PROGRESSIVE EFFECTS OF *Prosopis juliflora* (S.W.) (DC) ON GRAZING NATURAL PASTURE AND BROWSE PLANTS IN BARINGO COUNTY, KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for award for a degree in any other University.

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DEDICATION

This work is dedicated to my parents Mr. Kibungei Arap Kosgei and Mrs. Esther Jepterer Kosgei who although did not go through formal education, offered full moral support regarding my education, my beloved wife Sheila Ruth for her constant prayer, love, support and patience and my dear children Brian Kipkosgei and Brenda Jepkemboi for their moral support and prayers during my study period. May the Almighty God bless them.

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LIST OF ACRONYMS / ABBREVIATION

% CP	-	Percent Crude Protein
ADF	-	Acid Detergent Fibre
ADL	-	Acid Detergent Lignin
ADS	-	Acid Detergent Solution
AF	-	Annual forbs
AG	-	Annual grass
ALRMP	-	Arid Land Resource Management Programme
ANOVA	-	Analysis of Variance
ARDP	-	Agriculture and Rural Development plan
ASALs	-	Arid and Semi Arid Lands
ASDS	-	Agricultural Sector Development Strategy
B	-	Titration volume for blank
BLI	-	Block one.
BL2	-	Block two
BL3	-	Block three
BL4	-	Block four
BPSAAP	-	Baringo Pilot Semi-Arid Area Project
C1	-	65-100% *Prosopis* canopy cover category
C1	-	Canopy one = 83%
C2	-	31-64% *Prosopis* canopy cover category
C2	-	Canopy two = 54%
C3	-	0-30% *Prosopis* canopy cover category
C3	-	Canopy three = 21%
CF	-	Crude Fibre
CP	-	Crude Protein
CRD	-	Complete Randomized Design
D_1	-	Distance from one end of a tree canopy to the opposite end of the canopy of the same tree. (First Diameter of the canopy for a given tree or shrub)
D_2	-	Distance from one end of a tree canopy to the opposite end of the canopy of the same tree perpendicular to D_1 measurement (Second diameter for a given tree or shrub)
DC	-	District Commissioner

DLPO	-	District Livestock Production Officer
DM	-	Dry Matter Contents of Pasture Samples
DVO	-	District Veterinary Officer
ETFRN	-	European Tropical Forestry Network
F	-	Conversion Factor for Nitrogen to Protein (6.25)
FAO	-	Food and Agriculture Organization
G.P.S.	-	Geographical Position System.
GCP	-	Government Cooperative Programme
GDP	-	Gross Domestic Product
GoK	-	Government of Kenya
GPS	-	Global Positioning Systems
H_2SO_4	-	Sulphuric Acid
HCL	-	Hydrochloric Acid
ICIPE	-	International Centre for Insect Physiology and Ecology
ILRI	-	International Livestock Research Institute
IUCN	-	International Union for Conservation of Nature
ISO	-	International Standard of Organization
KEFRI	-	Kenya Forestry Research Institute.
KNBS	-	Kenya National Bureau of Statistics
KSH	-	Kenya Shillings
L	-	Loss upon ignition after 72% H_2SO_4 treatment.
MDGs	-	Millenium Development Goals
MoA	-	Ministry of Agriculture
MoL	-	Ministry of Livestock
MoLD	-	Ministry of Livestock Development
MoLFD	-	Ministry of Livestock and Fisheries Development
N	-	Normality of Acid
NDF	-	Neutral Detergent Fibre
NDS	-	Neutral Detergent Solution
NGO	-	Non Governmental Organization
PG	-	Perennial grass
PS	-	Perennial Sedge
Q1	-	Quadrat one = a
Q2	-	Quadrat two = b

Q3	-	Quadrat three = c
RAE	-	Rehabilitation of Arid Environments.
RCBD	-	Randomized Complete Block Design
S	-	Air dried pasture sample weight
S1	-	Site one, Lake Kichirtitt –Riverine wooded grassland
S2	-	Site two, Ng'ambo- Plain wooded grassland
S3	-	Site three, Kampi Samaki – Hillslopes wooded grassland
SD	-	Standard Deviation.
SPSS	-	Statistical Programme for Social Scientists
TVs	-	Titration volume for sample (ml)
T	-	Trees
UNDP	-	United Nation Development Programme
USA	-	United States of America
USAID	-	United State Agency International Development.
UNESCO	-	United Nation Educational Scientific and Cultural Organization
UNEP	-	United Nations Environment programme
W	-	Stands for mean mass of individual plant species in g/m^2.
Y	-	mean of individual plant species sampled at random from the 3 quadrats.
Z	-	The individual tree and tall shrub species were counted in the 20m x 20m plots and given value.

ABSTRACT

Prosopis juliflora, a fast spreading and coppicing tree, was introduced in Kenya in 1973 to rehabilitate the degraded lands. The trees quickly replaced the natural grazing grasses, sedges, forbs and browse plants important for livestock feeding in Marigat and have been classified by International Union for Conservation of Nature as an invasive species. To understand *Prosopis juliflora* effect on plant species and to eventually develop mechanisms of minimizing its spread, necessitated an ecological study on the effects its progressive spread has on the biomass production, density and nutrient composition of grasses, sedges, forbs, shrubs and trees leaves and twigs species. Three sites based on terrain and vegetation cover were chosen for the study, largely described as riverine wooded grassland, plain wooded grasslands and hillslopes wooded grasslands. Areas with 0-30%, 31-64% and 65-100% *Prosopis juliflora* cover were selected in each site using ocular estimation and line-intercept method. Random 20m x 20m study plots replicated 4 times were demarcated and their GPS coordinates recorded. A 1m x 1m quadrat was tossed 3 times randomly within each plot to enable identification, counting, sample clipping and weighing of different grasses, sedges, forbs, dwarf shrub and tree leaves and twigs for determination of biomass, count and nutrient contents. Samples were collected 2 months into the dry season, between 18th December 2008 and 23rd January 2009 when diversity, growth and nutrient content were expected to be optimal. Chemical analyses of collected samples was done to determine crude protein, and Crude fibre content in the different plant species under the 3 canopy covers of *Prosopis juliflora*. The study revealed a decline of count for different plant species as canopy cover increased from 21%, 54% and least at 83%. However, annual grasses under canopy 54% increased. Biomass yield of different plant species and their categories of palatability declined as canopy cover increased from 21%, 54% and least at 83%. The density of key palatable plant species changed with canopy 21%, 54% and least at 83%. However, shading did not affect the levels of Crude Protein, Acid Detergent Fibre and Neutral Detergent Fibre. The canopy cover of *Prosopis juliflora* affected the total biomass production by reducing the palatable and unpalatable species and increasing the biomass production of the medium palatable species significantly ($P<0.05$). The results pointed out that reduction in grazing pasture and browse plants was the biggest problem followed by *Prosopis juliflora* shading effects on the vegetation they come in contact with, therefore reducing grazing land. There is need therefore to identify spread control measures for *Prosopis juliflora,* canopy cover control and grass reseeding while at the same time developing technologies for its utilization

as animal feed and alternative land use systems. Definitions and operational terms were also defined.

Key words: *Prosopis juliflora*, plant habit, biomass, count composition, protein, fibre, palatability.

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND INFORMATION

The tropical dry part of Africa constitutes 38% of total land area and receives an average annual rainfall of less than 600mm per annum (Dicko and Sakena, 1992). Of the 38%, 45% is desert while 55% constitutes Arid and Semi a

rid Land (ASAL) zone, which is capable of supporting plant, animal life and 500 million human populations (Darkol, 1993). The ASAL zones experience recurring drought due to higher evapotranspiration than precipitation rates (Russell, 1988; Riveros, 1992). This has resulted in under-exploitation of the abundant land resource for crop production hence, reliance on livestock production for livelihood (MoLD, 2010) and has eventually led to lack of adequate and high quality pasture which is one of the major constraints to livestock production in the tropics (FAO, 1981).

Kenya has a land mass area of 596,646 Km^2. Over 80% of the country is Arid and Semi arid Land (ASAL) and supports 100% camels, 80% sheep and goats, 70% cattle and 20% human population which is estimated to be 10 million (Benke and Scoones, 1992; Malimo, 2004; Makokha, 2005; MoLD, 2005). Livestock production contributes 90% of employment opportunities in the ASALs and accounts for 95% of the family incomes and food security besides providing local industries with raw materials such as milk, meat, wool, hair, hides and skins (MoLD, 2008). In order to achieve both the National and sustainable goals, the economic pillar of Kenyan, vision, 2030, aims at achieving a 10% economic growth rate per annum and sustain it till the year 2030 (UNDP, 2000). Agriculture sector forms part of the economic pillar. In view of the above, the livestock sub-sector identified 7 flagship projects of which rehabilitation of rangelands, research on livestock breeds, livestock census and measures to control environmental degradation are very important to the ASALs (MoLD, 2008; Kiptarus, 2005).

1.2 STATEMENT OF THE PROBLEM

Among the invasive organisms on earth, plants pose the greatest threat (Mungroo and Tezoo, 2000). Biotic invasions present severe global hazards on man and natural resources. In 2004, *Prosopis juliflora* (S.W.) D.C was in International Union for Conservation of Nature new list

of 100 world's worst invasive alien species (Mwangi and Swallow, 2005) and East Africa was cited as one of the areas severely invaded by this tree. *Prosopis juliflora* has been termed as a strong invader because it survives amazingly through sprouting a fast coppice after cutting and burning, produces an amazing large amount of seeds that are difficult to destroy and have a great capacity to germinate, compete and survive Shiferaw, (2004). There is some uncertainty about the role of alien tree species in shaping communities in Baringo County which has been invaded by *Prosopis juliflora* (Michieka R.W. 2005, 2016). However, it has some benefits. Harnet (2008) reported that it can be used as fodder crop, source of gum, construction poles, furniture making, source of energy and timber. Choge *et al.* (2002) and Mooney *et al.* (2001) reported that *Prosopis* seed pods are sweet, nutritious and have low concentration of tannins and other unpalatable chemicals and have moderate to high digestibility. It is also reported that, leguminous browse plants, such as *Prosopis* species generally contain higher levels of crude protein than other shrub families (Wilson, 1969) and are often good sources of pasture reserves. In natural grazing lands where *Prosopis* seedpods are abundant, livestock consume the seedpods voluntarily during grazing and browsing. In many species the seedpods contain a sweet, dry, yellow pulp and the seeds contained in the pods are high in protein 34-39% (Gutteridge and Shelton, 1998) and therefore it plays a big role as a nutritious feed to animals. Despite these benefits, the inhabitants of Baringo (the Ilchamus) claim that *Prosopis juliflora* has reduced the available grazing land, which initially had a good cover of grasses and browse plants. The reasons for its negative effects on pasture productivity could be attributed to shading of large canopies (Nakano *et al.*, 2003).

Although *Prosopis juliflora* was introduced in Baringo County to reduce negative impact of environmental degradation, its invasion has been associated with decline of pastureland (Pasiecznic, 1999). It may also be annihilating palatable pasture and browse species that were once abundant. Its spread has caused a 68% decline in pasture productivity in one of the sites in Marigat area (Mwangi and Swallow, 2008). This has threatened the livelihoods of pastoralists, who solely depend on livestock for their survival, and could lead to poverty increase for a large section of the population that depend on the natural resource base. In the local term, *Prosopis juliflora* has been nick named "dryland demon," because of its serious negative effects. Loss of grazing land *Prosopis juliflora* invasion has also led to loss of cultivatable land and it is a human and livestock health hazard (Bionet-Eafrinet, 2011). Diseases like malaria, dental condition in goats, which the Ilchamus call "Mudomo bend" meaning bent jaws as a result of chewing very hard *Prosopis juliflora* seeds have been linked

to the tree (Mwangi and Swallow, 2005). Owing to its rate of dispersal and the prevailing environmental conditions, ASALs of this country (437,317Km^2) are at risk of invasion, therefore there is an urgent need to contain its spread and reclaim the invaded land.

1.3 JUSTIFICATION

Since the introduction of *Prosopis juliflora* in Baringo County, its woody cover has increased, reducing pasture and browse species such as Acacia tortilis (Maundu et al., 2009) and could reduce the carrying capacity for both domestic and wild animals. Kahi et al., (2009) reported that, *Prosopis juliflora* had reduced the underneath growth of herbaceous plant species in Marigat lowland by 27% compared to the open land. It has been reported that, most people in Marigat want *Prosopis juliflora* eradicated because of its negative effects on livestock health and productivity and also its invasion of crop land (Mwangi and Stefan, 2004), (Michieka R.W., 2004). Once *Prosopis juliflora* invades a place, it may not be possible to completely eradicate it (Pasiecznik, 1999). Therefore, there is need to slow down its invasion of new areas and control it in the affected areas. To do so, knowledge is required on how it spreads and the effect of its spread on the population of different grass and browse plant species. Little research has been done on the effects of *Prosopis juliflora's* spread on existing grasses and browse in Marigat. There is also need to identify grass and browse species that can coexist successfully with *Prosopis juliflora* so as to be used for reseeding. Plate 1.1 below is a photo showing natural grazing pasture and brose plants in Marigat before introduction of *Prosopis juliflora* in 1982.

Plate 1.1: Natural grazing pasture and browse plants in Marigat before introduction of *Prosopis juliflora* in 1982

Source: Author's survey (2009)

1.4 OBJECTIVES OF THE STUDY

1.4 .1 Main objective

The overall objective is to determine the effects of the progression of *Prosopis juliflora* invasion on yield (biomass), distribution (count) and nutrient composition of preferred grasses, sedges, forbs, shrubs and tree browse plants in Arid and Semi-Arid Lands and recommend plant species that make good pasture for livestock and that co-exist with *Prosopis juliflora.*

1.4.2 Specific objectives

i) To evaluate the effect of *Prosopis juliflora* density on the yields (biomass production) of grasses, sedges, forbs, shrubs, tree leaves and twigs in Marigat.
ii) To evaluate the influence of *Prosopis juliflora* density on counts frequency/abundance of grasses, sedges, forbs, shrubs, tree leaves and twigs in Marigat.
iii) To determine the influence of *Prosopis juliflora* density on nitrogen and fibre composition of grasses, sedges, forbs, shrubs, tree leaves and twigs in Marigat.

1.4.3 Research questions

i) Does *Prosopis Juliflora* density affect the yields of grasses, sedges, forbs, shrubs, tree leaves and twigs in Marigat?
ii) Is there an influence of *Prosopis Juliflora* density on distribution of grasses, sedges, forbs, shrubs, tree leaves and twigs in Marigat?
iii) Does *Prosopis Juliflora* density influence the nitrogen and fibre content composition of grasses, sedges, forbs, shrubs, tree leaves and twigs in Marigat?

1.4.4 Hypotheses

i) *Prosopis juliflora* density does not affect the yields of grasses, sedges, forbs, shrubs, tree leaves and twigs in Marigat.
ii) *Prosopis juliflora* density does not affect the distribution of grasses, sedges, forbs, shrubs, trees in Marigat.
iii) *Prosopis Juliflora* density does not affect nitrogen and fibre contents composition of grasses, sedges, forbs, shrubs, tree leaves and twigs in Marigat.

CHAPTER TWO: LITERATURE REVIEW

2.1 OVERVIEW OF LIVESTOCK SUB SECTOR IN KENYA.

Kenya has an estimated livestock population comprising 17.5 million (zebu, exotic and grade) cattle, 27.7 million goats, 17.1 million sheep, 3.0 million camels, 1.8 million donkeys, 32 million poultry, 335 thousand pigs, 470 thousand rabbits and 1.8 million beehives all valued at Kshs 308 billion and products valued at Kshs 302.9 billion per year (MoLD 2009, 2008). The livestock sub-sector contributes about 12% of the Gross Domestic Product (GDP), over 30% of farm gate value of agricultural commodities and employe 50% of agricultural labour force (MoLD, 2008; 2002; FAO, 2005).

Livestock production is a major economic and social activity for the communities that live in the high rainfall areas for dairy production and in the Arid and Semi-Arid Lands (ASALs) for beef production (Kiptarus, 2005) and it is estimated that by 2020, half of the population in the developing countries will live in cities where consumption of meat is high (Mugunieri and Omiti, 2008) thus, these ASAL`s areas are good potential for providing meat. About 60% of Kenyan livestock is found in the ASAL areas and contributes 90% of employment opportunities and nearly 95% of the family incomes and food security (MoLD, 2008).

Currently, the government has 4 National Livestock Policies namely; National Livestock Policy (2008), National Dairy Development Policy (2008), National Poultry Policy (2008) and National Bee keeping Policy (2008). All have been put together in the National Livestock Policy of 2008. The industry has potential and can play a strategic role in line with the on-going socio-economic reforms as stipulated in key policy documents such as Ministry of Agriculture and Marketing Report (1985-1994, the Agricultural and Rural Development Plan (2002), the 9th National Development plan 2002-2008, Agricultural Sector Development Strategy, Kenya Vision 2030 and the Millennium Development Goals (MoLD, 2010; UNDP, 2000).

2.2 LIVESTOCK POPULATION IN BARINGO COUNTY

Baringo County is one of the counties of the Kenyan ASALs. The ASALs are renowned for pastoral cattle, sheep and goat rearing which form the main livelihood in the County. Livestock counts by the year 2008 were 376,286 cattle being the second position after Moyale, 1,018,397 goats being the second position after Turkana County, 278,248 sheep, 18,443 donkeys, 5,561 camels and 594,645 poultry (Table 2.1). There are few records on

ostriches, pigs, rabbits, fish, ducks and geese because of their insignificance in the ASAL (Muriithi *et al.*, 2007; MoLD, 2008). Mitaru and Okeyo, (2004) reported that, inability to feed animals adequately throughout the year is the most widespread technical constraint in the semi arid areas.

Table 2.1: Livestock numbers by species and breed in Baringo

Livestock type	Breed	Numbers
Cattle	Sahiwal	385
	Zebu	371,440
	Ayshire	1,062
	Fresian	2,647
	Zebu X Sahiwal	752
	Total	**376,286**
Goats	Galla	1,050
	Small EA	1,016,699
	Total	**1,018,397**
Sheep	Black-Head Persian	40,360
	Red Masai	219,848
	Dorper	1,610
	Dorper Cross	2,300
	Dorper and RMS x BHP"	6,440
	Cross	7,560
	RMS and BHP Cross	130
	Total	**278,248**
Camel	Turkana	5,561
Donkey	-	**18,443**
Poultry	Indigenous	594,300
	Geese	118
	Ducks	227
	Total	**594,645**
Other animals	Dogs	55,973
	Cats	39,917

Source: Muriithi *et al.*, (2007). Livestock Survey in the arid land districts of Kenya for Arid Lands Resource Management Project.

2.3 ORIGIN, DISTRIBUTION AND SPREAD OF *Prosopis juliflora* INVASION IN VARIOUS PARTS OF THE WORLD

Origin

Prosopis juliflora is native to the continent of South America, Central America and the Caribbean. The native range of the *Prosopis juliflora-pallida* complex covers a broad geographical region from latitudes 22-25 degrees north to 18-20 degrees south. Countries in

this range include; Mexico (Smith, 1967), Guatemala, El Salvador, Honduras, Nicaragua, CostaRica, Panama, Colombia, Venezuela, Ecuador, Peru (D`Antoni and Solbrig, 1977), the Caribbean and Galapagos Island. The genus *Prosopis* contains 44 species, of which most of them are found in the southern and central regions of the American continent (Mwangi and Swallow, 2005).

Distribution and spread of *Prosopis juliflora* invasion in various parts of the world

In Africa, *Prosopis* was introduced in 25 countries, Kenya being among them. Countries in North Africa include: Morocco, Algeria, Tunisia, Libya and Egypt. In West Africa they include: Cape Verde, Senegal, Gambia, Mauritania, Mali, Burkina Faso, Niger, Ghana and Guinea-Bissau, Nigeria and Chad in the Sahel region. In the East and horn of Africa we have Tanzania, Kenya, Sudan, Eritrea and Ethiopia while in Southern Africa we have Zimbabwe, Namibia, Reunion, and South Africa (Mwangi and Swallow, 2005; Pasiecznik, 1999). Earliest documentations show that *Prosopis* was first introduced in Senegal (1822), South Africa (1880) and in Egypt (1900) (Zimmerman, 1991; Pasiecznik *et al.*, 2001).

Three species are distributed from tropical Africa through to south-western Asia (Streets, 1962; Pederson, 1980). There are about 40 species of *Prosopis* reported in Kenya, Ethiopia, Sudan and other countries in Africa. The most common species are *Prosopis juliflora*, *Prosopis chilensis* and *Prosopis pallida* with *Prosopis juliflora* being the most invasive (Catterson Thomas, 2003, USAID, 1993). In 2004, *Prosopis juliflora* was in IUCN's new list of 100 world's worst invasive alien species.

Introduction and spread of *Prosopis juliflora* in Kenya

By 1970's and 1980's there was a need for deforestation inorder to avail firewood. This brought the planting of *Prosopis juliflora* and other trees across the world and hence it was brought in Kenya in 1973 at Bamburi cement factory (Choge *et al.*, 2003). The seeds were sourced from Brazil and Hawaii and were planted to rehabilitate quarries near the coastal city of Mombasa (Mwangi and Swallow, 2005; Johansson, 1985). It was later introduced in the semi-arid counties of Baringo, Tana River and Turkana in 1982 (Anderson, 2005) as a forestry tree for the purpose of ensuring self-sufficiency in wood, to make land habitable and take care of natural plants and reduce man misuse of land (Kariuki, 1993).

Currently, it has become an invasive vegetation occupying over 6000Km^2 and the most affected administrative Counties in Kenya are; Baringo, Garissa, Turkana, Tana River, Taita Taveta and Wajir (Choge and Chikamai, 2004). Specific areas that are alleged to have been invaded are; Lodwar, along the shores of Lake Turkana, Kalokol, Kainuk, Kakong, Kaputir, Kalemngorok, Keekunyuk, Lorogon, Katilu in Turkana county, Marsabit, Moyale, Mandera, Isiolo, Samburu, West Pokot, Kerio Delta, along the shores of Lake Victoria, Kajiado, Kilifi, Malindi, Suba, Homabay and Karachuonyo in Homabay county (Choge *et al.*, 2002; Mwangi and Swallow, 2005; Michieka 2014). Large-scale *Prosopis* invasions are mainly concentrated around Tana River and Pokot areas (Mwangi and Swallow, 2005). The spread of *Prosopis juliflora* to important wetlands such as riparian, riverine or deltaic, most of them being habitats rich in unique flora and fauna, is likely to negatively affect bio-diversity within such conservation areas. Such habitats in Kenya include for example the River Tana Delta, Lorian Swamp among others (Choge and Chikamai, 2004). It is commonly known as "Mathenge" in Kenya having been introduced by a Provincial Commissioner by the name "Mathenge" (Kariuki, 1993). During discussion on *Prosopis juliflora* invasions, it was found that there were counties invaded those under threat and those without threat.

The initial spread of *Prosopis juliflora* in Marigat District

The main purposes of introducing *Prosopis juliflora* in Marigat were: to establish suitable tree species for arid and semi-arid conditions, land for proper use of the land, to support and strengthen forestry extension activities and to suggest the necessary improvements (Mwangi and Swallow, 2005). The locations invaded by *Prosopis* in Marigat District are: Marigat, Ng'ambo, Salabani, Kiserian, Eldume, Ilng'arua, Loboi, Sandai and Kapkuikui. According to pastolists, civil servant and welfare based in Baringo, the spread of *Prosopis juliflora* is severe in Marigat locations. Ng'ambo is the initial planting site and represents the highest density of *Prosopis juliflora*. It has formed as formed impenetrable forest and this forest of *Prosopis juliflora* covers must part of grazing land around Lake Bogoria and National Reserve and have strands of *Prosopis juliflora*.

In Marigat, it spreads mainly around Marigat town and towards the East of cultivated areas (Stefan Anderson, 2005). No forest of *Prosopis juliflora* trees have been formed in the area. Streams and lakes are known to be one of the factors which have contributed to the spread of the seeds of *Prosopis juliflora* to various parts which later germinate resulting to its spread (Sankhala *et al.*, 1965). *Prosopis juliflora* is a prolific seeder and grows vigorously near

water sources and it has become a formidable invader of other land use in this area (Kahi, 2004). From Chemeron dam, its spread is wide. According to the locals, goats taken to drink from the dams disperse the seeds with their faeces all the way to Kimorok (Stefan Anderson, 2005). In the shoreline of Lake Baringo the *Prosopis juliflora* trees have formed thick forest that prevents swimmers. To the south of the lake, *Prosopis juliflora* has invaded the eustuary of Perkerra River. Goats eat the mature pods that are dropped and it germinates (Geesing *et al.,* 2004).

Plate 2.1: Grassland of *Cynodon dactylon* before the invasion of *Prosopis juliflora* in Marigat Division, Baringo South

Source: Author's survey (2009)

2.4. BOTANY, BIOLOGY AND ECOLOGY OF *Prosopis juliflora*

Botany of *Prosopis juliflora*

Prosopis Linnaeus emend, is in the family of leguminosae (Fabaceae), and belongs to the sub-family Mimosaceae (Mimosoidae). The family Mimosaceae has 4 genera and 44 species and a number of varieties have been described (Burkart, 1976; Elias, 1981; Lewis and Elias, 1981). Of the many *Prosopis* species, all of which are native to a region from Mexico to Peru, only a few are of major ecological and economic significant in the dryland, particularly *Prosopis juliflora* and *Prosopis pallida* and their respective varieties and forms (Pasiecznik *et al.,* 2001; Choge and Chikamai, 2004). *Prosopis juliflora* is a fast growing, nitrogen fixing and evergreen tree with a deep root system (Mwangi and Swallow, 2005).

Plate 2.2 is showing *Prosopis juliflora* as a shrub and plate 2.3 is a mature *Prosopis juliflora* trees showing the characteristics of being an evergreen tree in the canopy cover of 0-30% in site 2.

Plate 2.2. Photos showing *Prosopis juliflora* as a shrub

Source: Author's survey (2009)

Plate 2.3: Mature *Prosopis juliflora* trees showing the characteristics of being an evergreen tree in the canopy cover of 0-30% in site 2

Source: Author's survey (2009)

It is a thorny plant with small flowers which are light greenish yellow with hooded teeth. The pods become yellow when ripe and are high in sugars, carbohydrates and protein. The stem is green-brown, sinuous and twisted with axial thorns situated on both sides of the nodes and branches. The bark is rough, dull red and grayish brown in colour. The leaves are dark green with one or sometimes two pairs of rachis. The tree may attain a height of up to 20m under favourable conditions while in very dry environments, it is reduced to a shrub. Its low branching and bushy nature, together with its excellent coppicing power makes it a very suitable soil binder and windbreaker (Choge and Chikamai, 2004). Plate 2.4 is showing the *Prosopis juliflora's* branch with immature pods while plate 2.5 is showing the position of seeds and plate 2.6 is showing the ripening of yellow pods of *Prosopis Juliflora* tree.

