectrum over the incoming total radiation. NDVI is defined as NDVI = (NIR-RED)/ (NIR+RED),

Where NIR (band 4) and RED (band 3) stand for the spectral reflectance measurements acquired in the near-infra red and red regions respectively with NDVI values ranging from -1.0 to +1.0. Analysis of Landsat satellite images revealed:

1) An increase in ground vegetation cover or improvement of existing vegetation condition,
2) A decrease of ground vegetation cover or deterioration of existing vegetation condition,
3) Stable conditions either in pre-existing vegetation cover or other ground condition.

Evaluation of three contrasting vegetation change scenarios revealed that:

(a) Encroachment of the ecosystem by Prosopis, regeneration of *Hyphaene compressa* H. Wendl. and forest rejuvenation (flushing of new leaves) were the main factors associated with increase in ground vegetation cover or improvement of existing vegetation condition.

(b) Conversion of riverine forest to farmlands and destruction of forest by floods and tree phenology were the main factors associated with decrease of ground vegetation cover or deterioration of existing vegetation condition.

(c) Areas without any change detection were dominated by forest patches.

(d) Prosopis invasion was mostly a result of habitat disturbance through farming (Table 1)

(e) Occurrence of *Acacia tortilis* in the riverine forest is declining with a contrasting increase of Prosopis species occurrence (Figure 1).

2.2.2 Prosopis invasiveness

Three contrasting canopy types (*Acacia tortilis*, Prosopis species and a mixture of *A. tortilis* and Prosopis) identified during a study on drivers of ecosystem invasibility [above] were selected from Turkwel riverine forest. Vegetation under the three canopy types was studied, soils sampled and analyzed. In addition, fresh leaves were harvested from *A. tortilis* and Prosopis trees growing in the riverine forest and used in greenhouse studies to further elucidate mechanisms of Prosopis species invasiveness (Muturi, 2012).

In the field, Prosopis invasion manifested in high tree density, low herbaceous species diversity and ground vegetation cover, and lack of *A. tortilis* regeneration (Tables 2a and b). Phosphorous mining by Prosopis species is implied by the significantly higher phosphorous concentration in Prosopis leaves than in *A. tortilis* leaves (Figure 2a), and a previous field study that revealed significantly lower phosphorus under *P. juliflora* than under *A. tortilis* (Kahii *et al*., 2009). Therefore, competition for nutrients between Prosopis and herbaceous species could be amongst the invasion mechanisms of Prosopis species. Prosopis tree canopy is deeper than that of *A. tortilis* (Kahii *et al*, 2009) and therefore the low herbaceous species ground vegetation cover can also be partly attributed to its greater shading effects.

Laboratory studies have revealed that freshly ground *A. tortilis* leaves have higher concentration of soluble phenols than freshly ground Prosopis species leaves (Figure 2b). However, the soluble phenols are leached faster from *A. tortilis* leaves than from Prosopis species leaves. This may explain the finding that fresh Prosopis leaves inhibited the germination of *A. tortilis* and Prosopis seeds more strongly than fresh *A. tortilis* leaves and that leached leaves of both species had not effects on seed germination when either litter type was added to potted soils separately (Figure 3). It was therefore concluded that allelopathy is another invasive mechanism exhibited by Prosopis species in *A. tortilis* dominated woodlands in riverine forests.

2.2.3 Management interventions

Prosopis stands have high tree densities (3,031 stems per hectare), low herbaceous species productivity and biodiversity, and lack of *A. tortilis* regeneration (Muturi *et al*., 2013). On the other hand, *A. tortilis* stands have low tree density (387 stems per hectare) and high herbaceous species productivity and biodiversity. Based on these facts, Prosopis thinning trials were conducted to determine if thinning can mitigate the adverse ecological impacts of Prosopis invasion. Thinning trials revealed that herbaceous species ground vegetation cover can be optimized at an approximate tree spacing of 6m x 6m (Figure 4). This translates to a tree density of about 277 stems per hectare, which is below the mature *A. tortilis* tree density found in the study site (Muturi *et al*., 2013). Therefore, it's likely that a higher Prosopis tree density could be admissible since the results may have been influenced by accumulated allelopathic litter that was still decomposing during trials period.

3.0 Socio-economic impacts of Prosopis invasion

3.1 Recognition of the Prosopis invasion challenges

The wet years of late 1996 to 1999 (El Niño weather phenomenon) triggered the massive spread, establishment and colonization of grasslands and biodiversity by Prosopis species, making its weediness and negative impacts visible for the first time in Kenya. Currently, the species is estimated to cover over 2% of Kenya's land cover (1.5 million ha); and about 3.0 to 27.7 million along the drylands river channels are potentially invasible (Muturi *et al*., 2010). For a country like Kenya where rural communities are more dependent on natural resources for livelihoods, such invasion trends are bound to raise public concerns. Like other natural resources in drylands, Prosopis was not under any management and therefore lack of tree management technologies was one of the constraints in invasion management. In addition, land is communally owned and communal tenure system can be a disincentive to proper land husbandry.

Initial efforts of Prosopis invasion management in Kenya entailed experimenting on the use of Farmer Field School (FFS) through a joint collaborative project by KEFRI and FAO in Baringo. The project facilitated formation of Farmer Field Schools (FFSs) and piloted integrated management to contain further spread. Since then, there has been a number of initiatives targeting the utilization of Prosopis in other parts of Kenya. Currently the main utility interventions are summarized as follows:

3.1.1 Utilization of Prosopis for charcoal production

Charcoal is the main source of energy in Kenya, of which over 80% is obtained from drylands (Bailis, 2009). According to UNEP (2000), charcoal production is almost the only viable livelihood option during prolonged droughts. Since droughts are frequent, and demand for charcoal in rural areas are on the increase, then charcoal burning has become a permanent activity. The government has recognized this fact through charcoal rules in 2009 (GoK, 2009), which provides a framework for sustainable charcoal production. *Acacia tortilis* is the most common tree in drylands and also the most preferred for charcoal production. Therefore availability of Prosopis biomass in the drylands provided a more viable solution to promoting charcoal as a livelihood and for conserving indigenous Acacia species.

To streamline use of Prosopis for charcoal production, community members have been organized into Charcoal Producers Associations (CPAs). These associations are required to comply with government regulations by adhering to the charcoal production, transportation and marketing policies. This method is working well for Prosopis management as exemplified by charcoal income trends in Baringo, Garrisa and Tana River Counties (Table 3). Prosopis based charcoal business is therefore positively changing the livelihoods of many pastoral communities in these counties of Kenya.

3.1.2 Utilization of Prosopis pods for livestock feeds and as human food supplements

Partnerships aimed at managing the spread of Prosopis through utilization of its fruits (pods) as a strategic feed for livestock in Kenya have been initiated. These include KEFRI, the International Livestock Research Institute (ILRI), Association for Strengthening Agricultural Research in East and Central Africa (ASARECA), Ministry of Livestock Development/ADB/ALLPRO, the University of Nairobi and livestock feed manufacturing companies. A national stakeholder workshop was held in 2007, and successful pilot collection, processing and marketing of 160 tonnes of Prosopis based livestock feeds were conducted. Lack of community structures to collect the pods and the long distances covered have slowed down the process, with a huge potential of collecting over 200,000 tonnes per month of Prosopis pods. Focus now has now shifted to facilitating communities to process pods for local formulations and feeding of livestock while leaving the option of trading excess to feed manufacturers open.

3.1.3 Utilization of Prosopis biomass for electric power generation

In the recent past, there has been increased interest in the use of Prosopis biomass for electricity power production through gasification. Already one gasification plant has been established in Baringo County of Kenya. The factory has facilitated the establishment of Community Forest Associations (CFAs) that supply biomass harvested from their localities to the company.

4.0 Policy

Efforts to manage Prosopis invasion was prioritized in various forums immediately the problem was identified. This culminated in a national policy recommending management of *Prosopis juliflora* invasion through utilization as articulated in Kenya's Vision 2030 (GoK, 2007). Moreover, management is further anchored in the suppression of noxious weeds act (Cap 325) through declaration of *Prosopis juliflora* as noxious weeds in the whole of Kenya with effect from 30th December, 2008 vide Kenya Gazette Notice Vol. CXI-No. 2. of 9th January, 2009. This is more effective in areas under cultivation. To operationalize utilization, Kenya Forest Service has continued to issue permits for Prosopis charcoaling to Community Charcoal Producers Associations (CPAs) that comply with provisions of the Forest (Charcoal) Rules of 2009. Subsequently, local communities have continued to draw increasing incomes from Prosopis charcoal sales thereby contributing to invasion management.

5.0 Conclusion

Much effort and investment have been made in understanding and overcoming the challenges associated with Prosopis since the invasions were first brought to the limelight. This entailed sharing of information with partners from within and outside Kenya to enhance our understanding on the species. At all levels, there is more awareness of Prosopis invasion challenges and opportunities. With the enhancement of capacity of the affected pastoral communities on management through utilization, Prosopis is increasingly being considered as a valuable resource in Kenya. However, gaps still exist in proper quantification of the resource contribution to local and national economies. There is therefore need to quantify the resource through proper mapping, and data collection on products sales and trade at all levels. This can be best achieved through the development of national and county governments' strategies and their operationalization.

Table 1: Vegetation change status in plots sampled under various types of land use or land cover assessment of Prosopis invasion according to land use or land cover along the Turkwel Riverine Ecosystem

Land use/ Land cover	Image analysis vegetation change status			No of plots not invaded	No of invaded plots	Total	% Invasion
	Increased	Stable	Decreased				
Riverine forest	25	31	20	51	25	76	33
Abandoned farms	11	1	4	2	14	16	88
Active farms	4	6	5	9	6	15	40
River bed	0	1	7	7	1	8	13
Bare land	1	2	2	4	1	5	20
Total	**41**	**41**	**38**	**73**	**47**	**120**	

Table 2a: Characteristics of trees and herbaceous plants in three canopy types (*Acacia,* Mixed species and *Prosopis*). An analysis of variance results are shown by F and corresponding P-values. Means and standard errors are shown; values in the same row followed by a different letter are significantly different at P<0.05 (Tamhane or Tukey post-hoc tests).

Plant variable	F	P	Acacia	Mixed	Prosopis
Stem density (#/ha)	9.9	0.000	333±61 b	756±138 b	1225±198 a
Merchantable stems (#/ha)	57.2	0.000	387±60 b	889±190 b	3031±254 a
Basal area (m^2/ha)	15.7	0.000	37.6±4.09 a	36.3±3.24 a	15.5±2.04 b
Seedling density (#/ha)	8.6	0.001	9464±3024 ab	19722±3760 b	71093±16294 a
Herb cover (%)	24.9	0.000	33.5±3.90 a	29.3±3.93 a	5.3±1.84 b
Herb density (#/m^2)	6.3	0.004	41±7.8 a	38±13.2 a	7±4.6 b
Species number (#/ 4 m^2)	20.5	0.000	15±1 a	14±3 a	6±1 b
Herb diversity (H')	3.6	0.042	1.75±0.11 a	1.40±0.20 ab	1.18±0.13 b

Table 2b: Mean tree seedlings density (No./ha) found under each canopy type (*Acacia*, Mixed species and *Prosopis*). Chi square and P-values are shown for the three species with a sufficient number of individuals.

Species	Acacia	Mixed	Prosopis	X^2	P
Acacia tortilis	6167	0	0	61.7	<0.001
Prosopis spp.	4500	14444	58594	351.1	<0.001
Ficus sycomorus	833	4167	1719	13.2	<0.01
Grewia bicolar	167	0	0	-	-
Hyphaene compressa	167	0	313	-	-
Ricinus communis	0	0	156	-	-
Ziziphus mauritiana	333	278	0	-	-

Table 3: Charcoal production and revenue from three counties in Kenya

Variable	County	Year					
		2007	2008	2009	2010	2011	2012
Charcoal production (25-30 kg) bags	Baringo	41,090	75,875	358425	266,855	128,855	29,265
	Tana River	1,797	2,425	10,200	128,050	74,824	12,160
	Garissa	1,500	7,500	3,400	11,710	8,911	5,143
	Total	**44,387**	**85,800**	**372,025**	**406,615**	**212,590**	**46,568**
Recorded Government revenue (US$)	Baringo	8,218	15,169	71,685	53,171	25,771	5,853
	Tana River	359	485	2,040	25,610	14,965	2,432
	Garissa	300	1,500	680	2,342	1,782	1,029
	Total	**8,877**	**17,154**	**74,405**	**81,123**	**42,518**	**9,314**
Estimated Community revenue (US$)	Baringo	202,725	379,225	2,150,550	1,595,133	901,985	204,855
	Tana River	8,985	12,125	61,200	768,306	523,768	85,120
	Garissa	7,500	37,500	20,400	70,260	62,377	36,001
	Total	**219,210**	**428,850**	**2,232,150**	**2,433,699**	**1,488,130**	**325,976**

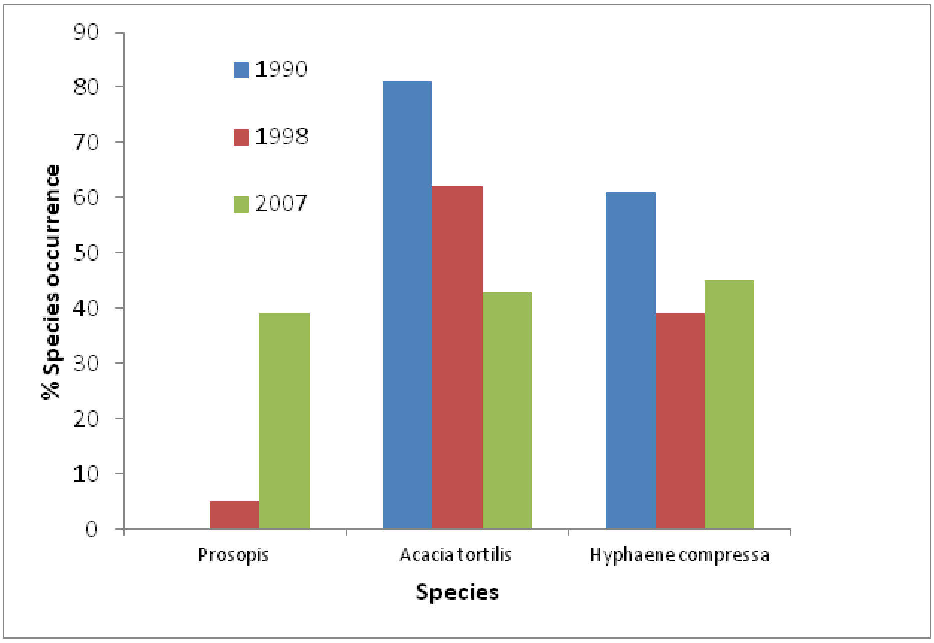


Figure 1: Occurrence of Prosopis species, *Acacia tortilis* and *Hyphaene compressa* in Turkwel Riverine Forest between in 1990, 1998 and 2007 (Adopted from Stave *et al.,* 2003; and Muturi *et al*., 2010)

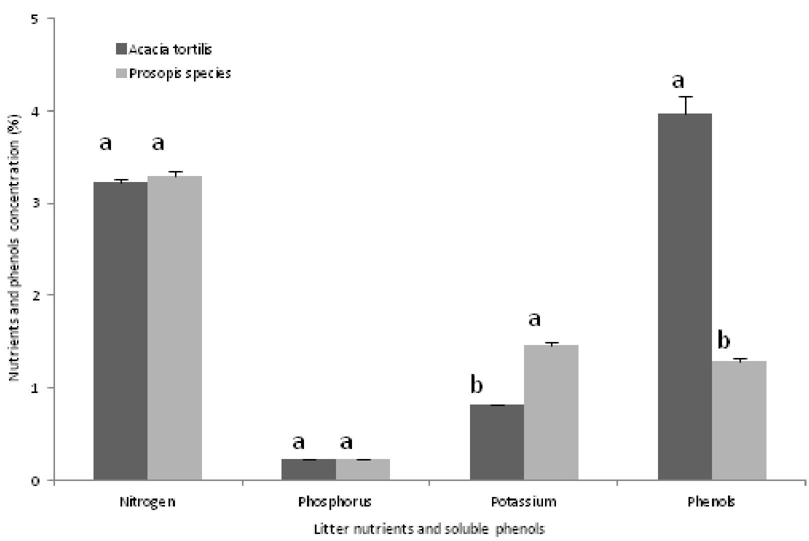


Figure 2a: Nitrogen, phosphorus, potassium and soluble phenols concentration in fresh *Acacia* litter (dark shading) and *Prosopis* species litter (light shading). Bars accompanied by a different letter are significantly different at P<0.05. The bars are standard error of the means

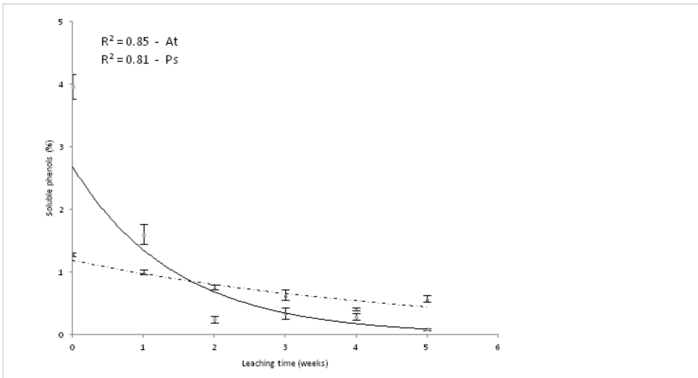
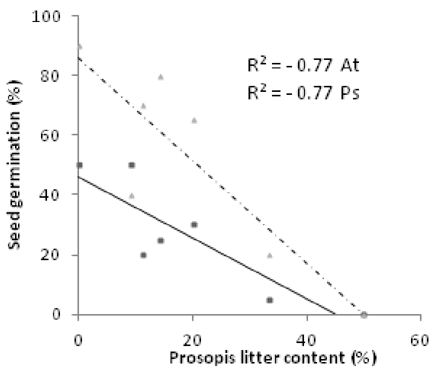


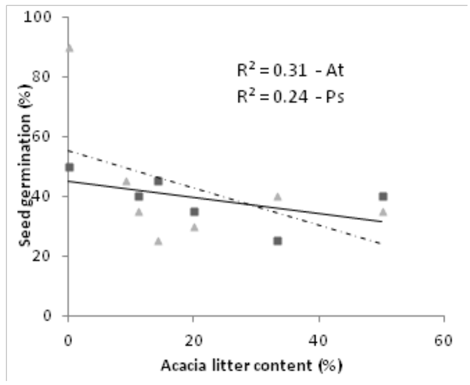
Figure 2b: Exponential time-dependent decline in soluble phenols in *Acacia* litter (square symbol, continuous line) and *Prosopis* litter (triangles, dotted line). The bars show the standard errors of the mean

Unleached litter

a.

