MAPPING STUDY (VALUE CHAIN ANALYSIS) ON COMMERCIALIZATION OF PROSOPIS JULIFLORA IN MANDERA COUNTY

Final Report

Submitted By;

Sigmund Peak International Ltd.

TABLE OF CONTENTS

List of Tables

List of Figures

List of Abbreviations

BORESHA	Building Opportunities for Resilience in the Horn of Africa
DRC	Danish Refugee Council
EPSG	European Petroleum Study Group
FGD	Focus Group Discussions
GIS	Geographical Information System
GMM	Gaussian Markov Model
L1C	Sentinel 2 Level 1C
L2A	Sentinel 2 Level 2A
LM	Lower Midland
NDMA	National Drought Management Agency
NDVI	Normalized Difference Vegetation Index
NRM	Natural Resource Management
SCP	Semi-automatic Classification Plugin
UTM	Universal Transverse Mercator
WGS-84	World Geodetic System 1984
WVI	World Vision International

1. EXECUTIVE SUMMARY

The Building Opportunities for Resilience in the Horn of Africa (BORESHA) project was a cross-border intervention targeting community NRM management in the Mandera Triangle which covered parts of Kenya, Ethiopia and Somalia. The project was led by a consortium led by Danish Refugee Council (DRC) and comprising of CARE International, WYG and World Vision International (WVI). Under the BORESHA Consortium, CARE International was taking the lead in cross border rangeland and other shared natural resources programming to ensure they are equitably and sustainably managed. BORESHA's project's commitment to innovation and CARE Kenya as an agency is keen to experiment and adopt new technologies and approaches that solve real life problems that enhance economic self-reliance from environmental sound technologies that use available natural and human resources. In line with this focus, BORESHA undertook a comprehensive assessment to chart a viable pathway for commercial exploitation of Prosopis Juliflora in Mandera. The main objective of the study was to undertake a comprehensive assessment to chart a viable pathway for commercial exploitation of Prosopis Juliflora in Mandera County.

A cross sectional survey design was used to collect data from household heads using questionnaires, key informant interviews and Focus group discussions. A mixed method approach of data collection was used which incorporated both qualitative and quantitative data collection. Secondary data containing population demographics was collected from the existing reports. A primary data on opinion expressed on the Prosopis juliflora utilization was collected in Mandera East and Mandera North. Descriptive statistics were derived using SPSS. GIS mapping was equally carried out along river Dawa and coordinates recorded. A total of 241 household members were surveyed, 4 focus groups held and Eight key informant interviews conducted.

Main Findings

The finding from the study indicated the following results. There are two main species of Prosopis in Mandera County -*P. juliflora* (A) and *P. pallida* (B) *(adapted from Díaz Celis 1995. P. juliflora* was however found to be largely distributed compared to the *P. pallida species.* 52% of the households interviewed had the Prosopis plant in their own farmlands while 42% had interacted with the plant in the community land. Mandera County experiences an increase in Prosopis Species in the last 5-10 years as mentioned by 81% of the respondents surveyed.

The negative impacts of Prosopis on the communities included; that the prosopis shrubs encroached on the grazing land hence smothering other local plants, physical injuries to domestic animals and people due to the poisonous thorns and pods. 12 % of the respondents however believed the Prosopis plant had positive uses which included; charcoal, briquettes, fencing, animal fodder, (pods) timber for construction, firewood, and shade for animals and human beings.

Based on normalized difference vegetation index (NDVI) classification, the quantity and distribution of Prosopis Juliflora per sub-county as at 10th January 2022 was computed. The standing biomass was estimated at 10.56 tonnes /ha for the stems only and 23.83 tonnes /ha for the whole biomass including leaves and branches. An annual yield of 1.4 tonnes per Ha was used to compute the potential wood yield per sub-county. Involvement in Prosopis business was limited in the Mandera due to inadequate knowledge and resources to commercialize the utilization of the species. There was thus no clear existing linkage among the market value chain players. However, among the persons and organizations mentioned as engaged in business for prosopis products included, CARE Kenya who were involved in the capacity building programmes on utilization of prosopis. Community groups were equally mentioned as gatherers/producers of the Prosopis products. No legislative or regulatory policies/instruments were found to be in existence in Mandera County.

Conclusion

The mapping study has established that in the lens of majority of the residents of Mandera County are generally of the opinion that the benefits of *Prosopis* plant is a menace that should be eradicated. The measures put in place to by the government and NGOs to control the spread of the species have not been significant and at the same time, the beneficial uses of the plant have not been optimized and promoted. Many agree that any intervention aimed at managing the invasion of the plant and promoting commercial use of its product in the County is timely. Information gathered from both primary and secondary data show that the potential for *Prosopis* is largely not exploited. Many other uses like wood and timber products, charcoal briquettes, Pods for both human food and animal feed, Leaves for animal feed and composting, Use of the flowers for nectar extraction by the bees, manufacturing sweets from the sweet *prosopis* gums, Extraction of tannin, dyes and fibres, ethno-medicice and pharmaceutical industry among others.

Recommendation

1. Capacity building the communities in the county to enable them utilizes prosopis for the following products- TimbeR, Posts and Poles, Firewood and charcoal, Pods for human food, Pods as Livestock feed and exploiting gums and tannins and medicine.
2. Develop legislations, regulations and policies for the development and utilization of prosopis nationally and within the county
3. Initiate a commercially-oriented intervention to manage the spread of prosopis plant in Mandera County. This should be a joint venture between the affected communities, county government of Mandera, relevant government institutions, BORESHA Project and other stakeholders
4. There is need to promote efficient production of charcoal production from prosopis wood.in the county to ease the pressure on indigenous tree species which are threatened by charcoal burning activities.
5. Re-activate community groups trained by BORESHA project on Prosopis plant charcoal briquette and animal feeds processing. More new groups should be trained to complete the efforts of the existing ones.
6. Care and other interested stakeholders should work with the County Environment Committee to draft a policy paper on Prosopis for discussion and adoption at different level of the County Government.

2. INTRODUCTION

2.1 Background of the Project

The Building Opportunities for Resilience in the Horn of Africa (BORESHA) project was a cross-border project funded by EU trust fund and was implemented by a consortium of 4 organizations namely; World Vision, Danish Refugee Council (DRC) (Danish Refugee Council), CARE and WYG. The overall project objective was to promote economic development and greater resilience, particularly among vulnerable groups by addressing the drivers of instability, irregular migration and displacement in the Kenya-Ethiopia-Somalia border, sometimes referred to as the Mandera Triangle.

Under the BORESHA Consortium, CARE International was the lead on component of the project aimed at enhancing sustainable and equitable management of cross-border rangeland and other shared natural resources. The project supported regional efforts to build sustainable livelihoods, improve natural resources management and strengthen resilience.

Livestock production is the dominant land use pattern in the Mandera. Along the riverine areas i.e. Daawa River (Mandera, Dollo Ado, Doolow), Genale River (Dollo Ado) and Juba (Doolow), agro-pastoralism is a dominant land use pattern with majority of the farmers practising irrigated farming. Land Use Change analysis for the project area was conducted for the period 2015 to 2018 to determine Prosopsis juliflora invasion. Some study findings carried out indicate that proliferation of invasive Prosopis juliflora has increased, largely caused by changing settlement patterns with decreasing human mobility while retaining mobile pastoralist herds, especially in along R. Dawa and Ganale. The increased spread of Prosopis juliflora is attributed to livestock movement towards watering areas. This combined with rapid and unregulated clearing of land for farming and dry season pasture along the riverine sections creates a conducive environment for spread of the species. Another cause is over grazing which is evident in most parts of this region. This rapid spread of Prosopis could cause an ecological shift, where the dominant vegetation types are displaced by Prosopis.

BORESHA's project's commitment to innovation and CARE Kenya as an agency is keen to experiment and adopt new technologies and approaches that solve real life problems that enhance economic self-reliance from environmental sound technologies that use available natural and human resources. In line with this focus, BORESHA seeks to undertake a comprehensive assessment to chart a viable pathway for commercial exploitation of Prosopis Juliflora in Mandera.

The Project has adopted this far-sighted and sustainable management approach in Mandera Triangle and has built the capacity of local communities to control the spread of Prosopis plants while deriving the possible economic and livelihoods benefits. It has supported various community groups from 18 villages in Mandera County (Kenya) and Gedo region (Somalia) with technologies to process Prosopis into charcoal briquettes and livestock feed. It has trained 305 people (including 95 female) from natural resource management (NRM) groups, farming associations, government extension agents and other community groups on the use of simple technologies to make charcoal briquettes and livestock feed from the pods of Prosopis. The trained groups and associations were given seven briquette-making machines and thirteen Prosopis pods millers.

Utilizing the Prosopis plants to produce these products has not only provided extra employment opportunities, income, livestock feed, and high-quality household energy sources to the community, but also controlled its further spread. As a result, the community is now increasingly seeing Prosopis as a valuable local natural resource rather than “unwanted” and “unknown” plant.

BORESHA project has built the capacity of local communities to control the spread of Prosopis plants while deriving the possible economic and livelihoods benefits. The project has trained natural resource management (NRM) groups, farming associations, government extension agents and other community groups on the use of simple technologies to make charcoal briquettes and livestock feed from the pods of Prosopis. The project trained 305 people (among them, 95 females) from 18 project targeted villages in Kenya, Somalia and Ethiopia with more than 1,800 people benefiting indirectly from the Prosopis utilization skills training. The project supplied seven briquette-making machines and thirteen Prosopis pods millers to groups and associations.

Leveraging on best practices and lessons learnt from BORESHA and other similar interventions, there is evident opportunity to scale up and diversify livelihoods. There are also opportunities to create extra jobs and income for individuals and households through enhanced investment in Prosopis value chain.

Capacity Building initiatives by BORESHA in Mandera County

BORESHA project through care has implemented a capacity building initiative in support of sustainable natural resource management and livelihood uplift. The capacity building entailed sensitization to communities in Mandera County on the utilization and management of the Prosopis Juliflora including information sharing on technological innovations that can be employed to general value added products from the species. To achieve this, Care offered 3-day training in Mandera County - Border Point 1 and Neboi locations. The training targeted community representatives from NRM and DRR committees, farmer groups and agriculture pastoral field school groups.

The overall objective of the training was to enhance knowledge and skills of pastoralist, farmers and agro-pastoralist in the management and economic utilization of Prosopis plants for feed and charcoal energy. The expected training output was designed to have more of practical skills passed to community in Prosopis tree utilization using locally available technology.

This training also targeted the youth to form a pool of common interest groups with potential to create income generation activities from the tree to help fight unemployment that has resulted to insecurity and increased poverty in the project areas.

Despite Prosopis being a challenge to the communities in Mandera County, the participants were trained on how to manage of the Prosopis on their field through uprooting and clearing. Similarly, the participants were trained to use the invasive species for economic benefit where the parts of the tree are processed into livestock feed and quality charcoal briquettes which can then be sold hence generating income to the households. To implement the innovative technologies, they were taught – Care International procured and supplied processing equipment to the community groups which they used to produce the livestock feed as well as develop the briquettes.