Plate 2.4: Photo showing the *Prosopis juliflora's* branch with immature pods

Source: Author's survey (2009)

Plate 2.5: Photo showing the Position of seeds.

Source: Author's survey (2009)

Plate 2.6: Photo showing the ripening of yellow pods of *Prosopis Juliflora* tree

Source: Author's survey (2009)

Biology and ecology of Prosopis Species

Prosopis species thrives in dry climate and is a prolific seed bearer. It starts fruiting at the age of 3-4 years and studies have shown that a 10 year old tree can yield up to 90Kg of pods with 10-30 seeds per pod on an annual basis. These pods have a tough pericarp and a cartilaginous endocarp, which does not allow the seeds to escape easily. When eaten by livestock, the seeds are passed as undigested in the animal gut and are able to germinate readily under favourable conditions (Choge and Chikamai, 2004). Plate 2.7 is showing *Prosopis juliflora* pods and Plate 2.8 is showing *Prosopis juliflora's* sharp thorns.

Plate 2.7: *Prosopis juliflora* 13pods

Source: Author's survey (2009)

Plate 2.8: Photo showing *Prosopis juliflora's* sharp thorns

Source: Author's survey (2009)

Prosopis juliflora is propagated by means of seeds, which are dispersed by animals feeding on the pods (Felker, 2003). Seeds of *Prosopis* are highly prolific, with each mature plant producing 630,000-980,000 seeds per year (Zimmerman, 1991; Harding, 1988; Felker, 1979). The plant poses a serious problem in arid areas, as it has affected pasture and browse availability because of its deep and extensive sub-surface, large crown and an open canopy that shades underneath. *Prosopis juliflora* discourages grass growth displacing native plant communities and reducing the grazing potential of invaded patches (Harding and Bate, 1991). Studies in South Africa have shown that with good rainfall, the invasion rate in *Prosopis* species increases three fold. Cullis *et al.,* (2007) estimated that as much as 16.1% of the country's water yield can be lost if invasive plants in the mountain catchments and riparian areas are left unchecked. At least 6 *Prosopis* species have been introduced in South Africa which includes *Prosopis chilensis*, *Prosopis glandulosa* (*Van torulosa*) and *Prosopis velutina* (Poynton, 1988).

Characteristics of *Prosopis juliflora* compared to other woody plants.

Prosopis juliflora is an armed tree with sharp and strong thorns. This adaptation protects the plant from external invaders such as grazing livestock and wildlife. Its coppicing potential, low branching and its bushy nature are all factors and adaptations that have made it survive in the dry and harsh environments and it synthesis its food throughout the year (Choge and Chikamai, 2004). It also has a deep root system (Mwangi and Swallow, 2005; Kahi, 2004). Studies of xylem water potential show that *Prosopis* species are highly stress resistant and adaptable and can survive in areas without ground water as long as the rooting depth is sufficient (Sharifi *et al.*, 1982).

The maximum leaf conductances recorded for *Prosopis* (6.5 – 6.9mm/sec) are comparable with those of other species with similar deep rooting (e.g *Acacia greggis*) but much higher than those for evergreen, shallower rooted shrubs (e.g. *Harrea tridentate*) and deciduous species in the same environment (Nilsen *et al.,* 1984). Its maximum rate of leaf conductance is slightly higher than those from eucalyptus (5.3mm/sec) and conifers (5.7mm/sec) but lower than those for grasslands (8.0mm/sec) and agricultural crops (11.0mm to 12.2mm/sec) (Kelliher *et al.,* 1995). The leaf level measurements can be scaled upto the whole plant (Jarvis, 1985). However, the error goes up with increasing transpiration rate (Ansley *et al.,* 1994; Gutschick, 1996). *Prosopis juliflora* is also an allelopathic weed a character that enables it to kill the other plants growing near it.

2.5 EFFECTS OF *Prosopis juliflora* ON UNDERSTOREY PLANT SPECIES

Effects of *Prosopis juliflora* on pasture quality and quantity

Prosopis juliflora has been reported to have reduced grass cover in Baringo county and this was attributed to their excessive absorption of moisture from pasture land and shading of vegetation underneath, thus denying them light for photosynthesis (Kahi, 2004). In addition, *Prosopis* leaves that fall down have allelopathic effects on the vegetation they come in contact with (Mwangi and Swallow, 2005). On the other hand, *Prosopis* has been observed to exhibit some beneficial effects on pasture growth. It was observed that *Prosopis* fix atmospheric nitrogen in the soil and contributes to organic carbon and phosphorous build up and fodder crops such as *Atriplex cordobensis* and *Justicia species* have been reported to co-exist well in association with *Prosopis* (Bhatia *et al.,* 1998).

Since the introduction of *Prosopis juliflora* in the dry grazing land of Marigat, it has caused reduced carrying capacity for both domestic and wild animals. Once *Prosopis juliflora* invades a place, it is there to stay and the only way to overcome its disadvantages is to learn how to live with it (Pasiecznik,1999). The plant also forms extensive thickets that choke native plant species of Socialeconomic importance and has led to displacement of people from their homes.In Kampi Samaki, *prosopis juliflora* trees are dense and they are even deep into the water of lake Baringo, submerged due to increase in water levels. They hinder people from getting in and out with their boats. The canopy shade of *Prosopis juliflora* suppresses the growth of forbs and perennial grasses and all these observations show the extent to which invasion has led to reduction of grazing pasture and browse plants in Baringo County (Kahi, 2004: Wasonga, 2001).

Effects of *Prosopis juliflora* on Biomass production of plant species

Smoliak, (1956) noted that potential understorey biomass yields might be reduced by the effects of associated shrubs and trees. Pase, (1958) reported that different understorey species reacted differently to fluctuations in canopy density, with graminoids showing the greatest changes in terms of weight per unit area to reduction in canopy diameter and found that some herbaceous plant species virtually disappeared at maximum canopy density. Cooper, (1959) predicted that no herbaceous vegetation would be found at canopy densities above 75%. Heady, (1960) reported that heavy bush thickets reduce herbaceous pasture production and that most pasture produced in dense thickets is invariably inaccessible to livestock. Cable and Tschirley, (1961) reported that clearing of forests increases herbaceous biomass yield. He

attributed this phenomenon to higher competition for light, water and nutrients and possible negative chemical effects including allelopathy, the inverse relationship between the effects of tree canopies and herbaceous plant species productivity is possible. Arnold, (1964) found that there was less total herbaceous biomass productivity within the canopy zone than outside the canopy.

Sankhla *et al.,* (1965) observed that *Acacia tortilis* and *Prosopis juliflora* are allelopathic in nature and this may also explain the relatively low biomass production of herbaceous plant species obtained under tree canopies. Sen and Sachwan, (1970) stated that *Prosopis juliflora* trees inhibit growth of understorey plant species due to phytotoxic effects of their leaves. Martin, (1975) and Cable, (1976) noted that grass and forbs biomass increase with decrease in the density of the canopy cover but if herbaceous plant biomass was maintained at a low level for a sufficiently long time, for instance, through several years of sustained intensive grazing, then the soil surfaces would change in terms of degree of compaction and encrustment leading to reduced infiltration rate. Hence herbaceous biomass is a critical factor in determining the rate and amount of water that percolates into the soil (Walker, *et al.,* 1981; Walker, 1982).

There is, therefore, need for high herbaceous cover to enhance higher infiltration of water into deeper soil layers. *Prosopis juliflora* tree forest (same as 83% canopy cover of *Prosopis juliflora*) with pasture produced 1.2 ton/ha of herbaceous biomass compared to 0.8 tons/ha from pastures with 17% *Prosopis juliflora, (*same as 21% *Prosopis juliflora* canopy cover) an indicator of its usefulness in retaining water soil content (Galt *et al.,* 1982). Lower bulk densities can be as a result of trampling by large animals seeking shade or pasture, under tree canopies than in the open areas (Warren *et al.,* 1986; Belsky *et al.,* 1989; Weltzin and Coughenour, 1990; Frost and Edinger, 1991). Harrington and John, (1990) observed that herbaceous biomass was negatively co-related with canopy density of eucalyptus species and attributed this phenomenon to the combined effects of shading and chemicals contained in leaves of eucalyptus trees on the understorey herbaceous plant species. Pieper, (1990) reported that canopy of the woody plant is viewed as a critical factor in the evolution of herbaceous layer characteristic. Ratiff *et al.,* (1991) stated that explanations for the complex and often beneficial interaction between woody and herbaceous plants are largely fallacious and overly simplistic. Belsky *et al.,* (1993) reported lower biomass production from herbaceous plant species under tree canopies than in the open areas. Kinyamario *et al.,* (1995)

observed that understorey plant species composition was generally different from that of the area immediately outside the canopy.

Bhatia *et al.,* (1998) observed a significant reduction in the soil reaction (pH) under the canopies of *Prosopis juliflora*. Boutton *et al.,* (1998) observed that plant development is normally limited by low soil moisture. Wasonga, (2001) observed less herbaceous vegetation production under the canopy of *Balanites glaber* than in the zone outside the canopy. Kahi, (2004) observed that *Acacia tortilis* and *Prosopis juliflora* are alellopathic in nature and this may also partly explain the relatively low biomass production of herbaceous plant species obtained under the tree canopies.

Overstorey and understorey plant species in relationship to palatability and counts.

Effects of tree canopies on productivity of herbaceous plant species

Annual and perennial grasses/sedges/forbs

Medina, (1982) reported that, two main plant life form exist globally: grasses and woody plants. These two have different requirements and frequently occupy distinct niches. Menault *et al.,* (1985) reported that, in Africa savannas are characterized by the presence of a continuous graminoid stratum and a discontinuous woody stratum that forms the upper canopy of the vegetation. Young, (1987) reported that, trees and shrubs in the dry regions have the potential to increase grass production (silvopastoralism), increase crop production (agro forestry) and hold or reverse desertification. Cox and Waithaka, (1989) reported that energy flux from the sun is more important in terms of plant development where growth period is experienced per year. Frost, (1990) noted that the shading effect of the evergreen woody species, such as *Prosopis juliflora* might limit herbage production.

Ellison and Houston, (1958) noted an inverse relationship between the tree canopy and herbaceous understorey production. Brock *et al.,* (1978) noted that cool-season grass species which are normally found in the canopy zones decreased because of mesquite removal. Pratt and Gwynne, (1977) observed that areas with different production potentials also respond differently to the canopy covers in terms of productivity. This is important because rangelands are inherently heterogeneous comprising a mosaic of different range sites. Lee, (1978) pointed out that a dense forest canopy drastically modifies the climate of the underneath; especially net radiation, wind speed and amount of precipitation. He found out

that on average, rainfall deficits under mature hardwood canopies may vary from less than 10% during the leafless period, to more than 20% during the growing season, while the relative humidity under the canopy exceeds that of the area immediately outside the canopy.

Wenner, (1981) reported that areas under the canopies of *Prosopis juliflora* trees had a dense stand of perennial grass cover (24% more than areas outside the canopies). Jacoby *et al.,* (1982) reported that there is higher herbage production away from *Prosopis glandulosa Torr* trunk than near it in Texas rangelands. He attributed the findings to the competition between the trees and associated grasses for moisture. Weltzin and Coughenour, (1990) observed that shading by tree canopy might be the most important factor affecting understorey habit production and composition in African Savanna. Jeltsch *et al.,* (1996) reported that different herbaceous plant species will respond differently to different types of tree canopies. Gachanja, (1996) reported that different tree or shrub densities with their associated canopy cover have variable effects on herbaceous plant cover and production, with the amount of available pasture being reduced by competition as density increases.

McGines and Anorld, (1939); Parker and Martins, (1952); Fisher *et al.,* (1973) noted that when *Prosopis juliflora* becomes established, its lateral roots grow in all directions and take up soil moisture that could be used by herbaceous vegetation. Moore, (1960) observed that co-existing herbaceous and shrub species compete for soil moisture supplies and at the same time shared the favourable effects arising from the joint microclimate. Pressland, (1973) recorded a six-fold increase in the amount of water trapped in the sub-soil below a tree canopy, compared to that trapped in the area outside the canopy. Whysong and Bailey, (1975) reported that the amount of rainfall in rangelands is insufficient to maintain grasses if they have to compete with woody vegetation, which is better adapted to withstand an arid climate. Jacoby, (1986) reported that the woody vegetation has an extensive root system, often accompanied by a deep tap root, high sprouting ability, and reduced palatability. These characteristics provide competitive advantage to trees over grasses and forbs for drought survival. Kinyamario and Macharia, (1992) observed that production in the tropics can take place throughout the year and is normally limited by precipitation. Angus, (1958) reported that trees by virtue of their height attract more dew than grasses which grow below them.

Benhard-Reversat, (1982) concluded that trees are an important ecological component that maintains soil fertility as a result of nitrogen fixation and accumulation of organic matter

through litter fall. Grouzis and Akpo, (1997) reported that improved soil fertility beneath the tree could be due to accumulation of top fertile soil that has been eroded from the open areas. Jones, (1971) indicated that in grass-dominated savanna soils, residues from the natural vegetation is usually poor in nitrogen and seems likely to initiate a period of soil nitrogen immobilization when returned to the soil as the grass residues are low in nitrogen: carbon ratios which may also explain the low total nitrogen obtained in the open areas. Felker, (1978) reported 50-100% higher organic carbon under the tree canopies. Kelly and Walker, (1976) demonstrated that the rate and amount of infiltration in a loamy savanna soil is about ten times greater under a grass cover than on a bare soil surface.

Effects of shrub canopies on productivity of understorey plant species

An international symposium on the biology and utilization of wildland shrubs (McKell *et al.*, 1972) was a good attempt to correct this bias, but there was need for follow-up effort. Burrows, (1993) argued that there is beneficial contribution of woody species to the fragile savanna ecosystems especially where trees are spatially distributed within the grasslands (trees are cleared from rangeland by expensive mechanical and chemical techniques without considering the effect of such practice on the fragile arid and semi-arid ecosystem). However, trees and shrubs in the dry regions have the potential to increase grass production (silvopastoralism), increase crop production (agro forestry), and hold or reverse desertification Steppler and Nair, (1987).

Tiedmann and Klemmedson, (1973) reported that perennial plants, particularly shrubs, tend to accumulate soil nutrients beneath their canopies. Pressland, (1976); Maranga, (1986) reported that raindrops are intercepted by tree canopies, reducing their impact, and therefore, influencing infiltration rate, amount of runoff and total soil moisture storage. Kinyua, (1996) reported that there is concentration of carbon and nitrogen in the soils within the canopy than in soils in the adjacent open areas and also there is the justifications for these practices (of intercropping leguminous trees with pasture) that bush clearing enhances livestock production through increased pasture production.

Effects of tree canopies on productivity of understorey plant species

Le Houerou, (1978) found a high dependency of rangeland grazing animals on trees and shrubs to satisfy their protein requirements, especially during the dry seasons and he also pointed out that nearly one third of the world's land surface is natural grazing land and to varying degrees the shrub-tree component is a crucial source of animal feed. Barth and

Klemmedson, (1982) reported that trees and shrubs play an important role in terrestrial ecosystem, hence the need to understand their ecological role, especially in arid and semi-arid areas where they are important component of the vegetation.

Carlton, *et al.*, (1983) reported that to increase livestock production on rangelands with high shrub and tree densities, it is necessary to manipulate the present woody vegetation density by mechanical, chemical and biological means. Tiedmann and Klemmedson, (1977) observed that elimination of mesquite shade and roots resulted in increased foliar cover of understory vegetation in the canopy one from 19% with intact mesquite trees to 24% in the open areas. In contrast, production in the tropics can take place throughout the year. Burrows, (1990) reported that some studies have shown pasture production is often reduced by trees that compete with understory plant species for water, nutrients, and light. Weltzin and Coughenour, (1990) observed that shading by tree canopy might be the most important factor affecting understory habit production and composition in African Savanna. Dunham *et al.*, (1991) reported that soils were less acidic within than outside the canopies. Garg and Jain (1996) reported that the lower soil bulk density observed under the tree canopies than in the adjacent open areas could be attributed to tree canopies that protect the soil from the force of raindrops. The high bulk density in the adjacent open areas could be attributed to increased soil compaction as a result of animal activities or raindrop effect. Plate 2.9 is showing a caption of canopy 0-30% canopy cover.

Plate 2.9: Photo showing a caption of canopy 0-30% canopy cover of *Acacia totilis*

Source: Author's survey (2009)

Nye, (1961) reported that under moist tropical forests, the net annual contribution of dead roots was approximately 2,600kg ha^{-1}. Apart from the direct contribution of the woody species to the soil nutrients around the canopy, spatial transfer of nutrients is considerable even under normal grazing practices. Paulsen, (1975) observed an increase in average soil moisture content in areas where *Prosopis* trees had been removed compared to areas where the trees were still intact. Kinyamario *et al.,* (1995) observed that the canopy cover in the other two areas (i.e. in the forest and in the tree scattered area) assists in moisture conservation in the soil and reduced transpiration promoting higher plant growth.

Maranga, (1986) reported that raindrops are intercepted by tree canopies, reducing their impact, and therefore, influencing infiltration rate, amount of runoff and total soil moisture storage. Dregne, (1992) observed that trees utilize deep water tables, improve soil physical conditions, reduce raindrop splash effect and ground level wind speed, and hence, the overall ecosystem productivity. Brimson, *et al.,* (1980) reported that the other known avenues through which nutrients are added to the sub-canopy zone of trees includes: litter-fall, dead leaves, fruits and branches. Aggarwal, (1980) reported that soils under *Prosopis cineraria* have more organic matter, nitrogen and micronutrients than soils in the open areas. Benhard-Reversat, (1982) concluded that trees are an important ecological component that maintains soil fertility as a result of nitrogen fixation and accumulation of organic matter through litter fall. Plate 2.10 is a Photo showing a caption of canopy cover category of 65-100%.

Plate 2.10: Photo showing a caption of canopy 65-100% canopy cover of *Prosopis juliflora*

Source: Author's survey (2009)

2.6 FACTORS SHAPING PERCEPTIONS OF ALIEN INVASIVE SPECIES

People's feelings of invasive prosopis species will depend on their financial implications that are met by the species. In the Indian province of Rajasthan for example, local peoples' perceptions of *Prosopis juliflora* were favourable during the early stages of its introduction. At that time, it was welcomed as a field boundary marker and helped avert a significant fuel wood shortage.

People's perceptions changed later as the negative effects of the invasion, its sharp thorns, suppression of grasses and crops became more pronounced (Binggeli, 2001; Pasiecznik *et al.*, 2001). Income levels and dominant livelihood strategies/occupations are also important determinants of how individuals perceive invasive species (Pasiecznik *et al.*, 2001). In India the more affluent who can afford bottled gas for cooking, for instance, view *Prosopis juliflora* negatively, while the rural poor who cannot afford bottled gas value it as a fodder and fuel tree (Mwangi and Swallow, 2005; Choge *et al.*, 2002; Silbert, 1996).

Similarly, ranchers and pastoralists whose main livelihood strategy is livestock keeping view it negatively because it invades valuable pastures. In an aggressive program to re-vegetate India's saline lands with *Prosopis juliflora*, small, marginal farmers, landless laborers and women emerged as the prime beneficiaries. It has been suggested that, there are other factors that influence people's perceptions of invasive species. These include: how damaging the species is to property and/or natural ecosystems (e.g. weeds in a crop, insects eating a crop, destruction of native trees); whether or not the species is physically appealing; the opinions of powerful, charismatic and influential individuals; the media's portrayal and the costs of managing the species, (Veitch and Clout, 2001).

However, accounts of invasive species management elsewhere in the world suggest that private property rights may be neither necessary nor sufficient to check the spread of invasive species. Although the United States has a well-developed system of private property rights for land ownership, the spread of invasive species across property boundaries continues to be a major concern (Mwangi and Swallow, 2005).

2.7 ECONOMIC IMPORTANCE OF *Prosopis juliflora*

Benefits of *Prosopis juliflora* in the World

The earliest documentation of the history of its uses by human being have come from archeological evidence, the chronicles of early European soldiers, explorers, missionaries and priests as well as from histories documented from native inhabitants in the Central and South Americas (Pasiecznik *et al.*, 2001). These documentations show that, *Prosopis* was one of the most widespread and well used tree species mainly in the drylands as early as 6500 BC in Mexico (Smith, 1967) and 2500 BC in Peru (D`Antoni and Solbrig, 1977).

The first utilizations were mainly as a source of food, fuel, and basic raw materials for construction. (Felker, Peter and James Moss (editors), 1996), making of household and farm implements. Pods were commonly chewed fresh or roasted, pounded in pestles or stones into flour. The flour was (and still is) utilized in variety of ways such as: baking bread (patay), eaten sun dried (atole), making glue, fresh drinks (anapa or yupisin) or even fermented (aloja) or removal of excess water by evaporation to form sweet syrup (Mel or allgarrobina). These products are still produced today, some on a commercial scale in some countries.

The utilization of *Prosopis* as a source of food for human beings declined as alternative foods such as wheat and barley became more widely available, but it became an important livestock feed for the rising numbers of livestock. The demand for *Prosopis* timber increased in the 16th century (1500 AD) during colonization of South American countries such as Argentina, Bolivia, Paraguay and Uruguay among others. *Prosopis* wood was needed due to the increased number of industries such as mining of gold and silver and railway construction, (D`Antoni and Solbrig, 1977). In South Africa, it is estimated that *Prosopis juliflora* reduces mean annual run off by about 481 million cubic meters across the country (Impson *et al.*, 1999). It also plays an important role in improving soil fertility and reducing soil salinity by increasing soil organic carbon, total nitrogen, available phosporous and exchangeable potassium, calcium and magnesium (Bhojvaid and Timmer, 1998; Bhojvaid *et al.*, 1996; Kahi, 2003).

Improvements have also been shown in soil water movement, moisture holding capacity and hydraulic conductivity due to root penetration in soils planted with *Prosopis juliflora* (Bhojvaid and Timmer, 1998; Singh, 1995; Maliwal, 1991). Being a legume, *Prosopis juliflora* can sustain 2,000 to 6,000 $KgNha^{-1}yr^{-1}$ nitrogen removals as opposed to only 300 $KgNha^{-1}yr^{-1}$ dry matters removed due to the limitation of nitrogen from non-leguminous plants in the ASAL that receives 500mm annual rainfall (Le Houėrou, 1980). Thus, *Prosopis juliflora* can be used as crop rotation to increase nitrogen in the soil in rangelands. *Prosopis juliflora* also improves soil texture and organic matter under the tree canopy (El Fadl, 1997; Kahi, 2003). *Prosopis juliflora* seedlings have the highest survival rate, height gain, girth growth, primary biomass production and a tremendous potential for pod production in ASAL areas compared to other tree species such as *Albizia lebbec*, *Azadirachta indica*, *Dalbergia sissoo*, *Morus indica*, *Populus deltoids*, *Syzigium cuminii* and *Syzigium fructicosum* (Mwangi and Swallow, 2005; Varshney,1996).

Planting *Prosopis* has been found to have high economic yield than mascar bean, corn, and arboreal cotton (Mwangi and Swallow, 2005; De Sousa Rosado, 1988). In India, the bark is used as an antiseptic medicine (Sharma, 1981). In Niger and South America, pods are processed into flour, which is used for human consumption and as a substitute for coffee (Geesing *et al.*, 2004). Examples of other possible uses *of Prosopis juliflora* are; timber, chipped wood products, honey, wax, tannins and gum (Sharma, 1981; Khanna *et al.*, 1997; Pasiecznik *et al.*, 2001; Stefan Anderson, 2005). In Central Mexico, mesquite pods are sold

for cash in rural areas and they are also a local source of nutritious livestock feed (Silbert, 1996). *Prosopis juliflora* is also used to fence farms and homesteads.

Benefits of *Prosopis juliflora* in Baringo County

Unlike in other parts of the world where *Prosopis juliflora* was found to be beneficial, potential benefits seem not to have been captured in Baringo County and the inhabitants in the Lake Baringo and Lake Bogoria areas seem not to realize its net benefit since its introduction in 1982 (Mwangi and Swallow, 2005). In Baringo County, *Prosopis juliflora* is used for making construction poles, furniture, ropes and firewood which burns well even when green. The communities also benefit from honey harvesting which occurs in the periods following the onset of the long and short rains in April and October (Mwangi and Swallow, 2005; Choge *et al.*, 2002). Its flowers are an important source of nectar and pollen for high quality honey.

It plays a leading role in the afforestation of arid lands and its ability to grow on degraded land under arid conditions has made it especially suitable for this purpose. Being a multipurpose tree, *Prosopis juliflora* fits very well into dry land agroforestry systems, controlling soil erosion and stabilizing sand dunes (Pasiecznik *et al.*, 2001; Pasiecznik, 1999). When the pod is eaten whole by livestock the protein in the seed is not utilized because it goes through the alimentary canal without being assimilated in the body**.** KEFRI and Department of Forestry in 2007 studied the best ways to use the obnoxious weed such as in charcoal production and also the weed`s pods are ground by hammer miller and further ground by posho mill and made into blocks which are high in protein and sugars energy mixed and leaves as livestock feed.

They also showed that products from *Prosopis juliflora* could earn farmers in ASALs Kshs.155, 000 per household per year. *Prosopis juliflora* has sharp thorns on the branches thus they are used for fencing and wood cravings. The Company, Cummins Cogeneration (Kenya) Limited in partnership with power Africa and USAID is set to generate 12 megawatts of renewable power using *Prosopis juliflora*. *Prosopis juriflora* (Mathenge weed) has now turned out to be a key raw material in power generation. This has given Baringo residents a reason to cultivate it as a commercial crop. They can now harvest and sell it to a biomass power generation plant. Cummins cogeneration Kenya limited officially launched in 2014 its multi-billion shilling biomass project in Baringo County and is set to buy the raw

materials from *Prosopis juliflora* farmers at a cost of Ksh 1,700 per tone. Residents will also benefit from the electricity, which will increase output from green energy sources and job opportunities that will arise. This will improve the standard of life.