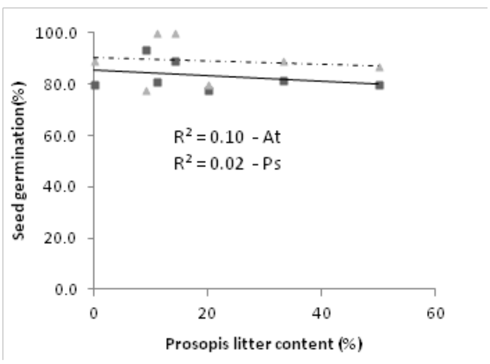


b.



Leached litter

c.



d.

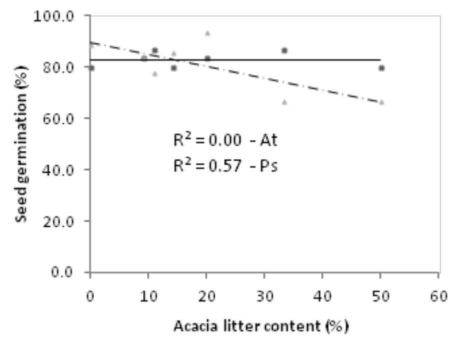


Figure 3: Germination of *Acacia tortilis* (At, square symbol, continuous linear regression line) and Prosopis species (Ps, triangle symbol, dotted regression line) seeds as a function of concentration of unleached *Prosopis* litter (a), unleached *Acacia* litter (b), leached *Prosopis* litter (c) and leached *Acacia* litter (d). Unleached Prosopis reduced seed germination significantly (R^2 = 0.77, P< 0.05), whereas litter effect on germination was insignificant in all other cases

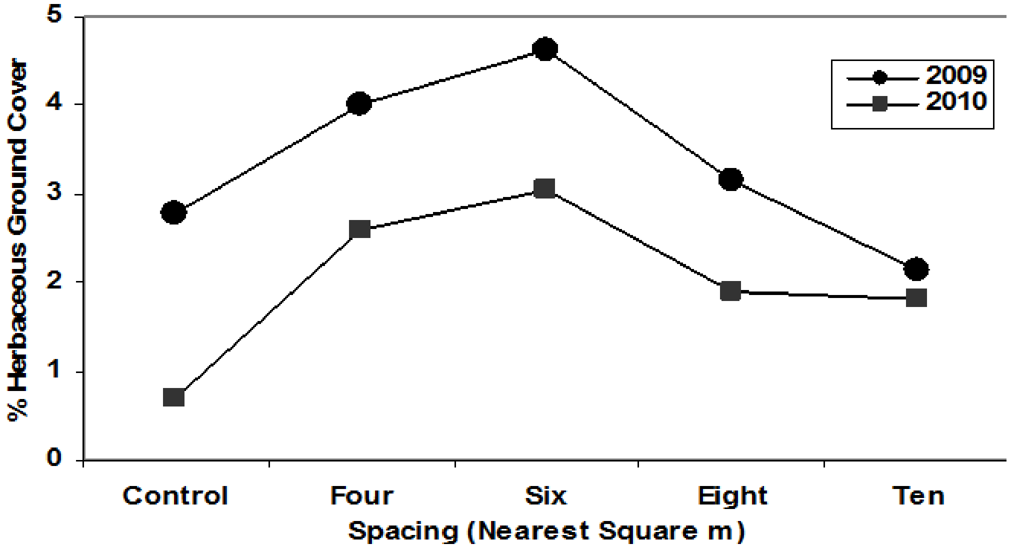


Figure 4: Percentage herbaceous ground vegetion cover at Prosopis spacing of four, six, eight and 10 meters compared to unthinned control

References

Bailis, R. 2009. Modeling climate change mitigation from alternative methods of charcoal production in Kenya. Biomass and Bioenergy 33: 1491-1502.

Barrow, E.G.C., 1980. Multipurpose trees, current experience and future possibilities. pp 499-505 in Buck, L. (editor) Proceedings on Kenya National Seminar on Agroforestry. 12-22 October 1980, Nairobi.

Callaway, R.M. *et al*,. 2008. Novel weapons: Invasive plant suppresses fungal mutualists in America but not in its native Europe. Ecology 89: 1043-1055.

Callaway, R.M., Ridenour, W.M. 2004. Novel weapons: invasive success and the evolution of increased competitive ability. Frontiers in Ecology and the Environment 2: 436-443.

Darkoh, M.B.K. 1998. The nature, causes and consequences of desertification in the drylands of Africa. Land Degradation and Development 9: 1-20.

Dregne, H.E. 2002. Land degradation in the drylands. Arid Land Research and Management 16: 99-132.

Eriksen, S., Lind, J. 2009. Adaptation as a Political Process: Adjusting to Drought and Conflict in Kenya's Drylands. Environmental Management 43: 817-835.

Gallagher, R.V. *et al*. 2011. Invasiveness in introduced Australian Acacias: the role of species traits and geneome size. Diversity and Distributions 17: 884-897.

Government of the Republic of Kenya (GoK) 2007. Kenya Vision 2030: A globally competitive and prosperous Kenya.

Government of the Republic of Kenya (GoK) 2009. The Forests (Charcoal) Rules, 2009. Government Printers. Nairobi, Kenya.

Government of the Republic of Kenya (GoK) 2012. Vision 2030 development strategy for Northern Kenya and Other Arid Areas

Herlocker, D.J., Barrow, E., Paetkau, P., 1980. A preliminary report on trial plantings of woody species in Arid and Semi-Arid Northern Kenya. pp 511-578 in Buck, L. (editor) Proceedings on Kenya National Seminar on Agroforestry. 12-22 October 1980, Nairobi.

Hughes, F.M.R. 1990. The influence of flooding regimes on forest distribution and composition in the Tana River Floodplain, Kenya. Journal of Applied Ecology 27: 475-491.

Inderjit *et al*. 2011. Volatile chemicals from leaf litter are associated with invasiveness of a Neotropical weed in Asia. Ecology 92: 316-324.

Kahii, C.H., Ngugi R.K., Mureithi, S.M., Ng'ethe, J.C., 2009. The canopy effects of *Prosopis juliflora* (DC.) and *Acacia tortilis* (Hayne) trees on herbaceous plants species and soil physico-chemical properties in Jemps Flats, Kenya. Tropical & Subtropical Agroecosystems 10**:** 441-449

Kassas, M. 1995. Desertification – A general review. Journal of Arid Environments 30:115-128.

Lockwood, J.L., Hoopes, M.F., Marchetti, M.P. 2007. Invasion ecology. Blackwell Publishing, Oxford

Maghembe J.A., Kariuki E.M., Hallerm, R.D., 1983. Biomass and nutrient accumulation in young *Prosopis juliflora* at Mombasa, Kenya. Agroforestry Systems 1:313-321.

Morgan, W.T.W. 1981. Ethnobotany of the Turkana – use of plants by a pastoral people and their livestock in Kenya. Economic Botany 35: 96-130.

Muturi, G.M., Poorter, L. Mohren, G.M.J and Kigomo, B.N. 2013. Ecological Impact of Prosopis invasion in the Turkwel Riverine Forest, Kenya. Journal of Arid Environments 92:89-97.

Muturi, G.M.,2012. Ecological impacts of Prosopis invasion in riverine forests of Kenya. PhD thesis Wageningen University, the Netherlands

Muturi, G.M., Mohren, G.M.J., Kimani, J.N. 2010. Prediction of Prosopis species invasion in Kenya using geographical information system techniques. African Journal of Ecology 48: 628-636.

Mwangi, E., Swallow, B. 2008. *Prosopis juliflora* invasion and rural livelihoods in Lake Baringo area of Kenya. Conservation and Society 6: 130-140.

Mworia, J.K., Kinyamario, J.I., Omari, J.K., Wambua, J.K. 2011. Patterns of seed dispersal and establishment of the invader *Prosopis juliflora* in the upper floodplain of Tana River, Kenya. African Journal of Range & Forage Science 28: 35-41.

Ngunjiri, F.D., Choge, S.K., 2004. Status and impact of Prosopis species in Kenya. In Choge S.K. and Chikamai, B.N. (eds) Proceedings of the workshop on integrated management of Prosopis species in Kenya. KEFRI.

Paetkau, P. 1980. Tree seed distribution report – August 1979 –July 1980. In L. Buck (editor) Proceedings on Kenya National Seminar on Agroforestry. Pp 603-609.

Pasiecznik, N.M., Felker P., Harris, P.J.C., Harsh, L.N., Cruz, G., Tewarri, J.C., Cadoret, K., Maldonado, L.J. 2001. The *Prosopis juliflora-Prosopis pallida* complex: A monograph. HDRA.

Pimentel, D. *et al*. 2001. Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture Ecosystems & Environment 84: 1-20.

Rosenschein, A., Tietema, T., Hall, D.O. 1999. Biomass measurement and monitoring of trees and shrubs in a semi-arid region of central Kenya. Journal of Arid Environments 42: 97-116.

Schierenbeck, K.A., Ellstrand, N.C. 2009. Hybridization and the evolution of invasiveness in plants and other organisms. Biological Invasions 11: 1093-1105.

Sietz, D., Ludeke, M.K.B., Walther, C. 2011. Categorisation of typical vulnerability patterns in global drylands. Global Environmental Change-Human and Policy Dimensions 21: 431-440.

Sombroek, W.G., Braun, H.M.H. Van Der Pouw 1980. Exploratory soil map and agro-climatic map of Kenya. Scale 1:1,000,000. Kenya Soil Survey Nairobi

Speranza, C.I., Kiteme, B., Wiesmann, U. 2008. Droughts and famines: The underlying factors and the causal links among agro-pastoral households in semi-arid Makueni district, Kenya. Global Environmental Change-Human and Policy Dimensions 18: 220-233.

Stave, J. *et al*. 2003. Spatial and temporal woodland patterns along the lower Turkwel River, Kenya. African Journal of Ecology 41: 224-236.

Stave, J., Oba, G., Nordal, I., Stenseth, N.C. 2007. Traditional ecological knowledge of a riverine forest in Turkana, Kenya: implications for research and management. Biodiversity and Conservation 16: 1471-1489.

te Beest, M. Le Roux, J.J., Richardson, D.M., Brysting, A.K., Suda, J., Kubesova, M., Pysek, P, 2012. The more the better? The role of polyploidy in facilitating plant invasions. Annals of Botany 109:19-45

Timberlake, J., 1994. Venacular names and uses of plants in northern Kenya. Journal of East African Natural History 83: 31-69.

UNEP 2000. Devastating droughts in Kenya: Environmental impacts and responses, Nairobi, Kenya.

van Kleunen M., Dawson, W., Schlaepfer, D., Jeschke, J.M., Fischer, M. 2010. Are invaders different? A conceptual framework of comparative approaches for assessing determinants of invasiveness. Ecology Letters 13:947-958

Wyant, J.G., Ellis, J.E., 1990. Compositional Patterns of Riparian Woodlands in the Rift-Valley of Northern Kenya. Vegetatio 89: 23-37

III. Overview of Nutritional and Feeding Value of *Prosopis juliflora* Pods

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Introduction to Prosopis

Prosopis juliflora and *Prosopis pallida* complex, locally known as *mathenge* and hereafter referred to simply as Prosopis, were introduced into the degraded drylands of Kenya in the 1970s and 1980s. In the last 25 or so years it has grown and colonized large tracts of the areas of its introduction. At the same time it has elicited strong resentment from some of the local communities where it was introduced, who consider it as a curse imposed on them by the government (Aboud *et al*., 2005). Contrary to that view, international sources of information consider Prosopis as a largely beneficial tree that can confer multiple blessings to man, though it is not the intentional of this paper to debate these views. The paper looks at the reported use of its pods in feeding animals and explores the possibilities of exploitation of pods in the feed industry in Kenya. Its exploitation may assist in its control and at the same time bestow both nutritional and monetary benefits to the complaining communities.

Prosopis have now spread widely in seven counties of Kenya, and are a major problem plant in four; Baringo, Garissa, Tana River and Turkana. Estimated to currently cover over one million hectares, the species is continuing to invade due to dissemination of seed by livestock, and current threaten a number of native species and habitats. A detailed study was conducted (Choge *et al*., 2002) which was pivotal in directing policy towards the possibility of increasing the utilization of these trees as a means for their control, as local people were already making use of them. Suggestions to changes in policy required to facilitate 'control by utilization' have been summarized (Choge and Pasiecznik, 2006).

Prosopis are fast growing, nitrogen fixing, very salt and drought tolerant trees and shrubs. Most are thorny, though thornless types are known. Animals that eat the pods spread seeds widely and trees develop a shrubby growth form if cut or browsed. Prosopis often colonises disturbed, eroded, over-grazed or drought-affected land, forming dense, impenetrable thickets. In pastures, grass cover and stocking density are reduced, threatening the livelihoods of ranchers or pastoralists. Invasion into agricultural land, along irrigation channels and water-courses is also a major problem.

The trees are believed to deplete groundwater reserves and to reduce growth of neighbouring crops. Several species have become weedy in native ranges, but it is where Prosopis has been introduced that the debate is strongest, in Africa, Australia and Asia.

Prosopis grows rapidly flowers and bears fruit at about 2 - 3 years of age. The fruit contain the seed and the amount of fruit will depend on age and season, there being more pods produced in the wet season. Application of manure or nitrogen fertilizers increases seed production and forage yield. It is estimated that mature trees may produce at least 100 kg of dry pods annually, with best trees exceeding 400 kg per annum (Pasiecznik *et al*., 2001). The pods when dry fall to the ground around the tree. The pods are heavy and thus are not carried by wind. In a heavy storm some pods or seeds from rotten pods may be carried by storm water to the riverbeds where they establish new colonies. However, the most effective means of distribution is through ingestion by animals which later drop seeds embedded in their droppings. Recovery of seed from cattle is almost 100% while in sheep it may range between 20 and 40%, as sheep are able to grind the seeds during rumination. Therefore, to prevent undesired *P. juliflora* propagation in pastures or subsistence farming lands, it is advisable to feed the animals ground pods, either alone or combined with other fodder. Fresh or dry fruits are palatable to almost all species of domestic animals, particularly bovines, equines, ovines and caprines. Goats may pick up Prosopis pods directly from the ground. This should be more common in the dry season or during drought when other preferred browse is not freely available. Cattle do not particularly appreciate collecting fruit from the ground, especially during the rains and Prosopis pods decompose quickly under moist conditions (Karlin and Díaz, 1984).

Feed products from Prosopis

Foliage

During dry season or drought, when all the other plants in the semi-arid zone are practically devoid of leaves, Prosopis is easily noticeable because of its persistent lush green foliage. However, foliage of Prosopis is almost entirely unpalatable, but there are regular demands for further research to make use of this high volume source of otherwise highly nutritional fodder. The problem seems to be the presence of condensed tannins and possibly alkaloids, though these take time to develop and do degrade, thus very new, and dried leaves, have increased palatability (Pasiecznik *et al*., 2001).