2.2 Purpose and Objectives of the Study

The overall objective of the value chain analysis was to identify and document; the different species of Prosopis found in Mandera and their characteristics in terms of underground water consumption; differentiation between the use of the different parts of the plant/bush (i.e. the trunk, leaves and pods/seeds) and establish the volumes of the species and plant parts.

Specifically, the study aimed to:

a) Expound on the supply side – quantity and distribution of Prosopis Juliflora that can be exploited sustainably, and for how long including technologies to maximize on the same. The different species of Prosopis found in Mandera County and their characteristics in terms of underground water consumption. Determine the possible commercial uses of Prosopis – against the species and plant part.
b) Prosopis cover – map out the major sources of Prosopis in Mandera County current utilization and contribution to livelihoods, threats and opportunities to community in utilization.
c) Provide the demand/market perspective – possible clients, volumes needed, purchase price per unit volume and the possible uses.
d) Develop a framework on how internal and external stakeholders' capacity can be enhanced to increase the commercial use of Prosopis Juliflora.
e) Document the due diligence needed by CARE Kenya/BORESHA Consortium to ensure possible Prosopis commercialization is environmentally sound and based on & informed by a proper environmental impact assessment and backed up by relevant regulatory authorizations at county & national levels including all the relevant regulatory frameworks and policies at National and county level that affect or impact commercialization of Prosopis.
f) Evaluate existing briquette/charcoal value chains in Kenya, and possible leverage points to engage in to advance commercialization of Prosopis in Mandera County
g) The feasibility of commercialization of Prosopis; exploring options of use as charcoal briquettes
h) Establish community and County Structures perception on large and small-scale commercialization of Prosopis.
i) Identify and quantify the local, county, national and sub-regional markets demand for Prosopis products**.** List of entities engaged in trade of Prosopis-based products and source of the plant part used; a) Quantifiable and verifiable value and volume of current demand, b) Verifiable estimate of growth volumes and value, c) Value proposition analysis in the short term and longer term
j) Conduct gross benefit analysis of the cost and benefits of Prosopis briquettes production and value addition for: Primary producers, Aggregators and Processors.
k) Propose an action plan to: Commercialize the Prosopis value chain with clear milestones (including a detailed value chain map of the proposed action) and how communities can be supported on marketing of Prosopis products and practical value addition options including branding and packaging for better markets.

2.3 Situation Analysis

Prosopis is a small, fast growing, drought-resistant, evergreen, tree of tropical American origin. The *Spp* are amongst the most common tree species to be found in the dry tropics. They are native to arid and semi-arid zones of the Americas, Africa and Asia, with several American species widely introduced throughout the world over the last 200 years. In recent decades these 'exotic' *Prosopis* have attracted much attention. They are extensively planted as fast-growing and drought tolerant fuel and fodder trees, but in many countries they have also spread out of control as invasive weeds. However, because they grow wild and in abundance on common lands, they are a 'free' resource, especially important to poor farmers and the landless.

Prosopis Juliflora is invasive in parts of Kenya and Tanzania (Global Invasive Species Database) and in northern Uganda (A.B.R. Witt pers. obs.). In Kenya the species was originally introduced in the 1970s, among other species from South America to rehabilitate the Arid and Semi-Arid Areas (ASALs), due to its resilience, fast growth rate and its many uses for fodder, honey production, shade, windbreak, firewood, building poles and quickly turns bare arid environments green. In addition, Prosopis pods are valuable source of carbohydrates, sugar and proteins for livestock and, occasionally human population during dry seasons. Although the plant provides all those benefits, if left unmanaged, it has direct and indirect negative impacts to man and the environment which includes: – Colonization and devastation of critical grazing land, farmlands and rangelands, Blockage of roads, footpaths, human settlement, irrigation canals, river banks and water points and other habitats, death of livestock through over eating of pods (causing indigestion) and occasional tooth decay (due to high sugar content of pods) among others.

Prosopis juliflora invasion in Kenya has been a challenge to the arid and semi-arid areas of the country. The tree has invaded key grazing resource areas, greatly affecting the traditional pastoral production system, with a major blow to loss of indigenous and native grass and tree species. The trees effects on suppressing understorey growth have been a big challenge in pasture fields. The agro-pastoralists have also not been spared by the trees effects in colonizing old irrigation schemes and other dry farmlands within the rangelands of Kenya. The tree has proved to be well adapted and out-compete most indigenous vegetation, being highly tolerant to droughts and other biophysical conditions like salinity and low nutrient soils.

Prosopis can survive on inhospitable sites where little else can grow, tolerating some of the hottest temperatures ever recorded, and on poor, even very saline or alkaline soils. Because they are nitrogen-fixing trees, Prosopis have also been noted to improve the fertility and physical characters of soils in which they grow. They are deep-rooted, allowing trees to reach water tables and grow and fruit even in the driest of years providing an invaluable buffer during droughts. Many species appear to require access to a water table to survive, and some people believe they are responsible for the depletion of ground water reserves.

Leaves of Prosopis species, although not eaten by man directly as a food source, are often consumed indirectly when used as a food for animals The use of leaves varies widely between Prosopis species and between the different animals that may consume them. A minority of species are known to have leaves

which are palatable to livestock and which are highly valued as a source of fodder or forage *(Lee et al 1992).*

Apiculture has been recorded from most regions where Prosopis species are native and widespread, and from several areas where introduced. Mexico is the world's largest exporter of honey, and much referred to as 'acacia' honey may actually derive from *Prosopis* flowers. Large amounts of top-quality honey were exported from Hawaii for several decades, based on the large woodlands of introduced *P. pallida (Esbenshade 1980).*

The bark, stem wood and root wood that are generally used for extracting tannins primarily for use in curing leather. Tannin is generally obtained by boiling the macerated bark or wood but can also obtained as a by-product from the processing of timber for other chemical extractives *(Parker 1982b).*

All parts of *P. juliflora* and *P. pallida* are used in the preparation of medicinal products to treat human ailments. There are many records of the use of these products from historical literature where Prosopis species are native and from recent descriptions where they have been introduced.

Both *P. juliflora* and *P. pallida* are often planted on sites deemed too poor to support other more productive land uses, and have been shown to improve soil quality significantly within 15 years (e.g. Singh 1996). Prosopis have proved particularly suitable for stabilising sand dunes and easily erodable soils (*Rao 1951, Prajapati and Nambiar 1977).* This is because of their ability to survive and grow on poor sites that few other species will tolerate, and the extensive lateral root system which binds soil particles, particularly in the upper 60 cm. Induced changes in the microclimate from the shade and shelter provided, offers physical protection and, combined with improved soil conditions, this favours the growth of other herbaceous species furthering the control of soil erosion.

Other than the above, Prosopis has been used for Biodiversity and carbon sequestration, Live fencing and shelterbelts, tannins and dyes, exudate gums, Bio-control agent, leaf compost, fuel, and the pods of *P. juliflora* and *P. pallida* has been used in many forms including Coffee substitute, Pulp floor, Syrup, Alcohol through fermentation, Protein enriched floor, Bakery and excretion cooking product, additives to the diatetic foods among others.

The species native to Africa and Asia, notably *P. africana* and *P. cineraria,* are less adaptable to other areas and do not establish well if introduced to different regions (*Felker et al 1981a,)* probably due to specific environmental requirements which are not understood. Other species that have rarely been successfully introduced are those of section Strombocarpa, notably *P. tamarugo* and *P. pubescens*, again assumed because of the specific conditions found in their respective native ranges, particularly so for *P. tamarugo.* Most species of Prosopis have ability to coppice and sprout very quickly, grow quickly and in dry or poor soils where little else will grow.

2.3.1 Uses of Prosopis Tree Products

1. Fuel Wood

The wood is probably the single most important natural resource from Prosopis species for use either as a fuel or for structural purposes. Prosopis species produce a wood which is a very high quality fuel,

having a high calorific value of approximately 5000 kcal/kg *(NAS 1980, FAO 1997)* The wood does not spit, spark or emit much smoke, burns slowly with a hot and even heat, and is referred to as 'wooden anthracite' by some sources (NAS 1980). The wood contains aromatic hydrocarbons, and the smoke from some species is said to impart a pleasant flavour to food cooked over it (Maga 1986). Prosopis wood can even burn when not dried though the dry ones burn better.

2. Charcoal

The charcoal obtained from the wood of Prosopis species is also of very high quality and can be produced as easily from green wood as from dried wood. Ten kg of green wood will make 1-2 kg of charcoal using traditional earth kilns, normally in 2-4 days (Lea 1996, Varshney 1996).

3. Timber

This tree species with the potential of producing larger volumes of straighter branches and trunks have always had greater importance as sources of fuel and timber for local population. The wood of *P. tamarugo* is generally the heaviest of common Prosopis species tested, followed by *P. chilensis*, *P. pallida, P. glandulosa* and *P. juliflora*. The wood has a relatively high dimensional stability over other timbers meaning less shrinkage and cracking, and abundant wood elements give a high tensile strength (Tortorelli 1956, Weldon 1986).

4. Pods

The fruit produced by Prosopis species are legume pods, high in sugars, carbohydrates and protein. Pods have been a historic source of food for human populations where Prosopis species are found, increasingly becoming less important as a human food and more important as a livestock feed during the last few centuries. The mesocarp varies in taste from tart and bitter to the sweet pods preferred for human and animal consumption. There have been no anti-nutritional factors detected in the pods in regard to human consumption (*Becker and Grosjean 1980, Grados and Cruz 1996).* Where Prosopis are common, pods are an invaluable source of food for wild animals which are hunted by man hence helps in biodiversity.

5. Leaves

Tender green shoots and young leaves of all species are occasionally consumed by livestock, particularly when limited alternate forage is available. Leaves of all species are eaten only when no other fodder is available (Lee et al 1992). Leaves of Prosopis species, although not eaten by man directly as a food source, are often consumed indirectly when used as a food for animals. Immature foliage and dry, fallen foliage both have higher palatability than mature, fresh foliage on the tree.

6. Honey and Wax

The flowers produce copious quantities of pollen and nectar over relatively long periods of time, as a nutritive reward for potential insect pollinators. Larger bee species with longer flight ranges are thought to be the principal pollinating agents (Simpson et al 1977). Prosopis honey is light yellow in colour and generally of good quality with a pleasant taste and only a slight aroma.

7. Exudate gums

Prosopis 'gum' is sometimes ambiguous, as seed gums are also used. Prosopis exudate gums are water soluble, liquid and yellow when fresh, slowly hardening and darkening in colour Prosopis gums were chewed and eaten by some North American tribes and used in the manufacture of confectioneries. Gum, or bark covered with gum, was used in North America to produce a Prosopis-derived paint for skin, pottery and leather or as a basketry dye (Felger 1977). A simple treatment has been developed in India that stimulates mean average production of exudate gum to over 0.5 kg/tree/year (Tewari et al 2000).