Effects of *Prosopis juliflora* on livestock and human health

Problems associated with *Prosopis juliflora* includes diseases like malaria, dental condition in goats, damaging and removal of animal's hooves, strong poisonous thorns, declining pasture, reduced farmlands, ground cracking and drainage problem. *Prosopis juliflora* discourages grass growth because of its deep extensive rooting system that consumes much moisture as well as its thick canopy that shades underneath.

The continuous process of clearing the *Prosopis juliflora* bushes is an added cost to farming activities. Herders seem to be the hardest hit by the proliferation of *Prosopis juliflora*, in spite of its benefit of being valuable fodder during periods of scarcity (Mwangi and Swallow, 2005). *Prosopis juliflora* has blocked key paths for humans and livestock, and has made people trespass on other peoples' land, which has led to community conflicts. The plant also forms extensive thickets that choke other plants, and has led to displacement of people from their homes. In addition, *Prosopis juliflora* is said to consume underground water, threatening the Beisha oasis in western Sudan (Sudan Update, 1997).

Tabosa *et al.,* (2000) reported that goats that were fed on pods of *Prosopis juliflora* had Mandibular tremors during chewing and most of them died after sometime. Intoxication by pods of *Prosopis juliflora* causes impairment of cranial nerve function in goats and cattle (Tabosa *et al.,* 2006). The weed has also disfigured the jaws of livestock which feed on it due to the hard pods while causing tooth decay resulting from the pods high sugar content. In more severe cases animals have lost their tongues and even died.

Dense stands of *Prosopis juliflora* may sometimes harbor predators, which prey on young goats. Its sharp, strong and poisonous thorns were cited as a major problem. Thorns make it difficult for individuals to penetrate the dense thickets to harvest fuel wood. More commonly, thorns cause serious inflammation that may take a week to subside. In some cases, if left untreated, infections may require amputation of limbs. Pollen from *Prosopis juliflora* is alleged to cause allergy and inflammation of the lungs. *Prosopis juliflora* leaf droppings make water bitter. *Prosopis juliflora* strands interfere with drainage, blocking watercourses

and exacerbating the periodic effects of flooding. Its extensive rooting system results in deep cracks in the ground (Mwangi and Swallow, 2005).

Other effects of *Prosopis juliflora*

Prosopis juliflora weed which spreads fast has blocked rivers such as Molo and Weseges changing their course and causing them to flood villages. Its pods are too sweet for goats to resist but the effects are disastrous. The Government through the Ministry of Livestock came up with a project dubbed.

Constraints of *Prosopis juliflora* in other parts of the World

Prosopis juliflora is alleged to lower the water table leading to the drying up of swamps and ponds in a generally water scarce environment. *Prosopis juliflora* has been reported to have destroyed rangelands in South Africa, Australia and Coastal Asia (Pasiecznik, 1999). It has also invaded Gash Delta of the Atbara River in Northern Sudan (Catterson, 2003; Sudan Update, 1997). In the Awash basin of Ethiopia, it has aggressively invaded pastoral areas in the Middle and Upper Awash Valley and Eastern Harerge. It is one of the 3 top priority invasive species in Ethiopia and has been declared a noxious weed. Since *Prosopis juliflora* has the ability to survive cutting and resprout with fast coppice growth, the species is a very strong invader (Shiferaw, 2004). It reduces grazing land good for grasses and browse plants and it also has allelopathic effects on vegetation and shading of large canopies (Nakano *et al.*, 2003).

2.8 MANAGEMENT OF INVASION OF *Prosopis juliflora*

Management of invasion of *Prosopis juliflora* in other parts of the world

Although for over 50 years ranchers in South-western USA and Argentina have tried a range of techniques to eradicate *Prosopis*, a cost effective programme has not been found. South Africa and Australia are also experimenting with biological control methods using seed-eating beetles. Because eradication efforts have been neither cost-effective nor technically successful, the remaining option is to adapt management by manipulation of land use. Reduction in stocking rates can encourage good grass cover, which may prevent seedling establishment.

Existing dense strands may be thinned and/or pruned; cut stumps treated and timber products harvested from existing strands (Pasiecznik, 1999). To prevent undesired *Prosopis juliflora* propagation in pastures or subsistence farming lands, animals are fed on ground pods, either alone or combined with other fodder, so that the seeds are totally destroyed and plants do not proliferate through seeds embedded in animal droppings (Ribaski, 1988). Suitable ingredients such as urea, cotton seed meal or molasses must be included in the feed.

Management of invasion of *Prosopis juliflora* in Baringo County

In Marigat District, there is a heavy presence of government administration, including line Ministries such as Agriculture, Livestock and Marketing, Environment and Health which has been playing a great role in *Prosopis* management. The Rehabilitation of Arid Environments (RAE) Trust is a non-governmental organization that has also been active in range rehabilitation and reseeding in various parts of the District for more than 20 years (Mwangi and Swallow, 2005). Most individuals uproot or cut *Prosopis juliflora* trees on their crop fields, usually once a year during land preparation (Perrings *et al.,* 2002).

Communicating and incooperating a system of governance to regulate the use of *Prosopis* which includes definition of rules, monitoring of behavior and the enforcement of rules can be devised (Ostrom, 1990). Government policies can also shape responses to invasive species by creating incentives or disincentives that affect how people utilize invasive species and the extent of their utilization (Perrings *et al.,* 2002). Educating the local communities on the advantages and disadvantages of *Prosopis* management can play a major role in encouraging them to invest in its management and eradication on their own private land (Mwangi and Swallow, 2005).

Man's intervention in the restoration of grazing land is important and cannot be left to nature once the invasion of *Prospis juliflora* has been curtailed. Reduction of seed stock in the life cycle of *Prosopis juliflora* is the most efficient strategies to tame its invasion. However, this strategy does not address already invaded land. Pod collection is the most effective strategy in *Prosopis Juliflora* wood management, which takes care of clearing of excessive undergrowth. Although eradicating it completely would be a long and costly process due to the ability of the species to resprout after cutting. Studies have shown that to prevent regrowth, the trees have to be cut below ground level and reseeded immediately (Geesing *et al.,* 2004). *Prosopis* can be very important crop in ASAL areas, if its invasive habit can be

controlled and the thorns that limit its wide spread use are reduced. This can be achieved through production of new erect *Prosopis* clones with small thorns and high production of highly palatable pods for human consumption (Felker, 2002; Singh 1996).

CHAPTER THREE: MATERIALS AND METHODS

3.1 DESCRIPTION OF THE STUDY AREA AND SITES

Location of study area

The study area was Marigat and North Baringo Districts of Baringo County.

Physical features in Baringo County

The study was conducted in Marigat and North Baringo Districts which is located in Baringo County in the Great Rift Valley. It is called Baringo Valley because Lake Baringo, Bogoria and Kichirrtitt are its most prominent feature.

The Tugen Hills (Block Mountains) divide the Great Rift into two parallel North-South valleys; the Kerio Valley to the west and the Baringo Valley to the east. It is a flat-bottomed valley with a range of high hills to the west. Poorly developed soils structure of the Ilchamus flats has resulted into poor infiltration, loss of rain water and soil through run-off (Gavande, 1985).

There are 6 lakes in Baringo county namely; Baringo ($33Km^2$), Kichirtitt (Lake 94), Lake Solai, Lake Kapnarok and Lake Tilam which are freshwater lakes and Lake Bogoria which is salt-water. Lakes Tilam is a few kilometers away to the north. To the west of the lakes lies the Tugen escarpment and to the east is the Laikipia escarpment and Lake Solai (The Director survey of Kenya). Lake Kamnarok is found in Kerio valley and is an oxbow Lake being source of water for other wild animals even from the neighbouring Rimoi Game Reserve. Lake Bogoria is globally renowned for its high population of migratory birds and hot springs (Anderson, 2005). Lake Turkana is far from Lake Baringo to the north.

Neighbouring Counties

The neighbouring Counties of Baringo are; to the North; Turkana and West Pokot; to the East; Samburu and Laikipia; to the South; Nakuru and Kericho and to the West; Nandi, Uasin Gishu and Keiyo Marakwet (DC Baringo County, 2009).

Size and location of the county

Baringo covers a land area of $8,665Km^2$ of which $140.5Km^2$ is covered by water (JICA, 1999) and Marigat is located about 100Km North of Nakuru town as seen in figure 3.1.

Baringo County is one of the arid and semi-arid counties in the country with most of it (70%) falling within ecological zones IV and V. Marigat district which covers 900Km^2 is located between latitudes 0 020'N and 0 044'N and longitudes 35057'E and 36012'E (FAO,1992; Choge *et al.,* 2002). The area is mainly flat lands and scarp elevations between 1000m and 2930m above sea level. It falls within eco-climatic zone IV classified as semi-arid (Pratt and Gwynne, 1977; Sutherland *et al.,* 1991; Kahi, 2004).

Rainfall

Rainfall is low, erratic and poorly distributed throughout the year (BPSAAP, 1984). Total annual rainfall ranges between 600mm to 900mm described as low, unreliable, highly localized and of bimodal distribution (Ekaya *et al.,* 2001; Griffiths, 1962). It is with weak bimodal peaks recorded from March to May and June to August. It is also highly variable both annually and inter-annually. These drier zones are here classified as very arid (receiving less than 250mm rainfall 4 years in 5 seasons), arid (receiving between 250mm and 500mm rainfall 4 years in 5 seasons), or semi-arid (receiving between 500mm and 750mm rainfall 4 years in 5 seasons). This ecological zone corresponds very closely to the ecological zones IV, V and VI as described by Pratt et al., (1966). Evapotranspiration potential is 1,600mm to 2,300mm indicating 1,000mm to 1,400mm moisture deficit (Anderson, 2005). The main reason for choosing Baringo County as the study area is that, Prosopis juliflora has invaded large tracts of dry grazing land that has generated a lot of conflict among the pastoralists communities and the government. In addition, the area was chosen because previous studies show the presence of man and livestock conflict due to large invasion of Prosopis juliflora. Also the invasion rate and spread is higher in Baringo than in the other 5 Counties namely; Garissa, Turkana, Tana River, Taita Taveta and Wajir (Choge and Chikamai, 2004).

Temperature

The temperature varies from 30^0C to 35^0C and can rise to 37^0C in some months. The monthly mean maximum temperature is usually 30^0C with a mean minimum varying from 16^0C to 18^0C and annual temperature is 28^0C and a maximum of 38^0C(Le Houerou, 1980; Kahi, 2004; Anderson, 2005). The mean annual temperature lies between 22^0C and 25^0C (Griffiths, 1962).

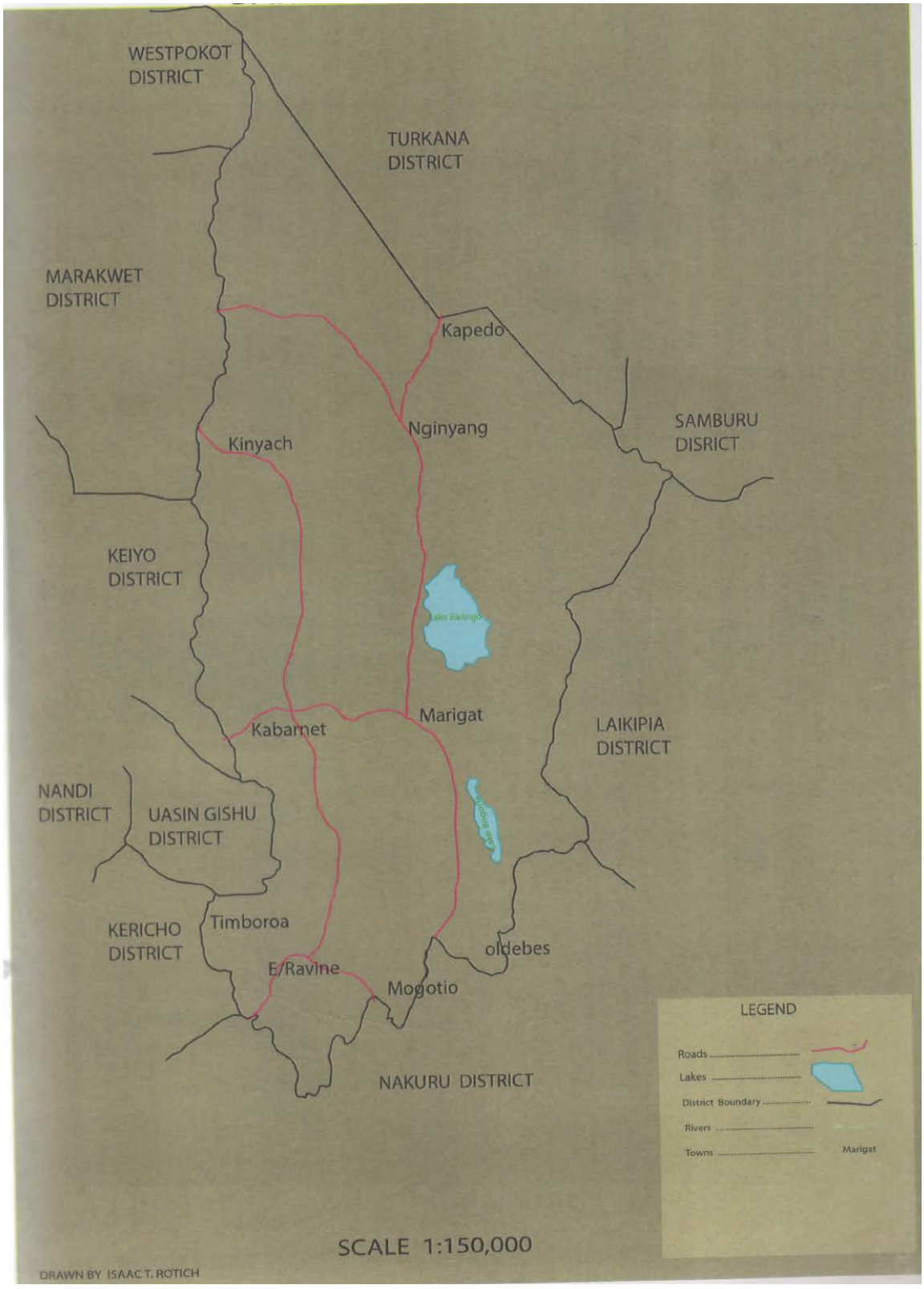

Figure 3.1: Map showing Baringo County and the neighbouring counties

Source: The Director survey of Kenya, (1983)

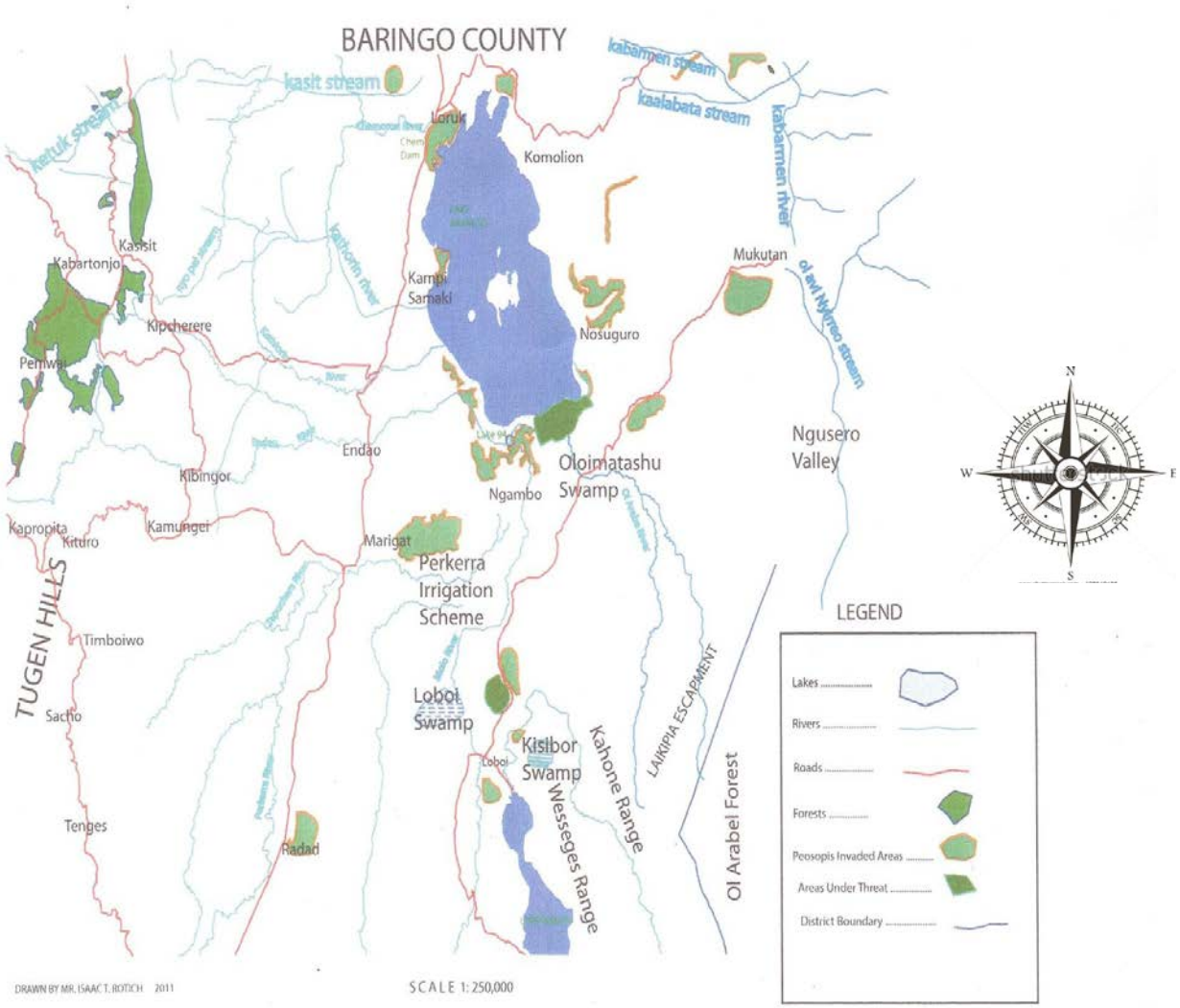

Figure 3.2: Map showing the study area and sites in Baringo County

Source: Surveys of Kenya (1983)

3.2 TOPOGRAPHY AND DRAINAGE IN BARINGO COUNTY

Vegetation

Its vegetation comprises of *Acacia* trees mainly: (*Acacia tortilis*, *Boscia species* and *Balanites aegyptiaca*) and bushes of *Salvadora persica* with the ground generally bare springing up with ephemeral herbs when it rains. This sparse vegetation gradually gives way to bush savanna grassland towards the uplands in the eastern, western and southern extremities (Choge *et al.,* 2002). There are ranches in the area, whose major economic activities are livestock production, farming and fishing (Mwangi and Swallow, 2005).

Soils in Marigat and North BaringoDistricts

Marigat District is an ASAL area which lies East of Baringo County. Jaetzold and Schmidt, (1983) reported that, the main soil type is fluvial-lacustrine characterized by poor general structure, high erodability and low infiltration rate.

Drainage in Baringo County

The rivers Perkerra (Tikirich), Loboi, Molo, Endao and several others flow from the Tugen escarpment while rivers Ntukai (Mukutani) and Nkasotok and streams Olarabal (Tarajani) and Tangulbei drain from Laikipia escarpment into Lake Baringo. Streams flowing to Lake Baringo are Labos, Chemanga, Chemeron, Chemorong'ion, Katiorin, Muyengwonin, Chepkoiyo and Kapsericho. Rivers that flow to Lake Baringo are Perkerra, Endao and Chemeron. River Molo (Ewasonanyokie) from Mau forest and streams Lokinyang and Ngejuolooru drain to Lake Kichirtitt. Rivers Waseges, Emsos and a number of streams from Laikipia escarpment drain into Lake Bogoria. Rivers Cheplogoi, Ketipborok and Chelaba flow from the escarpment and drain into Lake Kapnarok. The name originated from the word "Norokek" which is a species of water plant that was widely found in the Lake in the early stages of the lake formation. It is surrounded by vast indigenous *Acacia* trees. These rivers and streams drain to the 5 lakes during heavy rains on the hilly escarpments. The water in these lakes, rivers and streams flowing towards the Ilchamus flat has contributed to the fast spread of *Prosopis juliflora* (The Director survey of Kenya, 1983).

3.3 DRY SEASON DATA

Description of the study sites

Sites were choosen after a guided field visit and the study was carried out in 3 sites of 3 physiognomic classes within the count, which were selected based on land terrain at the proposed *Prosopis juliflora* canopy cover. Figure 3.3 is showing the satellite imagery of the 3 study sites in the study area namely Lake Kichirtitt, Ng`ambo and Kampi Samaki.

Figure 3.3: Satellite imagery of the 3 study sites in the study area namely Lake Kichirtitt, Ng`ambo and Kampi Samaki.

Source: Surveys of Kenya (1983)

Site 1: Lake Kichirtitt - Kiserian location

Site 1 was Lake Kichirtitt which is 35 km from Marigat and is formed by Molo river wetlands near Longiwan (Loitip). This site represented Riverine Wooded grassland. Figure 3.4 shows the satellite imagery of study site 1.

Site 2: Ng`ambo location.

Ng'ambo is situated in Ilchamus flats lowland and is heavily inhabited. It represented Plain wooded grassland sampling plots situated at 12Km from Marigat to the North East. Figure 3.5 is the satellite imagery of study site 2.

Site 3: Kampi Samaki

Kampi Samaki was near Lake Baringo, dry hillslopes, situated in North Baringo. Sections of the hills between Marigat and Kampi Samaki which were Site 3, represented the Hillslopes wooded grassland sampling plots situated at 20Km to the North along Marigat-Loruk road. Figure 3.6(a)and 3.6(b) is the Satellite imagery of study site 3.This site had sandy soils, chip stones, rocks and hillslopes. The climate of Kampi Samaki is very hot from sunrise to sunset and cool during the night because of the breeze from Lake Baringo. The average temperature is 39^0C during the day and 31^0C during the night. Rain in Kampi Samaki Hills is very rare almost throughout the year. It is unreliable and erratic**.**

Sampling and periods

The typical vegetations represented above are likely to be observed in areas where *Prosopis* occurs in Kenya. The study was conducted between 18th December 2008 and 23rd January 2009 which is 2 months into the dry season when plants are expected to have optimum nutrient content, biomass production and right plant diversity.

Table 3:1 Co-ordinates for plots of site 1

Canopy	Plot 1	Plot 2	Plot 3	Plot 4
0 – 30 %	E 036 05.587 N 00 29.217	E 036 06.010 N 00 29.227	E 036 06.065 N 00 29.133	E 036 06.110 N 00 29.065
31 – 64 %	E 036 05.576 N 00 29.213	E 036 06.012 N 00 29.194	E 036 06.039 N 00 29.129	E 036 05.579 N 00 29.254
65 – 100 %	E 036 06.064 N 00 29.090	E 036 06.050 N 00 29.124	E 036 05.564 N 00 29.220	E 036 06.027 N 00 29.163

Source: Author's survey *(2009)*

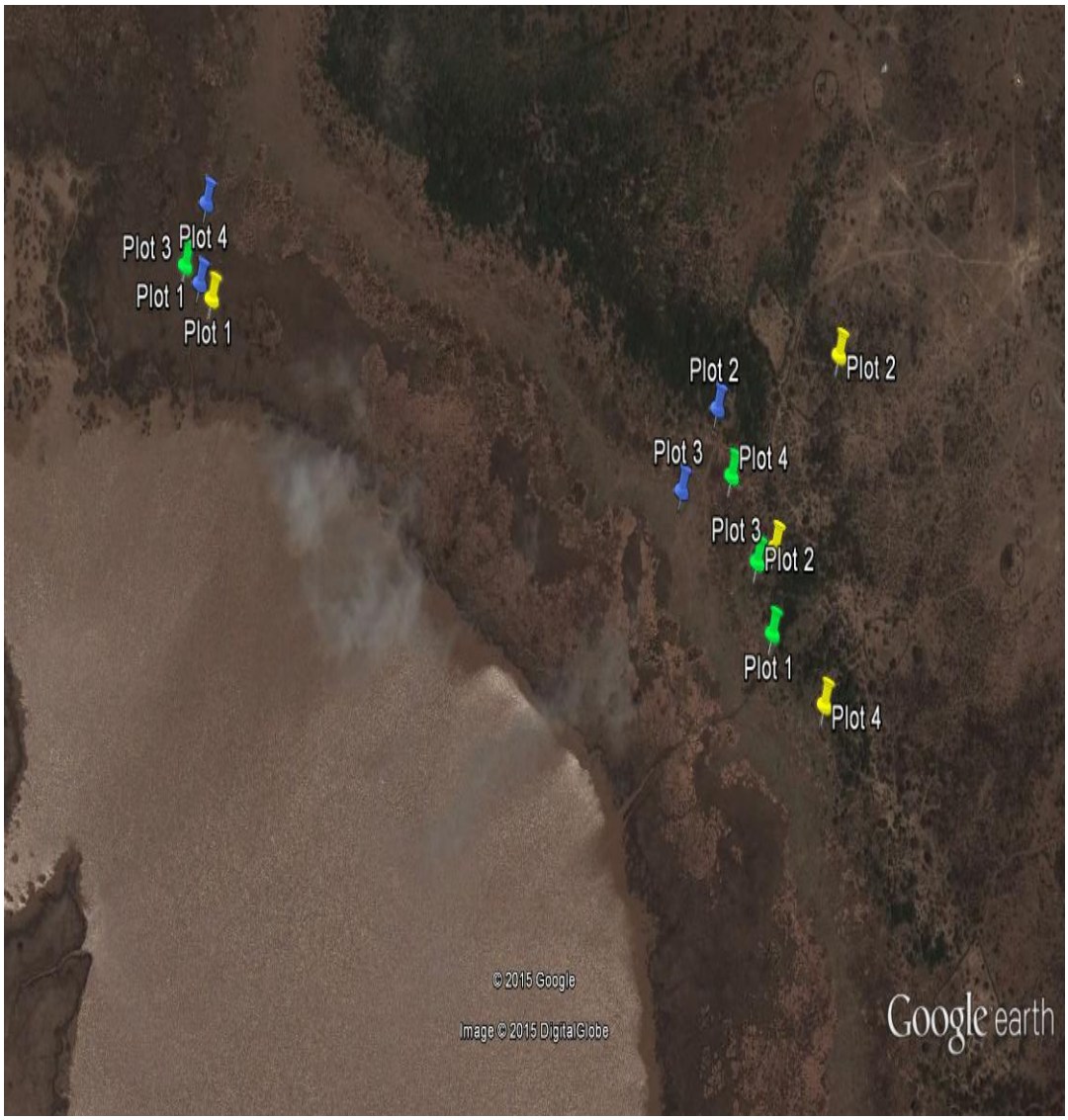

Figure 3.4: Satellite imagery of study site 1
Source: Surveys of Kenya (1983)