High availability of moisture, good soil type and depth may increase crown size and total leaf area, but may not necessarily lead to any increases in the rates of leaf turnover. Browse biomass is difficult to measure and unlikely to be accurate. Browsers tend to be highly selective and where vegetation choice is broad it is difficult to mimic them in sampling. However, analysis of proportions of total biomass partitioned to leaves can provide a ratio that would allow estimates based on calculations of woody biomass yields. In practice, where foliage is stripped from the trees to be fed as fodder or hay, total stripping at timed intervals may serve as an indicator of foliage biomass available for feeding. There is, therefore, little information on actual fodder biomass yields of Prosopis. The nutrient composition of Prosopis leaves is summarized in Table 1, and differences may reflect foliage in different stages of growth stage and leaf age. In addition, foliage chemical composition and palatability varies with proportion of leaves to stems (twigs), season and position within the crown (Blair and Hall, 1968; Blair and Epps, 1967; Lowry and Avard, 1965), these factors also affect digestibility and need to be put to account while harvesting Prosopis foliage for feeding.

Table 1: Range and mean of selected nutritional components of Prosopis leaves (from Gabar, 1995; Pasiecznik *et al*., 2001)

Component	**Low**	**Mean**	**High**
Dry matter, %	-	38.1	-
Energy, MJ/kg	-	10.2	-
Crude protein, %	13.7	18.3	26.3
Crude fibre, %	14.8	22.3	26.3
Crude fat, %	2.1	5.3	6.1
Nitrogen free extract, %	29.7	39.7	48.9
Ash, %	1.4	9.7	15.9
Calcium, %	1.01	1.87	2.25
Phosphorus, %	0.1	0.29	0.26

Pod composition and yield

The fruits of Prosopis are pods that, when dry, are pale to straw yellow in colour and range between 10 and 25cm long with an average weight of 12g (Table 2), characteristics described by Pasiecznik *et al*. (2001). The pulpy component of the pod is composed of the outer and the immediately inner coats (endocarp and mesocarp) that form about 56% of pod weight. The endocarp forms about 35% and encloses the seeds, which can only be extricated with difficulty. Each pod has about 25 seeds that collectively form 9% of the pod weight.

Table 2: Some characteristics of Prosopis pods

Component	Low	Mean	High
Whole pod			
Pod production (kg per tree)	2.2	86	360
Pod production (tonnes per hectare)	0.12	8.99	55
Pod length, cm	9	17.5	28
Pod weight, g	8	12	16

Prosopis yields fruit continuously throughout the year in the tropics. The volume of pods produced varies with rainfall and season but the variation has not been well studied. Since many arid and semi-arid lands of Kenya receive as much as 450 mm of rainfall annually, they fall within range of conditions considered optimal for bearing of Prosopis fruit (Gomes, 1964). Pod yield ranges between 2.2 and 360 kg per tree or 0.12 and 55 t/ha (Pasiecznik *et al*. 2001), large variations depending on age of tree, species, season, prevailing ambient temperature, precipitation, soils, tree health, protection from physical damage and production practice among others. Water availability is reported to be a major factor of fruiting and indeed where irrigated, Prosopis fruiting may take place in the first year of growth and the yield may be higher than otherwise (Felker *et al*., 1984, 1986b). In arid lands, watering is advantageous whereas yields decrease with increase in rainfall, especially in the temperate areas (Lee and Felker, 1992). Location of trees also contributes to yields, with trees on shallower soils and on higher elevations have lower yields than those on rich alluvial soils or on riverbanks. Many of these factors may initially not appear to be of great importance in Kenya where the tree is considered an obnoxious weed. But it is expected that as soon as communities start realizing benefits from the tree, the desire to optimise production will make it necessary to comprehend factors that may be manipulated to enhance yield.

Nutrient composition of pods and seeds

A synthesis of key nutrient composition of Prosopis pods is shown in Table 3. Mature pods have 12 - 19% moisture content (Riveros, 1996), reduced by sun drying to about 9 - 10%. Under humid conditions, pod quality may deteriorate quickly, thus there is a need to prepare practical collection and drying strategies. The crude protein and fibre percentage of the pods ranged between 7.1 and 21.8, and 10.9 and 32.2, respectively. This variation is considerable and would necessitate laboratory analysis to preclude ration formulation. Grading of pods at source may also reduce the variability. It is probable that visual assessment of pods in terms of size and colour shade is a reflection of nutrient quality. Size may determine the number and size of seeds within the pod. As the protein content is high and the fibre content low in the seed, their number in the pod is likely to be a strong factor in determining the nutritional quality. In making animal feeds, these components are of primary importance and should determine the value of the pods. Hence, from the very beginning of commercialization, of pod collection and also for animal health reasons, pod collectors should be encouraged to put quality first.

It is laborious to separate large amounts of seeds from the pulp (Barros *et al*., 1981), and to date, no efficient mechanization of the process has been developed. Thus it is not likely that the separate components will any time soon be available commercially for feeding in Kenya. However, it is worth noting that the pulp has a high fibre and simple sugar content, and very low starch content. In feeding ruminant animals, the rapid degradation of the sugars may tie in very well with non-protein nitrogen, thus offering a potential replacement for the conventionally used molasses. The seeds have such a high level of protein as to rival most local protein concentrates used in feeding. It is unfortunate that the pods are not more amenable to seed separation. Also, most Kenyan basal feedstuffs are based on maize and wheat and therefore poor sources of lysine and methionine. These amino acids are often limiting, especially in pig and poultry diets. Seeds and even the pods are, therefore, likely to form important sources of these important amino acids having relative high concentrations of each.

Table 3: Chemical composition of key nutritional components in Prosopis pods, pulp and seeds (from Gabar, 1995; Pasiecznik *et al*., 2001).

Key nutrient composition of whole pods			
Nutrient of Interest	**Low**	**Average**	**High**
Dry matter, %	77.8	86.6	92.6
Energy, MJ/kg	-	-	-
Crude protein, %	7.1	11.7	21.8
Crude fiber, %	10.9	20.1	32.2
Crude fat, %	0.4	2.1	4.9
Nitrogen free extract, %	29.7	58.6	75.2
Ash, %	1.4	4.4	8.4
Dry matter Digestibility, %	38		55
Key nutrient composition of pod pulp (ectocarp and mesocarp)			
Dry matter, %		87.3	
Crude protein, %	9.5	11.5	13.5
Crude fiber, %	16	24	31.7
Crude fat, %	1	1.5	2
Nitrogen free extract, %	44.8	53.2	61.5
Ash, %	4.5	7.0	9.3
Dry matter Digestibility, %	50.3	58.7	74.5
Key nutrient composition of Prosopis seeds			
Dry matter, %		90	
Energy, MJ/kg	11	12	13
Crude protein, %	27	39.9	61
Crude fiber, %	4	7.3	10.8
Crude fat, %	5.3	7.1	9
Ash, %	4.2	5.2	6.1

* ME (Mj/kg DM) = 0.012 CP + 0.031 (EE) + 0.005 (CF) + 0.014 (NFE)

Intake, digestibility and livestock performance

The following is not an exhaustive review of all the available literature on use of Prosopis pods and foliage as animal feed, but the selected examples cited are intended to provide an indication that substantial research has been undertaken, and that pods are a high value feed, foliage much less so. A number of experiments have been carried out on feeding of sheep and goats on Prosopis leaf hay and pods. The feed offered has varied from a complete diet of leaf hay and pods to a mixed ration including Prosopis pods among its ingredients. Sheep offered 2 kg of leaf hay and pods per day by Lanina (1966) only attained 62% live weight gain, 87.5% wool weight and 76.2% fertility as compared to those offered 1.5 kg lucerne hay. Both performed worse than those free ranging in a Prosopis forest, no doubt because they were able to select feed from Prosopis and other plants.

However, sheep fed on Prosopis pods had 15% higher protein digestibility than those fed on lucerne hay. Omani goats fed rations containing various proportions of Prosopis pods had highest intakes at 20% Prosopis, the rest being made up with Rhodes grass hay (*Chloris guyana*). Higher than 20% Prosopis pods in the diet reduced feed intake, growth rate and feed conversion but did not affect proportions of body components or carcass chemical composition (Mahgoub *et al*., 2005). Addition of Prosopis pods to rations had a positive effect on nitrogen balance. A tendency was observed for the N balance to increase as the Prosopis pod proportion was increased (Helmer and Bartley, 1971). This probably reflected previous diets that had insufficient energy content and therefore benefited from the highly degradable sugar content of the pods. It must have also depended on a protein source that was degraded at an equal pace as the sugars as the type of energy available for protein synthesis starting from non-protein nitrogen, has considerable effect on utilization of the same (Ruiz *et al*., 1977).

Pigs have been fed with a variety of rations based on Prosopis pods. Literature gives fairly generalized reports on Prosopis pod use in pig rations. For instance, Gomes (1961) observed that in Peru, a pig consumes 2-3 kg pods per day; with live weight gains were 0.25-0.60 kg per day. This must have led Duque (1980), studying *P. juliflora* ground pods to feed pigs, to conclude that, in spite of their good quality, they did not match standard rations. However, it is generally reported that as much as 30% of a pigs ration can be from Prosopis pods. Wheat bran is one of the main products used in manufacture of commercial animal feeds in Kenya. It forms as much as 10-20% of the ration depending on the feed standard. In Brazil poultry feeds, all wheat bran has been replaced with Prosopis pod meal with satisfactory results. Mean daily ration intake, mean egg weight, feed conversion rate and ration intake/kg egg weight remained similar after replacing all the 7.5% wheat bran in layer diet with Prosopis pod meal (da Silva, 1990). Since wheat is a scarce commodity in Kenya, such an alternative ingredient would come in useful.

Deleterious effects of Prosopis

The following indicate that there are numerous reports citing livestock ill health and death from consuming Prosopis, but almost entirely in concentrations higher than have already been recommended, and when using unground pods. Using ground/milled pods mixed in rations at no more than 30% have not been record to cause any ill health. There are also other unconfirmed reports of human discomfort from Prosopis. Prosopis thorns are sharp and easily penetrate the skin. The penetration is reported to cause more inflammation than expected from the physical injury. The irritation may be due to waxes. Using the wood in a fireplace has caused dermatitis, as has working with seasoned wood. The gum has irritant properties, and the pollen has been reported to cause allergies.

Lewis and Elvin-Lewis (1977) reported that ingestion of pods over long periods of time may result in death in cattle. Kingsbury (1964) reported cases where autopsies showed pods and seeds in the rumen 9 months after the cattle could have ingested them and probably causing death through induced permanent impairment of cellulose degradation. Although Felker and Bandurski (1979) reported cattle dying with a compacted pod ball in the rumen, and attributed the death to high sugar content repressing the rumen-bacterial cellulose activity; fast degradation of the sugars would have resulted in acidosis or a condition similar top grain overload. These two conditions are unlikely to occur together so a better explanation must be sought. In the Sudan, ewes and goats fed Prosopis pods progressively lost weight but at a slow rate (Ibrahim and Gaili, 1982; Ladrille *et al*., 1971) and after the 12th week of experiment the animals lost appetite and started dying. Postmortem findings revealed ruminal impaction, severe carcass emaciation and serious atrophy. Deaths were attributed to ruminal atony impairing rumen motility. The excessive accumulation of improperly digested pods favoured the proliferation of bacteria leading to the production of lactic acid in extensive amounts, thereby destroying the protozoa, cellulolytic organisms and lactate utilizing organisms. Progressive acidosis and subsequent dehydration lead to the death of the ewes. Mesquite feeding to pigs was promising during the first four weeks, deteriorating thereafter, perhaps due to phytohemagglutinins and trypsin inhibition. Feeding trials with sheep show a 15% higher protein digestibility coefficient for mesquite pods than for alfalfa hay (Simpson, 1977).

Objections to Prosopis in Kenya have been vocal enough to reach the media and the courts. The first objection is that the trees originally planted in degraded areas have grown into uncontrollable thickets chocking off all the other plant species and thus forcing livestock subsist on its sweet and yet harmful pods. The pods are then reported to cause infection of the livestock teeth leading to rotting and loss of teeth. This is a serious blow to community wholly dependent on livestock.

In addition, its thorns are poisonous causing slow healing wounds, itchy skins and its pollen causes allergy and inflammation of the lung. And yet the people cannot see any obvious benefits for having the tree (Aboud *et al.*, 2005).

From the above observations, Prosopis trees are blamed for having three negative qualities. One is the poisonous thorns and its allergic pollen, but these are common problems that may be overcome using conventional protective methods. The second is a hint of anti-nutritive factors in the pods and seeds. This intimation is given in an attempt to explain poor animal performance on diets composed largely or entirely of unground Prosopis pods. Literature contains no conclusive evidence of presence of any anti-nutritive factors. On the contrary experimental results on protein depletion recovery in rats show that the pods have the potential to alleviate symptoms of individuals suffering protein malnutrition. However this issue can be laid to rest through simple laboratory assays for recognized categories of anti-nutritive factors, which are recommended to be undertaken in Kenya. The third problem is given as its effect on the rumen and teeth; which the high proportions of reducing sugars in Prosopis pods do explain. If animals are allowed free grazing on Prosopis pods in absence of other plants to select from this may be a problem. On the other hand, meal feeding of properly formulated rations should not result in any ill effects. Although the data available could be expanded to include feeding trials for estimation of digestible, metabolizable or net energy for purposes of refining the formulation, existing knowledge permits use of Prosopis pods in limited proportions in poultry and ruminant rations.

Economic assessment of use of Prosopis feed products as feed in Kenya

Cost comparison on basis of nutrient composition is commonly used in consideration of value of feed ingredients for feed manufacturing. The simplest procedure calculates a weighted index of the nutrient composition of key nutrients. The weight commonly employed is a superlative value of the ingredient concerned. In this case, metabolizable energy (ME) in MJ/kg, Crude protein and Crude fibre % were used in the calculation of the index. In this comparison, crude fibre had a negative attribute of 25% of the positive attributes of energy and protein. The information available on metabolizable energy was scanty. The information used here was derived using equations on the basis of the proximate components of protein, fat and fibre of the Prosopis products considered. Although considerable information on amino acid levels in Prosopis products exists in literature, they were not included in this comparison. The reason is that amino acid assays are not routinely performed in Kenya and comparisons on the basis of literature may prejudice decisions not based on in-country analysis.

The indices calculated here (Table 4) called Equivalent worth and Net cost saving, after Dent (1983), ranked Prosopis seed flour very high, with pods and pulp meals low.

Table 4: Cost comparisons of a variety of feed ingredients commonly used in manufacturing of feeds in Kenya

Feedstuff	Metabolizable energy, MJ/kg	Crude protein, %	Crude fibre, %	Equivalent worth	Cost, Ksh/kg	Net Cost saving	Rank
Rice polishings	10.04	8.2	31.9	103	8	95	12
Molasses	9.80	2.9	0	127	25	102	11
Prosopis pulp meal	9.94	11.5	24	154	-	154	10
Prosopis pod flour	9.30	11.7	20.1	160	-	160	9
Wheat bran	8.37	15.5	15	201	8.4	193	8
Maize germ meal	11.51	12.4	10.2	214	11	203	7
Maize germ cake	9.20	17.4	6	251	15	236	6
Wheat pollard	11.72	16	8	257	10.5	247	5
Sunflower seed cake	7.95	27	28	279	14	265	4
Cotton seed cake	9.62	30	24	336	11	325	3
Soybean meal	10.46	44	6	530	36	494	2
Prosopis seed flour	12.95	39.9	7.3	510	-	510	1

Conclusion and Way forward

The foregoing discussion presents a potential of combating Prosopis spread within the areas of its introduction while deriving social and economic benefit. In doing so, for purposes of commercialization, further knowledge on the availability Prosopis pods is needed. This knowledge includes production, seasonal variation, potential cost, transport needs and nutrient composition. The methods of collection and processing at or near collection points also need to be standardized so as to present the best quality possible to the market. Some form of physical assessment with close correlation with its valuable nutrient composition as well as level of contamination by mycotoxins should be developed to assist grading in field. Finally, to ease its introduction as a feed ingredient to the feed industry, some rations for different classes of livestock should be prepared and tested.

References

Aboud A.A., Kisoyan P. and Coppock D.L., 2005. Agro-pastoralists' wrath for the Prosopis tree: the case of the Il Chamus of Baringo District, Kenya. Pastoral risk management project, Global livestock collaborative research support program. Egerton University, Kenya and the University of California, Davis, USA.

Alves A.Q., 1972. "Algaroba, uma experiencia válida," João Pessoa, SAIC, 20 p.

Alves J., 1981. "Consórcio de plantas forrageiras para as regiões do semi-árido da Paraíba," João Pessoa, Ministério do Interior, DNOCS, 29 p.

Azevedo G., 1955. "Algaroba," Natal, Ministério da Agricultura, Serviço do Acordo do Fomento da Produção Animal, 13 p.

Barros N.A.M.T. 1981. "Algaroba, uma opção válida para o Nordeste seco," Natal, Universidade Federal do Rio Grande do Norte, Centro de Tecnologia, Departamento Agropecuária, 81 p. (Mimeographed).

Carvalho R.F., 1963. "A Algarobeira," Anuário dos Criadores, São Paulo 10, 4 (4): 195-9.

Choge S., Pasiecznik N.M., 2006. The challenges of eradicating *Prosopis* in Kenya. Policy brief. HDRA, Coventry, UK. 2pp -http://www.gardenorganic.org.uk/pdfs/international programme/Prosopis Kenya Brief.pdf

Choge S.K., Pasiecznik N.M., Harvey M., Wright J, Awan S.Z., Harris P.J.C., 2006. *Prosopis* pods as a human food in Kenya. In: Symposium on Nutritional Value and Water use of Indigenous Crops for Improved Livelihoods, 19-20 September 2006. The Centre for Nutrition, Faculty of Natural and Agricultural Sciences, University of Pretoria, Pretoria, South Africa.