8. Tannins, dyes and fibres

Bark tannin along with that found in the wood and fruit extracts is used in the tanning and curing of animal skin, particularly cattle hides in leather production. This generally involves the boiling of plant parts to extract the tannin. Fibres have also been made from some Prosopis species. Roots, with bark removed, were used in North America to make strong ropes, basketry and regarded as a valuable possession (Felger 1977). Bark and gum was used to produce paints, dyes, cosmetics and hair cleanser (Felger 1977).

9. Extracts used as Medicine

Many medicinal uses have been recorded for extracts from Prosopis plant parts from studies on the ethnobotany of populations in areas of the entire native range of the genus. Three main groups of ailments are treated with leaf and bark extracts: mouth and throat infections including. In India, for example, an astringent decoction is made from boiling wood chips, a bark extract is used as an antiseptic on wounds, and gum is used to treat eye infections (Vimal and Tyagi 1986). In Brazil, P. juliflora flour is used as an aphrodisiac, syrup as an expectorant and tea infusion against digestive disturbances and skin lesions (Rocha 1990).

2.3.2 Other physical benefits realized from the Prosopis plant

1. Live fencing and shelter belts

Living fences are effective against cattle, horses and camels but have to be particularly dense, especially close to the ground, to prevent the entry of sheep and goats. Shelterbelts can comprise one or more rows of trees, commonly three but up to ten. In India, shelterbelts of P. juliflora were found to have a positive effect in reducing soil erosion compared with other species and control plots. Gupta et al *(1983*) noted a 36% reduction in the magnitude of wind erosion behind P. juliflora shelterbelts.

2. Shade and the urban environment

Prosopis is commonly planted as roadside trees in many arid and semi-arid areas and, if not coppiced for fuel, provide desirable shade for pedestrians and their animals. Large projects such as hotel complexes and golf courses in arid and semi-arid regions often incorporate P. juliflora and P. pallida in the landscaping as single trees, tree rows or even pruned hedges. P. juliflora and P. pallida are very common urban trees in many tropical cities in arid and semi-arid areas, both where native (Díaz Celis 1995) and where introduced *(Muthana and Arora 1983, Biondi 1990*).

3. **Soil stabilisation and soil amelioration**

   P. juliflora and *P. pallida* are often planted on sites deemed too poor to support other more productive land uses, and have been shown to improve soil quality significantly within 15 years (e.g. Singh 1996). The ameliorating effects involve reducing soil salinity, neutralising alkaline soils and improving soil nutritional status and physical properties.

4. **Biodiversity and carbon sequestration**

   The positive benefits of maintaining or increasing biodiversity on a global level by protecting existing Prosopis woodlands or establishing others is stressed, while also considering the negative aspects of Prosopis as an invasive weed and its negative impacts on biodiversity, e.g. in Brazil (Pasiecznik and Harris 1998) and India (Jadhav et al 1993).

   Prosopis trees and woodlands world-wide may account for a significant amount of sequestered carbon, though tree species in arid and semi-arid zones are not considered when calculating carbon balances at present. Felker et al (1990) estimated that carbon stored as woody biomass was equivalent to 2-20 t C/ha in P. glandulosa stands in the USA, with an additional 1.4-18.4 t C/ha sequestered as reserves of soil carbon, assuming 25% canopy cover (Geesing et al 1999)

Prosopis has different local names depending on its geographical location. In Kenya *Prosopi*s is known as Mathenge. In English it is known as iron wood, honey mesquite, mesquite and mesquite bean; kikwajukwaju in Swahili and Aligaroob in Somali language *(Anderson, S. (2005).* This shrub very sharp thorns and grows to a height of 5-10m. It produces non-scent pods with hard, dark brown oval seeds *(CRC Weed Management (2003).* It is a hardy and invasive species with the ability to tolerate droughts, waterlogged soils, low nutrient and saline or alkaline soils *(Geesing, D., Al-Khawlani, M. & Abba, M.L. (2004).* Thus, it is highly invasive and once established it is hard to control *(Maundu, P., Kibet, S., Morimoto, Y., Imbumi M. & Adeka R. (2009).*

The pattern and origins of introduction of *Prosopis* species into east Africa are not well known as it clearly existed before the large-scale introductions that occurred in the 1980s. P. juliflora may have been introduced by livestock from Sudan or southern Africa or by traders from India or southern Africa. Although it is considered that there were isolated *Prosopis* trees in Kenya in the 1930s. It is documented that the plant was introduced in Kenya in 1973 when seeds were imported from Brazil and Hawaii for the rehabilitation of quarries in the saline soils at Baobab Farm near Mombasa *(Jama and Zeila, 2005).*

It is also reported that the first major planting programmes of the 1980s occurred as part of a dry land forestation scheme supported by the FAO and funded by various aid agencies including Finland, along the Tana River, and Norway in Turkana District. After this, no effort was made to manage the first plantations and by 1990 naturalization and invasion were both observed. No interventions were made at that time as people were unaware of the risks posed by this non-native invasive species. So, throughout the 1990s, *Prosopis* quickly spread in almost the whole country aided by livestock, and local perceptions of *Prosopis* became increasingly negative.

According to a report by the Kenya Forest Research Institute (KEFRI), the plant was introduced in Kenya in the 1970s, among other species from South America to rehabilitate the Arid and Semi-Arid Areas (ASALs), due to its resilience, fast growth rate and its many uses for fodder, honey production, shade, windbreak, firewood, building poles among other uses. On establishment, the tree aggressively invaded areas of indigenous vegetation, and manifested negative impact on rural landscapes as well as on human and livestock health.

The largest biomass of Prosopis in Kenya is found in Tana River, Turkana and Baringo counties according to the report. Other areas where it is found are Taita Taveta, Malindi, Samburu, Isiolo, Mandera, Marsabit, Wajir, Kajiado and Migori Counties. Among other uses apart from those mentioned before, Prosopis pods are valuable source of carbohydrates, sugar and proteins for livestock and, occasionally human population during dry seasons.

Although the plant provides all those benefits, if left unmanaged, it has direct and indirect negative impacts to man and the environment which includes: – Colonization and devastation of critical grazing land, farmlands and rangelands, Blockage of roads, footpaths, human settlement, irrigation canals, river banks and water points and other habitats, death of livestock through over eating of pods (causing indigestion) and occasional tooth decay (due to high sugar content of pods) among others.

Studies of Prosopis growth in Kenya have shown that its invasive, gregarious and powerful colonization characteristics are best manifested in conditions of high water table in such areas as ravines floodplains and swamps. This leads to serious conflict with human activities. Some of the important wetlands already invaded or with high potential of invation include River Tana Delta, (Tana River County) Lorian Swamp (Isiolo/Garissa Counties) Lengurruahanga swamp (Kajiado) among others. The potential ecological disaster caused by prosopis invasion on the wetlands ecosystem is demonstrated by the near impossible complete eradication of the species once established.

Kenya Forestry Service KFS and KEFRI have taken numerous measures to address the prosopis menace among them;- Undertaking a National survey to determine the status and impact of prosopis species on livelihoods and on environment, developing a national strategy for the management of prosopis which underlines the management of prosopis through utilization, Soliciting technical support from Food and Agricultural Organization for the United Nations (FAO), (successful pilot project undertaken in Baringo County), to empower local communities in affected areas in mechanical control through thinning and pruning and killing of stumps, utilization (making various products) and trials in biological control.

Aligaroob, a Somali name for Prosopis juliflora is a common name not only in Marsabit County but in entire Northern Kenya. Pastoralists claimed that Prosopis shrub emerged in the County in 1980's after it was introduced by the government. It was introduced as a forestry tree majorly to rehabilitate the degraded environment, ensure self-sufficiency in fuel wood and conservation of the existing natural plants against human destruction. This was attributed to animal feeding on seeds and dispersing them as they graze. *Rotich, I. T*. (2016), observes that Prosopis is spread through its seeds where a mature plant produces between 630,000 and 980,000 seeds in a year. The seeds are highly productive and are dispersed by animals feeding on the pods.

In a study carried out in Baringo district (Aboud et al., 2005) based on 73 interviews, local people highlighted the following:

i. It was regarded as highly aggressive forming impenetrable thickets that choked out other plants and reduced biodiversity.
ii. It blocked irrigation schemes when it occurred near watercourses.
iii. It was also thought to actually encourage soil erosion because the understorey of herbaceous plants was eliminated by competition.
iv. By extensively drawing on groundwater, dense stands of Prosopis were thought to lower the water table.
v. It was also perceived to cause problems with livestock; although palatable, it was thought to cause tooth problems for goats, and digestive problems for sheep and goats if fed over a prolonged period

The spontaneous, uncontrolled spread of Prosopis plants has become a problem outside the initially intended purpose. In Mandera County, the plants have covered extensive areas and invaded key grazing resource areas, greatly affecting the traditional pastoral production system, with a major blow to loss of indigenous and native grass and tree species. The trees effects on suppressing understorey growth have been a big challenge in pasture fields. The agro-pastoralists have also been effected as the Prosopis trees have colonized irrigation schemes and other dry farmlands within the rangelands. The tree has proved to be well adapted and out-compete most indigenous vegetation, being highly tolerant to droughts and other biophysical conditions like salinity and low nutrient soils.

The total eradication of Prosopis plants is not only ecologically risky but also technically and economically impossible. The plant is able to re-generate within a short period making control efforts unsuccessful. Sustainable efforts to control the spread must therefore concentrate on integrated management while deriving maximum socio-economic benefits from the plant. The tree offers a number of uses, ranging from timber, source of energy through fuel wood, charcoal, direct feed to livestock from pods and leaves, nitrogen fixation being a legume, hand crafts, shade to humans and animals, erosion control among many others.

Future efforts to control the spread must therefore concentrate on integrated management while deriving maximum socio-economic benefits from the plant. (BORESHA Sheko, 2019). These include prevention of spread, selective eradication and full exploitation of the resource, while respecting its potential to fight desertification, provide fuel, good-quality fodder and sometimes even human food.

The need to maximize on the management by utilization of the tree is becoming important. This creates the opportunity to utilize technologies for use, which includes value addition to products. To support pastoral way of life and interests in livestock keeping, feed formulation becomes an easy win avenue. Luckily, Prosopis pods offers high quality feed from pods rich in crude protein and minerals. The utilization as feed will improve livestock performance and productivity. There is also great need to conserve feeds in drylands to cushion producers from climatic shocks that cause feed shortages. Prosopis pods provide ease of value addition in making feed for ease of storage, transportation and conservation.

3. METHODOLOGY AND APPROACHES

3.1 The Methodology

Participatory and collaborative approaches based on action learning were employed. A mixed methods approach was used: combining qualitative and quantitative methods. The study was also undertaken in a manner that is feasible given the current COVID reality and associated limitations on movement and convening.

3.2 Study design

A cross sectional descriptive study design was used. The study design used a mix of quantitative and qualitative methods. Secondary and primary data was collected, analyzed and interpreted in order to answer the study objectives. The data collection methods employed included household survey, desk reviews, key informant interviews, Focus Group Discussions and observations as explained below.