Key

%age canopy cover	Color
0 – 30	Yellow
31 – 64	Blue
65 – 100	Green

Table 3:2 Co-ordinates of plots for site 2

Canopy	Plot 1	Plot 2	Plot 3	Plot 4
0 – 30 %	E 036 03.429 N 00 30.249	E 036 03.456 N 00 30.394	E 036 03.395 N 00 30.438	E 036 03.408 N 00 30.457
31 – 64 %	E 036 03.457 N 00 30.271	E 036 03.425 N 00 30.317	E 036 03.474 N 00 30.404	E 036 03.420 N 00 30.375
65 – 100 %	E 036 03.495 N 00 30.314	E 036 03.475 N 00 30.312	E 036 03.494 N 00 30.279	E 036 03.505 N 00 30.286

Source authers survey (2009)

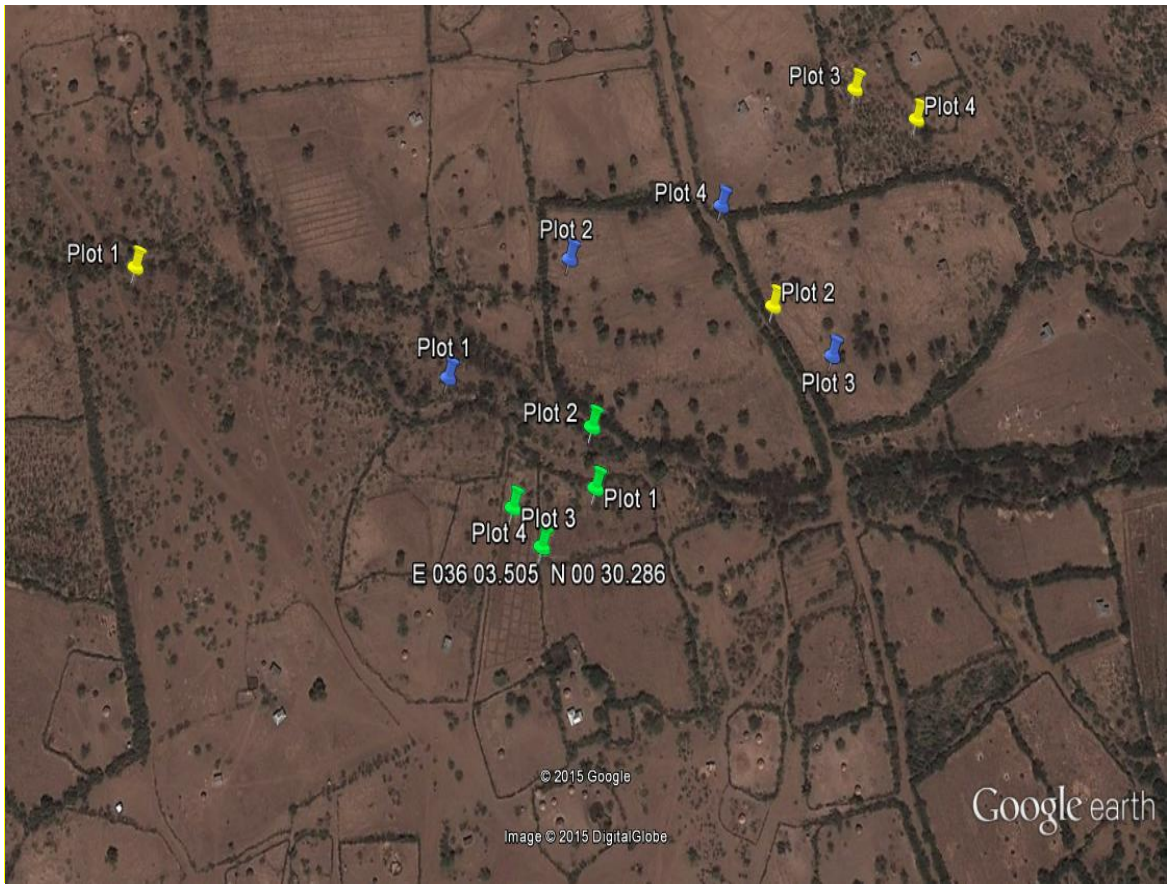

Figure 3.5 Satellite imagery of study site 2
Source: Survey of Kenya (1983)

Key

%age canopy cover	Color
0 – 30	Yellow
31 – 64	Blue
65 – 100	Green

Table 3.3 Co-ordinates of plots for site 3

Canopy	Plot 1	Plot 2	Plot 3	Plot 4
0 – 30 %	E 036 01.009 N 00 37.005	E 036 00.720 N 00 37.045	E 036 00.681 N 00 37.077	E 036 00.573 N 00 36.595
31 – 64 %	E 036 00.563 N 00 36.526	E 036 00.582 N 00 36.509	E 036 00.582 N 00 36.509	E 036 00.593 N 00 36.519
65 – 100 %	E 036 00.556 N 00 36.494	E 036 00.554 N 00 36.512	E 036 00.569 N 00. 36.512	E 036 00.578 N 00 36.490

Source authers survey (2009)

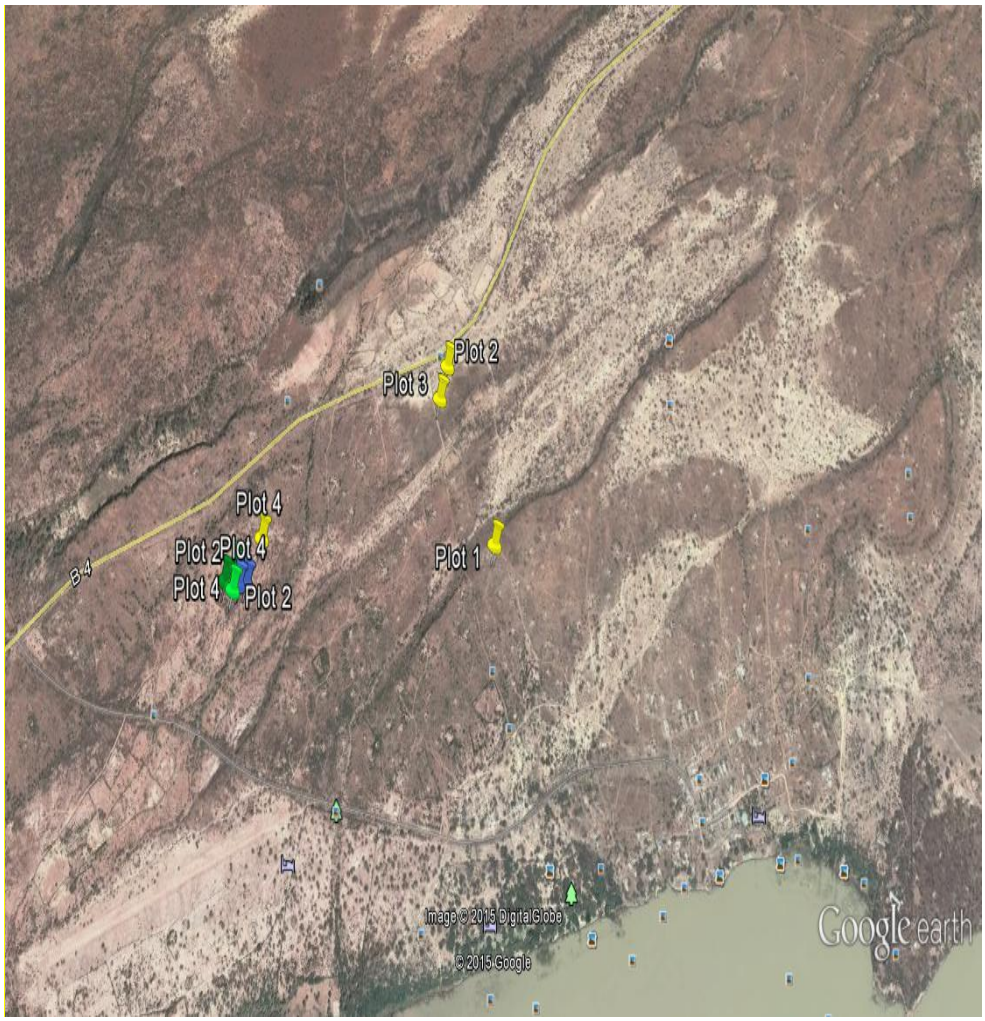

Figure 3.6(a) Satellite imagery of study site 3
Source: Survey of Kenya (1983)

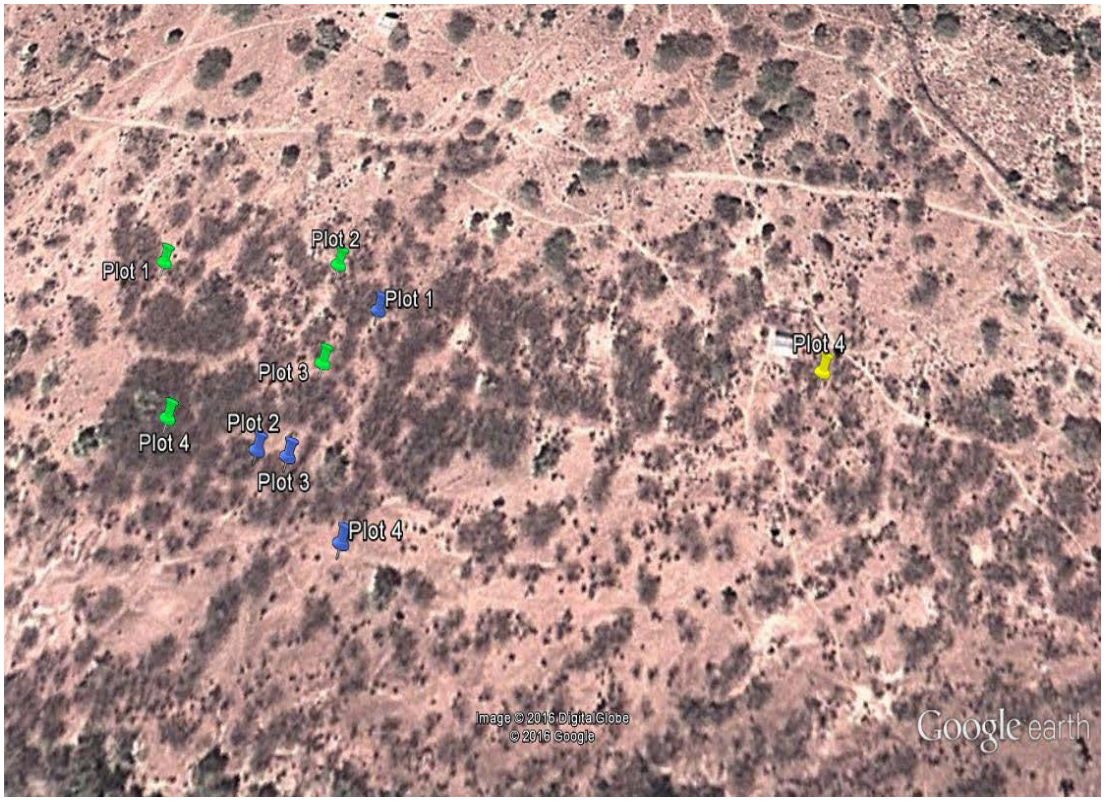

Figure 3.6(b) Satellite imagery of study site 3
Source: The Director survey of Kenya (1983)

Published by: The Government of United Kingdom Directorate of overseas surveys for the Kenyan Government

Key

%age canopy cover	**Color**
0 – 30	Yellow
31 – 64	Blue
65 – 100	Green

Monitoring and Evaluation

This was done in 2009 with a team from University of Nairobi and Allpro project. Figure 3.7 shows survey sites organograph.

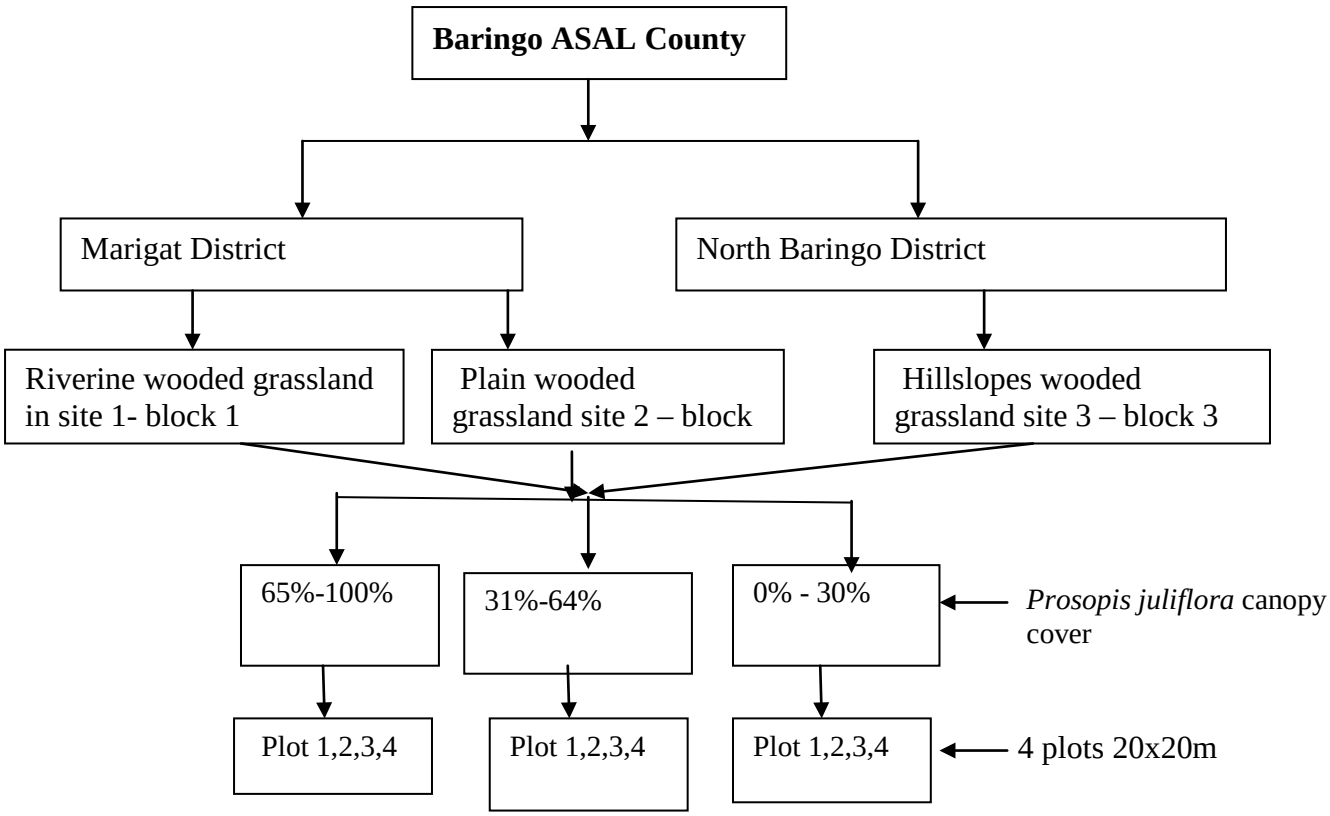

Figure 3.7: Survey sites organograph.

Source: Author's Survey (2009)

3.4 RESEARCH DESIGN AND TREATMENTS

Plant sampling involved the following steps; selection of sites, plant identification and density determination/counting. Each site was further subdivided into 3 categories based on percentage of *Prosopis juliflora* canopy covers. This percentage was determined first using the ocular method (Haydock and Shaw, 1975). This visual estimation was used to select 3 categories of canopy covers with 0-30%, 31-64% and 65-100%. It was then confirmed using line intercept determination method (Goebel *et al.,* 1958) where plots measuring 20m x 20m were demarcated, then the horizontal canopy length covered by one *Prosopis juliflora* plant was calculated by taking the average canopy diameter, $(D_1 + D_2)/2$, then recorded.

GPS was used to measure coordinates of these plots to place the coordinate for the plain. Canopy lengths of all *Prosopis juliflora* plants were taken over a horizontal length of 20m within the 20m x 20m plot, then added and divided by 20 and multiplied by 100 to get the percentage of *Prosopis juliflora* canopy. The categories of cover were grouped into 3, namely 0-30%, 31-64% and 65-100% *Prosopis juliflora* canopy covers (Lamprey, 1981).

The 3 sites are not similar due to varied terrain, climate, vegetation, soils and rock's nature. The experimental design used was Randomized Complete Block Design (RCBD) method (Clewer and Scarisbrick, 1991) where the 3 sites acts as blocks whereas the canopy cover acted as treatment on the plots that were replicated 4 times and the quadrats tossed acted as experimental units. Data collection was done from each treatment plot (canopy category). Similar procedures were followed in the 3 sites (Site 1- Riverine wooded grassland, Site 2- Plain wooded grassland and Site 3 - Hillslopes wooded grassland).

3.5. VEGETATION COMPOSITION, DIVERSITY AND DENSITY ESTIMATION TECHNIQUE IN THE STUDY AREA

Quadrat method

Plant species count quadrat method was used to determine characteristics of the vegetation (Connor, 2007; Morley, 1964; Weaver, 1918). A 1m x 1m quadrat was tossed 3 times at random within the 20m x 20m plot (Hoft *et al.*, 1999). The first quadrat to be thrown was labelled as Qa, the second and the third were labeled as Qb and Qc, respectively. From each quadrat, all the species of herbaceous plants and dwarf shrubs were identified, named and recorded. A secatteur was then used to clip each species at a height of 4cm above the ground. Each herbaceous plant species collected from each quadrat was put in a khaki paper and fresh weights determined using a weighing balance. Each khaki paper was then labeled for site, block, plot, quadrat number and species.

Reference Unit Method

Sampling of trees and shrubs species using reference Unit Method

In each of 20m x 20m plot, the identified trees and shrubs were sampled following the reference unit method. For each tree or shrub species, a representative branch was selected and cut. An estimate of the total number of branches that fit into the tree and shrub canopy was counted for each species, and then fitted in all the number of trees of the same species within 20m x 20m plot. The cut branch was completely stripped off leaves and twigs and then fresh weight was taken and multiplied by the number of branches which fit into the tree or shrub.

The species density of trees and shrubs were determined by counting the total number of every species in a plot and then divided by the total plot area (20m x 20m = 400m^2). Samples collected were appropriately labelled for date, site, terrain, canopy cover, plot number, and species, fresh and dry weight. The fresh weights of each sample species of herbs and leaves and twigs of shrubs and trees were sun dried for about 3 days, sealed using a masking tape and transported 300Km to Kabete Campus Animal Nutrition Laboratory, where they were oven dried at a temperature of 60^{o}C until constant in weight. Samples were then removed and immediately weighed using a weighing balance to obtain dry mass.

3.6 DETERMINATION OF PLANT BIOMASS PRODUCTION

The herbage was harvested by cutting at or very near to ground level to obtain an estimate of total above-ground biomass (Grassland Research Institute, 1961).

Grasses, Sedges, Forbs and dwarf shrubs

Plate 3.1 below is showing Forbs found in the study area. Dry weights of different species of grasses, sedges, forbs and dwarf shrubs were used in calculating biomass production using the formulae below:

$$\text{Biomass production} = \frac{\text{Mass (g) x } 10{,}000\text{m}^2}{\text{Area (20m x 20m) x1000g x 1000kg}}$$

The mean mass of each species per 1m x 1m quadrat was determined by getting an average mass in grams (g) from species sampled from the 3 quadrats ({Qa+Qb+Qc}/3) = W.

'W' stands for mean mass of individual plant species in g/m^2.

The mass of each species in a 20m x 20m plot was calculated as: W x 20m x 20m.

The biomass production was then calculated as follows:

$$\text{Biomass (tons/ha)} = \frac{\text{The dry weight yield of the individual plant in 20m x 20m plot x } 10{,}000\text{m}^2}{(20\text{m} \times 20\text{m}) \times 1000\text{g} \times 1000\text{ Kg}}$$

$$\text{Total individual species count/ha} = \frac{\text{W x } 10{,}000\text{m}^2}{20\text{m x } 20\text{m}}$$

W = mean mass of individual plant species in g/m^2.

Plate 3.1: Forbs found in the study area

Source: Authors survey (2009)

Tree/tall shrub leaves and twigs harvestings

The leaves and twigs harvestings of trees and tall shrubs which were oven dried were used for determination of biomass production. The dry weights of the leaf/twig leaves and twigs from representative branch were multiplied by the number of branches in a tree or tall shrub, to give an estimated dry weight of leaves and twigs per tree/tall shrub. Biomass production in 20m x 20m plot was determined as: the dry weight yield of the one tree/shrub multiplied by the number of trees in the 20m x 20m plot.

The biomass production of the leaves and twigs per hectare was then calculated as follows:

$$\text{Biomass (ton/ha)} = \frac{\text{the dry weight yield of leaves and twigs per tree in 20m x 20m plot x 10,000m}^2}{\text{(20m x 20m) x 1000 g x 1000 kg}}$$

3.7 DETERMINATION OF PLANT COUNTS

This was done by adding all the counts in the 4 plots under each canopy, for all types of plant species appearing in each of the 5 groups of plant species collected.

Grasses, sedges, forbs and dwarf shrub species

The average number of species counted in a 20m x 20m plot was calculated by getting a mean of individual plant species sampled at random from the 3 quadrats in the 20m x 20m plot. The mean number obtained was given value 'Y'. Therefore, the total count of individual species of grasses, forbs and dwarf shrubs per hectare was calculated as follows:

$$\text{Total individual species count/ha} = \frac{\text{Y x 10,000m}^2}{\text{20m x 20m}}$$

Y = mean of individual plant species sampled at random from the 3 quadrats

Tree and tall shrub species

The individual tree and tall shrub species were counted in the 20m x 20m plots and given value 'Z'.

$$\text{Total individual species count/ha} = \frac{\text{Z x 10,000m}^2}{\text{20m x 20m}}$$

The individual tree and tall shrub species were counted in the 20m x 20m plots and given value 'Z'.

3.8 DETERMINATION OF PALATABILITY OF GRAZING NATURAL PASTURE AND BROWSE PLANTS

The palatability of a plant was determined through: Administering questionnaires to the residents of the area where the plant is growing, regular and continous observation of the feeding of livestock on the plant, taking note of the most depleted plants after the grazing period and accessing the information from the internet.

Pastoralists in the 14 locations that fall within the 3 study sites were informally interviewed between 18th December 2008 and December 2009 to rank the palatability of grasses, sedges, forbs, shrubs and tree leaves and twigs. The pastoralists were able to give information voluntarily by describing how their livestock feed on various grasses, sedges, forbs, shrubs and tree leaves and twigs. They were able to differentiate the palatable, medium palatable and unpalatable. The medium palatable are grazed when there is scarcity of pasture.

3.9 DATA COLLECTION IN THE FIELD

The data collected included species richness and composition of annual grasses, perennial grasses, annual sedges, perennial sedges, annual forbs, perennial forbs, shrubs and leaves/ twigs harvesting of all tree species. Their names and fresh weights were recorded in the field. All the trees in the 20m x 20m plots were also identified, counted and recorded. All the plant species in the 3 categories of *Prosopis juliflora* canopy were studied and analyzed. This was done for all the sites, namely; Riverine wooded grassland, Plain wooded grassland and Hillslopes wooded grassland at 0-30%, 31-64% and 65-100%. Species that occur once were counted once even if the counts are more than one. This was to count for each type of plant species in the plot under each category of canopy. They were grouped by habit namely: grasses, sedges, forbs, shrubs and trees in each of the 3 sites.

Number of samples for the laboratory chemical analysis

Table 3.4 shows a different plant species observed on the study sites and the number of samples for the laboratory chemical analysis was selected as per the terrain as follows:

Table 3.4 Different plant specuies observed on the study sites

Site 1	Site 2	Site 3
Riverine wooded grassland	**Plain wooded grassland**	**Hillslopes wooded grassland**
Commelina benghalensis *Satureia abyssinica* *Xanthium pungens* *Indigofera schimperi* *Commelina benghalensis* *Acacia mellifera* *Acacia nubica* *Acacia reficiens* *Acalypha fruticosa* *Balanites aegyptiaca* *Salvadora persica* *Panicum coloratum* *Hygrophilla auriculata* *Acacia tortilis*	*Bidens ugandensis* *Chenopodium fasiculosum* *Indigofera schimperi* *Justicia exigua* *Solanum nigrum* *Solanum dubium* *Xanthium pungens* *Eleusine indica* *Acalypha fruticosa* *Balanites aegyptiaca* *Cordia sinesis* *Prosopis juliflora* *Alternanthera pungens* *Chenopodium opulifolium* *Sida ovata* *Withania somnifera* *Cynodon dactylon* *Cyperus rotundus*	*Alternthera pungens* *Justicia exigua* *Solanum dubium* *Digitaria velutina* *Cynodon dactylon* *Acalypha fruticosa* *Baleria acanthoides* *Barleria diffusa* *Indigofera cliffordiana* *Sericocomopsis pallida* *Acacia tortilis* *Maerua pubescence* *Prosopis juliflora*

Source: Authors survey (2009)

3.10 LABORATORY DATA ANALYSIS

Laboratory analysis for nutrient of the selected grasses, sedges, forbs, shrubs and tree leaves and twigs was carried out at the Animal Production Laboratory, ISO 9001:2015 Certified, of the University of Nairobi.

Determination of Moisture Content

Moisture content was determined at both 60^0C and 105^0C. The wet sample of grass was weighed and its weight recorded and then air dried and then oven dried at 60^0C until constant weight was attained**.** The change in weight was taken as the moisture at 60^0C then the results were calculated. The air dried sample was ground using Witley mill of 1ml sieve to hormogenize it and distribute the sample evenly. The ground sample was put in a clean sample bottle and labelled. Moisture at 105^0C was determined according to Association of official Analytical Chemists, Haydock and Shaw, (1975) method and Proximate method (AOAC, 1990).