Correa, M.P., 1926. "Dicionário das plantas úteis do Brasil e das exóticas cultivadas," Rio de Janeiro, Imprensa Nacional, V. 1, pp. 68–9.

Duque, J.G., 1980. "O Nordeste e as lavouras xerófilas," 3rd Ed. Mossoró (RN), Escola Superior de Agricultura, Fundação Guimarães Duque, p. 289–93 (Coleção Mossorense, 153).

Felker, P., Clark P.R., Osborn J.F. and Cannell G.H., 1984. *Prosopis* pod production - comparison of North American, South American, Hawaiian, and African germplasm in young plantations. Economic Botany 38:36-51.

Felker, P., Clark P.R., Osborn J.F., and Cannell G.H., 1986. Utilization of mesquite (*Prosopis* spp.) pods for ethanol production. in Tree Crops for Energy Co-Production on Farms, November 12-14 1980. YMCA of the Rockies, Estes Park, Colorado, USA.

Mahgoub O., Kadim I.T., Forsberg N.E., Al-Ajmi D.S., Al-Saqry N.M., Al-Abri A.S. and Annamalai K., 2005. Evaluation of Meskit (*Prosopis juliflora*) pods as a feed for goats. Anim. feed sci. technol. 121: 319-327

Maldonado L.J., 2001. The *Prosopis juliflora* - *Prosopis pallida* Complex: A Monograph. HDRA

Pasiecznik N.M., Harris P.J.C., and Smith S.J., 2004. Identifying Tropical *Prosopis* Species: A Field Guide. HDRA, Coventry, UK. 30pp. www.gardenorganic.org.uk/pdfs/international programme/Identifying Prosopis Guide.pdf

Pasiecznik N.M., Felker P., Harris P.J.C., Harsh L.N., Cruz G., Tewari J.C., Cadoret K., Maldonado L.J., 2001. The *Prosopis juliflora* - *Prosopis pallida* Complex: A Monograph. HDRA, Coventry, UK. 162pp. www.gardenorganic.org.uk/pdfs/international programme/Prosopis Monograph Complete.pdf.

Pasiecznik N.M., 2001. *Prosopis* – management by exploitation, not eradication, required to control weedy invasions. ACOTANC 2001, the 9th Australian Conference on Tree and Nut Crops. 13-19 April 2001, Perth, Australia. www.aoi.com.au/acotanc/Papers /Pasiecznik 1/index.htm

Ruiz, A. and Ruiz, M.E., 1977. “Utilización de la gallineza en la alimentación de bovinos; II Utilización del nitrógeno de la relación en función de diversos niveles de gallineza y almidón,” Turrialba, 28: (2): 143–49.

Valdivia, S.V., 1972. “El algarrobo, una especie forestal prometedora para los trópicos áridos,” Peru, Ministry of Agriculture, 4 p. (Bol. de Divulgacão, 32).

IV. Charcoaling of Prosopis

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1.0 Introduction

Wood-fuel (charcoal and fuelwood) represent the main source of domestic energy in Kenya. About 90% of Kenyan rural households use wood-fuel. It is estimated that 83% of Kenyan urban households who are about 20% of the Kenyan population depend on charcoal for domestic energy. Charcoal with 5 to 9 KJ/g energy is preferred to fuelwood which has 3.5 - 5 KJ/g. It is also lightweight and thus easy to transport and store over long period of time. Charcoal is also known to produces less fumes and noxious compounds when burned. In most cities it is cheaper compared to kerosene, liquefied petroleum gas (LPG) or electricity and has the image of "modern" energy. Charcoal production in Kenya is dependent on the availability of wood. Unsustainable harvesting of trees for charcoal production is a threat to the environment. It is therefore important that conversion of wood to charcoal is efficient to maximize on conversion yield.

Three major factors that influence conversion yield are;

- Moisture content of the wood at time of carbonisation. The optimum moisture content should be 20% or less,
- Type of carbonising equipment used, and
- Adherence to the carbonization standards. High charcoal conversion efficiency and quality can be achieved through proper control of the carbonisation process. The choice of appropriate charcoal production technology is determined by; raw materials availability, scale of operation, alternative technologies available, cost and time.

2.0 Technology available for processing Prosopis charcoal in Kenya

In Kenya charcoal production technology generally falls into three broad categories; earth kilns, masonry kilns and metal kilns. Earth kilns can be traditional or improved. Traditional kiln is low in investment, can be sited near the wood source but requires high level of skill to make charcoal. It yields inferior charcoal quality due to lack of carbonisation control and soil contamination. Its recovery rate is between 10 to 20%. Improved earth kiln provides better carbonisation control due to inclusion of chimneys resulting in higher yields (about 30%) and better charcoal quality. Wood is first stacked for air drying to a moisture content of 18 - 20% which takes 4 - 6 weeks before carbonization. The fuel wood is stacked in the kiln as tightly as possible in a horizontal position and all gaps between the wood are filled with smaller fuel wood pieces to allow better heat transfer.

Two chimneys are placed at the opposite side to the lighting place. After lighting the kiln, carbonization of wood is closely monitored and any 'leakage' in the kiln is repaired. The carbonization cycle takes 3 - 6 days depending on the size of the wood stack. A $3m^3$ of wood produces 9 - 11 bags of charcoal after 5 - 6 days carbonization. Casamance kiln is a modified earth kiln, widely used in Senegal and yields high quality charcoal with a recovery rate of 32 - 38%. Wood is stacked in a circular manner with the wood positioned upright. It has one chimney placed at the opposite end of the lighting point. Air inlets pipes are placed around the base of the kiln.

Traditional earth kiln

Casamance kiln – improved earth kiln

Other kilns available in Kenya include; metal kilns, portable metal kilns and drum kilns. Portable metal kilns are made of 2 mm thick stainless/mild steel consisting of three interlocking cylindrical sectors and a conical cover. The bottom cylinder has eight air inlet/outlet channels arranged radially at the base. The kiln operates on reverse drought principle where carbonization starts from the top and progress downwards. This is aided by chimneys situated around the base of the kiln. The process provides better carbonization control and yield of up to 30% recovery. The portable kilns on the other hand are easy to move from one place to another. This kiln has a short production cycle of 16 - 24 hours. The cost of importation is high but local fabrication is possible.

Portable metal kiln being loaded (left) and in use to make charcoal (right)

There are several designs of Drum kilns but are basically constructed by modifying the ordinary metallic drum, with an adjustable lid specially fitted with a firing door. Air movement is controlled through a chimney attached at the side of the drum where it is covered with soil during the process of charcoaling. Conversion takes 6 - 12 hours and recovery is about 28 - 30%. A fully filled drum with wood yields about ¾ bag of charcoal. This technology is appropriate for domestic production where branches and small wood pieces can be used.

Masonry kilns are ordinarily made of bricks. The larger brick kilns of 5 - 7 m in diameter are constructed for commercial purposes producing about 80 - 120 bags of charcoal. Air inlets are located at the base of the kiln while chimneys which control air flow are mid-way to the top. Huge chunks of wood including stumps are used to make charcoal.

Vertical drum kiln

Masonry kiln

V. Trends in Commercialization of Prosopis Products

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1.0 Introduction

Prosopis juliflora (locally known as "Mathenge"), a native tree to South America and introduced for its adaptability to desert conditions, fast growth and source of fuelwood and fodder, is progressively becoming an invasive species, colonizing many parts of Kenya's arid and semi-arid areas (ASALs) (Choge *et al.,* 2002). The rapid spread of the tree is largely fueled by its prolific seeding, powerful ability to regenerate and re-grow/coppice in high densities, and lack of practical knowledge to tame and pressure to utilize it.

The outcry on spread of Prosopis in pastoral areas came in 1999 after the *El Nino* rains of 1997/8. Difficulties of managing the spread and lack of knowledge for processing and utilizing its products by communities ended up in calls to eradicate the species and replace with indigenous species of similar characteristics and qualities.

In an effort to address these concerns, the Government of Kenya through the Kenya Forestry Research Institute (KEFRI) and Kenya Forest Service (KFS) has successfully defined the status and impact of the species in Kenya. While acknowledging the negative environmental and socio-economic side effects associated with the species in a number of situations, pilot intervention measures carried out by KEFRI and KFS have also shown that the species presents more positive impacts to both the environmental conservation and improved livelihoods through strategic research and development initiatives geared towards effective management and utilization. This is in line with the global consensus now advocating for management of Prosopis through utilization as a critical resource in the drylands (Pasiecznik *et al.,* 2001; Tewari *et al*., 2009; HDRA, 2005a).

From 2007, the Government of Kenya embraced the concept of control of Prosopis through utilization for the first time in an effort to have an impact through reduction of further spread of invasions and to ensure active participation of the local communities in each of the target areas. This was done by lifting of the ban on production and transportation of charcoal from Prosopis and other wood products on a pilot basis (Choge *et al.,* 2006). This approach involves selective removal (thinning) of invasions using hand tools or other appropriate machinery and the processing of the resultant biomass to offset the felling costs, and make profits through commercialization of products. Treated areas are placed under active land use and regular follow-up activities to maintain the Prosopis densities at manageable levels. In addition, ripe fruits/pods – the main source and cause of reproduction and spread of the species - are collected and processed (by milling) and used as a raw material for manufacture of livestock feeds and occasionally, human food (Pasiecznik *et al.,* 2006). Several steps have been followed to effectively implement the concept. These steps are shown in the next section.

2.0 Control and management of Prosopis through utilization

2.1 Establishment of community structures

The pilot project in Baringo (2004- 2007) was the first attempt to involve local communities in the management and utilization of Prosopis invasions through formation of Farmers Field Schools (FFS). Formation of similar community based groups/associations in other parts of the country has been initiated whose activities have mainly been centered on Prosopis management, processing and trading. Each group has received initial minimum level of facilitation through capacity building and empowerment through the government of Kenya and development partners to enable them to implement the activities. A total of sixteen (16) active groups exist in Kenya mostly drawn from Baringo, Tana River, Taita Taveta and Garissa Counties (Choge *et al.,* 2012). The activities of these groups include; charcoal production, collection, processing and utilization of Prosopis pods/fruits and sale of poles and other Prosopis based products.

2.1.1. Charcoal production

Charcoal production has been the most popular, widely accepted and profitable activity carried out by most of the community groups in Prosopis prone areas in Kenya. The low initial capital outlay, use of traditional production methods, ready market and lifting of the ban on production and movement of Prosopis charcoal has made the production attractive. A recent appraisal survey on the production of charcoal and other Prosopis management activities in Baringo, Garissa and Tana River Counties was done and the results are described in the next sections.

2.1.1.1. Baringo County

Close proximity to urban markets and the advantage of hosting the first pilot project in Kenya, Baringo residents have benefited from sensitization, awareness and training programs in comparison with other Counties with similar invasions of Prosopis. This is reflected by the annual income from Prosopis charcoal in any given year estimated at Ksh 108 million with a monthly return estimated at Ksh 11 million (Table 1). These values are based on the basic minimum charcoal producer prices of Ksh 200 per bag. The prices have since more than doubled in the recent past thereby increasing the returns by a significant margin.

Table 1: Prosopis charcoal production statistics in Baringo County (2007-2012)

Period of production (in 25-30 kg standard charcoal bags costing Ksh 200/bag)							
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**Annual mean**
Annual Totals (Bags)	41,090	75,845	358,425	265,855	128,855	29,265	179,867
Revenue (GOK)	821,800	1,516,900	7,168,500	5,317,100	2,577,100	585,300	3,597,340
Annual income (Communities)	20,545,000	37,922,500	215,055,000	159,513,000	90,198,500	20,485,500	108,743,900
Monthly mean income	2,935,000	3,160,208	17,921,250	13,292,750	10,022,056	10,242,750	11,514,802

(Source: Records collected at KFS offices in Kabarnet and Marigat)

2.1.1.2. Tana River County

The use of Prosopis in charcoal production in Tana River County began in 2007 with a total annual output of 1,797 bags, rising gradually to 2,425 bags in 2008 and a peak output of 128,051 bags in 2010 (Table 2). In the 2007-2012, the communities had a monthly income of Ksh 3.6 million and annual income estimated at Ksh 29 million (Table 2).

Table 2: Prosopis charcoal production statistics in Tana River County (2007-2012)

Period of production (in 25-30 kg standard charcoal bags costing Ksh 200/bag)							
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**Annual mean**
Annual Totals (Bags)	1,797	2,425	10,200	128,051	74,824	12,160	45,891
Total revenue (Ksh) (GOK)	35,940	48,500	204,000	2,561,020	1,496,480	243,200	917,828
Annual income (Communities)	898,500	1,212,500	6,120,000	76,830,600	52,376,800	8,512,000	29,190,080
Monthly mean income	99,834	151,582	612,000	6,402,550	6,547,100	4,256,000	3,613,813

(Source: Records collected at KFS offices in Hola and Bura)

2.1.1.3. Garissa County

Charcoal output in Garissa County is fairly modest in comparison with Baringo and Tana River Counties possibly due to the limited distribution of Prosopis biomass in the County in communal areas. For the last three years (2010 - 2011), the charcoal production has been 11,710 bags in 2010, 8,911 in 2011 and 5,143 in the first two months of 2012 (Table 3). The estimated monthly income by the local communities from charcoal production is Ksh 981,316 and the annual income is estimated at Ksh 4.6 million.

Table 3: Prosopis charcoal production statistics in Garissa County (2007-2012)

Period of production (in 25-30 kg standard charcoal bags costing Ksh 200/bag)							
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**Annual mean**
Annual Totals (Bags)	1,500	7,500	3,400	11,710	8,911	5,143	7,632
Total-Revenue (GOK)	30,000	150,000	68,000	234,200	178,220	102,860	152,656
Annual income (Com-muni-ties)	750,000	3,750,000	2,040,000	7,026,000	6,237,700	3,600,100	4,680,760
Monthly mean income	187,500	535,714	340,000	1,003,700	1,039,616	1,800,050	981,316

(Source: Records collected at KFS offices in Garissa)

2.2.2. Collection, processing and utilization of Prosopis pods/fruits

2.2.2.1. Initiatives on the use of Prosopis pods in Kenya

Commercial utilization of Prosopis pods in Kenya began in early 2007 as an output of the a national workshop on integrated management of Prosopis species in Kenya. The workshop was supported by the International Livestock Research Institute (ILRI) in collaboration with KEFRI, KFS, KARI, University of Nairobi, the Ministry of Livestock Development (ALLPRO/ADB), Henry Doubleday Research Association (HDRA/UK) and the Department for International Development (DFID/UK).

The workshop theme was to link the livestock feeds industry to the Prosopis resource in Kenya. The workshop objectives were to bring together representatives of the livestock feed industry, researchers, development agents, communities, local administration and other stakeholders. The aim of the workshop was to share local and international experience in the use of Prosopis as a feed resource and generate initiatives to catalyze the interest of feed companies on the use of Prosopis pods as cost effective ingredient in the formulation of livestock feeds. Besides commercialization of Prosopis pods, focus was on self sufficiency in local supply of feed resources by communities in ASALs where feed scarcity is a major constraint to livestock production during drought crisis. The major output of the workshop was the appointment of a Taskforce on the use of Prosopis pods in Kenya. The task force was hosted by ILRI and co-chaired by Sigma Feeds Company and KEFRI.

2.2.2.2. Achievements of the Taskforce

In July/August 2007, the Taskforce on Prosopis pods enrolled pods collection agents in four districts of Turkana, Baringo, Garissa and Taita Taveta. These agents were taken through a basic induction course on; field pod collection procedures, their role and their contractual obligations, standards for Prosopis pods and storage procedures.

Facilitation of the agents to collect the Prosopis pods was undertaken by ILRI after the training. By end of November 2007, a total of 21.5 tonnes of pods had been delivered to Sigma Feeds Company for processing (Table 4).

Table 4: Quantities of Prosopis pods collected at various sources in Kenya in 2007

County	Quantity collected (Tonnes)	Prices/kg (Ksh)
Baringo	3.5	4.50
Turkana	7.5	3.00
Garissa	-	3.50
Taita Taveta	4.5	3.50
Tana River	6.0	4.00
Total	**21.2**	

The pods were processed and mixed with other ingredients at 10% level of initial inclusion on a trial basis for dairy meal and successfully distributed to markets within the country by Sigma Feeds Company. A total of 210 tonnes of Prosopis based feeds were sold out.

Owing to the problems brought by disruption of funding of the activities of the taskforce through ILRI, the taskforce was disbanded in mid-2008. Thereafter, the Ministry of Forestry and Wildlife (through KEFRI and KFS) lobbied for continuation of the activities on the use of Prosopis pods through several projects, namely the ASALs Based Livelihoods Support Project (ALLPRO/Ministry of Livestock Development), ASARECA, NALEP and Arid Lands Resource Management Project among others. These projects have facilitated to equip most of the existing groups through purchase of pods milling equipment, training and other related capacity building activities.