3.2.1 Desk review

The literature reviewed covered all the project activities, the training reports and all available project documents as listed below;

- Training report on utilization of Prosopis Juliflora as animal feed and charcoal briquettes in Mandera County
- Secondary data containing population demographics from the existing reports
- Boresha Project baseline and endline evaluation reports
- Projects M&E plan and Logframe
- Literature from IGAD

3.2.2 Key Informant Interviews (KIIs)

The KIIs were conducted using a predetermined guide with open ended questions cutting across the project activities and indicators. Key informants included to collect in-depth information from key stakeholders at Community, County and Partner levels. In consideration of the COVID-19 pandemic and restrictions posed on travel and meetings, these discussions were done virtually using zoom and phone voice-based communication systems

3.2.3 Household survey

A household survey targeting heads of household was conducted using a pre-tested, structured questionnaire on KOBO Toolbox (a mobile data collection platform). The questionnaire captured data on the demand aspects on Prosopis Juliflora value chain such as; the level of utilization of Prosopis; the impact of the species on the ecosystem (livestock and farmland); the sale of the Prosopis; existence of value addition to Prosopis products among others.

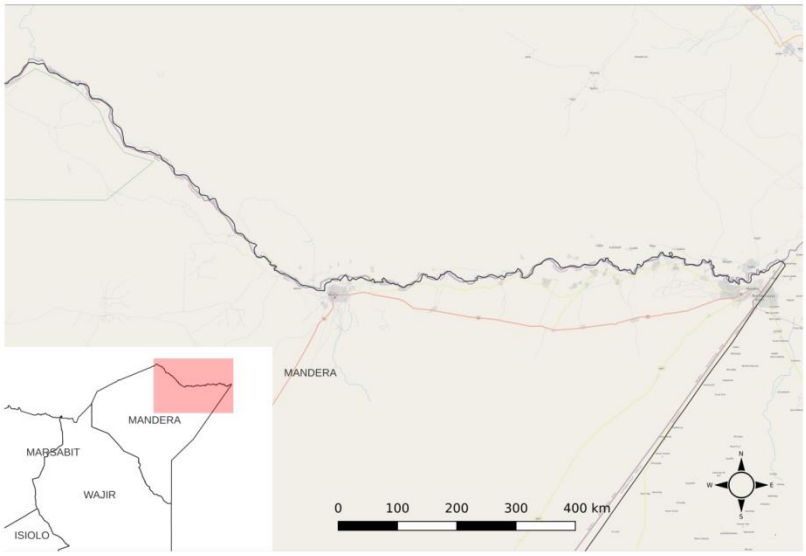
3.2.4 GIS mapping

Existing documentation and reports were obtained from Care and reviewed. GIS mapping was equally carried out along river Dawa within the quadrature marked by the survey assistants and coordinates recorded. The National Drought Management Agency (NDMA) Drought Early Warning bulletins [5], [6] and [7] were also reviewed. Several published studies on the use of remote sensing in mapping Prosopis

Juliflora were also reviewed [2], [3] and [4]. From these reports and studies, it was established that:

- Prosopis Juliflora is an evergreen crop and the best time to take data is during the dry season
- The lowest NDVI levels for Mandera County occur around January and June of each year
- Prosopis Juliflora presents with an NDVI of 0.644 and above
- Machine Learning can be used for the classification of Sentinel 2 satellite data over land covered by invasive species
- Groundwork is essential for confirming and directing the study
- Further consultations with the focal person at Care clarified the geographical scope of the study as the Valley of Dawa River.

Figure 1: Map of the Area of Interest:



Data Acquisition

The various data items required for the study were identified and the sourcing of the data proceeded

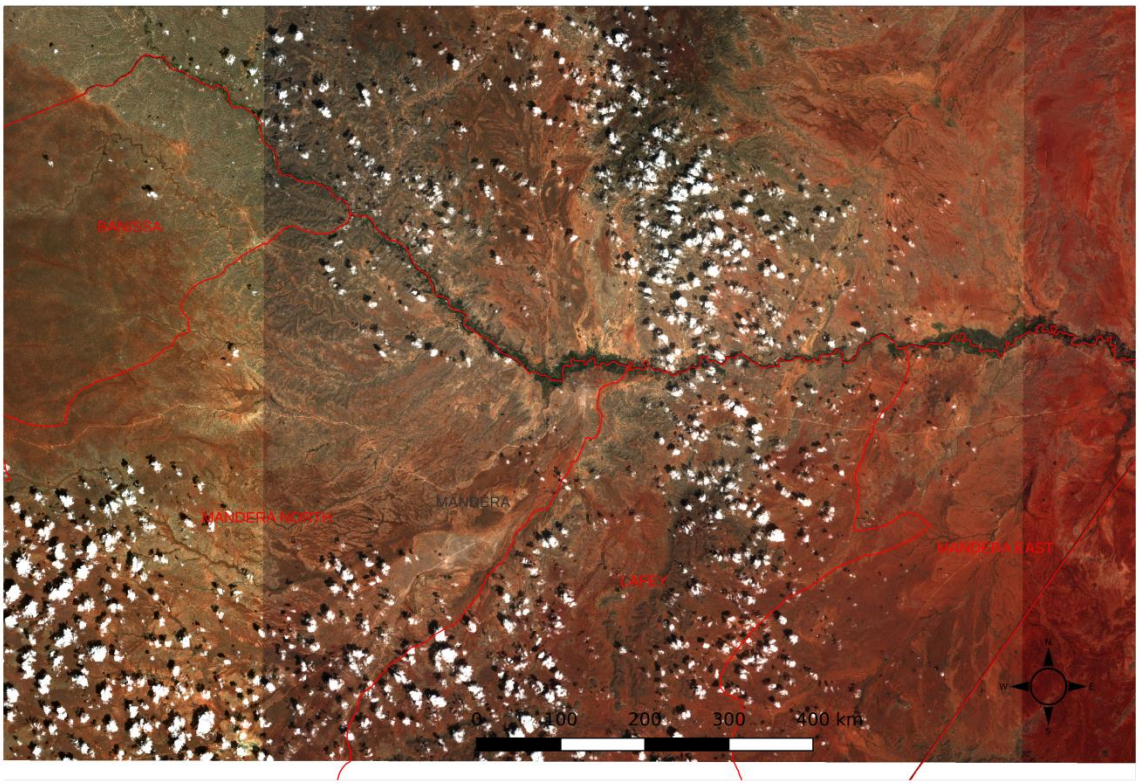
Satellite Data

The Sentinel programme of the European Space Agency (ESA) provides high resolution (10m) data at a global basis since 2015. Sentinel 2 satellite images were obtained from the Copernicus platform for the following dates:

- 10th January 2022
- 2nd October 2021
- 20th January 2021
- 21stJanuary 2020
- 21st January 2019
- 21st January 2018
- 6th January 2017

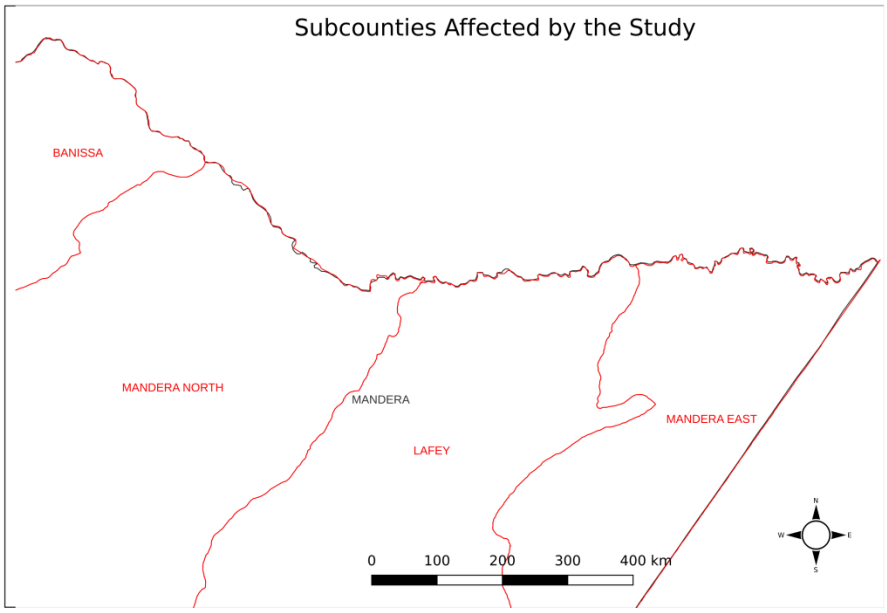
This provides a continuous dataset for monitoring vegetation changes over the past 5 years

Figure 2: River Dawa Valley



Administrative Data

Administrative data was sourced from the Humanitarian Data Portal. The data acquired included the ESRI shape files for counties [9] and sub-counties [10].



Biophysical Field Data

An Android based tool was designed for the collection of biophysical data in the field. This tool captured GIS data in sampled areas where Prosopis Juliflora is present within the study area. The diameter of stems, and height estimates was also captured. A team was then sent to collect this data in Mandera North and Mandera East subcounties.

GIS Preprocessing

- SCP was used to apply radiometric correction for L1 data
- A custom script was developed for the preprocessing of the data. The script was used to merge various tiles together into a single tile with all the Sentinel 2 data. The 60m bands (Band 1, Band 9 and Band 10) were excluded from radiometric correction
- A single Bandset was created for each epoch
- All downloaded data were converted to UTM Z37N on the WGS-84 datum (EPSG:32637)

3.2.5 Focus Group Discussions (FGDs)

Focus Group Discussions (FGDs) were conducted by trained enumerators, using a predetermined focus group guide with relevant probing questions. Each group of FGDs was identified by CARE and mobilized to attend a session with the enumerators. Each group consisted of between Ten (10) respondents. Four FGDs (One per location) were conducted and targeted; Community groups that were trained on utilization of Prosopis Juliflora by the BORESHA project. The participants comprised Men, Women and Youth in the four locations.

3.2.6 Observations

Planned visits to selected communities were done to provide more specific evidence and answers to the evaluation questions. These were done on the Prosopis value chain where the enumerators observed the support provided to farmer groups in the target locations by the project.

3.3 Population and Sampling

Mandera County has a total population of 867,457 of which the males are 434,976 and females recorded as 432,444 according to 2019 KNBS census report. The survey was carried out in Mandera East Sub County (and Mandera North Sub County. Mandera East has total population of 159,638 of which males are 83,538 and females are 76,095 in a land area of 2,507.7 Sq Km and Mandera North with a population of 143,850 from which Males are 77,008 and females are 66,835 in a land area of 5,087.3 sq Km.