Determination of crude protein and fibre content of plant species

Determination of crude protein and fibre content of the plant samples was done using Macro-Kjedahl method (AOAC, 1990), AOAC, International (1998), Official methods of Analysis, 16th Edition 4th revision volume I and II edited by Patricia Cunnilf and Bremner and Keeney (1965) method.

i. Association of official Analytical Chemists,Official methods 988.05, Protein (crude) in animal feed and pet food $CUSO_4/T_1O_2$ mixed catalyst Kjeldahl method, First action 1998 and final action 1990, AOAC.

ii. Official methods 973.18, Fibre (Acid detergent) and lignin in animal feeds. First action 1973 and final action 1977, AOAC, Van Soest, (1963, 1978, 1994, 1995): Van Soest *et al.*, (1991).

3.11 STATISTICAL DATA ANALYSIS

Data was entered in Microsoft Office Excel 2007 data sheet. Statistical Analysis was done for descriptive statistics (means, standard deviations, minimum, and maximum values), frequencies and percentages. Data on biomass production, categories of canopy covers, habit palatability, and counts (frequency) were subjected to analysis of variance (ANOVA) (Steel and Torrie, 1980, Clewer and Scarisbrick, 1991). The statistical programme used was Statistical Programme for Social Sciences (SPSS) and (Genstat Dicovery, 2007).

3.12 LIMITATIONS AND ASSUMPTIONS

During data collection, various limitations and assumptions were made as shown below;

Limitations

i. Lack of wet season data collection
ii. Time in the field was inadequate
iii. Overdrying of natural plants in the dry season
iv. Lack of adequate funding of the project

Assumptions

i. Plants were at their maturity stage
ii. *Prosopis juliflora* trees were 4 years and above
iii. Soils were the same in the 3sites
iv. Climate was the same in the 3 sites

3.13 CHALLENGES

During data collection, various challenges were encountered namely; poor road network, inadequate drinking water, wild animals, wild reptiles, sharp thorns of *Prosopis juliflora*, *Acacia* trees and shrubs, mosquitoes inhabiting in the dense forest of *Prosopis juliflora* and very high temperatures during the day. There were also Pokot cattle rustlers posing insecurity in the study area.It increased the cost of data collection by fueling vehicles to the three sites, taking more days collecting data because sites were far apart. Hiring field assistants, collecting data hurriedly in fear of cattle rustlers

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 CANOPIES, PLANT TYPES, BIOMASS AND COUNTS OF VARIOUS GRASSES, SEDGES, FORBS, SHRUBS AND TREE LEAVES AND TWIGS IN THE 3 STUDY SITES

Canopies of various plant species in the 3 study sites

Table 4.1 below, shows the results obtained from the survey which indicated a mean canopy cover for the 4 plots (i.e 1,2,3,4) of 21% in the open area of *Prosopis juliflora,* 54% for the less forested area and 83% for the forested area. The categories of cover were 3, namely 0-30%, 31-64% and 65-100% *Prosopis juliflora* canopy covers. The other tree species with their respective canopies are *Balanites aegyptiaca, Acacia mellifera, Acacia nubica, Acacia reficiens, Grewia tenax, Acacia tortilis* and *Salvadora persica* in Riverine wooded grassland, *Acalypha fruticosa, Balanites aegyptiaca* and *Lantana camara* in Plain wooded grassland, *Maerua pubescence, Acacia mellifera, Acacia tortilis* and *Acacia reficiens* in Hillslopes wooded grassland. They were less important because they covered less area, were more variable and the trees themselves are largely deciduous, thus providing less consistent shading of herbaceous shrubs and trees underneath than *Prosopis juliflora,* which is an evergreen tree.

Table 4.1: The range of canopy covers of *Prosopis juliflora* (%) in the 3 study sites

Prosopis tree cover	**Canopy Cover (%)**		
Site	**21 Low**	**54 Medium**	**83 High**
Riverine wooded grassland	14.0	61.5	80.2
Plain wooded grassland	24.4	52.8	93.4
Hillslopes wooded grassland	25.9	46.7	74.2
Average canopy cover (%)	21.4	53.6	82.6
Non *Prosopis juliflora* trees canopy cover (%)			
Riverine wooded grassland	31.3	11	13.8
Plain wooded grassland	13.7	0.0	3.0
Hillslopes wooded grassland	22.4	5.9	13.3
Average canopy cover (%)	22.5	5.6	10.0

Source: Author's survey (2013)

Types of plant species in the 3 study sites

Site 1: Riverine wooded grassland

Table 4.2 below, shows the types of plant species, under each canopy category. The significance of this table is that at a glance, one is able to see the type of vegetation observed in the study area. Four types of grass species were found under canopy 21%, 5 types in 54% and 3 types in 83% canopy covers. One type of sedge species was found under canopy 21% and 2 types in both 54% and 83% canopy covers. There was general decrease in sedge species as you move from forest to open grassland. Nine types of forb species were found under canopy 21%, 5 types in 54% and 8 types under 83% canopy covers. The results indicate that forbs were resistant to the effect of *Prosopis juliflora*. Six types of shrub species were found under canopy 21%, 0 types at 54% and 3 types under 83% canopy covers. Four types of tree species were found under canopy 21%, 2 types at 54% and 3 types under 83% canopy covers. This means *Prosopis juliflora* reduced the growth of shrubs and other types of tree species in the forest.

Site 2: Plain wooded grassland

Two types of grass species were found under 21%, 54% and 83% canopy covers. It can be observed that *Prosopis juliflora* forest reduced the type of grass species. There were no sedge species found under 21% and only 1 type under 54% and 83% canopy covers. Fourteen types of forb species were found under canopy 21%, 10 types at 54% and 13 types at 83% canopy covers. Forbs were therefore resistant to the effects of *Prosopis juliflora.* Two types of shrub species were found under canopy 21%, 0 types at 54% and 2 types at 83% canopy covers, which reveals that shrubs withstood the effects of *Prosopis juliflora.* Two types of tree species were found under canopy 21%, 1 type at 54% and 2 types at 83% canopy covers. The other trees resisted the effect of *Prosopis juliflora.*

Site 3: Hillslopes wooded grassland

Four types of grass species were found under canopy 21%, 8 types at 54% and 4 types at 83% canopy covers. Grasses in this terrain were resistant to the effect of *Prosopis juliflora.* One type of sedge species was found under both canopy 21% and 54% while there was 0 types at 83% canopy covers. The general decline of the sedge species indicates that, they do not withstand the effect of *Prosopis juliflora.* Five types of forb species were found under canopy 21% and 54% while there were 9 types at 83% canopy covers. The general number of forbs being constant indicates that they withstood the effect of *Prosopis juliflora.* Seven types of

shrub species were found under canopy 21%, 5 types at 54% and 2 types at 83% canopy covers. Their decline from the open Hillslopes wooded grassland to the forest of *Prosopis juliflora* was a result of the effect of *Prosopis juliflora* in this type of vegetation. Two types of tree species were found under canopy 21% and 3 types at both 54% and 83% canopy covers. Their constant number indicates that they were not affected by *Prosopis juliflora.*

Discussion on types of grasses, sedges, forbs, shrubs and trees in study sites

In the Riverine wooded grassland, forbs, shrubs and trees types reduced then increased as *Prosopis juliflora* percentage increased from 21% to 83% and the grasses increased then reduced while sedges increased steadily with increase in canopy cover. This agrees with the findings of Sen and Sachwan, (1970) who stated that *Prosopis juliflora* trees inhibit growth of understorage plant species due to phytotoxic effects of their leaves. It was observed that *Acacia tortilis* and *Prosopis juliflora* which are alellopathic in nature may also partly explain the relatively low biomass production of herbaceous plant species obtained under the tree canopies (Kahi, 2004). In the Plain wooded grassland, the counts of grasses and sedges were generally constant. Shrub and tree types reduced from 21% to 54% but increased at 83% of *Prosopis juliflora* canopy cover. In the Riverine wooded grassland and Plain wooded grassland forbs decreased with increase of *Prosopis juliflora* canopy from 21% to 54% but reduced at 83%. In the Hillslopes wooded grassland, they were constant at 21% and 54% but increased at 83%.

4.2 VEGETATION TYPES IN MARIGAT AND BARINGO NORTH DISTRICTS (PHYSIOGNOMIC CLASSES)

Site 1: Wood land – forest of *Prosopis juliflora*

This is a forest of *Prosopis juliflora* trees this is observed in riverine wooded glassland site1 The tree community is composed of; *Prosopis juliflora, Acacia tortilis, Balanites aegyptiaca, Maerua pubescence, Salvadora persica* and *Cordia sinensis* in descending order in terms of abundance. *Prosopis juliflora,* an introduced species, has become the most dominant species in some sections of the riverine vegetation forming monospecific strands almost phasing out the native woody species. Appendix 7(a) shows woody species density and their frequency in the study area. The understorey in the riverine forest is composed of *Acalypha fruticosa, Grewia tenax* and *Lantana camara.*

Table 4.2: Number of types of various habit in the 3 study sites by count

Site	Cover (%)	Habit				
		Grasses	Sedges	Forbs	Shrubs	Trees
Riverine wooded Grassland	21 Low	4	1	9	6	4
	54 Medium	5	2	5	0	2
	83 High	3	2	8	3	3
Plain wooded Grassland	21 Low	2	0	14	2	2
	54 Medium	2	1	10	0	1
	83 High	2	1	13	2	2
Hillslopes wooded grassland	21 Low	4	1	5	7	2
	54 Medium	8	1	5	5	3
	83 High	4	0	9	2	3

Source: Author's findings (2013)

Site 2: Wooded glassland

This type of vegetation is observed in plain wooded glassland-site 2**.** The herbaceous layer is dominated by annual grass and some few perennial grasses mainly in open spaces. Forbs dominate the areas under the dense canopies of *Prosopis juliflora* where grass species cannot thrive. Grass species found in this vegetation are*;* Annual grasses e.g *Digitaria velutina, Eragrostis tuneifolia*, *Eragrostis cilianesis*, *Aristida keniensis*, *Eleusine indica*, *Echinochloa colonum, Aristida mutabilis, Sporobolus marginatus, Dactyloctenium aegyptiaca, Tetrapogon spathecious* and *Tetrapogon tenellus. Echinochloa colonum* is an indicator of wet ground and poor soil drainage.

These are all increaser grass species which indicates that the range trend is going downwards in terms of grazing and the range condition is fair. Perennial grass species found in the study area were *Cynodon dactylon, Leersia hexandra, Echinocloa pyramndalis, Panicum coloratum, Echinochloa haploclada* and *Cenchrus ciliaris*. Most of these are decreaser species and their frequencies determine the state of the range as shown in the ranking Appendix 7(b). It is showing habit woodland-forest of *Prosopis juliflora* site 2.

Sedges (grass-like plants) are common in marshes and wetland sections in the study area. These have no significant value in terms of grazing though ecologically, very important in terms of indication of presence of water in the soil. There are no annual sedges found in this area. Perennial sedges are *Cyperus rotundus, Cyperus articulatus* and *Cyperus papyrus.* Forbs form the majority of herbaceous layer species in the wooded grassland. Due to high percentage of canopy cover of the forest, the frequency of grass species tends to be low. Most of the forb species below the canopy are invaders since grass species cannot do well under such canopy cover.

The understorey in this vegetation was covered by; *Sida ovata, Alternanthera pungens, Bidens ugandensis, Hygrophilla auriculata, Justicia exigua, Euphorbia crotonoides, Chenopodium opulifolium, Amaranthus spinosus, Ocimum bacilicum, Commelina benghalensis, Xanthium pungens, Ageratum conyzoides, Celosia antihelmintica, Glinus lotoides, Withania somnifera, Conyza floribunda, Indigofera schimperi, Commicarpus helenae, Cassia occidentalis, Solanum dubium, Satureia abbyssinica, Kalanchoe denseflora, Solanum nigrum, Trianthema triquetra, Borreria stricta, Amaranthus hybrindus, Abutilon mauritianum, Portulaca foliosa, Justicia striata, Heliotropium subulatum, Chenopodium fasiculosum, Sida rhombifolia, Nothosaerva brachiata, Aerva persica* and *Ipomoea cairica* being the only perennial forbs observed. Trees in this vegetation comprise of: *Acacia tortilis, Acacia seyal, Acacia senegal, Cordia sinensis, Ficus sycomorus, Boscia spp, Balanites aegyptiaca, Maerua pubescence, Prosopis juliflora* and bushes of *Salvadora persica.* Most of these are decreaser species and their frequencies determine the state of the range as shown in the ranking Appendix 7(b).

Site 3: Shrubland

This type of vegetation is found in hill slope wood glassland site 3 and is mainly composed of shrubs with few scattered trees (Lamprey, 1981). The herbaceous layer is mainly composed of annual grasses and forbs. The ground is bare for most part of the year springing up with ephemeral herbs when it rains as opposed to the riverine vegetation. The most dominant shrub species are: *Acacia reficiens* forming a monospecific strand to some extent, *Acacia mellifera, Acacia nubica, Grewia bicolor* in bottom land where soils are saline, *Acalypha fruticosa, Grewia tenax* along water courses and also *Lantana camara, Maerua subcodata* and *Grewia bicolor*. Dwarf shrubs were found dominating the ground layer, these include:

Barleria diffusa, Baleria acanthoides, Sericocomopsis pallida and *Indigofera cliffordiana.* Appendix 7(c) is showing habit woodland – forest of *Prosopis juliflora* site 3.

The presence of dwarf shrubs and their health in range shows the trend and condition of the range. They play a very important role in providing pasture for livestock wherever the perennial grasses are missing. *Prosopis juliflora* was also found in the shrubland, and it being plastic has taken a life form of shrub due to water deficiency. Their density on the shrubland is significant, indicating that it may phase out the native shrubs which are important browse plants in the study area e.g *Grewia bicolor.*

4.3 DESCRIPTIVE OBSERVATION AND RANKING OF PLANT SPECIES IN EACH CANOPY CATEGORY BY TOTAL COUNT

In the appendix 7(a, b, c) indicates all plant species under the 3 canopy categories in the 3 sites, and also shows the ranking of each species starting with the most abundant in each class.

Site 1: Riverine wooded grassland (Lake Kichirtitt)

In the appendix 7(a) indicates all plant species under the 3 canopy categories in Riverine wooded grassland (Lake Kichirtitt site I) and also shows the ranking of each species starting with the most abundant in each class.

Annual and perennial grasses

There were only 3 annual grasses in this site. These were: *Echinochloa colonum* being the most common with a total count of 8, *Dactyloctenium aegyptiaca* with a total count of 3 and the least common was *Digitaria velutina* with a total count of 2. They were all absent in canopy cover 83%. There were 4 perennial grasses in this site with *Cynodon dactylon* being the most common with a count of 1038, followed by *Leersia hexandra* with a count of 90, *Panicum coloratum* with a count of 33 and lastly, *Echinochloa haploclada* with 6 counts in the 3 categories.

Annual and perennial sedges

Annual sedges were not ranked in the site because they were not present as confirmed in Appendix 7(a). There were only 2 perennial sedges in this site. The most common was *Cyperus rotundus* with 464 counts followed by *Cyperus articulatus* with 2 counts.

Annual and Perennial forbs

There were 15 different types of annual forbs in this site and all had a count of 1. These were *Hygrophilla auriculata, Ocimum bacilicum, Commelina benghalensis, Xanthium pungens, Celosia antihelmintica, Satureia abyssinica, Indigofera schimperi, Cassia occidentalis, Solanum dubium, Borreria stricta, Justicia striata, Glinus lotoides, Nothosaerva brachiata, Portulaca foliosa* and *Alternanthera pungens.* The only perennial forb present in this site was *Ipomoea cairica* and was found under canopy cover 83% with a count of 2.

Shrubs

There were only 6 species of shrubs in this site. The most dominant was *Grewia tenax* with a total count of 10, followed by *Acacia nubica* and *Acacia reficiens* with a count of 6 each. *Acacia mellifera* and *Acalypha fruticosa* were in third position with a total count of 4. The least common was *Maerua subcodata* with a count of 1.

Trees

Only 4 trees were present in this site. *Prosopis juliflora* was the most common with a total of 231 trees in all the 3 canopies. *Acacia tortilis* and *Salvadora persica* were the second most common with a total count of 4. *Balanites aegyptiaca* was the least common tree with a total count of 2 in the entire site.

Discussion on riverine wooded grassland

Appendix 7(a) indicates the total number of plant classes (habit) under each canopy category. This was done by adding all the counts in the 4 plots under each canopy for all types of plant species appearing in each of the 5 classes of plant species collected in the 3 sites. In Lake Kichirtitt, grasses increased from 528 counts in 21% to 469 counts in 54% then dropped to 183 count in 83%. *Prosopis juliflora* affected grasses by decreasing their growth and numbers. Sedges decreased from 297 counts under 21% to 22 counts in 54% then increased to 147 counts in 83%. Sedges were severely depressed by moderate *Prosopis juliflora* invasion than those in the forest which withstood the invasion. *Prosopis juliflora* therefore affected grasses and sedges negatively by decreasing their growth and numbers in general.

Forbs decreased from 102 counts in 21% to 40 counts in 54% then increased to 73 counts under 83%. Invasion were more affected than those in the forest because those in the forest withstood the effect of *Prosopis juliflora* probably due to increased nitrogen fixed by the

legume tree.This means that *Prosopis juliflora* affected forbs negatively by decreasing their growth and numbers in general. They decreased from the forest to the open wooded grassland. When they happen to grow, they withstood the effect of *Prosopis juliflora* as they were seen to grow old categories of canopies. Shrubs decreased in 21% from 23 counts to 0 in 54% then they increased to 8 counts in 83%. *Prosopis juliflora* therefore affected their growth at moderate invasion but there were those shrubs that withstood invasion in a forest of *Prosopis juliflora.* The density of trees increased steadily across the 3 categories of *Prosopis juliflora* canopies. There were 29 counts in 21%, 78 counts in 54% and 134 counts in 83%. This is because the *Prosopis juliflora* trees are the ones that formed the 3 categories of canopies from none invaded to invaded areas.

Site 2: Plain wooded grassland (Ng`ambo)

In the appendix 7(b) indicates all plant species under the 3 canopy categories in Plain wooded grassland (Ng`ambo, Site 2) and also shows the ranking of each species starting with the most abundant in each class.

Annual and perennial grasses

The only annual grass in site 2 was *Eleusine indica* with a total count of 9. There were only 2 perennial grasses present. The most common was *Cynodon dactylon* with a count of 49 while *Echinochloa pyramidalis* was in second position with a count of 43.

Annual and perennial sedges

Annual sedges were present under canopy 21% as shown in Table 4.2 but they were not found in the ranking of Appendix 7(b). The only perennial sedge which was found in this site is C*yperus rotundus* with a total count of 402. It was present in all canopies except in 21%.

Annual and perennial forbs

There were 21 different types of annual forbs. The most common was *Sida ov*ata with a count of 509. It was followed by *Alternanthera pungens* with a count of 255, 3rd position was *Bidens ugandensis* with a count 117, 4th position was *Chenopodium opulifolium* with 42 counts, 5th was *Amaranthus spinosu*s with 40 counts, 6th was *Ageratum conyzoides* with 21 counts, 7th position was *Glinus lotoides* with 19 counts, 8th position was X*anthium pungens* with 18 counts, 9th was *Withania somnifera* with 17 count, 10th was *Conyza floribunda* with 15 counts, 11th position was *Cassia occidentalis* and *Solanium dubium* with 12 counts, 13th

position was *Satureia abyssinica* with 9 counts, 14th was *Solanum nigrum* with 7 counts, 15th was *Indigofera schimperi* with 3 counts, 16th position was *Amaranthus hybridus* with 2 counts, 17th position were *Heliotropium subulatum, Chenopodium fasiculosum, Commelina benghalensis, Ocimum bacilicum* and *Sida rhombifolia* all with a count of 1. Perennial forbs were not present in this site as shown in Appendix 7(b).

Shrubs

There were only 2 types of shrubs in this site. The most common was *Acalypha fruticosa* with 12 counts, followed by *Lantana camara* with 7 counts.

Trees

There were 3 types of trees in this site. The most common was *Prosopis juliflora* with a total of 145 counts. *Cordia sinensis* and *Balanites aegyptiaca* were the 2nd most common with 1 count each.

Discussion on plain wooded grassland

Appendix 7(b) indicates the total number of plant classes (habit) under each canopy category. This was done by adding all the counts in the 4 plots under each canopy for all types of plant species appearing in each of the 5 classes of plant species collected in the 3 sites.Grasses increased from 42 counts in 21% to 47 counts in 54% and then dropped drastically to 12 counts under 83%. Grasses therefore withstood moderate invasion and the shading enhanced their growth. However, they decreased in a forest of *Prosopis juliflora* as it affected them severely. Sedges were absent in 21%, but present in 54% with a count of 147. They increased in 83% to 255 counts, which indicated that sedges grew well in both the moderate and a forest of *Prosopis juliflora.* Forbs increased from 288 counts in 21% to 482 counts in 54%.

The study revealed that the moderate forest of *Prosopis juliflora* enhanced their growth in this site. However, the count decreased from 482 to 330 under 83%, which means that the *Prosopis juliflora* affected the growth of forbs. There were 8 shrubs in 21% and 0 in 54%. Shrubs therefore grew where there was little *Prosopis juliflora* but they do not grow where there was moderate invasion. In 83% there were 11 counts meaning that shrubs grew in a forest of *Prosopis juliflora* in the plain wooded grassland. The density of trees increased steadily across the 3 canopy categories from 19 counts in 21%, 59 counts in 54% and 69

counts in 83%. This is because it was the effect of the progressive invasion of *Prosopis juliflora* that was being studied on pasture and browse species from 83% invasion.

Site 3: Hillslope wooded grassland (Kampi Samaki)

In the appendix 17(c) indicates all plant species under the 3 canopy categories in Hillslope wooded grassland (Kampi Samaki site 3) and also shows the ranking of each species starting with the most abundant in each class.

Annual and perennial grasses

Digitaria velutina was the most common annual grass in this site with a total of 329 counts. It was followed by *Eragrostis tuneifolia, Eragostis cilinensis, Aristida keniensis, Aristida mutabilis, Sporobolus marginatus,* and *Tetrapogon spathecious* with counts of 60, 39, 13, 7, 6 and 2 respectively. The 7 types of annual grasses were palatable and therefore very important for livestock in the Hillslopes wooded grassland. They germinate and mature within 4 weeks whenever it rains. The only perennial grass present in this site was *Cynodon dactylon* and appeared only in canopy 54% and 83% as shown in Appendix (c). It had a total of 10 counts. This means that perennial grasses do not grow in this terrain and climate compared to the annual grasses where the most common had a total count of 329.

Annual and perennial sedges

This site had only 1 type of annual sedge. It was *Cyperus species*. It appeared under canopy 54% with a count of 6. *Cyperus rotundus* was the only perennial sedge present in this site with a total count of 182. The count was present in canopy 21% only. The small quantities of count 6 for annual sedges shows that, they do not survive in the Plainwood hillslopes because of the rocky soils and very high temperatures while a large count of perennial sedges of 182 means that they withstand the harsh climate.

Annual and perennial forbs

The most common annual forb was *Justicia exigua* with a total of 59 counts, followed by *Euphorbia crotonoides, Alternanthera pungens, Indigofera schimperi, Commicarpus stellatum, Kalanchoe denseflora* and *Solanum dubium* with counts of 54, 45, 15, 13, 8 and 5 respectively. *Commelina benghalensis* and *Trianthema triquetra* had a count of 4. *Abutilon mauritianum* and *Portulaca foliosa* had a count of 2. There was only one plant species with 1 count under canopy 21%. It was *Aerva persica.*

Shrubs

There were 7 types of shrubs and of these, the most common was *Barleria diffusa* with a count of 622. *Acacia mellifera* and *Acalypha fruticosa* follow with counts of 39 and 36 respectively. *Barleria acanthoides* and *Sericocomopsis pallida* had 15 counts each. *Acacia reficiens* and *Indigofera cliffordiana* had 11 and 5 counts respectively.

Trees

Among the trees in this site, *Prosopis juliflora* was the most common with a total count of 557. *Acacia tortilis* was the second most common with a total count of 40. *Maerua pubescense* was the least common with a total count of 3.

Discussion on Hillslope wooded grassland

Appendix 7(c) indicates the total number of plant classes (habit) under each canopy category. This was done by adding all the counts in the 4 plots under each canopy for all types of plant species appearing in each of the 5 classes of plant species collected in the 3 sites.Kampi Samaki Hills is very hot and dry. Grasses increased from 113 counts in 21% to 255 counts in 54% and then decreased to 98 counts in 83%. The increase indicated that the moderate *Prosopis juliflora* cover allowed them to grow because they do not get direct sun rays. In the forest, the count of grasses decreased because the forest trees of *Prosopis juliflora* compete for water with them suppressing their growth. Those in 21%, 113 counts, were more than those in the forest because the density of *Prosopis juliflora* was very low and could not therefore compete for water with them.

Grasses were dominant in Kampi Samaki Hills because of the rocky terrain and harsh climate. They grew and mature within 4 weeks and then disappear. Sedges were 182 counts under 21%, 6 in 54% and 0 in 83%. They therefore grew in Kampi Samaki Hills but their growth was affected by moderate and forest of *Prosopis juliflora* which competed with them for moisture and nutrients.The population of forbs increased steadily across the 3 categories of canopies from 13 counts in 21%, 95 in 54% and 104 in 83%. The study revealed that the invasion of *Prosopis juliflora* encouraged their growth in hillslopes grassland. There were 227 counts of shrubs in 21%, 226 in 54% and 290 in 83%. The counts of shrubs increased with the degree of *Prosopis juliflora's* invasion. The growth of shrubs was therefore encouraged by *Prosopis juliflora* as it protected them from direct sun rays given that Kampi Samaki Hills is very hot and dry hence shrubs grew under that protection. The count of trees

increased steadily from 101 counts in 21%, 241 counts in 54% and 258 counts in 83%. This is because the degree of invasion increased from 0-100% canopy cover of *Prosopis juliflora* trees.

General discussion on most abundant palatable plant species by proportion of the total number of plants in:

Site 1: Riverine wooded grassland (Lake Kichirtitt)

There were 3 types of palatable annual grasses with a total count of 13. Four types of perennial grasses were present with a count of 1167 and all were palatable. *Echinochloa* which is an annual grass was the most abundant annual species by proportion of the total number of plants.They were 0.0 at 21%, 61.5 at 54% and 0.0 at 83%. This means that annual grasses can grow in moderate *Prosopis juliflora* and do not withstand the forest. *Cynodon dactylon,* which is a perennial grass, was the most abundant palatable plant species by proportion of the total number of plants. There were 45.5 at 21%, 36.6 at 54%, and 8.1 at 83%. *Cynodon dactylon* does not withstand the effect of *Prosopis juliflora* as it grew well in the open and declined in the forest.