All these initiatives were to contribute to the groups self-reliant in meeting the local demand for Prosopis based livestock feeds for the various species of livestock through competitive processing and value addition. At the moment, most of the groups are still undergoing an intensive period of training on machine handling, servicing and collection, storage, processing of pods and marketing.

The most active groups in the processing of pods are in Tana River and Garissa Counties where they have each made substantial progress in collecting and processing Prosopis based feeds. For example, the Watajir Group in Garissa collected 7 tons of pods in late 2011, milled and made both feed blocks and feed flour that is now being sold locally within the County. In Tana River County, one group (Biskidera Jabesa) have collected 4 tonnes of pods and processed into feed flour by mixing with maize stovers and other local agricultural residues. Generally, there is an increase in use of processed Prosopis pods by many communities for feeding livestock.

2.2.3. Trade in poles and other Prosopis based products

Other Prosopis products being traded in many parts of the country include; poles, firewood, sawn timber and honey. Trade in these products is not regularized and therefore current estimates of quantities cannot be ascertained. However, Turkana and Garissa Counties are the best examples where the presence of refugee camps has continued to provide a market for Prosopis poles, withies and firewood for construction of huts, manyattas and cooking energy.

In Turkana County around Kakuma camp, the trade in Prosopis poles and withies is estimated at Ksh 4 million per year while firewood sales are valued at Ksh 25 million per year. However, the proportion of Prosopis wood in the firewood supply is currently estimated at 51% of the total firewood supply or about Ksh 13 million annually. With the intervention by the Government of Kenya, the proportion of Prosopis firewood is gradually rising to 75% and eventually 100% in the coming years (NRC, Personal communication, 2013). In Garissa, trade in Prosopis firewood and poles is estimated at Ksh 2 million per month, and continues to rise with expansion of the refugee camps.

It is difficult to estimate the quantities of honey primarily associated with Prosopis due to lack of reliable research data. Prosopis flowers most of the year and therefore the proportion of the honey attributed to the species is significant. However, studies to estimate the production of honey from Prosopis are recommended.

2.2.4 Green energy production using Prosopis biomass in Kenya

The rapid expansion of the Kenyan economy urgently requires more energy to power its growth from the current installed capacity of about 1,300 MW to about 2,000 MW to meet peak demand in the next four years. The private sector players are being encouraged through policy re-orientation, to actively participate in the green energy generation in Kenya. Prosopis has been identified as a potential source of biomass for electricity production in Kenya. This arises from similar experiences in India where about 5 Prosopis based electricity production plants are in operation. Baringo County is hosting the first investor to pilot the production of electricity from Prosopis biomass in Kenya. Production of 4 MW of power into the national grid has been scheduled to start in 2015 and gradually increased to 10 MW if the level of biomass permits. The Government of Kenya is facilitating and monitoring the entire process.

References

Choge S.K., Ngujiri F. D., Kuria M.N., Busaka E. A and Muthondeki J.K. 2002. The status and impact of *Prosopis* spp in Kenya. KEFRI, Kenya. pp. 5.

Choge S., Odee D., and Okeyo M. 2006. Management and control of *Prosopis juliflora* tree species in Kenya. Final Technical report for the TCP/KEN/3002 project. KEFRI (Unpublished)

Choge S., 2005. The challenges of eradicating *Prosopis* spp in Kenya. International policy brief. KEFRI, HDRA, FRP and DFID.

Choge S.K. and Mutitu E. 2005. Management and control of *Prosopis* spp: Experiences from South Africa. Trip Report supported by FAO. pp 34.

Choge S.K, Wahome R., Kyuma, R and Tendwa J. 2010. Management and utilization of *Prosopis* species: Experiences from Peru and Argentina in South America.Technical trip report. KEFRI. (unpublished).

Choge S., Clement, N. Gitonga M. and Okuye J. 2012. Status Report on Commercialization of Prosopis tree Resources in Kenya. Technical report for the KEFRI/KFS Technical Forest Management and Research Liaison Committee. KEFRI (Unpublished).

HDRA 2005a. Realistic approaches to the management of *Prosopis* species in South Africa: Policy brief.United Kingdom.

Pasiecznik N.M., Felker P., Harris P.J.C., Harsh, L.N., Cruz G., Tewari J.C., Cadoret, K. and Macdonado, L. J. 2001. The *Prosopis juliflora – Prosopis pallida* Complex: A Monograph. HDRA, Coventry, UK. pp. 162.Pasiecznik N.M, Choge S.K, Muthike G.M, Chesang S, Fer C, Bakewell-Stone P, Wright J, Harris PJC. 2006. Putting Knowledge on Prosopis into Use in Kenya. Pioneering Advances in 2006. KEFRI, Nairobi, Kenya and HDRA, Conventry, UK. 13pp.2006.

Tewari J.C, Harsh, L.N., and Vittal K.P. 2009. Advantages of *Prosopis juliflora*. CAZRI, Jodhpur, India.

VI. Emerging Issues on Prosopis (Etirae) from Turkana Community Perspective

Sikiria A., Ebenyo E.J., Maraka J., Kisangau E. and agr. Ute Schneiderat

Introduction

Focal areas with Prosopis affecting Turkana community include; Kakuma, western shores of Lake Turkana, Lodwar, Kerio delta, and Katilai. The highly invaded areas have had adverse effect on livestock as it prevents growth of undergrowth vegetation which is a source of fodder to livestock. In some areas communities have tried to clear Prosopis bushes and even reclaimed some portion for planting of crops.


Non-invested area near Napuu


Managed Prosopis site in Naurien Puu

Positive issues from Prosopis

The following are positive issues associated with Prosopis in Turkana;

- Source of poles used in building and construction of houses and fences hence replacing use of *Cordia sinensis* (Edome),
- Source of charcoal and firewood hence reducing exploitation of acacia trees,
- Pods are a source of animal fodder during dry spell,
- Provides shade to animals and human,
- A source of raw materials for making carvings and artifacts e.g. walking stick and sitting chairs,
- Source of medicine especially use of leaves in the treatment of wounds, and
- Improves soil fertility as a result of decomposition of Prosopis leaves and stems into manure and thus enhancing agro pastoralism.

Negative issues arising from Prosopis

The following negative issues arising from Prosopis have been identified;

- Encroachment into; grazing areas and associated loss of grazing territory, crop fields and wetlands hence reducing their value for watering and dry season grazing,
- Frequent deflation and damage of vehicle and bicycle tyres by Prosopis thorns,
- Increased malaria incidences that are associated with *Prosopis juliflora* thickets close to homes,
- Known to erode the teeth of livestock especially goats,
- Thorns are a major cause of lameness to animals and human from injuries associated with being pricked by Prosopis thorns,
- A source of insecurity resulting to cattle rustling and increased human wildlife conflict,
- Inaccessibility of roads and path ways due to extensive encroachment of Prosopis,
- Frequent damage of water pipes by Prosopis roots thus resulting to disruption of water supply.

Recommendations

The following are recommendations to address challenges posed by Prosopis;

- Provide pod grinding machines at community/household level to reduce seed dispersal,
- Undertake training and capacity building on Prosopis management,
- Create awareness on utilization of Prosopis for various products including; poles for building, making of charcoal and fodder production,
- Develop a grazing plan, and
- Undertake research to address the high sugar content in the fodder.

VII. Gasification of Biomass for Electric Power Generation in Baringo County

Cummins Cogeneration Kenya Limited

Introduction

Cummins Cogeneration Kenya Limited is an investment company that is set up in Baringo County to convert the large tracts of invasive Prosopis into a commercially viable venture through its use in production of electricity. The company aims to work with the community towards realizing economic benefits from Prosopis and ensure that financial benefits are provided in a consistent way.

The cycle involves the following steps: Harvesting of Prosopis from the field where the harvested raw materials are transported to the power generation site, quantified and stored. The supplier receives payment for the quantity delivered as illustrated in Figure 1.

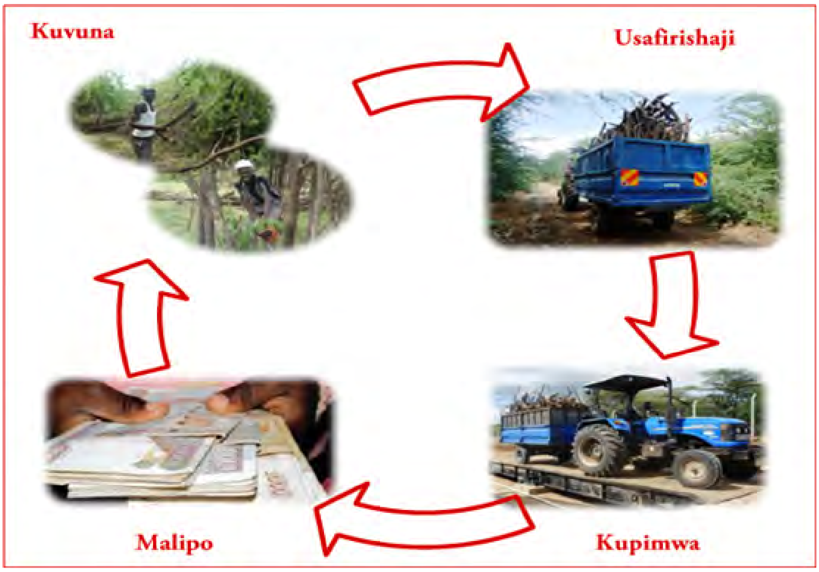


Figure 1: Harvesting and supply cycle

Cummins works with CBO partners and facilitates: CBO training – supports operations and finance; provision of tools and working capital; and harvesting operations. The Biomass Energy Power Plant can operate to convert a wide range of plant biomass to electric energy including: wood chips, forestry chips, sunflower husk, pellets, sawdust, rice husk, dry manure, bark, fine fraction and dust, and straw. This particular venture however focuses on Prosopis biomass.

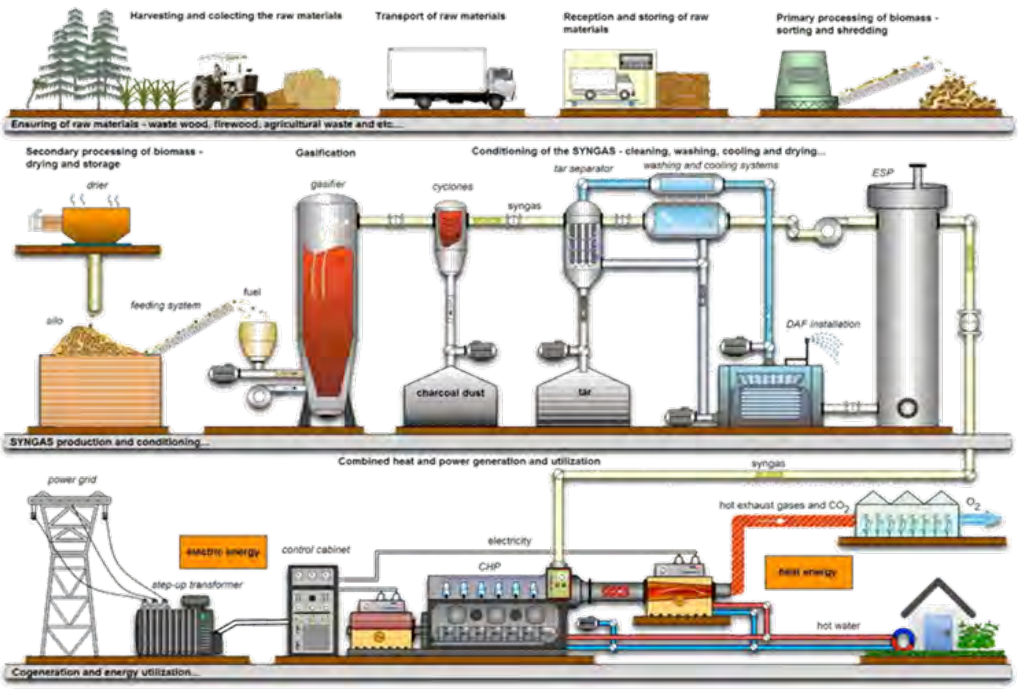
Feedstock Pre-treatment

The received raw material undergoes primary processing of sorting and shredding - for continuous operation of the plant, raw material should be chopped up to 10 -50 mm. Using part of the waste heat from power production, the fresh raw material chips undergoes secondary processing of drying up to 10% moisture content. Dried biomass chips for energy production and pellets are stored in a covered and ventilated halls.

Block Flow Chart

The process begins with biomass which is passed through biomass gasification system into syngas engine genset and finally producing electricity.

Flow Diagram



Biomass Gasification is in 4 Steps:

Drying of moisture in feedstock (endothermic reaction); pyrolysis of volatile compounds (endothermic reaction); oxidation of pyrolysis gases and fixed carbon (exothermic reaction); and reduction of product gases to producer gas (endothermic reaction).

Biomass Gasification Process

Air (N_2+O_2) and biomass combinned undergo combustion and thermal cracking in the gasifier resulting in different gases in various proportions as follows:

N_2(50%) CO_2(15%) CO(15.5%) H_2(3.5%) CH_4(6%) CnHm(1.5%) O_2(1%) H_2O(7.5%)

Products of Biomass Gasification are several and include:

- **Producer Gas:** Target product
- **Heat - Engine Exhaust:** Used for VAC Chiller, Drying, LP; Steam Gas Cooling Unit: Lost
- **Biochar** - Ash and Carbon: Gasified or Sold
- **Process Water Treatment Solids:** Fine Char Particulates: Gasified Tars: Gasified
- **Gas Filtration Media Saw Dust:** Gasified Wood Chips: Gasified Charcoal: Gasified.

By-products of the process are: Production of high-quality and calorific (4570 kcal/kg) pellets from charcoal dust; and soil conditioners.

Syngas Power Generation Set

Issues and Lessons Learnt from this Venture

- Low priority is placed on biomass based power generation
- Feed-in Tariff escalation.
- Setting of the plant had a long gestation period and high pre-development cost.
- Location of the biomass are most often in remote areas – away from 'power-hungry' cities.
- Biomass's supply chain.
- No policy in place on production of electricity using biomass.
- There is limited biomass related data.

VIII. Prosopis Biomass Assessment for Estimation of Carbon Sequestration

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Introduction

Prosopis trees like any other tree in the forest have the potential of climate change mitigation through carbon sequestration. In this way carbon sequestration becomes one of the major services that trees and forests provide. This has been internationally recognized and adopted by United Nations Framework Convention on Climate Change (UNFCCC). However, there exists a challenge on methods of estimating carbon stock in forestry. The objective of this study was therefore, to develop novel approach and techniques to estimate biomass and carbon stocks on areas invaded by Prosopis in Kenya.

Objectives

The study was guided by the following objectives;

- To develop a regression equation for estimating the carbon stocks sequestered by Prosopis trees
- To estimate the amount of carbon sequestered by mature Prosopis trees
- To establish the potentiality of Prosopis based carbon trade as an alternative source of livelihoods to communities in invaded areas of Kenya

Probability and non-probability as well as destructive sampling techniques were used to select trees for development of biomass allometric equation. A regression equation was fitted based on the generalized linear model of the logarithmic form of which DBH was found the best parameter that predicted above and below ground biomass. There was a positive relationship between DBH and above and below ground biomass. The developed biomass equation of the form $Ln\ AGB = 0.1219 - 0.025 lnDBH$ and root to shoot ratio of 0.2568 that is approximately 27 per cent is suitable for estimating below ground biomass and carbon stock of Prosopis in Kenya.

Methodology

Three sites were selected for this study, namely, Baringo, Garissa and Tana River Counties. For the purpose of developing the biomass allometric equation, Baringo County was selected. An estimated areas infested by Prosopis was about 9958 ha (or 100 km^2). The estimated areal extent of each zone is shown in Table 1. In each of these zones, sampling plots of 50 m by 100 m were randomly selected using GIS techniques and located, proportional to the areal extent of each zone and accounting for an allowable error for estimating the required number of plots. Specifically, stratification and simple random sampling techniques were used in establishing a total of 128 plots with at an allowable error of 15%. The stratification was based on administrative boundaries and site aspect, resulting to six zones namely, Eldume, Ngambo, Salabani, Kiserian, Lake 94 and Loboi, with a total area of 9522 ha.

Table 1: Areal extent of the five Prosopis species occurrence zones

Zone	Block size (ha)	No of plots based on 15% allowable error
Eldume, Zone B	1218	16
Ngambo, Zone C	2718	37
Salabani, Zone D	1789	24
Kiserian, Zone E	1614	22
Lake 94, Zone F	1769	24
Loboi, Zone A	414	6
Total	**9522**	**129**

Procedure of developing biomass allometric equations

The procedure/approach adopted for developing allometric equations for Prosopis was as follows.

i) The tree diameter classes at interval of 5 cm DBH were set for biomass assessment (Table 2).

ii) A total of 44 trees were selected across the diameter classes and destructively sampled for measurements of total tree height, DBH, crown diameter, foliage, twig, stem weights, branch weights and roots

iii) Total fresh weight of the whole tree, samples from roots, stems, branches, foliage/twigs were collected.