CARE Kenya through BORESHA project reached 1,331 beneficiaries (831 through training on natural resource management/planning and 507 through NRM mapping and training). A sample of 240 households was therefore computed from the population for the evaluation.

i) Sampling techniques

Probability and non-probability sampling methods were used. A two-stage sampling was used; first the sub-counties where the program was implemented were purposively chosen, then the second was the locations The sample size was equally distributed across the locations. Purposive sampling was then done to pick villages based on where the Prosopis Juliflora is found. Heads of households were picked through consecutive sampling. The key stakeholders were purposively picked due to their contribution to the program. From the groups that were subjected to the focused group discussion, a convenient sampling was used as these were groups that had been targeted for the BORESHA capacity building in Mandera North and Mandera East.

ii) Sample computation

To generate the sample size from the population, Krejcie and Smith, 1979 formula was used to arrive at the total households to be targeted for the study. The sampling formula was used as it guarantees randomness in selection of respondents, validity and reliability of data collected.

Formula:

$$S = \frac{X^2 NP\,(1-P)}{d^2\,(N-1) + X^2 P\,(1-P)}$$

Where:

S: Required sample size

N: Population size

X^2: Table value of chi-square for 1 degree of freedom at the desired confidence level (3.841).

P: population proportion (assumed as 0.50 since this would provide the maximum sample size)

D: the degree of accuracy expressed as a proportion (0.05)

The application of the formula gave a sample size of 298. The sample was distributed across the respondent categories as shown in table 1. A total of 239 household heads were interviewed of which 120

were from Mandera east and 119 from Mandera North. Out of this 119 were females and 120 were males. Key informant interview was also carried out amongst County, National government staff and other organizations like Care- Kenya. A total of 8 key informants were interviewed during the study.

Table 1: Sample Distribution

Data Collection Approach	Sample (n)	Response rate
Household Survey	240 (60 per location)	239
FGDs	48 (12 per Location)	40
KII	10	8
Total	**298**	**287**

3.4 Quality control measures

To ensure quality data, the following measures were taken:

a) Training for enumerators and supervisors on ethics and method of data collection including best possible quality data collection during COVID-19 pandemic;
b) In-built mechanisms in the checklist/schedules to cross-check consistency of the responses;
c) Pilot study to ensure the tool is tested for reliability. Errors identified were adjusted and the tool refined for final field administration
d) Probing techniques to ascertain the appropriateness/relevance and consistency of answers, and wherever necessary elaboration of answers;
e) Close supervision of the work of the enumerators;
f) Random check on the work of the enumerators;
g) Feedback by supervisors and solution to bottlenecks, as and when arisen.

3.5 Ethical principles for the evaluation

The enumerators observed the three universal ethical principles, including *respect for participants*, *beneficence* and *justice*[1]. Since this was an evaluation for the purposes of learning, there was no risk associated with participation. There was also no direct benefit given to respondents. All information was treated with strict confidentiality with respondents' names not being recorded on any data collection forms. Other ethical principles observed are a follows;

a) The lead person gave adequate consideration to the existing literature, knowledge of the people in the area and hence therefore during data collection their opinion were also considered as valid
b) The groups who were considered for data collection were notified in advance and explanation provided for the purpose of the study to ensure good explanation to their interest for their social justice
c) The information received from the interviewees were treated with autonomy, rights and dignity and therefore their participation was explained to them as voluntary
d) Attention was given to collect information: from all types of stakeholders including relevant government departments; NGO, private sector players and households currently engaged in Prosopis utilization activities, with special focus on women and youth

[1]The Nuremberg Code; The Declaration of Helsinki; Belmont Report; U.S. Code of Federal Regulations, etc.

e) Initial findings and recommendations made as a result of the assessment was fed back to BORESHA, partners and right holders in a meaningful way, so they have an opportunity to discuss the recommendations before they are finalized.
f) All team members administering the questionnaires were sensitized to respect the participants involved and protect autonomy, the rights and dignity of the participants. The participation of the individuals was voluntary based on the informed consent
g) All the information and records provided by the participants or obtained directly or indirectly on/ about the participants are kept confidential.
h) All participants were cautioned to minimize the risks and maximize good outcomes for science and humanity. They were taxed to avoid unnecessary risk, harm or wrong in whatever form.
i) The questionnaires and the interview schedules were made short in order to not to consume time for those administering and also other survey participants. This also helped them not to lose other resources or income
j) The participants were informed that the outcome of this survey would be share with them and even all the organizations that took part.
k) Accountability, transparency and objectivity were strived in all the communication in as far as data required. Also the data collected was interpreted as is and not falsified.
l) All the secondary data collected has citations from the authors and this contributed to totality of responsibility. The responsibility for due observance of all principles of ethics and guidelines on all directly involved in the study.

3.6 Safety, Security and COVID-19 related policy and procedures

The following guidance was considered:

1) All enumerators wore Three ply face masks while interacting with respondents
2) At the site of the focus group discussions, physical distancing of minimum 1.5 meters was maintained as a safety precaution against infection or spread of COVID-19.

3.7 Data analysis

Qualitative data was analyzed using basic thematic sorting and frequencies in N-Vivo software. Quantitative data captured in mobile phones was transferred as Comma Separated Values (CSV) to Excel, then to SPSS version 27 for analysis. Presentation is in form of charts and tables. The data was presented in form of descriptive and inferential statistics. Descriptive statistics entailed mean, frequencies to describe the characteristics of respondents. Inferential statistics such as correlation and test of significance was conducted to test the relationship between variables. The primary data findings were triangulated by findings from secondary documents reviewed.

GIS Preprocessing

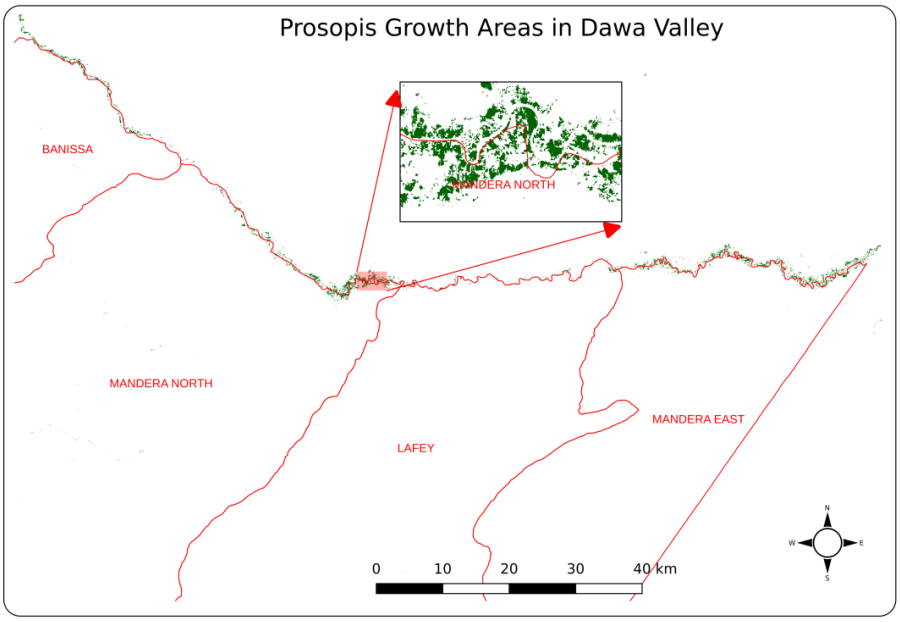
SCP was used to apply radiometric correction for L1 data. A custom script was developed for the preprocessing of the data. The script was used to merge various tiles together into a single tile with all the Sentinel 2 data. The 60m bands (Band 1, Band 9 and Band 10) were excluded from radiometric correction.

A single Bandset was created for each epoch and all downloaded data were converted to UTM Z37N on the WGS-84 datum (EPSG:32637).

GIS Analysis

- NDVI was computed for each epoch
- The evergreen filter was generated (>0.7)
- Training Data was generated and used for machine training guided by data collected from the field
- GMM and Rainforest classification was undertaken using the Dzesarka plugin on QGIS
- The evergreen filter was compared with the automatic classification data

Figure 3: Map of Prosopis Areas



- The outline of Dawa river bank was digitized from a high resolution Bing Maps layer
- The outline was then matched with administrative data and adjusted to ensure each administrative area (sub-county) touches the actual river bank
- The acreage of the evergreen land was acquired and compared with fieldwork studies

Biomas Estimation

The total amount of biomass was estimated using the valued provided by FAO [12]

$$W = a + b\ .n\ .(C/\pi)^2 \cdot H$$

Where

W = weight of the biomass in kg

a = regression constant

b = regression coefficient

n = Number of Stems

C = Girth / Circumference of the stems

Using this formula, the green biomass per tree was obtained [12] as:

$$W1 = -0.1685 + (0.3061 * n *(C/\pi)^2 * H)$$

$$W2 = 0.0224 + (0.6882 * n *(C/\pi)^2 * H)$$

Where

W1 = stem weight in kg

W2 = total weight (stem+ branches+ leaves) in kg

The biophysical data collected was then used to compute the quantity of standing biomass in Kg. The total weight of biomass within a quadrant was then obtained by adding the masses of all trees within that quadrant. It was then established that the average density of Prosopis biomas was 10.56681 Kg/m2 for stem weight and 23.8377 Kg/m2.

These values were then used to obtain estimates of biomass from the acreage of evergreen vegetation during the dry season.

3.8 Study limitations

Main limitation in this study was time and cost, as the team would have wished to have more time and reach out to all elements in the study, education level disparities and general ignorance, some respondent declined to fill the questionnaire which led to more time allocation for purpose of explanation of importance of the study to them. This affected the team's budget as more time was needed to exhaust the questionnaire.

The team overcame the limitations by selecting research assistants from the area where study was carried out, setting time frames for conducting interviews. This shortened the time for data collection since they were familiar with the terrain, culture, local language and even the groups that provided the data. Research assistants were of minimum of form iv level of education, able to understand the contents of the questionnaire and would even translate in the local language.

4. FINDINGS

4.1 Demographics of Respondents

4.1.1 Respondents particulars

Respondents were categorized in the following categories; Eight key informants were chosen from CARE-K, National Environmental Management Authority, Forest department, Natural resource management Committees, Local administration and Disaster Risk Management Committees at the Locations. 40 Focus group discussion participants were selected from the groups in the four locations where BORESHA project was implemented. Household heads were randomly selected from the four locations. In the three cases mixed method sampling was adopted.

a) Household Interviews

A total of 239 household members were interviewed in four Locations of Ashabiti and Girisa in Mandera North Constituency and Boda Point 1 and Neboi in Mandera East sub-Constituency. Out of these 49.8%, were female while 50.2 % were male. The unemployed were the majority (33%), followed by pastoralist (23%) and farmers at 21%. Table 1 below highlights the socio-economic characteristics of the household members interviewed.