Annual sedges were absent as shown in the table below. This means annual sedges do not grow under *Prosopis juliflora* canopy. However there were 2 types of palatable perennial sedges. These were *Cyperus rotundus* and *Cyperus papyrus* with a total count of 510 out of 3 types of perennial sedges with a total count of 512. Among the perennial sedges, *Cyperus rotundus* was the most abundant palatable plant species by proportion of the total number of plants.They were 58.2 at 21%, 4.1 at 54%, and 28.6 at 83%. Perennial sedges decrease drastically in a moderate forest of *Prosopis juliflora* but are resistant in the forest.

There were 8 types of palatable annual forbs with a count of 144 out of 16 types of annual forbs with a total of 213 counts. Only 1 palatable perennial forb was present which *Ipomoea cairica*. *Indigofera schimperi* which is an annual forb was the most abundant palatable plant species by proportion of the total number of plants.There were 6.3 at 21%, 0.7 at 54% and 12.9 at 83%. This means this annual forb is resistant to the forest of *Prosopis juliflora,* which promoted its growth than in the open grassland. *Ipomoea cairica* was the most abundant palatable perennial forb plant species by proportion of the total number of plants. They were 0.0 at 21%, 0.0 at 54%, and 100.0 at 83%. The forb is resistant to *Prosopis juliflora* and grow well in the forest but does not grow in the open.

There were 6 types of shrub strippings with a total count of 31. Of these, 4 types were palatable with a count of 28. *Grewia tenax* was the most abundant palatable shrub plant species by proportion of the total number of plants. They were 19.4 at 21%, 0.0 at 54% and 12.9 at 83%. The shrub grows well in the open but decrease in the forest of *Prosopis juliflora*.

There were 4 types of trees with a total count of 241. Of these 4, 3 types were palatable tree strippings with a count of 10 out of the 241 count. The 241 was very high because *Prosopis juliflora* had been classified medium palatable hence not included in the count of palatable plant species. *Salvadora persica* was the most abundant palatable tree plant species by proportion of the total number of plants. They were 0.4 at 21%, 0.8 at 54% and 0.4 at 83%. *Salvadora persica* is not therefore affected by *Prosopis juliflora* whether in a forest or in a grassland.

Site 2: Plain wooded grassland (Ng`ambo)

There were no types of annual grasses in plain wooded grassland. Annual grasses do not withstand the effect of *Prosopis juliflora* in plain wooded grassland. There were only 2 types of perennial grasses; these were *Cynodon dactylon* and *Echinocloa pyramidalis. Cynodon dactylon* was the most abundant palatable plant species by proportion of the total number of plants. They were 0.0 at 21%, 48.9 at 54%, and 4.3 at 83%. *Cynodon dactylon* grow well in a forest of *Prosopis juliflora* but does not withstand a thicket of it in Plain wooded grassland. *Cyperus rotundus* was the only type of perennial sedge present with a count of 402 and was the most abundant palatable plant species by proportion of the total number of plants. They were 0.0 at 21%, 36.6 at 54%, and 63.4 at 83%. This means *Cyperus rotundus* grew well in the forest and moderate forest of *Prosopis juliflora* and did not grow in open plain wooded grassland.There were 21 types of annual forbs with a total of 1102 counts, of these, 11 types were palatable with a count of 708.

There were 2 types of shrubs strippings with a total count of 19, of the 2, *Acalypha fruticosa* is a palatable shrub with a count of 12. It was the most abundant palatable plant species by proportion of the total number of plants. There were 31.6 at 21%, 0.0 at 54% and 31.6 at 83%. *Acalypha fruticosa* can grow in the open and in the forest of *Prosopis juliflora* hence not affected by degree of *Prosopis* canopy.There were 3 types of trees.Out of these, 2 were palatable with a total count of 2. The total count of the 3 was 147. The 147 count was very

high because *Prosopis juliflora* had been classified medium palatable hence not included in the count of palatable plant species. *Balanites aegyptiaca* is the most abundant palatable tree plant species by proportion of the total number of plants.They were 0.7 at 21%, 0.0 at 54%, 0.0 at 83%. This means *Balanites aegyptiaca* was affected by *Prosopis juliflora* as it does not grow in its forest.

Site 3: Hillslopes wooded grassland (Kampi Samaki)

There were 7 types of annual grasses with a total count of 456 and all were palatable. *Digitaria velutina* was the most abundant palatable annual grass plant species by proportion of the total number of plants. They were 18.2 at 21%, 35.1 at 54% and 18.9 at 83%. This means *Digitaria velutina* is affected by *Prosopis juliflora* in the open while in moderate forest it thrives because it is shaded from the harsh rays of the sun by *Prosopis juliflora*. However, it does not thrive in the forest of *Prosopis juliflora*.

The only type of perennial grass present was *Cynodon dactylon* with 10 counts and is palatable. It is a perennial grass and the most abundant palatable plant species by proportion of the total number of plants. They were 0.0 at 21%, 80.0 at 54% and 20.0 at 83%. This means the growth of *Cynodon dactylon* is encouraged by moderate forest of *Prosopis juliflora* but affected by its forest as it growth reduced at 83% and does not grow in an open hillslopes. This is due to hot climate in the hillslopes. There were no annual sedges in the Hillslopes wooded grassland (Kampi Samaki Hills) this is because of the very hot climate in the hillslopes terrain.

Cyperus rotundus was the only type of perennial sedge present, with a count of 182. *Cyperus rotundus* was the most abundant palatable plant species by proportion of the total number of plants. They were 100.0 at 21%, 0.0 at 54% and 0.0 at 83%. *Cyperus rotundus* decreased from the open to the forest. *Cyperus rotundus* is affected by moderate and thick forest of *Prosopis juliflora.* There were 11 types of annual forbs with a total of 99 counts. Of the 11 types, 6 are palatable with a count of 59. *Indigofera schimperi* which is an annual forb and the most abundant palatable plant species by proportion of the total number of plants.They were 14.1 at 21%, 1.0 at 54% and 0.0 at 83%. *Indigofera schimperi* count decreased from the open forest to the thicket meaning that it does not withstand in the forest of *Prosopis juliflora.* There were 7 types of shrub strippings with a total count of 743, of the 7 *Barleria diffusa* is a palatable shrub with a count of 622 and it was the most abundant palatable plant

species by proportion of the total number of plants.They were 18.4 at 21%, 27.2 at 54% and 38.1 at 83%. *Barleria diffusa* count increases from the open forest of *Prosopis juliflora* to the thicket in Hillslopes wooded grassland of Kampi Samaki Hills. It also thrives well in this vegetation of *Prosopis juliflora* probably due to the shade against it provides hot rays from the sun.

Finally, there were 3 types of tree strippings with a total count of 600 of which 2 are palatable with a count of 43. *Acacia tortilis* was the most abundant palatable plant species by proportion of the total number of plants. They were 6.0 at 21%, 0.2 at 54% and 0.5 at 83%. *Acacia tortilis* is affected by *Prosopis juliflora* degree of canopy where the trees decreased from the open wooded grassland to the moderate and forest wooded grassland. If the invasion of *Prosopis juliflora* progresses it would kill all *Acacia tortilis* trees in this type of vegetation.

Discussion of most abundant palatable plant species by proportion of the total number of plants

Table 4.3 above shows the most abundant palatable plant species by proportion of the total number of plants. In the Riverine wooded grassland, *Echinochloa colonum* an annual grass was the most abundant palatable plant species by proportion of the total number of plants, with value of 61.5 at 54% canopy cover. There were no annual grasses in Plain wooded grassland while in the hillslope wooded grassland *Digitaria velutina* decreased as the *Prosopis juliflora* increased from 21% to 83% which means the grass grows well but its growth is affected by *Prosopis juliflora* canopy. *Cynodon dactylon,* a perennial palatable grass, was ranked the topmost in the 3 sites. It decreased from 54% to 83% *Prosopis juliflora* in proportion of the total number of plants as the canopy of *Prosopis juliflora* increased from 54% to 83%. The grass which is the most common palatable perennial grass is affected by *Prosopis juliflora* canopy in the 3 vegetation types.

There were no annual sedges being top most in the 3 sites but *Cyperus rotundus* was found in Riverine wooded grassland and Hillslope wooded grassland. The proportion reduced as the canopy cover increased from 21% to 83%. However, in plain wooded grassland *Cyperus rotundus* increased as the canopy cover increased from 21% to 83% which means in Riverine wooded grassland and hillslope wooded grassland *Prosopis juliflora* affects *Cyperus rotundus* but in the plain wooded grassland encourages its growth.

In the Riverine wooded grassland, *Indigofera schimperi* was the most abundant palatable plant species by proportion of the total number of plants. It's not affected by *Prosopis juliflora* whose value was 6.3 at 21%, 0.7 at 54% and 12.9 at 83% canopy cover. *Indigofera schimperi* grows better in the forest of *Prosopis juliflora*. It was absent in plain wooded grassland while in hillslope wooded grassland its value was 14.1 at 21%, 1.0 at 54% and 0 at 83% of *Prosopis juliflora* canopy cover. This decrease means its growth is affected by *Prosopis juliflora* hence reducing pasture for ruminants in this vegetation. *Ipomoea cairica* was the only palatable perennial forbe and was only found in Riverine wooded grassland with a value of 100 at 83% and 0 at 21% and 53%. This means the plant is not important to ruminants because it is scarce in the 3 sites and in the 3 category *Prosopis juliflora* canopy covers. In riverine wooded grassland *Grewia tenax* (Illgogomi, Toronwee),which is a shrub was the most abundant palatable plant species by proportion of total number of plants where it reduced from value 19.4 at 21% to 0 and to 12.9 at 83%.This indicates that it is affected by *Prosopis juliflora*.

In plain wooded grassland, *Acalypha fruticosa* which is a shrub was the most abundant palatable plant species by proportion of total number of plants with the value 31.6 at 21% and 83% and 0 at 54% canopy cover. This means it is not affected by *Prosopis juliflora* therefore can be selected as ruminant feed in this site. *Barleria diffusa* is the most abundant palatable plant species by propotion of total count in the hillslopes wooded grassland with the value of 18.4 at 21% 27.2 at 54 and 38.1 at 83%. It is increasing with increase of *Prosopis juliflora* canopy. *Barleria diffusa* is not therefore affected by *Prosopis juliflora* hence it promotes its growth in the hillslopes wooded grassland.

Barleria diffusa is a major feed for goats in this vegetation. *Salvadora persica* was the most abundant palatable tree by proportion of total number of plant species in the riverine wooded grassland whose value were 0.4 at 21% and 83% and 0.8 at 54%.This shows that *Salvadora persica* is not affected by *Prosopis juliflora* in this vegetation. The tree can therefore be grown among the *Prosopis juliflora* trees and be used as fodder crop during drought by lopping. *Balanites aegyptiaca* was the most abundant palatable tree in plain wooded grassland with a value of 0.7 at 21% and 0 at 54% and 83%. *Prosopis juliflora* affects the growth of *Balanites aegyptiaca* and hence reduces browse pasture for ruminant during drought in this site. However; it was a palatable tree for ruminant and can be used as their feed.

In the hillslopes wooded grassland, *Acacia tortilis* was the most abundant palatable tree by proportion of the total number of plant species with the values of 6.0 at 21% 0.2 at 54% and 0.5 at 83% under *Prosopis juliflora* canopy cover. *Prosopis juliflora* affects the growth of *Acacia tortilis* because its amount reduced from the open to the forest. *Acacia tortilis* is fodder for goats in the hillslopes wooded grassland and its reduction reduces ruminant feed.

Table 4.3: Most abundant palatable plant species (proportion (%) of the total number of plants)

Site	**Plant Habit**	**Plant species**	**21** Low	**54** Medium	**83** High
Riverine	Annual Grass	*Echinochloa colonum*	0.0	61.5	0.0
wooded	Perennial Grass	*Cynodon dactylon*	45.5	36.6	8.1
grassland	Perennial sedge	*Cyperus rotundus*	58.2	4.1	28.6
	Annual forb	*Indigofera schimperi*	6.3	0.7	12.9
	Perennial forb	*Ipomoea cairica*	0.0	0.0	100.0
	Shrub	*Grewia tenax*	19.4	0.0	12.9
	Tree	*Salvadora persica*	0.4	0.8	0.4
Plain	Perennial Grass	*Cynodon dactylon*	0.0	48.9	4.3
wooded	Perennial sedge	*Cyperus rotundus*	0.0	36.6	63.4
grassland	Annual forb	*Sida ovata*	4.5	28.7	12.9
	Shrub	*Acalypha fruticosa*	31.6	0.0	31.6
	Tree	*Balanites aegyptiaca*	0.7	0.0	0.0
Hillslopes	Annual Grass	*Digitaria velutina*	18.2	35.1	18.9
wooded	Perennial Grass	*Cynodon dactylon*	0.0	80.0	20.0
grassland	Perennial sedge	*Cyperus rotundus*	100.0	0.0	0.0
	Annual forb	*Indigofera schimperi*	14.1	1.0	0.0
	Shrub	*Barleria diffusa*	18.4	27.2	38.1
	Tree	*Acacia tortilis*	6.0	0.2	0.5

Source: Author's finding (2009)

4.4 EFFECTS OF *Prosopis juliflora* DENSITY ON BIOMASS PRODUCTION UNDER *Prosopis juliflora* CANOPY COVER ON GRASSES, SEDGES, FORBS AND SHRUBS AND TREES IN MARIGAT

4.4.1 Descriptive observation of biomass (tonnes/ha) produced by different plant habit observed under different canopy covers of *Prosopis juliflora* in the 3 sites

Table 4.4 shows the quantitative variation of biomass production for different plant habit.

Site 1: Riverine wooded grassland

Lake Kichirtitt was a site representing the lake/riverine terrain with wooded grassland type of vegetation. In table 4.4, grass biomass production declined with increase of *Prosopis juliflora* canopy. The production of grasses decreased from 3.75 tons/ha to 2.5 tons/ha and to 1.72 tons/ha, as *Prosopis juliflora* invasion increased from 21% to 83%. This means that grasses did not withstand the effect of *Prosopis juliflora* as they disappeared in the forest. The production of sedges increased from 0.33 tons/ha to 0.82 tons/ha under canopy 21% to 54% but dropped drastically at 83% as shown in table 4.4 meaning that the *Prosopis juliflora* affected the sedges at 0.2 tons/ha under canopy 83%. In the canopy 21% and 54% sedges withstood the invasion.

Due to high canopy cover in semi-arid lands, most of the herbaceous species were not likely to survive in the shady condition and high moisture competition.The production of forbs declined almost by half from 0.87 tons/ha under 21% to 0.47 tons/ha under 54% and then increased by half to 0.89 tons/ha under 83%. Forbs resisted the effect of *Prosopis juliflora* at high degree of invasion as compared to moderate invasion.

The production of shrub leaves and twigs was affected by *Prosopis juliflora* canopy cover as it dropped drastically from 0.17 tons/ha under 21% to zero under 54% and appeared under 83% with little amounts of 0.07 tons/ha. The production of tree leaves and twigs biomass increased with the degree of *Prosopis juliflora* invasion from 1.10 tons/ha under 21% to 3.01 tons/ha under 54% and increased steadily to 6.23 tons/ha under 83% canopy cover. This is because all the *Prosopis juliflo*ra trees and any other tree in the 12 plots were counted and their production calculated. This was done with the assumption that livestock feed on leaves, flowers, twigs and pods of *Prosopis juliflora.*

Table 4.4: Total Biomass (tonnes/ha) produced by different plant habit under different canopy covers of *Prosopis juliflora* in the 3 sites

Site	Cover (%)	Habit			
		Grasses	Sedges	Forbs	Shrubs
Riverine wooded grassland	**21** Low	3.75	0.33	0.87	0.17
	54 Medium	2.50	0.82	0.47	0.00
	83 High	1.72	0.20	0.89	0.07
Plain wooded grassland	**21** Low	1.25	0.41	4.44	0.02
	54 Medium	0.17	0.06	1.45	0.00
	83 High	0.12	0.10	1.43	0.02
Hillslopes wooded grassland	**21** Low	0.62	0.00	1.23	1.90
	54 Medium	0.20	0.00	0.08	3.03
	83 High	0.13	0.00	0.30	1.18

Source: Author's survey (2009)

Site 2: Plain wooded grassland

Ng'ambo location represented a land of plain terrain with wooded grassland type of vegetation. *Prosopis juliflora* degree of invasion affected the production of grasses progressively. Production dropped 9 times from 1.25 tons/ha under 21% to 0.17 tons/ha under 54% canopy cover and remained at the same level of production 0.12 tons/ha under 83%. Perennial grasses did not therefore withstand the effect of *Prosopis juliflora* from 54% but withstood it under canopy 83% in plain terrain. Sedges were present in all the 3 canopy covers. Their production dropped from 0.41 tons/ha under 21% to 0.06 under 54% and then increased to 0.1 tons/ha under 83%.

The production of sedges was affected by *Prosopis juliflora* but it had some resistance at 83% canopy cover and can therefore withstand the invasion. Forbs reduced almost 4 times from 4.44 tons/ha under 21% to 1.45 tons/ha under 54% and maintained the same level of production at 1.43 tons/ha under 83%. In this plain terrain, forbs did not grow where *Prosopis juliflora* was, thus they were negatively affected by *Prosopis juliflora.* The constant production level under 54% and 83% implies that the growth of forbs tolerates the effects of *Prosopis juliflora*. Due to high canopy cover in semi-arid lands, most of the herbaceous species were not likely to survive in the shady condition and high moisture competition. The production of shrubs and shrub leaves and twigs under 21% is 0.02 tons/ha and dropped to 0 tons/ha under 54%. It then appeared under 83% with the same amount as that under 21% of 0.02 tons/ha. This reveales that the production of shrub leaves and twigs in this site was very little and when it grew it was affected by moderate invasion of *Prosopis juliflora.*

Woody shrubs that were found under canopy 83% are those that were there before *Prosopis juliflora* invasion. Production of tree leaves and twigs increased steadily from 1.29 ton/ha under 21%, 2.81 ton/ha under 54% and 3.65 ton/ha under 83% canopy cover. The production was for all the tree species that were found and stripped in the 12 plots. The production was very high because the tree density of *Prosopis juliflora* was equally high and due to the nature and design of the study which was done in the order of *Prosopis juliflora's* degree of invasion.

Site 3: Hillslope wooded grassland

The production of grasses reduced from 0.62 ton/ha under 21% to 0.2 ton/ha under 54% and 0.13 ton/ha under 83%. Grasses under 21% received direct sunrays which increased the rate

of transpiration. Thus it was higher than that of canopy 54%, which subsequently reduced the growth rate of grasses and biomass production. The production of grasses under 83% was reduced from 0.2 ton/ha under 54% to 0.13 ton/ha under 83%. This indicates that *Prosopis juliflora* affected the growth of grasses by chocking them. It also implies that grasses at 83% did not withstand the stress brought about by *Prosopis juliflora.*

Sedges were absent in canopies 21%, 54% and 83%. The production of forbs dropped from 1.23 ton/ha under canopy covers 21% to 0.08 ton/ha under 54% then it increased to 0.3 tons/ha under 83% canopy cover. The growth of *Prosopis juliflora* therefore reduced the production of annual forbs as it spreads to colonize new places. The production of forbs increased 3 times under canopy cover 83% which means that they can tolerate the effect of *Prosopis juliflora* because the forest cover reduced the sun rays impact on them hence reducing transpiration, thus promoting the growth of forbs under canopy 83% compared to canopy 54% where there was no increase in their growth. Forbs that were resistant to harsh climatic conditions grew under canopy 21% in large numbers because the plant density was low under this canopy. Production of shrub leaves and twigs increased with the increase of *Prosopis juliflora* density from 1.9 ton/ha under 21% canopy to 3.03 ton/ha under 54%. This indicates that low and medium density of *Prosopis juliflora* encouraged their growth. The tall and sparse trees of *Prosopis juliflora*, reduced the intense sun rays reaching the shrubs which happen to be shorter, hence their growth was uninterrupted. However, as the *Prosopis juliflora* density increased to 83% canopy cover, the production reduced from 3.03 ton/ha under 54% to 1.18 ton/ha under 83%.

The high density of *Prosopis juliflora* at 83% canopy cover affected the growth of shrubs and the subsequent reduction in their production. This happened because the tall, dense *Prosopis juliflora* trees prevented the sun's rays from penetrating into the shrubs underneath for photosynthesis to take place. Shrubs carried out inadequate photosynthesis which subsequently reduced the total biomass production of all shrubs under 83% canopy cover. Biomass for the tree leaves and twigs increased steadily from 0.5 ton/ha under canopy cover 21%, to 1.47 ton/ha under 54% and 11.1 ton/ha under 83% canopy cover.

Prosopis juliflora trees contributed to the ultimate total biomass production. This was because the design of the study was done in such a way that the sampling plots (points) had varying densities of *Prosopis juliflora* of 3 categories of canopy covers (21%, 54% and 83%).

Here it was assumed that the total biomass from the tree leaves and twigs was consumable by livestock which included leaves, flowers, pods and small twigs which means that there would be more production of biomass in canopy covers 83% followed by 54%.

4.4.2 Effects of *Prosopis juliflora* cover on biomass production of different types of habit in the 3 sites

Table 4.5 shows effects of *Prosopis juliflora* cover on biomass production of different types of habit in the 3 sites.

Site 1: Riverine wooded grassland (Lake Kichirtitt)

Grasses

Prosopis juliflora cover had no significant (P≤0.05) effect on biomass production of grasses in this site where all grasses are palatable.

Sedges

Prosopis juliflora cover had no significant (P≤0.05) effect on biomass production of sedges in this site. Palatable sedges had more biomass compared to medium palatable species and unpalatable species.

Forbs

Prosopis juliflora cover had no significant (P≤0.05) effect on biomass production of forbs in this site. Palatable forbs had more biomass compared to medium palatable and unpalatable species.

Shrubs

Prosopis juliflora cover had no significant (P≤0.05) effect on biomass production of shrubs in this site. There were no significant biomass differences among palatable, medium palatable and unpalatable species.

Trees

Prosopis juliflora cover had no significant (P≤0.05) effect on biomass production of trees in this site. There were no significant biomass differences among palatable, medium palatable and unpalatable tree species.

Site 2: Plain wooded grassland (Ng'ambo)

Grasses

There was marginal significant (P≤0.05) interaction between *Prosopis juliflora* cover, and the different categories of palatable grass species in determination of biomass production of grasses in this site. Palatable grass species had significantly higher biomass at 21% cover of *Prosopis juliflora* compared to 54% and 83% covers. There were no unpalatable grass species in the site and generally, palatable grass species had higher biomass than medium palatable species.

Sedges

Prosopis juliflora cover had significant (P≤0.05) effect on biomass production of sedges in this site and all the sedges in the site were palatable.

Forbs

Prosopis juliflora cover had a significant (P≤0.05) effect on biomass production of forbs in Riverine wooded grassland of Marigat district. Among the three covers of *Prosopis juliflora*, 21% canopy cover had the highest biomass of forbs compared to 54% and 83%.

Trees

Prosopis juliflora cover had no significant (P≤0.05) effect on biomass production of trees in this site, and all the trees were palatable.

Site 3: Hillslopes wooded grassland (Kampi Samaki) of North Baringo District.

Table 4.5 shows the effects of *Prosopis juliflora* cover on biomass production of different types in habit in Hillslopes wooded grassland.

Grass

The canopy cover of *Prosopis juliflora* had no significant effect (P≤0.05) on biomass production of grass species in this site. It was further observed that, all grasses in the site were palatable.

Forbs

Prosopis juliflora cover did not have a significant (P≤0.05) effect on forbs in this site.

Shrubs

The canopy cover of *Prosopis juliflora* had no significant effect ($P \leq 0.05$) on biomass production of shrub species in this site. All shrubs in this site are palatable.

4.4.3 Discussion on biomass production

The typical vegetations represented are likely to be observed in areas where *Prosopis* occurs in Kenya. The study was conducted 2 months into dry season when plants are expected to have optimum nutrient content, biomass production and right plant diversity. Results for variability of biomass yields and palatability of different plant species shrubs and trees are shown in Table 4.5.

Palatable Plants

There was an increase in palatable plants biomass production, with decrease in canopy cover from the *Prosopis juliflora* forest to the open grassland. This phenomenon was observed in the 3 sites i.e. Riverine wooded grassland, Plain wooded grassland and Hillslope wooded grassland. This means that *Prosopis juliflora* is shading the undergrowth, allowing less sunlight access by the plants, thus minimizing its photosynthetic capacity leading to reduced plant development and eventual reduction in biomass. Cable and Tshirley, (1961) reported that, clearing of forests increases herbaceous biomass yield. This is because of competition for light, water and nutrients, and possible negative chemical effects including allelopathy, the inverse relationship between the effect of tree canopies and herbaceous plant species productivity is possible. Arnold, (1964) found that there was less total herbaceous biomass productivity within the canopy zone than outside the canopy. Sen and Sachwan, (1970) stated that, *Prosopis juliflora* trees inhibit growth of understorey plant species due to phototoxic effects of their leaves. Belsky *et al.*, (1989) reported that, there are lower biomass productions from herbaceous plant species under tree canopies than in the open areas.

Other authors who have similar observations do exist namely, Weltzin and Coughenour, (1990) observed that shading by tree canopy might be the most important factor affecting understorey habit production and composition in African Savanna.