Table 2: Number of trees destructively sampled for developing biomass and volume equation of Prosopis

Diameter Classes	Number of trees assessed
0-5	10
5-10	6
10-15	7
15-20	8
20-25	3
25-30	2
30-35	2
35-40	2
40-45	2
45-50	2
Total	**44**

iv) Sub samples for trunk, branched, twig and roots were collected for oven dry weight at 105^0C. This was repeated till there was no change on weight.

v) The total above ground biomass (trunck, branches and foliage) of the tree biomass were computed using the formula;

$$\text{Above ground biomasss} = \frac{(\text{Fresh weight*dry weight of the sample})}{(\text{Fresh weight of the sample})}$$

vi) The above ground biomass was correlated with DBH using regression analysis procedures.

vii) A regression analysis based on generalized linear model of the form ln AGB =Constant+blnDBH was fitted. The product of tree height and diameter was fitted in the model. The model with higher coefficient of determination was selected

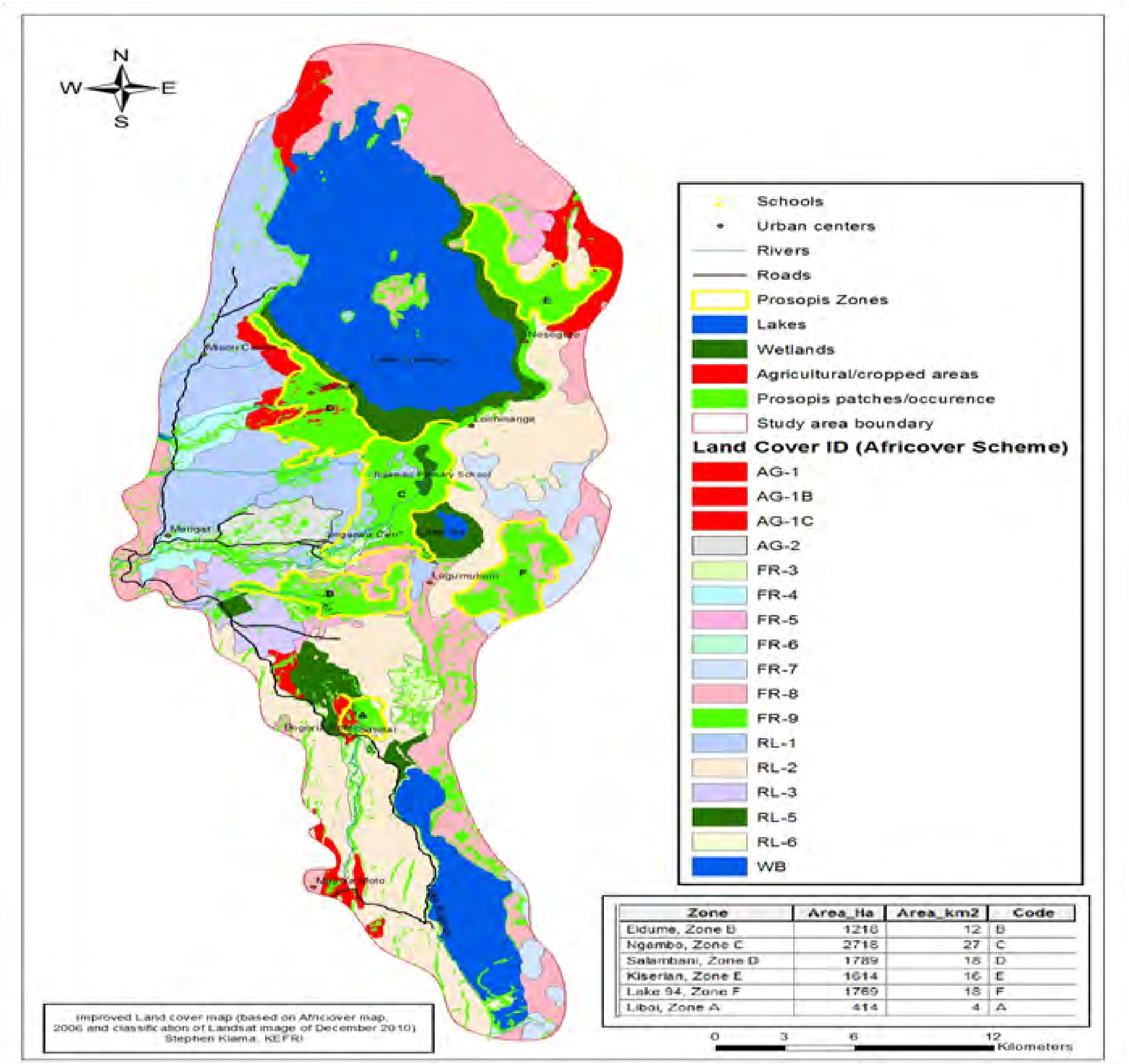
viii) Model validation was undertaken and margin error was calculated.

ix) A conversion factor of 0.49 was used for estimating available carbon stock from approximated above and below ground biomass

Results

Distribution of Prosopis in Baringo County

Maps (Figure 1, 2 and 3) showing the distribution of Prosopis, sampling plots and density in Baringo were generated. A total of 128 plots were laid in various zones infested by Prosopis so as to estimate the total biomass available for pods and charcoal production. The results on biomass assessment demonstrate the potential of aiding development of management plan for sustainable utilization of the resources available.



Zone	Area_Ha	Area_km2	Code
Eldume, Zone B	1218	12	B
Ngambo, Zone C	2718	27	C
Salambani, Zone D	1789	18	D
Kiserian, Zone E	1614	16	E
Lake 94, Zone F	1789	18	F
Liboi, Zone A	414	4	A

Figure 1: Zones with high occurrence of Prosopis spp. (based on Dec. 2010 Landsat image) overlaid Africover Landcover map

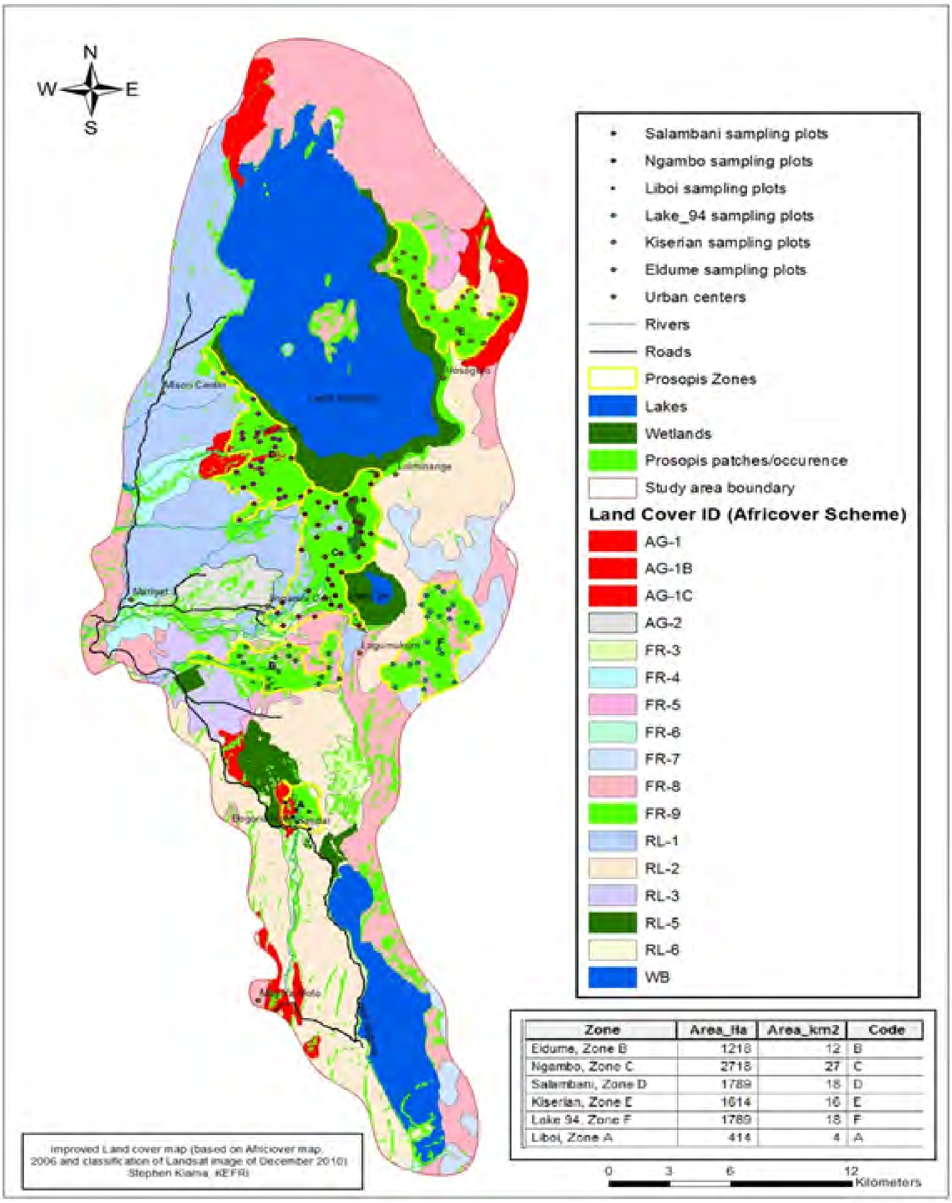


Figure 2: Distribution of sampling plots per zone

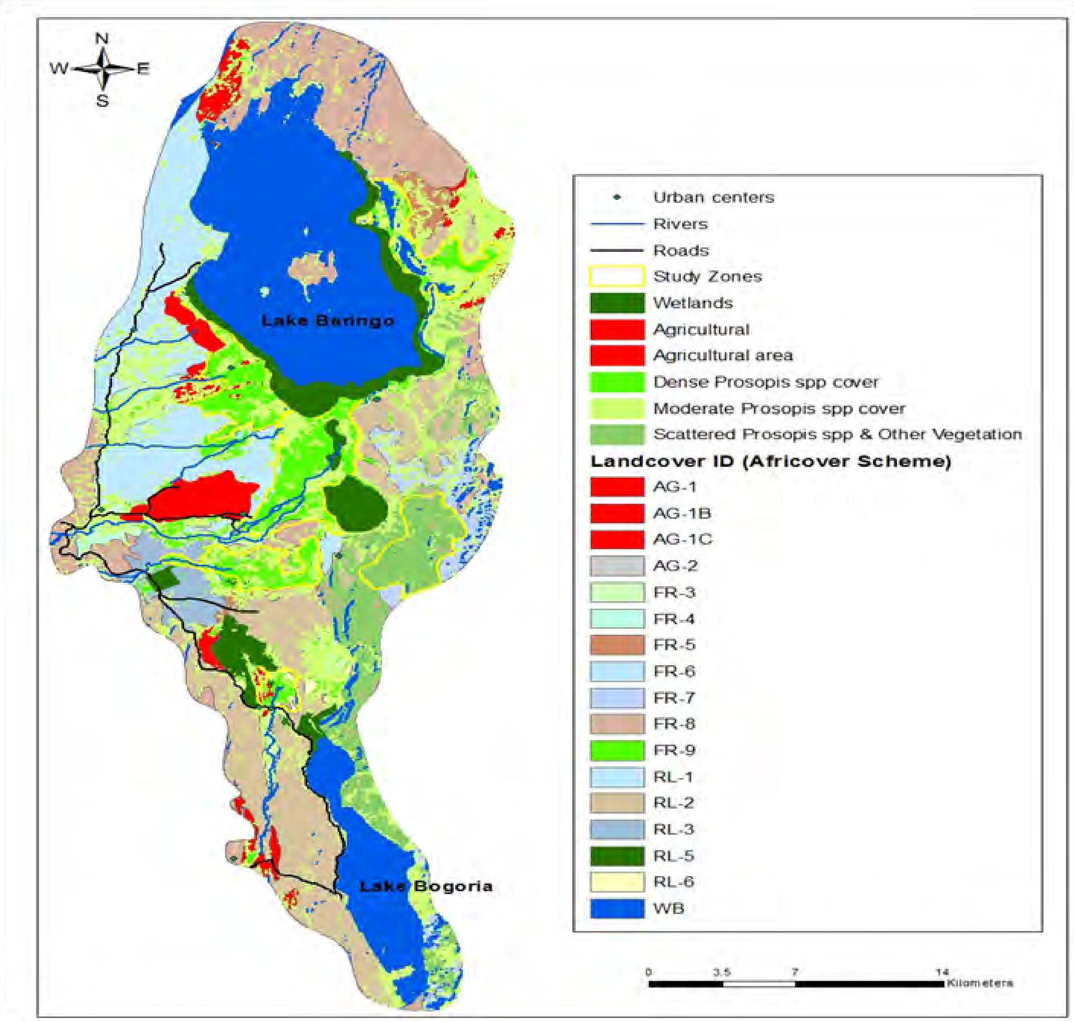


Figure 3: Cover density variation of Prosopis spp.

Growth assessment

The total number of stems assessed in various plots was above 1000 (Table 3) across the study sites/zones at Baringo.

Table 3: Summary of the number of stems assessed for biomass and carbon stocks across selected zones at Baringo County

Site	D_{30}(cm)	DBH(cm)	Height(m)	Crown cover(m)
Eldume	159	156	159	163
Kiserian	78	78	78	78
Lake 94	93	93	93	93
Liboi	68	68	68	68
Ngambo	545	543	545	544
Salabani	352	330	352	358
Total	**1295**	**1268**	**1295**	**1304**

The D_{30}, DBH, tree height and crown cover was consistently high at Loboi due to few number of plots assessed as compared to other study sites (Table 4). Overall, the growth parameters significantly varied among the study zones at Baringo County. This showed the differentials on the biomass stock that may be related to the rate of utilization. Lake 94 had the lowest averages of growth parameters assessed.

Table 4: Averages of growth parameters assessed for biomass and carbon stocks across selected zones at Baringo County

Site	D_{30}(cm)	DBH(cm)	Height(m)	Crown cover(m)
Eldume	7.1	5.5	5.1	4.6
Kiserian	3.8	3.0	2.8	3.7
Lake 94	3.3	2.3	2.9	2.9
Liboi	9.7	8.2	6.6	5.3
Ngambo	6.3	5.2	4.9	4.3
Salabani	7.6	6.2	5.6	5.0
Average	**6.6**	**5.3**	**4.9**	**4.4**

Relationship between growth parameters

Diameter and height

There was a significant relationship ($p<0.05$) between DBH and height of the measured trees across the selected zones (Figure 4).

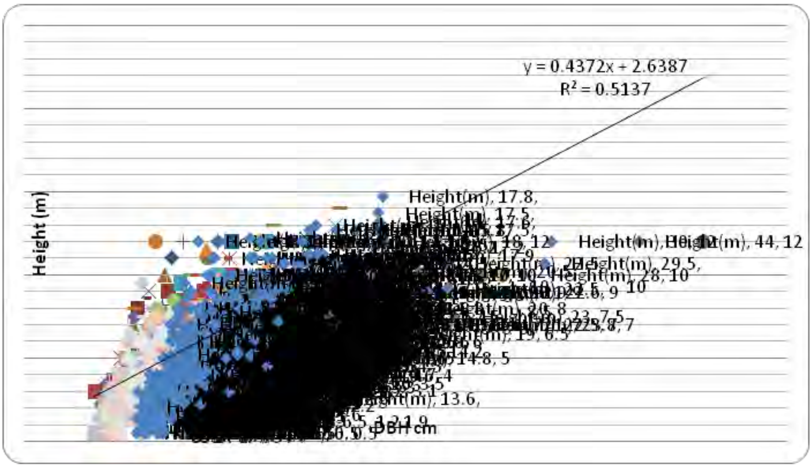


Figure 4: Relationship between DBH and height among sampled and measured Prosopis trees across selected zones in Baringo County

Overall, there was significant correlation ($p<0.05$) among D_{30}, DBH, height and crown cover of the sampled and measured Prosopis trees (Table 5).

Table 5: Correlation among growth parameters of sampled Prosopis trees at Baringo County

	D_{30}(cm)	DBH(cm)	Height(m)
D_{30} (cm)			
DBH(cm)	0.9611		
Height (m)	0.7028	0.7196	
Crown cover (m)	0.7035	0.6731	0.5639

Biomass equation for carbon sequestration

Above-ground measurements

Various tree at different diameter classes were assessed both for below and above-ground biomass (Figures 5-9) for developing biomass allometric equation.

Figure 5: Taking measurements before felling the tree

Figure 6: Partitioning felled tree for sizeable weights

Figure 7: Fresh weight of truck section of the tree and foliage

Below-ground measurements

Figure 8: Scavating for the roots and stump to estimate below ground biomass

Figure 9: Measurement of fresh weights for roots and stump to develop below-ground biomass

Allometric equation for estimating biomass and carbon stock

Allometric equation for above-ground biomass

Based on the relationship between DBH and aboveground and below ground biomass, allometric equation of the form

Ln AGB =0.1219-0.025lnDBH was the best fit of the model that correctly predicted the above ground biomass of the Prosopis.

Biomass expansion and conversion factor for below ground-biomass estimation

The Root-Shoot ratio resulted from the data was Root: Shoot = 0.2568.
This was approximated to 0.27, implying that 27 per cent of the above ground biomass is below ground.