Table 2: Socio-Demographic Characteristics of the Respondents

Characteristics	Description	Frequency (Number)	%
Gender	Female	119	49.8
	Male	120	50.2
	Total	239	100
Occupation	Business (trader)	13	5
	Casual Laborer	18	8
	Farmer	49	21
	Pastoralist	54	23
	Salaried Employment	14	6
	Self Employed	11	5
	Unemployed	80	33
	Total	239	100

b) Focus Group Discussions

Two focus group discussions were held in Mandera North and Mandera East Constituencies. They were attended by 40 members of various community groups as shown below

Table 3: Focus Group Discussion Participants

Location	Participants (Gender)	Frequency (Number)	%
Ashibito and Garisi Locations	Female	11	55
	Male	9	45

Boarder Point 1 and Neboi Locations	Female	11	55
	Male	9	45
Total		**40**	**100**

4.1.2 Land Size and tenure

In Mandera County, land is mostly communally owned with a few privately owned plots within towns, this kind of land tenure system discourages investment and long term development specifically with physical structures like housing for rentals and business premises. This is the same to the two sub Counties namely; Mandera North and Mandera East. On the other hand, this tenure system has helped stabilize and protect grazing areas from wanton destruction and this fact has aided in securing the livestock population.

The County Councils holds in trust on behalf of the local community the trust lands (unregistered land). The optimal utilization of land in the county is hindered by the current land tenure system. Tenniel issues in the pastoral areas revolve around communal use of grazing resources without control over individual actions.

The main challenge in the two sub counties is land degradation resulting in some areas rendered unsuitable for crop production. The available land for agriculture has not been fully exploited due to resource constraints. The areas mentioned fall under Lower Midland (LM) 1V-V1zone.

4.2 Spread and Uses of Prosopis in Mandera

4.2.1 The different species of Prosopis found in Mandera

Data gathered from survey participants from the county report that there are two main species in the county. The respondents described the two main species of prosopis found in the two sub counties and were generalized as illustrated here below.

	Species A	**Species B**
1.	Leaflets are tend to be spaced apart	Leaflets are approximate
2.	Pods slightly bigger without parallel margins	Pods smaller and with parallel lines
3.	Tend to be thorny	Less thorns compared to the other one
4.	Green in colour	Tend to be dark green in colour
5.	Many leaves per node	Fewer leaves per node
6.	More leaf pairs per pina	Less leaf pairs per pina
7.	Slightly bigger fruits	Smaller fruits

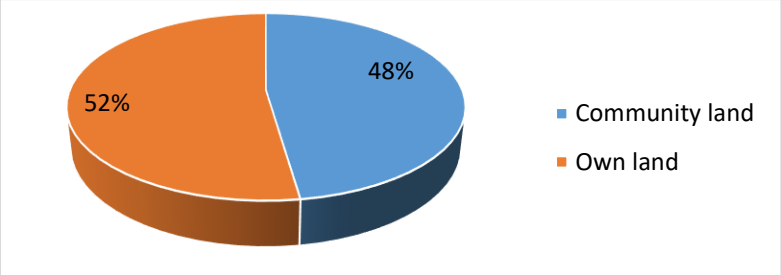
From the descriptions given above, it gives full description of the two main species as *P. juliflora* (A) and *P. pallida* (B). *(adapted from Díaz Celis 1995.* The community members interviewed agreed that *P. juliflora* is largely distributed than the *P. pallida.* This may be attributed to the its physical characteristics that make it not to be more disturbed because of its thorniness.

4.2.2 Degree of Invasiveness of the Prosopis species

The study sought to establish level of awareness and perception of community members about the invasion of the Prosopis species in their area. These are important factors in influencing the decision of community members to be involved in the efforts to manage the invasive plant.

Fifty-two percent of the households interviewed had the Prosopis plant in their own farms. The remaining 42% had interacted with the plant in the community land, as indicated in figure 4.

Figure 4: Ownership of the Invaded land



On the spread of the species, 81% percent of the respondents indicated that Prosopis species has been increasing in their community in the last 5-10 years. This group feel that Prosopis is an invasive plant that was spreading fast and covering more land in the area. Sixteen percent believed that it had decreased. This is the group that may be slow to involve itself in the interventions aimed at managing the invasion of the plant.

Table 4: Spread of the Prosopis Plant.

Invasion of Prosopis Plant	Frequency	Percent
Decreased	38	16
Don't know	8	3
Increased	193	81
Total	**239**	**100**

The respondents were asked about the effect of Prosopis Plant on their farmland and 64 % had a negative perception about Prosopis plant. They believed that prosopis shrubs were encroaching on grazing and smothering other local plants, negative effect on animal health, causing physical injuries to domestic animals and people. 23% of the respondents believed the plant had no effects while 12 % of the respondents of the plant saw the positive effects of the plant.

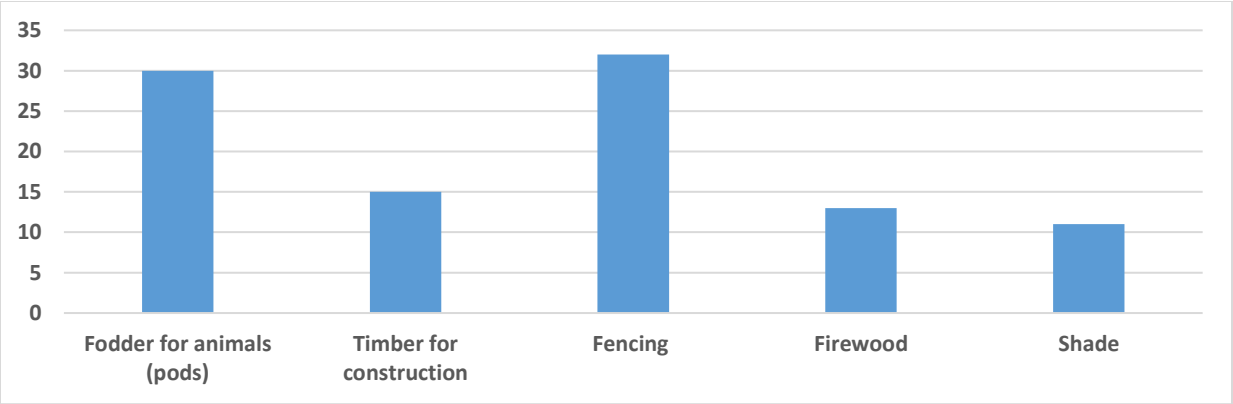
Table 4: Effects of Prosopis Plant

Effects	Frequency	Percent
Negative effects	154	65
No effect	56	23.
Positive effect	29	12.
Total	**239**	**100**

4.2.3 Uses of Prosopis Plant

Forty-two per cent (42%) of the respondents reported other uses of the Prosopis plant besides charcoal or briquette. The uses were ranked in the following descending order: fencing, animal fodder (pods) timber for construction, firewood, and shade for animals and human beings. Use of pods as fodder for animal was not ranked the highest because it is mostly consumed during dry seasons. This may imply the need for more sensitization and awareness creation on Prosopis products. Figure 5 below highlights the uses of the plant.

Figure 5: Uses of Prosopis Plant



During the introduction of Prosopis in the early 1970s to 1980s in the county, it is reported that pastoralists embraced the shrub because of its perceived benefits. They included reduced desertification, provision of shade to animals and provision of fuel wood. From the information gathered in the FGDs and KIIs, the people of Mandera use Prosopis in the following ways:

i. **Livestock feeds:** The most common method was direct feeding of livestock with the pods during drought. Free-ranging animals eat the pods directly from the shrubs or the pods are collected and fed to animals. During drought, the Prosopis pods are sold as livestock feeds in the markets. The second method involved the use of Prosopis pods as raw material for processing livestock feeds. Concentrate of Prosopis pods has been used in feed production by mixing the dried pods with farm produce.

ii. **Source of Fuel wood:** *Prosopis* was the main source of fuelwood in Mandera North and East sub Counties. In rural areas, it was the only source since it was readily available and at no cost except harvesting labour which was provided by women and children.

iii. **Source of Construction Materials:** Construction materials obtained from Prosopis included building and fencing poles, rafters and twigs. They are mostly used in the construction of temporary houses which are very common in rural, peri-urban and urban areas of the two sub counties. These structures and houses were made of Prosopis poles and twigs.

iv. **Sources for handles for jembes and other farm equipment:** Information got from those interviewed, reported that they cut the poles for making handles for farm equipment like jembes, pangas, rakes and many others.

v. **Used as fences for the farms:** The plant regenerates very fast and therefore has been used in the area to fence farms. Its thorny ness helps to put away trespassing animals and human beings from the farms.

vi. **Shades in the compounds:** The plant offers a good source for shade in the hot sun for both livestock and human beings.

vii. **Ordinary Charcoal /Charcoal briquettes burning:** Some community members use Prosopis from their farms to burn charcoal. Charcoal briquettes are also produced in small scale from those who benefitted from the machines from CARE-K.

4.2.4 Harvesting of Prosopis Products

The key informants reported that the quantities of Posopis products harvested vary with the part of the tree and season. Harvesting of the mature tree for charcoal was not being done on a large scale. The branches were however harvested in large quantities by households for use in fencing and fire wood. The pods were also harvested in large quantities during dry season. There were no records on the quantities of the products harvested, as well as revenue generated from the sale of these products, as highlighted in Table 5.

Table 5: Harvesting of Prosopis Plant Products.

Part of the Prosopis Tree	Volume harvested	Quantification
Stems	Small	Not quantified
Branches	Large	Not quantified
Leaves	Large (dry season)	Not quantified
Seeds/pods	Large (dry season)5	Not quantified

Large scale harvesting of prosopis products in the Mandera County is hampered by many factors. Charcoal burning and selling is affected by the laws that are restricting the movement and sale of forest products. The charcoal from the tree as lack market locally due to completion from charcoal produced from indigenous trees which are considered to be of good quality. Prosopis branches have dangerously strong thorns that are also poisonous, thus making harvesting difficult. The tree itself is a hardwood species, its stem very hard and it wears down simple cutting tools.

4.2.5 Recommended Interventions

The household members and key informants interviewed recommended a number of interventions for managing the Prosopis plant in Mandera and enhancing its value chain in the county. Top among these was provision of harvesting tools, machines and storage facilities for Prosopis products. This was followed by market linkages and capacity building of more community groups on the use of the utilization of the products, as elaborated on table 5 below.

Table 6: Recommended Interventions.