Table 4.5: Effects of *Prosopis juliflora* on biomass production (tonnes / ha) of Palatable, Medium palatable and Unpalatable of different habit in the 3 sites of Marigat and North Baringo Districts

Site	Canopy (%)	Habit	Palatable	Medium palatable	Unpalatable	Mean of *Prosopis juliflora*
Site 1- Riverine wooded grassland Lake kichirtitt	83 High	Grasses	0.411	0.000	0.000	0.137
	54 Medium		0.626	0.000	0.000	0.209
	21 Low		0.937	0.000	0.000	0.312
	Mean of palatability		**0.658**	**0.000**	**0.000**	
	83 High	Sedges	0.051	0.000	0.000	0.017
	54 Medium		0.195	0.010	0.000	0.068
	21 Low		0.083	0.000	0.000	0.028
	Mean of palatability		0.110	0.003	0.000	
	83 High	Forbs	0.101	0.000	0.123	0.074
	54 Medium		0.118	0.000	0.000	0.039
	21 Low		0.149	0.005	0.063	0.072
	Mean of palatability		0.122	0.002	0.062	
	83	Shrubs	0.0179	0.0000	0.0000	0.006
	54 Medium		0.0000	0.0000	0.0000	0.000
	21 Low		0.0405	0.0025	0.0005	0.0145
	Mean of palatability		0.0194	0.0008	0.0002	
	83 High	Trees	0.000	0.362	0.000	0.121
	54 Medium		0.028	0.000	0.000	0.009
	21 Low		0.087	0.000	0.000	0.029
	Mean		0.038	0.121	0.000	
Site 2- Plain wooded grassland Ngambo	83 High	Grasses	0.030	0.000	0.000	0.010
	54 Medium		0.037	0.005	0.000	0.014
	21 Low		0.297	0.014	0.000	0.104
	Mean of palatability		0.121	0.006	0.000	
	83 High	Sedges	0.0257	0.0000	0.0000	0.0086
	54 Medium		0.0158	0.0000	0.0000	0.0053
	21 Low		0.1025	0.0000	0.0000	0.0342
	Mean of palatability		0.0480	0.000	0.000	
	83 High	Forbs	0.256	0.043	0.071	0.123
	54 Medium		0.079	0.038	0.259	0.125
	21 Low		0.331	0.395	0.385	0.370
	Mean of palatability		0.222	0.158	0.238	

Site	Canopy (%)	Habit	Palatable	Medium palatable	Unpalatable	Mean of *Prosopis juliflora*
	83 High	Shrubs	0.00300	0.00156	0.00000	0.00152
	54 Medium		0.00000	0.00000	0.00000	0.00000
	21 Low		0.00375	0.00100	0.00000	0.00158
	Mean of palatability		0.00225	0.00085	0.0000	
	83 High	Trees	0.001	0.000	0.000	0.000
	54 Medium		0.000	0.000	0.000	0.000
	21 Low		0.191	0.000	0.000	0.064
	Mean of palatability		0.064	0.000	0.000	
Site 3-Hillslopes wooded grassland Kampi samaki	83 High	Grasses	0.0396	0.0000	0.0000	0.0132
	54 Medium		0.0473	0.0000	0.0000	0.0158
	21 Low		0.0450	0.0000	0.0000	0.050
	Mean of palatability		0.0440	0.0000	0.0000	
	83 High	Forbs	0.063	0.002	0.015	0.027
	54 Medium		0.026	0,0	0.005	0.01
	21 Low		0.033	1.12	0.185	0.112
	Mean of palatability		0.04	0.041	0.068	
	83 High	Shrubs	0.294	0.000	0.000	0.098
	54 Medium		0.750	0.000	0.000	0.250
	21 Low		0.476	0.000	0.000	0.159
	Mean of palatability		0.506	0.000	0.000	
	83 High	Trees	0.01727	0.00000	0.00000	0.00576
	54 Medium		0.00633	0.00000	0.00000	0.00211
	21 Low		0.00240	0.00000	0.00000	0.00080
	Mean of palatability		0.00867	0.0000	0.0000	

Source: Author's findings (2013)

Harrington and John, (1990) observed that, herbaceous biomass was negatively co-related with canopy density of eucalyptus species and attributed this phenomenon to the combined effects of shading and chemicals contained in leaves of eucalyptus trees on the understorey herbaceous plant species. Wasonga, (2001) observed less herbaceous vegetation production under the canopy of *Balanites glabra*, than in the zone outside the canopy. Other observers have given explanations related to chemical reactions. Kahi, (2004) observed that, *Acacia tortilis* and *Prosopis juliflora* are alellopathic in nature and this may also partly explain the relatively low biomass production of herbaceous plant species obtained under the tree canopies.

Medium palatable biomass

It was observed that, there was an increase in biomass production of medium palatable plants with increase in canopy cover of *Prosopis juliflora* as one moves into the forest in the 3 sites i.e. Riverine wooded grassland, Plain wooded grassland and Hillslope wooded grassland. The *Prosopis juliflora* forest trees yielded leaves that were partially palatable especially when drying just before they are shed and also shortly after being shed. The trees were not shaded hence their photosynthetic capacity and that of the undergrowth was not affected. For this reason, there were fewer plant species compared in the forest because of the minimal photosynthetic capacity. Heady, (1960) reported that, heavy bush thickets reduced herbaceous pasture production and that most pasture produced in dense thickets was invariably inaccessible to livestock. Cable and Tshirley, (1961) reported that, clearing of forests increases herbaceous biomass yield. This is because of competition for light, water and nutrients, and possible negative chemical effects including allelopathy, the inverse relationship between the effect of tree canopies and herbaceous grasses, sedges, forbs productivity is possible.

Arnold, (1964) found that there is less total herbaceous biomass productivity within the canopy zone than outside the canopy. Belsky *et al.,* (1989) reported that there is lower biomass production from herbaceous plant species under tree canopies, than in the open areas. Boutton *et al.,* (1998) observed that plant development is normally limited by low soil moisture. It is noted that the medium palatable biomass production is higher in quantity, than the palatable and unpalatable. This is important for ruminants during time of drought when they feed on the less palatable but available plants. Thus they serve as conserved pasture for ruminants. However, the *Prosopis* thickets are mildly palatable plants and where thorns are

not too restrictive they could serve as a nutritive need for ruminants in the dry season or drought conditions. In this case, ruminants could move from the open grasslands into the denser *Prosopis juliflora* forest. However, livestock access to medium palatable plants in the *Prosopis juliflora* forest is difficult because the thickets are thorny and thus there is more biomass in the forest than in the open grassland where animals get access to all medium palatable plants.

Unpalatable Plants

There was a decrease in unpalatable plant biomass production in the Riverine wooded grassland with decrease in *Prosopis juliflora* canopy cover. The periodic flooding of the shores of Lake Kichirtitt choked plants when River Ewasonanyokie (Molo River) flooded its banks, thus minimizing plant growth. Cooper, (1959) predicted that, no herbaceous would be found at canopy density above 75%. This explains the reduction of biomass of unpalatable plants in the forest of *Prosopis juliflora* in Riverine wooded grassland. The shade minimized photosynthetic capacity of undergrowth leading to reduced plant development and eventual reduction in biomass. Kinyamario *et al.,* (1995) observed that understorey plant species composition was generally different from that of the area immediately outside the canopy. An increase in biomass production with decrease in *Prosopis juliflora* canopy cover in the Plain wooded grassland and Hillslopes wooded grasslands was observed.

In contrast, the canopy cover in the other two areas assists in moisture conservation in the soil and reduced transpiration promoting higher plant growth, especially of the annuals Kinyamario *et al.,* (1995). The biomass production of plant species increased with decreased canopy covers because the annual and perennial plants got greater illumination of sunlight for photosynthesis. Ratiff *et al.,* (1991) stated that, explanations for the complex and often beneficial interaction between woody and herbaceous plants were largely fallacious and overly simplistic. There were subtle relationships that were not easy to observe and when observed, they were not easily explained. Pieper, (1990), reported that canopy of the woody plant was viewed as critical factor in the evolution of herbaceous layer characteristic. This could explain the increase of unpalatable plants biomass in the forest of *Prosopis juliflora* in the Plain wooded grassland and Hillslopes wooded grasslands which could have evolved herbaceous layer characteristics.

General discussion on the effect of *Prosopis juliflora* density on palatable biomass production of grazing natural pasture and browse species in Marigat

In Table 4.6(a) (b) the study revealed that, the biomass of grasses and sedges in Riverine wooded grassland and Plain wooded grassland reduced as the canopy increases while in Hillslopes wooded grassland the *Prosopis juliflora* encouraged their growth but reduced at 83%. It was observed that grasses are more efficient than trees in extracting water from the upper layers of the soil, while below the grass root zone (sub-soil) woody vegetation has nearly exclusive access to the water that exists there (Moore, 1960).

In the Riverine wooded grassland and Hillslopes wooded grassland, biomass production of forbs was constant irrespective of the percentage canopy cover but in the Plain wooded grassland, production decreased with increased canopy. This was probably due to the variation of species of the plains which are 21 trees. Heady, (1960), Thomas and Pratt, (1967) reported that heavy bush thickets reduce herbaceous pasture production and that most pasture produced in dense thickets is invariably inaccessible to livestock. The shrubs decreased with increased canopy in the Riverine wooded grassland but they were constant in the Plain wooded grassland and Hillslopes wooded grassland. Smoliak, (1956) observed that potential understorey biomass yields might be reduced by the effect of associated shrubs and trees.

It was observed that the number of trees increased with the increase in canopy covers in the 3 sites. This confirmed that *Prosopis juliflora* was an invasive plant species because they grew very fast and become trees in a short time such that open grassland becomes wooded grassland within 4 years. It was observed that *Prosopis juliflora* out-competes other native palatable and thus can spread easily. Studies in South Africa have shown that with good rainfall, the recruitment rate in *Prosopis* species and native species of plants is a serious problem in arid areas, (Harding and Bate, (1991).

4.4.4 Interpretation of results on biomass

Effects of Prosopis juliflora cover on biomass production of different habit in the 3 sites

In the ANOVA Table 4.6 (b), the dry matter is significantly ($P<0.05$) influenced by cover, cohabit and palatability. Results on effect of canopy cover and cohabit on biomass (tonnes/ha) shows that, there is a significant ($P<0.05$) difference with decrease of canopy cover of *Prosopis juliflora*, from 83%, 54% and 21% for all the sites. This means that the

83% *Prosopis juliflora* canopy cover could be shading the undergrowth, allowing less sunlight access by the plants, thus minimizing its photosynthetic capacity leading to reduced plant development and eventual reduction in biomass compared to 54% and 21% canopy cover.

Table 4.6 (a): The effect of canopy cover on biomass yields (tonnes/ha, DM) of palatable, medium palatable and unpalatable palatable species

		Yield DM MT/ha		
Palatability	**Canopy, %**	**Lake Kichirtitt (site 1)**	**Ng'ambo (site 2)**	**Kampi Samaki (site 3)**
Palatable	65-100	0.08	0.07	0.07
Palatable	31 – 64	0.15	0.04	0.11
Palatable	0 - 30	0.18	0.13	0.10
Medium	65-100	1.56	0.38	2.20
Medium	31 – 64	0.59	0.30	0.28
Medium	0 - 30	0.12	0.17	0.20
Unpalatable	65-100	0.08	0.04	0.01
Unpalatable	31 – 64	.	0.09	0.02
Unpalatable	0 - 30	0.05	0.13	0.37

Table 4.6 (b): Tests of Between-Subjects Effects

Dependent Variable: (tonnes/ha, DM)

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	34.552(a)	29	1.191	18.005	.000
Intercept	1.701	1	1.701	25.698	.000
Cover	.818	2	.409	6.179	.002
Cohabit	3.997	4	.999	15.100	.000
Palatable	.476	2	.238	3.598	.029
Cover * Cohabit	3.684	8	.461	6.960	.000
Cover * Palatable	1.560	4	.390	5.892	.000
Cohabit * Palatable	4.470	5	.894	13.511	.000
Cover * Cohabit * Palatable	4.841	4	1.210	18.290	.000
Error	20.051	303	.066		
Total	65.671	333			
Corrected Total	**54.603**	**332**			

A R Squared = .633 (Adjusted R Squared = .59)

4.5 INFLUENCE OF *Prosopis juliflora* DENSITIES ON COMPOSITION AND COUNTS OF GRASSES, SEDGES, FORBS, SHRUBS AND TREES IN MARIGAT

4.5.1 Descriptive observation and discussion on count of different habit under different canopy covers of *Prosopis juliflora*

Palatability is the relish that an animal shows for a particular plant species, plant or plant part. The results for variability of counts, site, habit, cover and palatability of habit are shown in Table 4.7 below and also indicates the total number of different habit (habit) under each canopy.

In Table 4.7 below there was a steady increase of plants counts with steady decrease in canopy cover.

Palatable Grasses

Annual and perennial grasses

In riverine wooded grassland there is a steady increase in palatable grass counts with a steady decrease in canopy cover from *Prosopis juliflora* forest to the scattered tree area. This is because the forest *Prosopis juliflora* is shading the undergrowth, allowing less sunlight accessed by the plants, thus minimizing its photosynthetic capacity leading to reduced plant development and eventual reduction in palatable grass counts especially perennial grasses in the forest of *Prosopis juliflora.* It is normal because the riverine wooded grassland is generally wet most of the time in the year and plants are expected to grow when there is adequate lighting and water. Cox and Waithaka, (1989) reported that, energy flux from the sun is more important in terms of plant development where growth period is experienced per year. In contrast, production in the tropics can take place throughout the year (Jacoby, et al., 1982). There is higher herbage production away from *Prosopis glandulosa torr*. trunk than near it in Texas rangelands which attributed the findings to the competition between the trees and associated grasses for moisture. Some studies have shown pasture production is often reduced by trees that compete with understorey plant species for water nutrients and light demonstrating an inverse relationship between the tree canopy and herbaceous understorey.

Table 4.7: Counts of of plant stands of different habits observed under different canopy covers of *Prosopis juliflora* (count/ha) in the 3 sites

			Habit (Counts Per ha (000))				
Site	**Cover%**	**Palatability**	**Grasses**	**Sedges**	**Forbs**	**Shrubs**	**Trees**
Riverine Wooded Grassland	100-65	Palatable	77.1	122.5	16.2	0.1	0.0
		Medium palatable	0.0	0.0	0.0	0.0	0.8
		Unpalatable	0.0	0.0	21.1	0.0	0.0
	31-64	Palatable	142.7	165.0	21.1	0.0	0.0
		Medium palatable	0.0	3.3	0.0	0.0	0.5
		Unpalatable	0.0	0.0	6.7	0.0	0.0
	0-30	Palatable	196.3	381.1	34.8	0.1	0.0
		Medium palatable	0.0	0.0	13.3	0.1	0.2
		Unpalatable	0.0	0.0	20.8	0.0	0.0
Plain wooded Grassland	100-65	Palatable	14.4	232.5	90.0	0.2	0.0
		Medium palatable	0.0	0.0	4.4	0.0	0.4
		Unpalatable	0.0	0.0	29.0	0.0	0.0
	31-64	Palatable	145.6	122.5	154.3	0.0	0.0
		Medium palatable	6.7	0.0	6.0	0.0	0.4
		Unpalatable	0.0	0.0	56.7	0.0	0.0
	0-30	Palatable	181.1	845.8	33.3	0.2	0.0
		Medium palatable	11.7	0.0	15.3	0.1	0.1
		Unpalatable	0.0	0.0	48.3	0.0	0.0
Hillslope wooded grassland	100-65	Palatable	61.0	0.0	19.4	188.7	0.0
		Medium palatable	0.0	0.0	13.3	0.0	1.6
		Unpalatable	0.0	0.0	15.6	0.0	0.0
	31-64	Palatable	56.7	0.0	18.7	64.1	0.0
		Medium palatable	0.0	20.0	0.0	0.0	1.5
		Unpalatable	0.0	0.0	103.3	0.0	0.0
	0-30	Palatable	43.7	606.7	6.7	23.4	0.2
		Medium palatable	0.0	0.0	3.3	3.3	0.4
		Unpalatable	0.0	0.0	15.0	0.0	0.0

Source: Author' findings (2013)

Category A: Steady Increase of plants counts with steady decrease in canopy cover

In Plain wooded grassland there is a steady increase in palatable grass counts with decrease in canopy cover from *Prosopis juliflora* forest to the scattered tree area. This is because the forest of *Prosopis juliflora* is shading the undergrowth, allowing less sunlight accessed by the plants, thus minimizing its photosynthetic capacity leading to reduced plant development and eventual reduction in palatable grass counts especially perennial grasses in the forest of *Prosopis juliflora*. It is normal because the plain wooded grassland is generally moist most of the time in the year and plants are expected to grow when there is adequate lighting and water.

Lee (1978) pointed out that a dense forest canopy drastically modifies the climate of the underneath, especially net radiation, wind speed and amount of precipitation. He stated that on average, rainfall deficits under mature hardwood canopies may vary from less than 10% during the leafless period, to more than 20% during the growing season, while the relative humidity under the canopy exceeds that of the area immediately outside the canopy. Ellison and Houston (1958) noted an inverse relationship between the tree canopy and herbaceous understorey. Weltzin and Coughenour, (1990) observed that shading by tree canopy might be the most important factor affecting understorey habit production and composition in African Savanna. Some studies have shown pasture production is often reduced by trees that compete with understorey plant species for water nutrients and light.

Medium palatable Grasses

These are plants that are rarely consumed by grazing and browsing livestock in the free range and do not form the bulk of feed to ruminants. They are medium palatable because of tannins which have a propensity to form insoluble complexes with proteins which reduces the digestibility of pastures by inhibiting digestive enzymes as well as causing a decrease in protein availability to the animal (McLeod, 1974).

Annual and perennial grasses

In Plain wooded grassland there is a steady increase in medium palatable grass counts from 0.0 to 6.7 and then to 11.7 with decrease in canopy covers from *Prosopis juliflora* forest to the scattered tree area. This is because the forest of *Prosopis juliflora* is providing complete shading to the undergrowth, allowing less sunlight accessed by the plants, thus minimizing its photosynthetic capacity leading to reduced plant development and eventual reduction in

medium palatable grass counts in the forest of *Prosopis juliflora* while from the medium canopy cover to the open area, the medium palatable grass counts continue to increase steadily with decrease in canopy cover because there is the availability of sunlight thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase in medium palatable grass counts. It is normal because whenever there is complete shading plants do not grow (Moore, 1960). Herbaceous and shrub species co-existing competed for soil moisture supplies and at the same time shared the favourable effects arising from the joint microclimatic (Georgiadis, 1989).

Sub-canopy soil had five times more nitrogen and twice the amount of carbon than in areas immediately outside canopy and also soils under tree canopy had higher pH than those nearby open area. Pressland (1973) recorded a six-fold increase in the amount of water trapped in the sub-soil below a tree canopy, compared to that trapped in the area outside the canopy.

Palatable sedges

Annual and perennial Sedges

In Riverine wooded grassland; there is a steady increase in palatable sedge counts from forest of *Prosopis juliflora* to the open area with decrease in canopy cover. This is because from the forest of *Prosopis juliflora* to the open area there is a steady clearance which gives way to sunlight which maximizes its photosynthetic capacity leading to increased plant development and eventual increase in sedge counts in the Riverine wooded grassland thus contributing to the high number of palatable sedges in the open areas. In addition, in the forest of *Prosopis juliflora* the count of palatable sedges are not affected by periodic flooding of the shores of Lake Kichirtitt which chokes plants when River Ewasonanyoike (Molo River) floods its banks because there are some sedges whose habitat is in water and in wetlands. Weltzin and Coughenour (1990) observed that, shading by tree canopy might be the most important factor affecting understorey habit production and composition in African Savanna. Gachanja (1996) reported that, different tree or shrub densities with their associated canopy cover have variable effects on herbaceous plant cover and production, with the amount of available pasture being reduced by competition as density increases. Harding and Bate (1991) reported that, *Prosopis juliflora* discourages grass growth displacing native plant communities and reducing the grazing potential of invaded patches. Jacoby, (1986) reported that, the woody vegetation has an extensive root system, often accompanied by a deep taproot, high sprouting

ability, and reduced palatability. These characteristics provide competitive advantage to trees over grasses and forbs for drought survival.

Palatable Forbs

Annual and perennial forbs

In Riverine wooded grassland there is an increase in palatable forb counts with decrease in canopy cover from *Prosopis juliflora* forest to the scattered tree area. This is because the forest of *Prosopis juliflora* is shading the undergrowth, allowing less sunlight accessed by the plants, thus minimizing its photosynthetic capacity leading to reduced plant development and eventual reduction in palatable forb counts and also this is a vegetation that thrives by growing in numerous number and mature very fast contributing to the high number of palatable forb counts.

It is normal because the riverine wooded grassland is generally wet most of the time in the year allowing continous growth and getting adequate sunlight as you move from the forest Burrows (1990). Some studies have shown pasture production is often reduced by trees that compete with understorey plant species for water nutrients and light. Sub-canopy soil had five times more nitrogen and twice the amount of carbon than in areas immediately outside canopy and also soils under tree canopy had higher pH than those nearby open area. Lee (1978) pointed out that, a dense forest canopy drastically modifies the climate of the underneath, especially net radiation, wind speed and amount of precipitation. He found out that on average, rainfall deficits under mature hardwood canopies may vary from less than 10% during the leafless period, to more than 20% during the growing season, while the relative humidity under the canopy exceeds that of the area immediately outside the canopy.

Medium palatable

Annual and perennial forbs

In plain wooded grassland there is an increase in medium palatable forbs counts with decrease in canopy cover from the *Prosopis juliflora* forest to the open grassland. This is because the forest of *Prosopis juliflora* is shading the undergrowth, allowing less sunlight accessed by the plants, thus minimizing its photosynthetic capacity leading to reduced plant development and eventual reduction in medium palatable forb counts in the *Prosopis juliflora* forest. It is normal because the plain wooded grassland is generally moist most of the time in the year allowing continous growth and getting adequate sunlight as you move from the

forest. Ellison and Houston (1958), noted an inverse relationship between the tree canopy and herbaceous understorey. Weltzin and Coughenour (1990), observed that, shading by tree canopy might be the most important factor affecting understorey habit production and composition in African Savanna. Jacoby, *et al.,* (1982), reported that, there is higher herbage production away from *Prosopis glandulosa Torr.* trunk than near it in Texas rangelands which attributed the findings to the competition between the trees and associated grasses for moisture.

Category B: Steady decrease of plants counts with steady decrease in canopy cover

In Table 4.7 above there was a Steady decrease of plants counts with steady decrease in canopy cover.

Palatable Grasses

Annual and perennial grasses

In hillslopes wooded grassland there is a decrease in palatable grass counts with decrease in canopy cover from the *Prosopis juliflora* forest to the open areas. This is because in the *Prosopis juliflora* forest, the *Prosopis juliflora* shading encourages the growth and survival by assisting in moisture conservation in the soil and reduces transpiration promoting higher plant growth especially the annual grasses and low counts in the open area. It is normal because the hillslope wooded grassland is dry most of the time in the year experiencing inadequate moisture in the soil and increased transpiration thus reducing plant growth and low counts in the open area.

Wenner (1981), reported that, areas under the canopies of *Prosopis juliflora* trees had a dense stand of perennial grass cover (24% more than areas outside the canopies). Moore (1960), observed that, co-existing herbaceous and shrub species competed for soil moisture supplies and at the same time shared the favourable effects arising from the joint microclimatic. Coughenour *et al.,* (1990), reported that, trees shades reduce heat loads on both human and animals and reduce potential evapo-transpiration rates, thereby reducing the potential moisture stress for the sub-canopy herbaceous plants. Angus, (1958), reported that, trees by virtue of their height attract more dew than grasses which grow below them. Bhatia *et al.,* (1998), observed that, *Prosopis* fix atmospheric nitrogen in the soil, and contributes to organic carbon and phosphorous build up.

Palatable Forbs

Annual and perennial forbs

In hillslopes wooded grassland there is a decrease in palatable forb counts with decrease in canopy cover from the *Prosopis juliflora* forest to the open areas. This is because in the *Prosopis juliflora* forest, the *Prosopis juliflora* shading encourages the growth and survival by assisting in moisture conservation in the soil and reduces transpiration promoting higher plant growth especially the annuals and low counts in the open area. It is normal because the hillslope wooded grassland is dry most of the time in the year. Le Houerou (1989), reported that, although shrubs and trees are the most visible forms of plant life in arid lands, they have been neglected in most scientific research and land management policies.

Palatable Shrubs

Dwarf and tall shrubs

In the hillslope wooded grassland there is a steady decrease in palatable shrub counts with decrease in canopy cover from the *Prosopis juliflora* forest to the very open grassland. This is because *Prosopis juliflora* trees and other trees are studded in the hillslopes wooded grassland hence they grow in numerous number contributing to the high count of palatable shrubs in the forest and also the *Prosopis juliflora* shading encourages the growth and survival of palatable plant species by assisting in moisture conservation in the soil and reduce transpiration promoting higher plant growth in the forest of *Prosopis juliflora* while in the medium canopy and the open area, the palatable shrubs counts continue to decrease because there is little moisture conservation and also due to the hot and very dry climate in this terrain hence the palatable shrub counts is lower than in the forest. It is not normal because the growth of palatable shrubs is encouraged by shading in the hillslope wooded grassland which is a rocky terrain and dry land most of the time in the year.

Burrows (1993), argued that, there is beneficial contribution of woody species to the fragile savanna ecosystems especially where trees are spatially distributed within the grasslands (trees are cleared from rangeland by expensive mechanical and chemical techniques without considering the effect of such practice on the fragile arid and semi-arid ecosystem). Medina (1982), reported that, globally, two main plant life form exist: grasses and woody plants. These two have different requirements and frequently occupy distinct niches.

Menault, *et al.,* (1985), reported that, in Africa savannas are characterized by the presence of a continuous graminoid stratum and a discontinuous woody stratum that forms the upper canopy of the vegetation. Pressland (1976); Maranga (1986), reported that, raindrops are intercepted by tree canopies, reducing their impact, and therefore, influencing infiltration rate, amount of runoff and total soil moisture storage. Kinyamario *et al.,* (1995), observed that, the canopy cover in the other two areas assists in moisture conservation in the soil and reduced transpiration promoting higher plant growth. Lee (1978), pointed out that, a dense forest canopy drastically modifies the climate of the underneath, especially net radiation, wind speed and amount of precipitation. He found out that on average, rainfall deficits under mature hardwood canopies may vary from less than 10% during the leafless period, to more than 20% during the growing season, while the relative humidity under the canopy exceeds that of the area immediately outside the canopy.

Medium palatable trees

In riverine wooded grassland there is a decrease in medium palatable tree counts with decrease in canopy cover from the *Prosopis juliflora* forest to the open areas. This is because *Prosopis juliflora* trees are categorized as medium palatable hence they grow in numerous numbers in the forest than in the open areas thus contributing to the high count of medium palatable trees in the forest than in the open areas. It is normal because naturally in the forest of *Prosopis juliflora* there are more individual trees than in the open areas. Nye (1961), reported that, under moist tropical forests, the net annual contribution of dead roots was approximately at 2,600kg ha^{-1}. Apart from the direct contribution of the woody species to the soil nutrients around the canopy, spatial transfer of nutrients is considerable even under normal grazing practices. Moore (1960), observed that, co-existing herbaceous and shrub species competed for soil moisture supplies and at the same time shared the favourable effects arising from the joint microclimatic. Bhatia and Sharma (1998), observed that *Prosopis* fix atmospheric nitrogen in the soil, and contributes to organic carbon and phosphorous build up.Tiedmann and Klemmedson (1973), reported that, perennial plants, particularly shrubs, tend to accumulate soil nutrients beneath their canopies.