Estimated biomass and carbon stock at selected zones in Baringo County

There were variations on total biomass and carbon stock estimated among the sampled zones in Baringo County (Table 6).

Table 6: Estimated aboveground biomass, below ground biomass and carbon stock in kg among the sampled zones in Baringo County

Site	lnAGB (Kg/ha)	BGM (Kg/ha)	T-biom (Kg/ha)	Carbon (Kg/ha)
Eldume	14.5	3.7	18.3	8.9
Kiserian	12.9	3.3	16.2	7.9
Lake 94	14.2	3.6	17.9	8.7
Loboi	12.4	3.2	15.6	7.7
Ngambo	15.7	4.0	19.8	9.7
Salabani	16.1	4.1	20.2	9.9
Average	**15.1**	**3.9**	**19.0**	**9.3**

*AGB=Above ground biomass; BGM=Below-ground biomass; T-biom =Total biomass

Relationship between diameter and above-ground biomass

There a significant relationship ($p<0.05$) between DBH and above-ground biomass showing that DBH is a good predictor of above ground biomass (Figure 10).

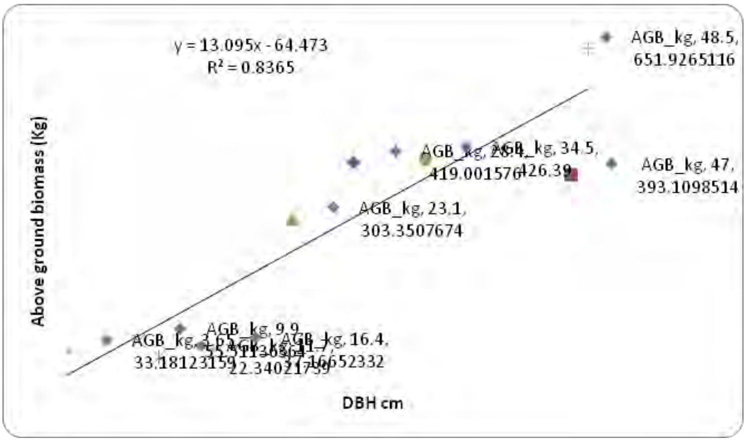


Figure 10: Relationship between DBH and above-ground biomass

Relationship between diameter and below-ground biomass

There a significant relationship ($p<0.05$) between DBH and below ground biomass showing that DBH is a good predictor of below-ground biomass (Figure 11).

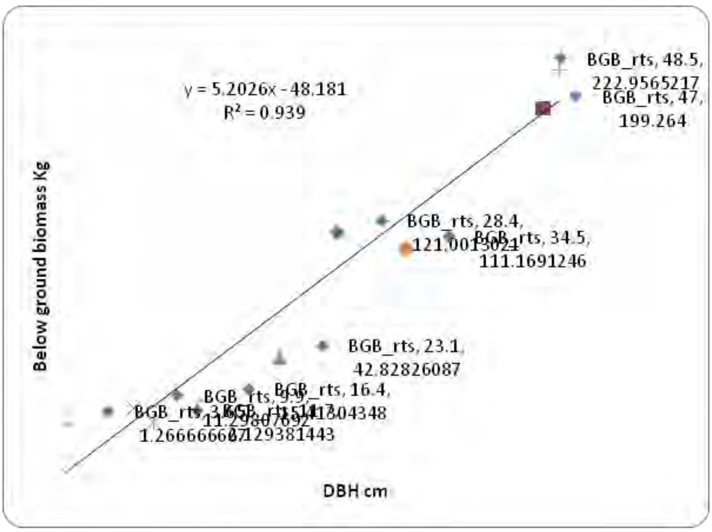


Figure 11: Relationship between DBH and below ground biomass

Conclusion and recommendations

The evergreen nature of Prosopis trees, their adaptation to arid and semi arid areas as well as their widespread nature makes them some of the best candidate tree species for carbon sequestration and trading. The study indeed established that Prosopis sequesters significant amounts of carbon estimated at 9.3 kg/ha in situations where trees grow sparsely on their own with little or no intervention on spacing. This yield can be much higher where trees are managed and closer spacing is encouraged to increase the biomass. With proper global markets and good facilitation from Government, Prosopis based carbon has the potential as a sustainable alternative source of income to communities. The study also established that the process of developing allometric equation is very involving and requires appropriate expertise in this field as well as adequate funds. For future development of similar and more accurate allometric equations, results demonstrate that the DBH is the best tree growth parameter that can be used to estimate the biomass and carbon stock.

References

Pohjola, J. and Valsta, L. (2007). Carbon credits and management of Scots pine and Norway spruce stands in Finland. Forest Policy and Economics. Vol. 9: 789-798

Sasaki, N. and Kim, S. (2009). Biomass carbon sinks in Japanese forests: 1966 - 2012. Forestry, Vol. 82, No. 1: 113-123

IX. Baringo County Government Experience on *Prosopis juliflora*

Tenges C.

CEC Member
Environment, Natural Resources, Energy and Mining

1.0 Introduction

Baringo County covers an area of 11,015.3 km^2 of which 165 km^2 is surface water comprising of 4 Lakes namely; Baringo, Bogoria, Kamnarok and Lake 94. The County has a population of 555,562 with a high annual growth rate of 2.9% per annum (KPC, 2009). Over 80% of the population live in rural areas and not connected to the national grid. Baringo has high poverty levels estimated at 58.7%. The forest cover is estimated at 29.9% out of which 6.7% is gazetted forest.

Baringo County is one of the 23 arid counties with fragile ecosystems. *Prosopis juliflora* tree was introduced in Marigat in Baringo in early 1980s to mitigate desertification and fuel wood shortages. The introduction was facilitated by Forest Department with the support of FAO. Desertification was addressed by attaining 100% tree cover for the Marigat lowlands and beyond. In 2006 the Ilchamus community won the historic civil case No. 281 of 2006 against the government that led to the declaration of Prosopis as a noxious weed and eradication order of the same issued on 17th December, 2008, by then minister for Agriculture, William Arap Too. The minister declared *Prosopis juliflora* (commonly known as Mathenge) as a noxious weed in the whole of Kenya through gazette notice No. 184.

2.0 Impacts of *Prosopis juliflora* in Baringo County

In the recent past *Prosopis juliflora* invasiveness has impacted the County in the following ways;

- Spreading to the dry areas of Tiaty, Baringo Central and North sub-counties
- Chocking indigenous tree species and grasses
- High percentage of acacia has been lost as the trees dry up
- Lack of grass in the dry season
- Creation of impenetrable thickets on the shores of Lakes Baringo, 94 and Bogoria as well as rivers
- Grows along the roads, and pathways, causing a challenge due to cost for removal
- Reduced food production due to high costs of Prosopis bush clearance annually; Perkerra Irrigation scheme and community schemes are affected

- Injuries occasioned by harmful thorns with some community members having lost fingers and toes
- Reduced grazing land on the flood plains of rivers in Baringo South. With no undergrowth, animals die in large numbers during the dry season

3.0 Interventions by Baringo County Government to prevent spread of Prosopis

- Awareness creation on environmental management and impacts of Prosopis
- Massive tree planting in the schools, homesteads; through provision of seedlings support. As a result some schools and farmers have cleared land invaded by Prosopis to pave way for fruit tree planting as a climate change adaptation measure
- Promotion of Farmer Managed Natural Regeneration (FMNR) approach of indigenous tree conservation in schools and villages
- Protection of forest blocks and indigenous trees by community scouts and environmental committees
- Investment in improved cook stoves for efficient utilization and conservation of energy
- Support to charcoal consultative forums for sustainable Prosopis charcoal production
- Promotion of *Prosopis juliflora* biomass use for electricity generation by investors by providing conducive working environment for feed-in-tariff engagement
- Training and exposure tours for stakeholders; youth, women and Charcoal Producers Associations (CPAs), Community Forest Associations (CFAs) and Water Resource Users Associations (WRUAs) on environmental conservation
- Support sustainable Prosopis charcoal production through modern kilns and briquettes making machines support for increased community incomes.

4.0 Challenges in management of Prosopis

- Inadequacy in communication between the community, governments and the private sector
- Loss of indigenous old trees especially Acacia through charcoal burning leading to loss of biodiversity
- Lack of community protocols and structures for engagement with investors in Prosopis value chain
- Limited finances to adequately build the capacity of the CPAs and invest in Prosopis value addition
- Insecurity due to cattle rustling; this affects timely dissemination of information to the communities in the affected areas leading to mass displacements and massive cutting of trees for charcoal production

5.0 Recommendations

- Facilitate formations of community structures and drafting of protocols to formalize engagements and consents for benefit sharing
- Enhance capacity building of the community and government teams on Prosopis management and utilization
- Enact policies and laws on natural resource management to include access and benefit sharing
- Establish Prosopis biomass and management plans
- Support community initiatives on Prosopis value addition
- Undertake research on toxicity of Prosopis utilization and control of pests on Prosopis trees
- Document and share Prosopis best practices

X. Policies and Laws Supporting Prosopis Management in the Devolved System of Government

Ndambiri J.K.
Kenya Forest Service

1.0 Introduction

Prosopis was introduced in most dry areas of the country which were experiencing severe soil erosion from wind and running water. Currently the species can be found in many dry regions of Kenya such as Eastern, North Eastern and Coast. Prosopis provides a wide range of good and services. Prosopis has some good attributes e.g. adaptability to arid environments, fast growth, provision of forage for bees, a good windbreaker and creates favorable microclimate. Pods provide fodder for livestock and also used for human consumption. Prosopis contribution to household energy through firewood and charcoal with attendant incomes cannot be ignored. However there is still dilemma on whether Prosopis should be eradicated due to its invasiveness or whether it should be utilized for environmental and economic gains.

2.0 Policies and legal framework supportive of forestry management

The Kenya's Constitution 2010 commits the Government to raise and maintain tree cover of at least 10% of the total land area. Kenya's Vision 2030, is also in harmony with the Constitution on increasing tree cover to 10% by 2030. Forest Act, 2005 and draft Forest Policy emphasize on increasing forest and tree cover, wood production for economic development and conservation of forests and woodlands. Other sectoral laws that support management of forests and trees include; the Energy Act 2006, EMCA 1999, and Water Act 2002.

3.0 Devolved forestry functions relevant to management of Prosopis

Distribution of sectoral functions between National Government and the County Governments is contained in the 4th schedule of the Constitution. Gazette Supplement No. 116 of 9th of August 2014 provides for devolution of the specified forestry functions to the County Governments including: "forestry including farm forestry extension services, forests and game reserves formerly managed by Local Authorities excluding forests managed by Kenya Forest Service, National Water Towers Agency, and private forests".

This broad policy pronouncement when "unbundled" grants county governments to undertake forestry related function including;

- Implementation of national policies that are applicable to county forests
- Formulation of county level specific by-laws and legislation
- Development and implementation of county forest management plans
- Development of nature based enterprises within county forests
- Forestation and rehabilitation of fragile and degraded ecosystem/forest in community lands
- Increasing tree cover in private, community and county lands
- Collection and management of county forest and farm forestry revenue
- Development of charcoal industry (promotion/use) within county forests and private farms
- Community awareness creation

Management of Prosopis like any other tree spp of economic value can and should be entrenched in the devolved forestry functions and part of operational plans of the affected counties. Key players can come together with the county Government and participate in the County Intergovernmental Forum as provided for in the County Government Act No.7 of 2012 to handle issues concerning management and utilization of Prosopis.

Other opportunities to leverage in management of Prosopis include:

- Current goodwill and commitment by Government in moving to dry areas
- Emerging community engagements and structures
- Increased awareness on conservation
- Existence of basic technologies on dryland forest management
- Increased interest by development partners
- Increasing demand for dryland forest products like charcoal
- Emerging carbon markets

CHAPTER 4

4.0 GROUP WORK

4.1 Formation of Groups

In order to go into details of various aspects related to Prosopis that had emerged during the workshop presentations and plenary sessions, participants were randomly divided into 5 groups as follows:

Group 1: Policy and legislation

- Ownership of resource
- Resource conflict resolutions
- Certification of products
- What is the role of County Governments (CG)
- Is Prosopis replacing livestock, we need a way forward

Group 2: Sensitization, communication and information dissemination

- Facts about Prosopis e.g. Declaration as obnoxious weed under the obnoxious act, did Prosopis achieve its objectives e.t.c
- Communication strategies

Group 3: Management issues

- Develop management objectives for Prosopis in relation to pods, energy and charcoal
- Management plans development
- Interventions by National Government (NG) and CG
- Resource base surveys
- Improving quality of products
- Capacity building for management

Group 4: Utilization aspects

- What are the current uses
- Potential uses
- Quality/certification
- What are the barriers to commercialization? inadequate supply, logistics of transport, harvesting methods and pricing
- Marketing strategies

Group 5: Cultural, social economic and emerging issues

- Existing structures/governance issues
- Role of CG
- Land tenure
- Poverty
- Conflicts
- Culture
- Gender

4.2 Group Presentations

4.2.1 Group 1: Policy and Legislation

Group Members

1. Mohamed Osman
2. David .K. Mwanzia
3. Peter M. Kioko
4. Emmanuel Kisangau
5. John M. Kahiga
6. Evans Busaka
7. George Parkes
8. Ahmed Omar
9. Allan A. Ongere
10. Richard Kyuma
11. Halima Nenkari
12. Jason G. Kariuki
13. Amina Aden
14. Selina Chesang

The group was guided by the following issues in their discussions

- Resource
- Conflict resolution
- Certification of products
- Role of County Government

Legal and Policy documents

- The gazette notice No.184 of August 2008 declared Prosopis as a noxious weed.
- Vision 2030 is very elaborate on the management of Prosopis to stop the spread of the noxious weed.
- Forest Act, 2005 forbids the introduction and propagation of foreign and invasive species in a forest area.
- Session paper No. 4 supports electricity production through renewable energy.
- Energy Act, 2004 support use of renewable energy including biomass.
- National Biomass Policy through cogeneration by producing 300 megawatts.

Issues, Current Status and Recommendations by Group 1

Issues	Current status	Recommendations
Prosopis task force	Not in place	Need to revive the task force: the task force will drive the process to review existing policy on Prosopis species
Ownership of resources	Communal	Sustain the same status
Resource conflict resolution	• Communal land is a source of conflict and is subject to the tragedy of the Commons • Competition for the resource for different uses is evident • Commercialization of the product and lack of proper information are a source of conflict	• Inventory and mapping of the resource • National Government /County Governments and other stakeholders to develop a management plan through participatory approaches • Legislations of laws by the county government
Certification of products	No certification of products due to lack of standards and lead agency	• Identify a lead agency to support Certification of Prosopis products
Role of county government	Low uptake of devolved forestry functions	• Capacity building and financial support to County governments to undertake devolved forestry functions • Protect community interest and rights in Prosopis value chain • Legislation of forest law for regulation of forest conservation and management • Create awarenes on management and utilization of Prosopis • Implement recommendations from the task force of 2007

Issues	Current status	Recommendations
Reduction of livestock due to Prosopis menace	The livestock population has reduced in the country due to: • Climate change • Off-take rates are higher than the birth rates.	• Adoption of modern management technologies to address inadequacy in fodder • Promote conflict resolution mechanisms among communities • Promote the use of Prosopis as a livestock feed • Demystify negative publicity on Prosopis

4.2.2 Group 2: Sensitization, Communication and Information Dissemination

Group members

1. Dr. Jared Amwatta - Chairman
2. Caroline Kahuria
3. Dr. Ahmed Abdi
4. Laban C. Labatt
5. Sahara Hassan
6. Leila Ndalilo
7. Mohamed Hassan
8. Dr.Vincent Oeba

The group was guided by the following issues in their discussions

- Facts about Prosopis e.g declaration of Prosopis as noxious weed under the noxious weeds act. Did Prosopis achieve its objectives?
- Communication strategy

1. Declaration of Prosopis as noxious weed

- On 17th December 2008, the Minister for Agriculture declared Prosopis as a noxious weed in the whole of Kenya through gazette notice No.184
- A task force to establish the extent of damage caused by Prosopis following conclusion of the case by the Illchamus community (Civil case No. 281 of 2006)
- Eradication is being done on small scale mainly by farmers but the key agenda for Prosopis is management through utilization. There is need to review Prosopis management to emphasis on utilization especially in rangelands. County assemblies should make by-laws emphasizing on management through utilization

2. **Were the objectives for introduction of Prosopis met?**

Positive aspects

- Forest cover increased in the drylands
- Dust storms have been eradicated
- Effective control of soil erosion in Prosopis prone areas
- Prosopis has become useful in provision of fuel wood, building materials, shade and hence this has contributed to conservation of indigenous trees
- Diversification of sources of livelihoods e.g. bee keeping, charcoal production and sale of animal feeds

Negative aspects highlighted include:

- Health hazards to human and livestock through injury caused by Prosopis thorns
- Insecurity, hideout for criminals
- Increased human/wildlife conflicts
- High cost of eradication in farmlands and rangelands
- Hinders undergrowth and therefore reduces pasture area
- Increases cost of maintenance of motor vehicles and tractors through damage of tyres
- Loss of biodiversity
- Social conflicts resulting from death of animals, squabbles over access to Prosopis for commercial exploitation