Proposed Intervention	Frequency	%
Clearing the shrubs to control the spread	36	15

Provision of harvesting tools, machines and storage facilities for Prosopis products	81	34
Linkage to ready market for the Products	39	16
Capacity building of more community members on prosopis utilization	38	16
Legalize tree cutting and charcoal burning	13	5
Formation of more youth and self-help group for management and utilization of the tress	19	8
No recommendation	13	5
Total	**239**	**100**

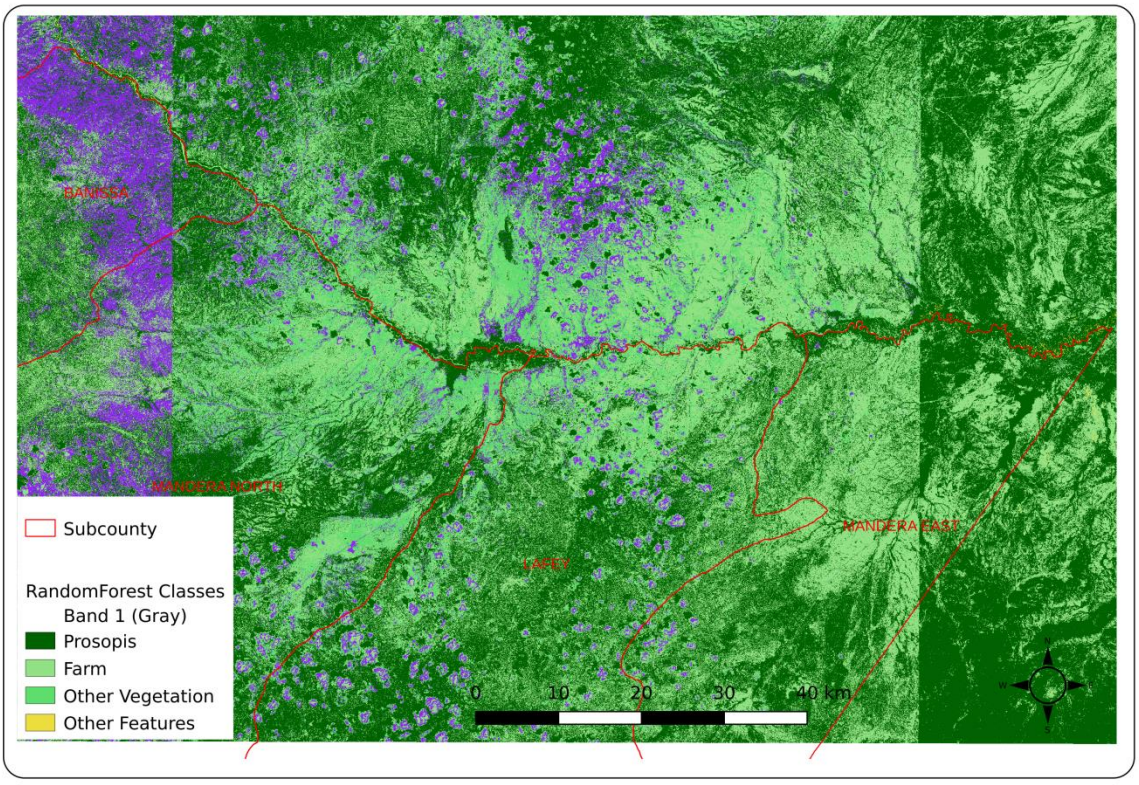
4.3 Supply and Demand of Prosopis

4.3.1 The Supply of Prosopis

4.3.1.1 Automatic Classification using Random Forest

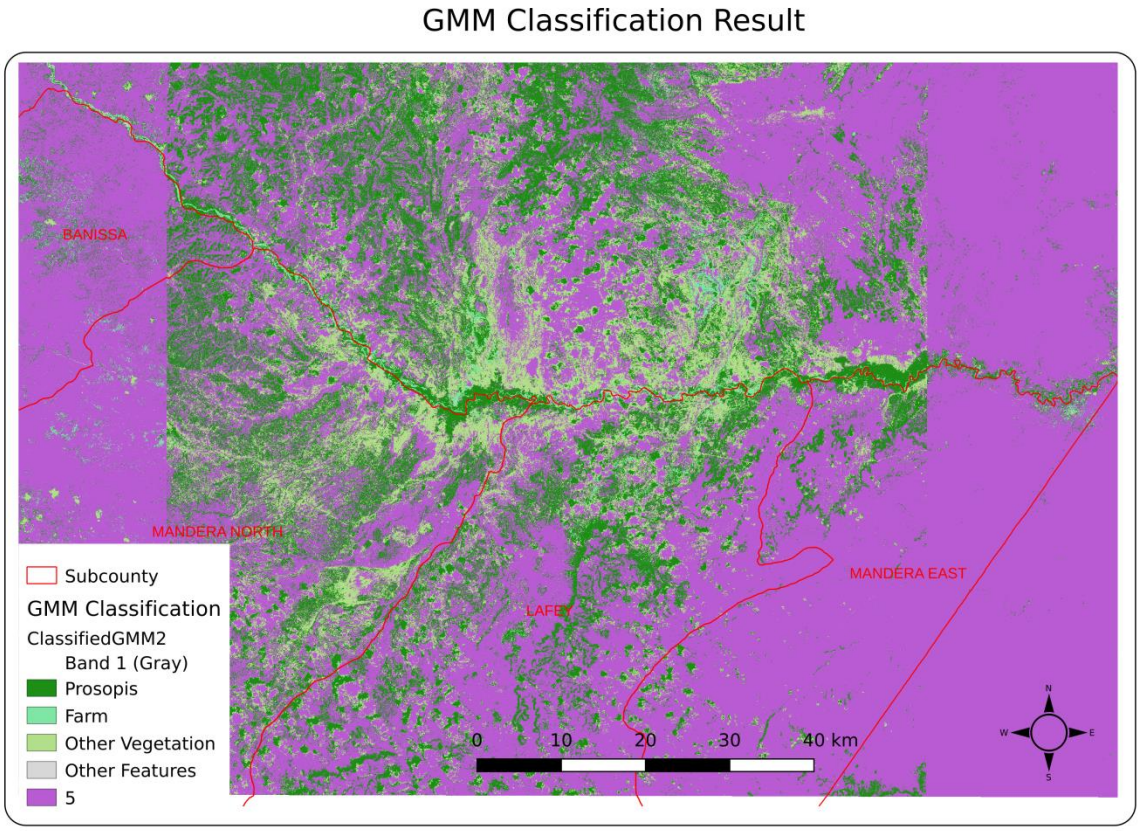
The Random Forest classification result was obtained but was deemed unsuitable for the area because of too many false positive values. This algorithm is known to have good results and an additional training data will be required to further refine the tool

Random Forest Classification Result



4.3.1.2 Automatic Classification using GMM

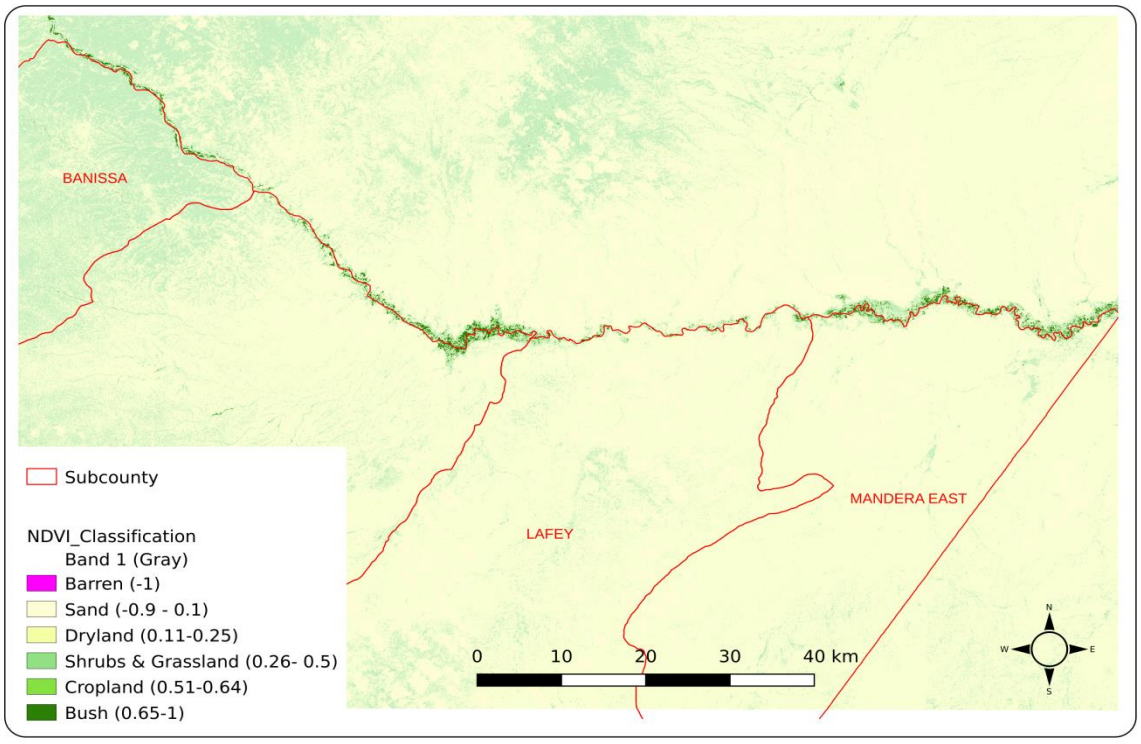
GMM showed very close correlation with NDVI within the valley. It was found to be a reliable estimation of Prosopis Biomas though the classification of other categories was not good.



4.3.1.3 Classification by NDVI

NDVI for satellite images taken during the dry season was found to be the best way of identifying Prosopis which is evergreen. The cutoff value of 0.7 was found to closely correspond to higher resolution Satellite imagery of the area. This is what was used as the basis of Prosopis identification.

NDVI Classification Result



Based on NDVI classification, the quantity and distribution of Prosopis Juliflora per subcounty as at 10th January 2022 is presented in Table 6. It was established that the standing biomass was 10.56 tonnes /ha for the stems only and 23.83 tonnes /ha for the whole biomass including leaves and branches. An annual yield of 1.4 tonnes per Ha is used to compute the potential wood yield [13] per subcounty.

Table 7: Biomass Estimates as at 10th January 2022

Subcounty	Area on the Kenya Side Under Prosopis (Ha)	Standing Tonnage (Stems) (Tonnes)	Total Standing Tonnage (Stems, Leaves, Branches) (Tonnes)	Potential Wood Yield (tones / year)
Mandera East	650.33	68,719.138	155,023.7	910.462
Lafey	98.74	10,433.669	23,537.35	138.236
Mandera North	539.89	57,049.153	12,8697.4	755.846
Banissa	221.62	23,418.165	52,829.12	310.268

Table 8: Biomass estimates on Kenya-Ethiopia Cross border

Sub-county	Area on the Ethiopia Side Under Prosopis (Ha)
Opposite Mandera East	567.76
Opposite Lafey	113.57
Opposite Mandera North	451.37
Opposite Banissa	203.96

4.3.2 The Demand for Prosopis/market perspective

Although majority (65%) of the respondents agreed that Prosopis had encroached their land, some (12%) saw that the plant had positive impact and could be encouraged, managed and be exploited for livelihood purposes. The respondents could not quantify the volumes needed for each products category but reported that a bag of Prosopis charcoal trade as much as Ksh 700 but demand from the indigenous trees charcoal is still higher. From the information gathered from most respondents, most community members have not been sensitized on other alternative Prosopis uses.

Secondary data from other counties indicate that ten Kg of green wood can make 1-2kg of charcoal using earth kilns which are traditional in 2-4 days. With the machines used by the BORESHA project for training, the duration is reduced and quantity produced not reported is likely to increase. At present the market for products is still in its infancy, but has shown some movement in the last years with more than six timber companies in Nairobi interested in seeing wood samples and a feed company putting in an order for 20 tons of pods.

4.3.2.1 Persons /Organizations Involved in Prosopis Products Business

The table below shows those involved in prosopis based products. However, the quantities required could not be mentioned by the categories of persons listed. Among the persons and organizations mentioned as engaged in business in prosopis products, CARE Kenya was mentioned by 51% of the respondents. This could be due to the organization's involvement in the training and provision of machines and equipment to the local groups. They were followed by the local traders and area Chief. (See table 7). It is interesting to note that the local NRM groups were mentioned by few respondents. This could imply that their reduced involvement in the management and utilization of Prosopis product after capacity building given by BORESHA Project.

Table 9: Engagement in Prosopis Product Business

Person/Organization	Frequency	%
Care Kenya	45	**51**
Local businessmen and women	19	21
Area Chief	13	15
NRM Committees	6	7
Animal Feed Sellers	1	1
Charcoal sellers	5	6
Total	**89**	**100**

4.4 Commercialization of Prosopis

4.4.1 Regulatory requirements

Prosopis is considered and invasive species in Mandera County, national measures should be combined with international measures, and international coordination of management of the plant.

(1) Re- legislation the laws that put prosopis a noxious weed. *Prosopis* is considered an invasive species in Kenya since the year 2008 when the Kenyan minister for agriculture declared *Prosopis juliflora* a noxious weed under laws of Kenya cap 325.
(2) Prevention of intentional introduction and spread – the prohibition of import, sale and movement of plants and seeds, as would be required under Kenyan and international regulations especially those listed by relevant departments.
(3) Prevention of secondary spread of the species – Removal of naturalized individuals and populations where known to exist as prevention of secondary spread once well-established over a large area is not possible.
(4) Surveillance measures to support early detection – Undertaking full surveys in the endangered area, including full literature reviews, with an obligation to report findings if the species was regulated.
(5) Management – manual control, and where widespread, countries must prepare and implement eradication and containment/management plans (that could also include mechanical, chemical and/or biological control methods)
(6) Development of the national strategic plan that provides guidance on best practices for weed management including *prosopis.*
(7) Kenyan government policy is that the production and transport of charcoal is illegal unless a license has been applied for and approved. This may be considered for lifting to motivate most pastoralists to produce charcoal from *prosopis* which is considered high quality.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Prosopis plant is considered an invasive species the lens of a pastoralist in the two sub counties which were under study. The plant is a menace that should be eradicated. Moreover, researchers argue that *Prosopis* is a gem in the ASALs. Taking cognizant that Prosopis has already colonized the rangelands of Mandera County and other ASALs in the Country and it cannot be easily eradicated. Only viable option is to manage and make good use of it by turning it into a valuable resource through utilization of tree products.

Information gathered from both primary and secondary data, potential for *Prosopis* is largely not exploited. Many other uses like wood products, Charcoal briquettes, Pods for both human and animal food, Leaves for animal feed and composting, Use of the flowers for nectar, extraction by the bees, manufacturing sweets from the sweet *prosopis* gums, Extraction of tannin, dyes and fibres, ethno-medicine and pharmaceutical industry.

More uses in form of Live fencing and shelter belts, shades and urban environment, soil stabilization and amelioration, biodiversity and carbon sequestration among others need to be exploited and this hill enhance the commercialization of the dreaded plant.

The mapping study has established that of majority of the residents of Mandera County are generally of the opinion that the benefits of Prosopis plant are outweighed by its undesirable properties. The plant has threatened their livelihood options of livestock keeping and farming. The measures put in place to by the government and NGOs to control the spread of the species have not been significant and at the same time, the beneficial uses of the plant have not been optimized and promoted. Any intervention aimed at managing the invasion of the plant and promoting commercial use of its product in the County is timely.

5.2 Recommendations

From the data collected and analyzed in the study, the following recommendations are made:

7. Capacity building the communities in the county to enable them utilizes prosopis for the following products
    a. Timber - Training and awareness-raising on timber processing used the simplest mechanical means available.
    b. Posts and Poles - Prosopis continues to meet an import need for local rural construction through the provision of poles for rustic rural structures, although the sapwood is easily and quickly attacked by insects. A recent development has been the contracting of the Forestry Department to provide long, thin, flexible sticks of Prosopis for making the framework of simple structures for Somali refugees in Garissa District.
    c. Firewood and charcoal- Prosopis has been seen as a saviour for many dryland households. Views commonly held by many people during the study, and women had to walk long

distances in search of firewood. Prosopis charcoal is widely acknowledged to be of high quality, and is more popular than that from other trees according to a recent KEFRI survey.

d. Pods for human food – These can be for local consumption and markets. Currently the pods are sucked and chewed by the children. The prosopis pods can be used can be milled into floor, prosopis cake, coffee substitutes among many other more uses.
e. Pods as Livestock feed –The pods are mixed with hay and other farm by products milled and fed as high value livestock feed
f. Exploiting other products from prosopis like gums, tannins and looking into ways of commercialization of the same.
g. Capacity building the community members on the medicinal values and trying to exploit how other products of medicinal value may be exploited from prosopis.

8. Control multiplication of the prosopis through seeds and seedlings for agro-forestry and afforestation purposes with proper management after putting in place policies and regulations on the exploitation of the same. Other uses than can be explored includes fencing of the homestead and use as wind breaks.
9. Develop legislations, regulations and policies for the development and utilization of prosopis nationally and within the county.
10. Initiate a commercially-oriented intervention to manage the spread of prosopis plant in Mandera County. This should be a joint venture between the affected communities, county government of Mandera, relevant government institutions, BORESHA Project and other stakeholders.
11. Conduct continuous awareness creation and sensitization of the local communities on the importance and potential uses of prosopis plant products. This is necessary for them to develop a positive attitude towards Prosopis plant as a resource.
12. Promote efficient production of charcoal from prosopis wood in the county to ease the pressure on indigenous tree species which are threatened by charcoal burning activities.
13. Re-activate community groups trained by BORESHA project on Prosopis plant charcoal briquette and animal feeds processing. More new groups should be trained to complete the efforts of the existing ones.
14. Care and other interested stakeholders should work with the County Environment Committee to draft a policy paper on Prosopis for discussion and adoption at different level of the County Government.

6. REFERENCE

Aboud, A.A., Kisoyan, P.K.D. and Coppock, D.L., 2005. *Agro-pastoralists' wrath for the Prosopis tree: the case of the Il Chamus of Baringo District, Kenya.* Research Brief 05-02. University of California, Davis,USA.

Amboka A.A, Ngigi TG. "Mapping and Monitoring Spatial-Temporal Cover Change of Prosopis Species Colonization in Baringo Central, Kenya", International Journal of Engineering Science Invention ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726, Volume 4 Issue 3 || March 2015 || PP.50-55 https://advancedscholarsjournals.org/full-articles/association-of-climate-variability,-prosopis-juliflora-spread-and-other-vegetation-trends-with-livestock-population-dynamics-in-kajiado-county,-kenya.pdf?view=download

Anderson, S. (2005). *Spread of the Introduced Tree Species Prosopis juliflora (Sw.) DC in The Lake Baringo Area, Kenya* (Doctoral Dissertation, SLU) 1(4) BORESHA SHEKO, 2019, Vol. 1 Issue: 11, 1st August 2020

C.R.C.Weed Management (2003*).Weed management guide: mesquite* – Prosopis species. Queensland, Australia

Copernicus Sentinel Portalhttps://scihub.copernicus.eu/dhus/#/homeLast Accessed 20th January 2022

Dr. Koech Oscar. Training report on utilization of prosopis juliflora as animal feed and charcoal briquettes in Mandera County, Kenya. May 2019

Felker, P., Clark, P.R., Laag, A.E. *et al. Salinity tolerance of the tree legumes*: Mesquite (*Prosopis glandulosa* var.*torreyana, P. velutina* and*P. articulata*) Algarrobo (*P. chilensis*), Kiawe (*P. pallida*) and Tamarugo (*P. tamarugo*) grown in sand culture on nitrogen-free media. *Plant Soil* **61,** 311–317 (1981

Geesing, D., Al-Khawlani, M. & Abba, M.L. (2004). *Management of introduced Prosopis species: can economic exploitation control an invasive species?* Unasylva - No. 217 - Forest threats. Vol. 55 2004/2. FAO

Gianvenuti, A., Farah, I., Yasmin, N., Jonckheere, I. and Xia, Z. 2018. Using Prosopis as an energy source for refugees and host communities in Djibouti, and controlling its rapid spread. Rome, Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/3/CA0163EN/ca0163en.pdf

Hoshino, B., Karamalla, A., Abd Elbasit, M., Manayeva, K., Yoda, K., Suliman, M., Elgamri, M., Nawata, H. & Yasuda, H. 2012. Evaluating the invasion strategic of mesquite (Prosopis juliflora) in Eastern Sudan using remotely sensed technique. Journal of Arid Land Studies, 4: 1–4.

Huho, Julius & Omar, Mohamed. (2020). *Prosopis Juliflora In Asals Of Kenya: A Friend Or A Foe Plant?*.International Journal of Scientific and Research Publications (IJSRP). 10. p9968. 10.29322/IJSRP.10.03.2020.p9968.

Jama, B. and Zeila, A., 2005. *Agroforestry in drylands of eastern Africa: a call to action. ICRAF Working Paper – No. 1.*Nairobi: World Agroforestry Centre

Kenya Counties Shapefilehttps://data.humdata.org/dataset/47-counties-of-kenyaLast Accessed 20th January 2022

Kyuma et al., 2020 *Estimation of Prosopis juliflora pod production in the drylands of Magadi region, Kajiado, Kenya.* East African Journal of Science, Technology and Innovation

LEE, S. G., E. J. RUSSELL, R. L. BINGHAM AND P.FELKER. (1992) *Discovery of thornless, non-browsed, erect tropical Prosopis in 3-year-old Haitian progeny trials*. Forest Ecology and Management 48:1-13.

NDMA, DROUGHT EARLY WARNING BULLETIN FOR December 2021, http://ndma.go.ke/index.php/resource-center/send/18-mandera/6301-mandera-december-2021

NDMA, DROUGHT EARLY WARNING BULLETIN FOR OCTOBER 2021, https://reliefweb.int/sites/reliefweb.int/files/resources/Mandera%20October%202021.pdf

Rotich, I. T. (2016), *Grazing Natural Pasture and Browse Plants in Baringo County, Kenya*. Master of Science in Animal Nutrition and Feeding Science Thesis, University of Nairobi.

Wainaina Daphne, Liaquat Victor and Koinange Ahamed. Association of climate variability, Prosopis juliflora spread and other vegetation trends with livestock population dynamics in Kajiado County, KenyaAdvanced Journal of Environmental Science and Technology ISSN: 2136-3468 Vol. 5(2), pp. 147-158, February, 2018. Available online at www.advancedscholarsjournals.org © Advanced Scholars Journals http://ijesi.org/papers/Vol(4)3/Version-1/I0431050057.pdf

7. ANNEXES

Data Collection Tools


Prosopis FGD Checklist.doc


Prosopis Key Informants Interview


Household Questionnaire.doc