3. **Communication strategies**

The gaps identified were

- Lack of clear communication strategy hence need for stakeholder identification and engagement and effective packaging of information to stakeholders

Way forward

- There is need to identify stakeholders including communities, county governments, national government, research institutions (national and international) extension agents, NGOs, development partners and higher learning institutions for experience sharing
- Identify stakeholder needs

Stakeholders, Needs and Means of Communication

Stakeholder	Needs	Means of communication
Community	• Livelihoods • Capacity building on management of Prosopis • Management e.g agronomic practices • Suitable technologies for utilization of Prosopis • Access to general information about the species	• Electronic (radio) and print media • Social media • Public barazas • Exchange tours • Field days • ASK Shows • Story telling • Dramatizing • Road shows
County government	• Access to general information about Prosopis • Capacity on sustainable use of Prosopis • Information on investment opportunities for Prosopis • Allocation of resources for management of Prosopis • Emerging issues on Prosopis	• Electronic (radio) and print media • Social media • Public barazas • Exchange tours • Field days • ASK Shows • Workshop and conferences
National government	• Knowledge creation • Information gathering and dissemination • Emerging issues e.g climate change • Capacity development	• Creation and maintenance of data bases • Electronic and print media • Social media • Exchange educational tours • ASK Shows • Public barazas
Research and institutions of higher learning		• Publication of extension materials • Undertake trainings to capacity building on management of Prosospis • Electronic and print media • Social media • Exchange educational tours • ASK Shows

Stakeholder	Needs	Means of communication
Extension staff	• Access to information about the Prosopis • Knowledge products e.g brochures, leaflets, fliers • Capacity building on Prosopis management and utilization	• Electronic (radio) and print media • Social media • Public barazas • Exchange tours • Field days • ASK Shows • Story telling • Dramatizing • Road shows
NGOs	• Access to information on Prosopis • Knowledge products e.g. brochures, leaflets, fliers • Capacity building on Prosopis management and utilization • Conducive legal framework	• Electronic (radio) and print media • Social media • Exchange educational tours • ASK Shows
Development partners	• Access to information on Prosopis • Resource requirements for stakeholders • Conducive legal framework	• Electronic (radio) and print media • Social media • Exchange educational tours • Proposals and business plans for funding

4.2.3 Group 3: Management Issues

Areas of discussion

Management objectives in relation to;

- Charcoal production and marketing
- Energy production
- Pod harvesting

Charcoal

- Use of mature Prosopis trees is recommeded for quality charcoal production to meet the market demands
- Use of improved technologies to enhance efficiency in charcoal production
- Establish community structures to enable compliance and adherance to charcoal regulations 2009

Energy production

- Management of Prosopis to ensure appropriate spacing for optimum biomass yield
- Promotion, breeding and cultivation of non-invasive species

Pod harvesting

- Identify and select high yielding Prosopis genotypes
- Selective harvesting to eliminate low pod yielding Prosopis trees

Development of management plans for Prosopis

- Define boundaries invaded by Prosopis spp
- Identify viable management units e. g: administrative units/locations
- Define the uses/user groups of the Prosopis resource base
- Ensure participation of communities and other stakeholders, in the drafting of the management plan
- Develop participatory community forest (Prosopis) management plan to include; thinning regimes, pruning schedules, and allowable cut of Prosopis

Interventions by national government

- Capacity building
- Provide financial support for implementation of Prosopis activities
- Enact policies and laws to support Prosopis management and utilization

Interventions by county governments

- Establish community structures to support implementation of Prosopis activities
- Enact county policies and laws to support Prosopis management and utilization
- Allocate resources to support forestry activities in the counties
- Enforcement of forestry related laws and regulations to support forestry activities

Resource base surveys

- Undertake detailed national surveys to map and establish the quality and quantities of available Prosopis resources in collaboration with county governments

Role of NGO's

- Provide technical and financial support for implementation of Prosopis activities
- In collaboration with relevant institutions support research and dissemination of findings

Improve quality of Prosopis products

- Clone high yielding variety from existing Prosopis resource base
- Undertake silvicultural practices of Prosopis for optimum production

Capacity building for management of Prosopis

- Build capacity of relevant stakeholders
- Streamline trainings on Prosopis and develop training curriculum for various target groups
- Establish a national centre of excellence on Prosopis management and utilization

Research gaps identified on Prosopis

- Total area under Prosopis in the country
- The rate of Prosopis spread
- Determine wood and biomass available
- Documentation of pests and diseases associated with Prosopis
- Silvicultural activities for best practices in the management of Prosopis

4.2.4 Group 4: Prosopis Utilization

Group Members

1. Prof. Raphael G.Wahome - Chairman
2. Abdikadir Aden, HSC - Secretary
3. Peter Koech
4. Mohamed A. Mohamed
5. Dr. Ute Schneiderat
6. Caroline Lentupuru
7. Abdiwahab Madker

Areas of discussion

- What are the current uses of Prosopis
- What are the potential uses of Prosopis
- Certification of Prosopis products
- Barriers to commercialization of Prosopis products
- Marketing strategies for Prosopis products

Current uses of Prosopis

- Animal feed
- Fuelwood
- Honey production (bee keeping)
- Building materials (poles)
- Power generation
- Wood carving
- Shade
- Soil protection
- Wind breaker
- Human food (pastries)

Potential uses of Prosopis

- Carbon trading: After establishing ownership and harvesting procedures communities may explore trading in carbon credits
- Medicinal value: Research on medicinal use of Prosopis
- Upholstery: For high quality bare wood furniture
- Revenue generation: From sale of Prosopis products

Certification of Prosopis products

- Standardization of all Prosopis products for quality control to protect both the producer and consumer
- Develop guidelines to guide in the certification process

Barriers to commercialization of Prosopis products

- Lack of awareness and inadequate information regarding; data generation, area under Prosopis, mapping of Prosopis resource and yield potentials.
- A disconnect between dissemination of research findings and uptake by end users
- Negative publicity of Prosopis
- Inadequate budgetary allocation to support Prosopis activities
- Poor linkages and coordination between government agencies
- Poor infrastructure that hinders movement and marketing of Prosopis products
- Negative cultural beliefs
- Limited value addition options for Prosopis products

Marketing strategies for Prosopis products

- Formation of a national organization to coordinate and promote Prosopis use and marketing
- Certification of Prosopis products to make it acceptable in the markets
- Partnerships between county government and private investors through Public Private Partnership (PPP)
- Identifying markets and middle men to drive the business
- Establish cooperatives to market Prosopis products
- Create awareness on Prosopis products through various communication channels

4.2.5 Group 5: Cultural, Social, Economic and Emerging Issues

Group Members

1. J. K. Ndambiri - Chairman
2. J. M. Maina
3. Joseph Njigoya
4. Peterson Thiongo
5. Dr. Paul Konuche
6. Dorothy Ochieng
7. Joyce Chege
8. Michael Kanyongo
9. Margaret Githinji - Secretary

Areas of discussion

- Existing structures
- Role of county government
- Land tenure
- Poverty alleviation
- Conflicts resolution
- Cultural values/heritage
- Gender issues

Existing Institutions/Organizations involved in Prosopis

- KFS - regulatory role
- KWS
- CBOs Registered under societies Act (CPA)
- KEFRI
- County Government
- NEMA
- Energy Regulatory Commision
- National Government (Interior Ministry)
- KPLC
- NGOs
- Investors
- Universities/Researchers
- Development Partners
- Middle Men/Transporters

Recommendations

- Zonation of resources - e.g. region for harvesting for electricity, charcoal
- Identify opportunities for integrated management, empower the community or CBOs especially on financial management
- Develop conflict resolution structures constituting all the stakeholders - How do we resolve our conflicts?
- Where land is not alienated the CG should take lead in management of the Prosopis through MoU between stakeholders.
- A portion of the income from the resources should be set aside for the purpose of alleviating poverty among the community members within the Prosopis zone. Both the CBO and CG should ensure this happens.
- Need to establish cooperatives to manage the various groups and or community members.

- The County Government should operationalize the Inter-governmental forum to address the Prosopis exploitation and management. (eg. County Environment Management Committees).
- It is important that where possible the investors have agreements with individual land owners rather than communities.
- It is noted that women play a big role in charcoal production and trade, thus policies should be developed with this in mind to protect them from exploitation.
- Some communities still hold onto pastoralism despite the invasion of Prosopis, different communities should be sensitized to embrace the various uses of Prosopis.

CHAPTER 5
5.0 ACTION PLAN AND WAY FORWARD

5.1 Action Plan

The following are the proposed Prosopis post-workshop activities:

No	Activity	By when	Responsible
1.	Finalize workshop report	Two weeks	Rapporteurs: Joseph Njigoya / Dorothy Ochieng
2.	Post a feature on the workshop on the KFS website	1st week of June	Caroline Kahuria
3.	Consultations between institutions dealing with Prosopis	Continuous	KEFRI/ KFS Dr Muturi/ Dr Clement Ngoriareng
4.	Revival of the National Prosopis Task Force	No timeline	KEFRI/KFS
5.	Workshop proceedings finalized and published	October 2015	Dr Muturi / Dr Clement Ngoriareng

5.2 Suggested Way Forward

1. Resolve tree ownership through cooperatives belonging to group ranch that takes advantage of shared overhead costs for processing and marketing.
2. Undertake research to address storage of Prosopis flour as it is hygroscopic and has high sugar content that attracts insects and fungi
3. Develop feed and food products including; Prosopis pod flour, feed blocks and pellets, syrup, beverages, wines, snacks and green pod vegetables
4. County Governments to allocate funds to support Prosopis activities. This will supplement the work of KEFRI and KFS in moving the process forward
5. Undertake inventory and mapping of Prosopis to determine the existing resource base
6. Finalize the national strategy on Prosopis that will involve all stakeholders in its implementation
7. Develop a participatory Prosopis management plan
8. Undertake research on allelopathic effects of Prosopis species
9. Undertake research to establish the role of Prosopis in blocking of water ways
10. Undertake research on the health effects of Prosopis smoke during charcoal production
11. Undertake Research on integration of Prosopis with crops
12. Explore opportunities of carbon trading utilizing Prosopis

CHAPTER 6
6.0 CLOSING CEREMONY

6.1 Vote of Thanks on Behalf of Participants by Abdikadir Aden, HSC

On my own behalf and that of the participants I wish to thank the organizers who made this workshop possible. The discussions and deliberations have been an eye opener to many members of communities from areas affected by Prosopis species. Participants now see the positive aspects of Prosopis as a resource with great potential rather than a menace. Let us all embrace the recommendations of this workshop and make the Prosopis agenda a reality.

Thank you and safe journey back home.

6.2 Closing Speech by County Executive, Environment, Natural Resources, Energy and Mining, Baringo County - Hon Caroline Lentupuru-Tenges

Ladies and gentlemen, this evening as we enjoy our dinner and refreshments I am happy that we can reflect back on deliberations of the last three days and say the workshop was a success. The discussions and deliberations have strengthened the case of Prosopis as a resource with great potential both environmental and economic.

I can now recall very vividly during my early child hood when I was in school, the wind storms were very intense due to lack of vegetative cover. At one point I was almost hit by an on-coming lorry that was not visible due to the intensity of the storm. The wind storm is no more thanks to the Prosopis cover. Economically, Marigat residents are a beneficiary of investment by a power generation company. This is in addition to income from charcoal production courtesy of Prosopis species.

I appeal to all participants as we go back to our respective counties to work closely with the upcoming task force on Prosopis and also look forward to being involved in the implementation of recommendations of this Second National Prosopis Workshop. This will require us to enhance awareness creation to communities and County Government teams on Prosopis issues in order to realize the dreams of our objectives.

Thank you and may I now declare this workshop officially closed.

ANNEXES

Annex 1: Workshop Programme

Second National Prosopis Workshop 18th - 21st May 2015, Soi Safari Club, Baringo

Day 1: Monday 18th May 2015

Time	Activity	Resource person
Afternoon/ Evening	Arrival and registration at Soi Safari Club	Ms Joyce Chege Ms Colet Wamukoya

Day 2: Tuesday 19th May 2015

Time	Activity	Resource person
SESSION 1: Opening session **Session chair Dr. Clement Ngoriareng, PhD**		
8.00 – 8.30 am	Registration	Ms Joyce Chege Ms Colet Wamukoya
8.30 – 9.45 am	Opening Remarks • KEFRI • KFS • GIZ • ASST. FAO Representative in Kenya • Official opening by Principal Secretary, Ministry of Environment Water and Natural Resources	• Dr. B. Chikamai, PhD • Mr. E. Mugo • Dr.agr.Ute Schneiderat, PhD • Mr. Robert Allport • Dr. Richard L. Lesiyampe, PhD, MBS
9.45 – 10.00 am	Group photo	
10.00 – 10.30 am	Health break	
SESSION 2: Research	**Session chair: Dr. Paul Konuche**	**Rapporteurs: Joseph Njigoya Dorothy Ochieng**
10.30 – 11.00 am	Overview of recommendations of first National workshop	Dr. Ben Chikamai, PhD
11.00 – 11.30 am	Estimation of Prosopis biomass	Mr. J. Kariuki
11.30 – 12.00 pm	Ecological Impacts of Prosopis Invasion	Dr. G. Muturi, PhD
12.00 – 12.30 pm	Nutritional value of Prosopis pods	Prof. Raphael Wahome

Time	Activity	Resource person
12.30 – 1.00 pm	Plenary	
1.00 – 2.00 pm	Lunch Break	
2.00 – 5.00 pm	Field visits	Mr. S. Choge and Mr. E. Busaka

Day 2: Wednesday 20th May 2015

Time	Activity	Resource person
SESSION 2: Research continued	**Session chair: Prof. Raphael Wahome**	**Rapporteurs: Joseph Njigoya Dorothy Ochieng**
8.30 – 9.00 am	Recap of Day 1 • Research • Field visits	
9.00 – 9.20 am	Use of Prosopis pods in livestock feed	Mr. Kyuma
9.20 – 9.40 am	Charcoaling of Prosopis	Mrs. N. Oduor
9.40 – 10.00 am	Trends in commercialization of Prosopis products	Mr. S. Choge
10.00 – 10.30 am	Plenary	Chair
10.30 – 11.00 am	Health Break	
SESSION 3: Management and Utilization	**Session chair: Mr. Jamleck Ndambiri**	**Rapporteurs: Joseph Njigoya Dorothy Ochieng**
11.00 – 11.15 am	Managing Prosopis	Mr.Lekosek/Kahiga
11.15 – 11.30 am	Reclamation of invaded areas	Mr. Nengonop/Mr. Labat
11.30 – 11.45 am	Sustainable utilization of Prosopis	Biskidera/Mr. Mohammed
11.45 – 12.00 pm	Integrated management	Morungo'le / Ochiel
12.00 – 12.15 pm	Managing invasion spread	Watanjiri/ Mr. Mwanzia
12.15 – 1.00 pm	Plenary	Chair
1.00 – 2.00 pm	Lunch Break	
2.00 – 5.00 pm	Practical demonstration of products processing/ Exhibitions	Mrs. Selina Mr.Kimwemwe Mr. Kyuma CBOs

Day 3: Thursday 21st May 2015

Time	Activity	Resource person
SESSION 4: Emerging Issues	**Session chair: Dr. Gabriel Muturi**	**Rapporteurs: Dorothy Ochieng Joseph Njigoya**
8.30 – 9.00 am	Recap of Day 1 • Research • Field visits	
9.00 – 9.15 am	Emerging issues on Prosopis (Etirae) from Turkana community perspective	Anthony Sikiria, Aineah Obed, Dr. Ute Schneiderat
9.15 – 9.30 am	Gasification of Prosopis biomass for electric power generation in Baringo County	Mr. Michael Kanyongo
9.30 – 9.45 am	Mobile charcoaling	Tinder
9.45 – 10.15 am	Effects of Prosopis invasion on fisheries in Lake Turkana	Dr. J. Amwatta, PhD
10.15 – 10.30 am	Exploring carbon credits	Dr. Vincent Oeba, PhD
10.30 – 11.00 am	Health Break	
SESSION 5: Policy	**Session chair: Mathenge Gitonga**	**Rapporteurs: Dorothy Ochieng Joseph Njigoya**
11.00 – 11.20 am	Experiences from County	CEC - Baringo
11.20 – 11.40 am	Prosopis management policy development	Mr. Mugo
11.40 – 12.00 pm	Policy linkage to devolution	Mr. Patrick Kariuki
12.00 – 12.30 pm	Plenary	Chair
12.30 – 1.00 pm	Group formation	Chair
1.00 – 2.00 pm	Lunch	
2.00 – 4.00 pm	Group work	All
4.00 – 4.30 pm	Health Break	
4.30 – 5.30 pm	Group presentations and way forward	All
5.30 – 6.30 pm	Freshening up	
7.00 pm >>	Cocktail and official closing	All

Day 4: Friday, 22nd May 2015
Participants leave at their pleasure

Annex 2: List of Participants

UNLOCKING THE ECONOMIC POTENTIALS OF PROSOPIS IN THE FACE OF CHANGING CLIMATE: SECOND NATIONAL PROSOPIS WORKSHOP - AT SOI CLUB, LAKE BARINGO

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