Swain (1979), reported that, most browses are known to contain relatively high quantities of tannins which are known to depress browse intake by decreasing its palatability and/or reducing the digestibility of proteins associated with them. McLeod (1974), reported that, tannins have a propensity to form insoluble complexes with proteins reduces the digestibility

of pastures by inhibiting digestive enzymes as well as causing a decrease in protein availability to the animal. Aggarwal (1980), reported that, soils under *Prosopis cineraria* have organic matter, nitrogen and micronutrients than soils in the open areas.

In plain wooded grassland there is a decrease in medium palatable tree counts with decrease in canopy cover from the *Prosopis juliflora* forest to the open areas. This is because *Prosopis juliflora* trees are categorized as medium palatable hence they grow in numerous numbers in the forest than in the open areas thus contributing to the high count of medium palatable trees in the forest than in the open areas. It is normal because naturally in the forest of *Prosopis juliflora* there are more individual trees than in the open areas. Kinyamario and Macharia (1992), observed that, production in the tropics can take place throughout the year and is normally limited by precipitation.

Pressland (1976), reported that, raindrops are intercepted by tree canopies, reducing their impact, and therefore, influencing infiltration rate, amount of runoff and total soil moisture storage. Angus (1958), reported that, trees by virtue of their height attract more dew than grasses which grow below them. Kinyamario *et al.,* (1995), observed that, the canopy cover in the other two areas assists in moisture conservation in the soil and reduced transpiration promoting higher plant growth. Aggarwal (1980), reported that, soils under *prosopis cineraria* have organic matter, nitrogen and micronutrients than soils in the open areas.

McLeod (1974), reported that tannins have a propensity to form insoluble complexes with proteins reduces the digestibility of pastures by inhibiting digestive enzymes as well as causing a decrease in protein availability to the animal. Jacoby (1986), reported that, the woody vegetation has an extensive root system, often accompanied by a deep taproot, high sprouting ability, and reduced palatability. These characteristics provide competitive advantage to trees over grasses and forbs for drought survival.

In hillslopes wooded grassland there is a decrease in medium palatable tree counts with decrease in canopy cover from the *Prosopis juliflora* forest to the open areas. This is because *Prosopis juliflora* trees are categorized as medium palatable thus at 83% canopy cover they form a high count of medium palatable trees in the forest and subsequently decrease with decrease in canopy cover thus low counts in the open area. It is normal because the hillslope

wooded grassland is dry most of the time in the year experiencing inadequate moisture in the soil and increased transpiration reducing plant growth and low counts in the open area.

Moore (1960), observed that, co-existing herbaceous and shrub species competed for soil moisture supplies and at the same time shared the favourable effects arising from the joint microclimatic. Kinyamario and Macharia (1992), observed that, production in the tropics can take place throughout the year and is normally limited by precipitation. Pressland (1976), reported that, raindrops are intercepted by tree canopies, reducing their impact, and therefore, influencing infiltration rate, amount of runoff and total soil moisture storage. Angus (1958), reported that, trees by virtue of their height attract more dew than grasses which grow below them. Kinyamario *et al.,* (1995), observed that, the canopy cover in the other two areas assists in moisture conservation in the soil and reduced transpiration promoting higher plant growth. Aggarwal (1980), reported that, soils under *prosopis cineraria* have organic matter, nitrogen and micronutrients than soils in the open areas.

Kellman (1979), reported that, one of the advantages commonly associated with tree canopy/herbaceous layer interaction is the improvement of soil fertility through addition of nitrogen and organic matter.

Category C: Increase of plants counts with decrease of canopy from the forest to the medium canopy area followed by a decrease from the medium canopy area to the open area

In Table 4.7 above there was an increase of plants counts with decrease of canopy from the forest to the medium canopy area followed by a decrease from the medium canopy area to the open area.

Medium palatable Sedges

Annual and perennial Sedges

In the Riverine wooded grassland; there is a steady increase in medium palatable sedge counts from 0.0 to 3.3 from the forest of *Prosopis juliflora* to the medium canopy and then drops to 0.0 from the medium canopy area to the open area with decrease in canopy cover. In the forest of *Prosopis juliflora* there are no medium palatable sedges because of their fragility. They are therefore affected by periodic flooding of the shores of Lake Kichirtitt which chokes plants when River Ewasonanyoike (Molo River) floods its banks thus

minimizing plant growth and also there is complete shading of plants in the forest of *Prosopis juliflora* which minimizes photosynthetic capacity of undergrowth leading to reduced plant development and eventual reduction in medium palatable sedge counts. In the medium canopy cover, the medium palatable sedge counts is high because *Prosopis juliflora* shading encourages growth by alienating the direct sun rays that could have studded the plant and also it assists in moisture conservation in the soil and reduced transpiration promoting higher plant growth, especially of the annuals.

On the contrary, in the open areas where there is few *Prosopis juliflora* trees, the medium palatable sedge counts drops to 0 because there is little shading of the undergrowth that encourages undergrowth growing by conserving moisture and shading that alienate the direct sun rays that kills the plant. It is normal because of the floods and complete shading that kill the medium palatable sedges in the forest of *Prosopis juliflora*. Bhatia *et al.*,(1998), observed that, *Prosopis* fix atmospheric nitrogen in the soil, and contributes to organic carbon and phosphorous build up.

In the hillslopes wooded grassland, there is a steady increase in medium palatable sedge counts from 0.0 to 20.0 from the forest of *prosopis juliflora* to the medium canopy and then drops to 0.0 from the medium canopy area to the open area with decrease in canopy cover. In the forest of *Prosopis juliflora* there are no medium palatable sedges because there is complete shading of plants in the forest of *Prosopis juliflora* which minimizes photosynthetic capacity of undergrowth leading to reduced plant development and eventual reduction in medium palatable sedge counts. On the medium canopy cover, the medium palatable sedge counts is high because *Prosopis juliflora* shading encourages growth by alienating the direct sun rays that could have studded the plant and also it assists in moisture conservation in the soil and reduced transpiration promoting higher plant growth, especially of the annuals.

On the contrary, in the open areas where there is few *Prosopis juliflora* trees, the medium palatable sedge counts drop because there is little shading of the undergrowth that encourages undergrowth growing by conserving moisture and shading that alienate the direct sun rays that studded the plant. It is not normal because in the open areas there is zero medium palatable sedge count and we expect them to grow because there is no complete shading. Benhard-Reversat (1982), concluded that, trees are an important ecological component that maintains soil fertility as a result of nitrogen fixation and accumulation of organic matter

through litter fall. Bhatia *et al.*, (1998), observed that, *Prosopis* fix atmospheric nitrogen in the soil, and contributes to organic carbon and phosphorous build up.

Lee, (1978), pointed out that, a dense forest canopy drastically modifies the climate of the underneath, especially net radiation, wind speed and amount of precipitation. He found out that on average, rainfall deficits under mature hardwood canopies may vary from less than 10% during the leafless period, to more than 20% during the growing season, while the relative humidity under the canopy exceeds that of the area immediately outside the canopy.

Palatable Forbs

Annual and perennial forbs

In the plain wooded grassland there is an increase in palatable forb counts with decrease in canopy cover from the *Prosopis juliflora* forest to the medium open grassland. However, it drops drastically from the medium canopy to the open areas with decrease in canopy cover. This is because in the forest of *Prosopis juliflora*, the *Prosopis juliflora* shading encourages the growth and survival of some types in palatable forbs that do not require much sunlight by assisting in moisture conservation and reducing transpiration thus promoting higher plant growth. In the medium canopy cover, the palatable forb counts is high because *Prosopis juliflora* shading encourages growth by alienating the direct sun rays that assists in moisture conservation in the soil and reduce transpiration and also there is maximum photosynthetic capacity leading to increased plant development and eventual increase in palatable forb counts in the plain wooded grassland. On the contrary, open areas where there are few *Prosopis juliflora* trees, the palatable forb counts drop because there is little shading of the undergrowth that encourages undergrowth growing by conserving moisture. It is not normal because at 54% canopy cover plants count is expected to reduce but in this case it has increased one and a half times in plain wooded grassland terrain.

Pratt and Gwaynne (1977), observed that, areas with different production potentials also respond differently to the canopy covers in terms of productivity this is important because rangeland are inherently heterogeneous comprising a mosaic of different range sites. Jeltsch *et al.*, (1996), reported that, different herbaceous plant species will respond differently to different types of tree canopies. Bhatia *et al.*, (1998), observed that *Prosopis* fix atmospheric nitrogen in the soil, and contributes to organic carbon and phosphorous build up.

Unpalatable Forbs

Annual and perennial forbs

In the plain wooded grassland there is an increase in unpalatable forb counts with decrease in canopy cover from the *Prosopis juliflora* forest to the medium open grassland. However, it drops drastically from the medium canopy to the open areas with decrease in canopy cover. This is because in the forest of *Prosopis juliflora*, the *Prosopis juliflora* shading encourages the growth and survival of some types of unpalatable forbs that do not require much sunlight by assisting in moisture conservation and reducing transpiration thus promoting higher plant growth. In the medium canopy cover, the unpalatable forb counts is high because *Prosopis juliflora* shading encourages growth by alienating the direct sun rays that assists in moisture conservation in the soil and reduce transpiration and also there is maximum photosynthetic capacity leading to increased plant development and eventual increase in unpalatable forb counts in the plain wooded grassland. On the contrary, open areas where there is few *Prosopis juliflora* trees, the unpalatable forb counts drop because there is little shading of the undergrowth that encourages undergrowth growing by conserving moisture hence reduced atmospheric nitrogen fixing in the soil. It is not normal because at 54% canopy cover plants count is expected to reduce but in this case it has increased twice in plain wooded grassland terrain. Jeltsch *et al.,* (1996), reported that, different herbaceous plant species will respond differently to different types of tree canopies. Coughenour, *et al.*, (1990), reported that, trees shades reduce heat loads on both human and animals and reduce potential evapo-transpiration rates, thereby reducing the potential moisture stress for the sub-canopy herbaceous plants.

In the hillslope wooded grassland, there is a drastic increase in unpalatable forb counts with decrease in canopy cover from the *Prosopis juliflora* forest to the medium open grassland. However, it decreases drastically from the medium canopy to the open grassland. This is because there is complete shading of plants in the forest of Prosopis juliflora which minimizes photosynthetic capacity of undergrowth leading to reduced plant development and eventual reduction in unpalatable forb counts.

In the medium canopy cover, the unpalatable forb counts is very high because *Prosopis juliflora* shading encourages growth by alienating the direct sun rays that could have studded the plant and also it assists in moisture conservation in the soil and reduced transpiration and fixing atmospheric nitrogen to the soil thus promoting higher plant growth, especially of the annuals.

On the contrary, in the very open areas where there is few *Prosopis juliflora* trees, the unpalatable forb counts drop because there is little shading of the undergrowth that encourages undergrowth growing by conserving moisture and reduce potential evapo-transpiration rates hence reduced atmospheric nitrogen fixing in the soil. It is not normal because at 54% canopy cover plants count is expected to reduce but in this case it has increased 7 times in hillslopes wooded grassland terrain and very dry climate throughout the year. Pratt and Gwaynne, (1977), observed that, areas with different production potentials also respond differently to the canopy covers in terms of productivity this is important because rangeland are inherently heterogeneous comprising a mosaic of different range sites. Bhatia *et al.,* (1998), observed that, *Prosopis* fix atmospheric nitrogen in the soil, and contributes to organic carbon and phosphorous build up.

Category D: Decrease of plants counts with decrease of canopy from the forest to the medium canopy area followed by an increase from the medium canopy area to the open area.

In Table 4.7 above there is decrease of plants counts with decrease of canopy from the forest to the medium canopy area followed by an increase from the medium canopy area to the open area.

Palatable Sedges

Annual and perennial Sedges

In the Plain wooded grassland there is a decrease initially from the forest of *Prosopis juliflora* to the medium canopy with the same amount of palatable sedge counts then drastic increase (4 times) with decrease in canopy cover from the medium canopy to the open grassland. This is because in the forest of *Prosopis juliflora*, the *Prosopis juliflora* shading encourages the growth and survival of some types of palatable sedges that do not require much sunlight by assisting in moisture conservation and reducing transpiration thus promoting higher plant growth.

In the medium open area, the palatable sedge counts decrease with decrease in canopy cover because there is only 54% shading compared to 83% canopy cover hence there is less shading which does not encourage some sedges growth. On the contrary in the very open area, there are numerous growth due to availability of sunlight thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase in palatable sedge

counts in the Plain wooded grassland because of its nature of terrains where the ground is moist throughout the year thus contributing to the high number of palatable sedges in the open areas. It is not normal because there are palatable sedges that grow in the forest and some others grow best in the open areas. Jeltsch, *et al.*, (1996), reported that, different herbaceous plant species will respond differently to different types of tree canopies.

Moore (1960), observed that, co-existing herbaceous and shrub species competed for soil moisture supplies and at the same time shared the favourable effects arising from the joint microclimatic. Pratt and Gwynne (1977), observed that, areas with different production potentials also respond differently to the canopy covers in terms of productivity this is important because rangeland are inherently heterogeneous comprising a mosaic of different range sites. Grouzis and Akpo (1997), improved soil fertility beneath the tree could be due to accumulation of top fertile soil that has been eroded from the open areas. Wilson (1969), reported that, leguminous browse plants, such as *Prosopis* species, generally contain higher levels of crude protein than other shrub families. Mwangi and Swallow (2005), reported that, *Prosopis juliflora* is a fast growing, nitrogen fixing and evergreen tree with a deep root system. Kinyamario and Macharia (1992), observed that, production in the tropics can take place throughout the year and is normally limited by precipitation.

Unpalatable Forbs

Annual and perennial forbs

In the Riverine wooded grassland initially there is a decrease in unpalatable forb counts from the forest of the *Prosopis juliflora* to the medium canopy area then an increase with decrease in canopy cover from the medium canopy area to the open grassland. This is because in the forest of *Prosopis juliflora*, the *Prosopis juliflora* shading encourages the growth and survival of some types of unpalatable forbs species that do not require much sunlight by assisting in moisture conservation and reducing transpiration thus promoting higher plant growth. In the medium open area, the plants counts decreased with decrease in canopy cover because there is only 54% shading compared to 83% canopy cover hence there is less shading which does not encourage some plant species growth.

On the contrary in the very open area, there are numerous growth due to availability of sunlight thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase in unpalatable forb counts and also some forb species grow best in

canopy 21% in the Riverine wooded grassland because of its nature of terrains where the ground moisture is moist throughout the year thus contributing to the high number of unpalatable forbs in the open areas. It is not normal because this observation indicates that there are some types of forbs species that grow in the forest and some grow best in the open areas.

Lee (1978), pointed out that, a dense forest canopy drastically modifies the climate of the underneath, especially net radiation, wind speed and amount of precipitation. He found out that on average, rainfall deficits under mature hardwood canopies may vary from less than 10% during the leafless period, to more than 20% during the growing season, while the relative humidity under the canopy exceeds that of the area immediately outside the canopy. Coughenour, *et al.,* (1990), reported that, trees shades reduce heat loads on both human and animals and reduce potential evapo-transpiration rates, thereby reducing the potential moisture stress for the sub-canopy herbaceous plants. Jones (1971), indicated that, in grass-dominated savanna soils, residues from the natural vegetation, is usually poor in nitrogen and seems likely to initiate a period of soil nitrogen immobilization when returned to the soil as the grass residues are low in nitrogen: carbon ratios which may also explain the low total nitrogen obtained in the open areas. Pratt and Gwynne (1977), observed that, areas with different production potentials also respond differently to the canopy covers in terms of productivity this is important because rangeland are inherently heterogeneous comprising a mosaic of different range sites. Tiedmann and Klemmedson (1973), reported that, perennial plants, particularly shrubs, tend to accumulate soil nutrients beneath their canopies.

Medium palatable Forbs

Annual and perennial forbs

In the hillslopes wooded grassland, initially there is a drastic decrease in medium palatable forb counts from 13.3 to 0.0 from the forest of the *Prosopis juliflora* to the medium canopy area then slight increase from 0.0 to 3.3 with decrease in canopy cover from the medium canopy area to the open grassland. This is because *Prosopis juliflora* trees are studded to the size of shrubs in the hillslopes wooded grassland and their shading encourages the growth by alienating the direct sun rays that could have studded the plant and also it assists in moisture conservation in the soil and reduced transpiration promoting higher plant growth in the forest especially of the annuals and fixing atmospheric nitrogen to the soil.

While in the medium canopy cover, the medium palatable forb counts decreased to zero because there was no adequate shading as in the forest of *Prosopis juliflora* meaning that there is less conservation of moisture and less growth of medium palatable forb. On the contrary, in the very open area in the hillslopes wooded grassland, there are growth of some forbs because of the frequent short rains, nature of climate and the characteristics of the medium palatable forbs i.e. they grow and mature fast before soil moisture is lost in the open wooded grassland due to high evapo-transpiration. It is not normal because where there are trees there is low count of undergrowth and normally at 83% canopy cover, plants count is expected to reduce but in this case it is 13 times higher than medium canopy cover in the hillslopes wooded grassland terrain and very dry climate throughout the year. Bhatia *et al.*, (1998), observed that, *Prosopis* fix atmospheric nitrogen in the soil, and contributes to organic carbon and phosphorous build up. Coughenour *et al.*, (1990), reported that, trees shades reduce heat loads on both human and animals and reduce potential evapo-transpiration rates, thereby reducing the potential moisture stress for the sub-canopy herbaceous plants.

Palatable Shrubs

Dwarf and tall shrubs

In the Riverine wooded grassland, initially there is a slight decrease in palatable shrub counts from 0.1 to 0.0 from the forest of the *Prosopis juliflora* to the medium canopy area then slight increase from 0.0 to 0.1 with decrease in canopy cover from the medium canopy area to the open grassland. This is because *Prosopis juliflora* trees are studded to the size of shrubs in the Riverine wooded grassland and their shading encourages the growth by alienating the direct sun rays that could have studded the plant and also it assists in moisture conservation in the soil and reduced transpiration promoting higher plant growth in the forest. While in the medium canopy cover, the palatable shrub counts decreased to zero because there was no adequate shading as in the forest of *Prosopis juliflora* meaning that there is less conservation of moisture and less growth of palatable shrubs.

In the contrary, in the very open area in the Riverine wooded grassland, there is growth of palatable shrubs because they are those shrubs that grow in the open where there is adequate lighting. It is not normal because where there are trees there is low count of undergrowth and normally at 83% canopy cover, plants count is expected to reduce but in this case it is 1 times higher than medium canopy cover in the Riverine wooded grassland terrain. Benhard-Reversat (1982), concluded that, trees are an important ecological component that maintains

soil fertility as a result of nitrogen fixation and accumulation of organic matter through litter fall.

In the plain wooded grassland, initially there is a drastic decrease in palatable shrub counts from 0.2 to 0.0 from the forest of the *Prosopis juliflora* to the medium canopy area then slight increase from 0.0 to 0.2 with decrease in canopy cover from the medium canopy area to the open grassland. This is because *Prosopis juliflora* trees are studded to the size of shrubs in the plain wooded grassland and their shading encourages the growth by alienating the direct sun rays that could have studded the plant and also it assists in moisture conservation in the soil, reduced transpiration and atmospheric nitrogen fixing in the soil promoting higher plant growth in the forest. While in the medium canopy cover, the palatable shrub counts decreased to zero because there was no adequate shading as in the forest of *Prosopis juliflora* meaning that there is less conservation of moisture and less growth of palatable shrubs. On the contrary, in the very open area in the plain wooded grassland, there is growth of palatable shrubs because they are those shrubs that grow in the open where there is adequate lighting thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase in palatable shrubs.

It is not normal because where there are trees there is low count of undergrowth and normally at 83% canopy cover, plants count is expected to reduce but in this case it is 2 times higher than medium canopy cover in the plain wooded grassland terrain He found out that on average, rainfall deficits under mature hardwood canopies may vary from less than 10% during the leafless period, to more than 20% during the growing season, while the relative humidity under the canopy exceeds that of the area immediately outside the canopy. Coughenour *et al.*, (1990), reported that, trees shades reduce heat loads on both human and animals and reduce potential evapo-transpiration rates, thereby reducing the potential moisture stress for the sub-canopy herbaceous plants.

Category E: Zero count in the forest followed by an increase with decrease of canopy from the forest to the medium canopy area and then a decrease from the medium canopy area to the open area.

In Table 4.7 above there was zero count in the forest followed by an increase with decrease of canopy from the forest to the medium canopy area and then a decrease from the medium canopy area to the open area.

Palatable Sedges

Annual and perennial sedges

In hillslopes wooded grassland, initially there were no palatable sedges in the forest of the *Prosopis juliflora* and in the medium area but it increases drastically from the medium canopy cover to the scattered tree area with decrease in canopy cover. This is because there is complete shading of plants in the forest of *Prosopis juliflora* and at the medium area which minimizes photosynthetic capacity of palatable sedges (undergrowth) leading to reduced plant development and eventual reduction in palatable sedge counts. In addition, the *Prosopis juliflora* trees lateral roots grow in all directions and take up soil moisture that could be used by herbaceous vegetation (palatable sedges). From the medium canopy cover to the open area, the palatable sedge counts continue to increase drastically with decrease in canopy cover because there are the availability of sunlight thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase in palatable sedge counts in the hillslopes wooded grassland because of its nature of terrains and the perennial sedges which regenerate and mature fast before the ground get dry thus contributing to the high number of palatable sedges in the open areas.

It is normal because at 21% canopy cover, plants count is expected to increase as observed in this case where it has increased 606 times in the open areas in hillslopes wooded grassland terrain. Burrows (1990), some studies have shown pasture production is often reduced by trees that compete with understorey plant species for water, nutrients and light. McGines and Anorld (1939); Parker and Martins, (1952); Fisher *et al.*, (1973), noted that, when *prosopis juliflora* becomes established, its lateral roots grow in all directions and take up soil moisture that could be used by herbaceous vegetation. Ellison and Houston (1958), noted an inverse relationship between the tree canopy and herbaceous understorey production.

Medium palatable forbs

Annual and perennial forbs

In Riverine wooded grassland, there are no medium palatable forbs in the forest of *Prosopis juliflora* and in the medium canopy but they are found in large quantity in the open grassland. This is because they are few in number and they are affected by periodic flooding of the shores of Lake Kichirtitt which chokes plants when River Ewasonanyoike (Molo River) floods its banks and also there is complete shading of plants in the forest of *Prosopis juliflora*

which minimizes photosynthetic capacity of undergrowth leading to reduced plant development and eventual reduction in medium palatable forbs.

However, in the open area they grow because there is the availability of sunlight thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase of medium palatable forbs. It is normal because the medium palatable forbs are few in count thus they are killed by water easily. Pratt and Gwynne (1977), observed that, areas with different production potentials also respond differently to the canopy covers in terms of productivity this is important because rangeland are inherently heterogeneous comprising a mosaic of different range sites. Paulsen (1975), observed an increase in average soil moisture content in areas where *prosopis* trees had been removed compared to areas where the trees were still intact. Frost (1990), noted that, the shading effect of the evergreen woody species, such as *Prosopis juliflora* might limit herbage production.

Medium palatable shrubs

Dwarf and tall shrubs

In Riverine wooded grassland, there are no medium palatable shrubs in the forest of *Prosopis juliflora* and in the medium canopy but they are found in small quantity in the open grassland. This is because generally this terrain is not shrubland and thus shrubs are few in number and they are affected by periodic flooding of the shores of Lake Kichirtitt which chokes plants when River Ewasonanyoike (Molo River) floods its banks and also there is complete shading of plants in the forest of *Prosopis juliflora* which minimizes photosynthetic capacity of undergrowth leading to reduced plant development and eventual reduction in medium palatable shrubs.

However, in the very open area in the Riverine wooded grassland, there is growth of medium palatable shrubs because they are those shrubs that grow in the open where there is adequate lighting thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase medium palatable shrubs. It is normal because the medium palatable shrubs are few in count thus in the event of flooding they are killed by floods easily. Weltzin and Coughenour, (1990), observed that, shading by tree canopy might be the most important factor affecting understorey habit production and composition in African Savanna. Cox and Waithaka, (1989) reported that, energy flux from the sun is more important in terms of plant development where growth period is experienced per year. In contrast, production in the

tropics can take place throughout the year. Jacoby, *et al.,* (1982), reported that, there is higher herbage production away from *Prosopis glandulosa Torr* trunk than near it in Texas rangelands which attributed the findings to the competition between the trees and associated grasses for moisture.

In Plain wooded grassland, there are no medium palatable shrubs in the forest of *Prosopis juliflora* and in the medium canopy but they are found in small quantity in the open grassland.This is because generally this terrain is not shrubland and thus shrubs are few in number and they are affected by periodic flooding of the shores of Lake Baringo which chokes plants when River Perkerra (Tikirich River) floods its banks and also there is complete shading of plants in the forest of *Prosopis juliflora* which minimizes photosynthetic capacity of undergrowth leading to reduced plant development and eventual reduction in medium palatable shrubs. However, in the open area they grow because there is the availability of sunlight thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase in medium palatable shrubs. It is normal because the medium palatable shrubs are few in count thus they are killed by floods easily. Weltzin and Coughenour (1990), observed that, shading by tree canopy might be the most important factor affecting understorey habit production and composition in African Savanna.

In hillslopes wooded grassland, initially there were no medium palatable shrubs in the forest of the *Prosopis juliflora* and in the medium area but it increases from the medium canopy cover to the scattered tree area with decrease in canopy cover. This is because there is complete shading of plants in the forest of *Prosopis juliflora* and at the medium area which minimizes photosynthetic capacity of medium palatable shrubs (undergrowth) leading to reduced plant development and eventual reduction in medium palatable shrub counts. In addition, the *Prosopis juliflora* trees lateral roots grow in all directions and take up soil moisture that could be used by woody vegetation (medium palatable shrubs). From the medium canopy cover to the open area, the medium palatable shrubs counts increases with decrease in canopy cover because there is the availability of sunlight thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase in medium palatable shrub counts because of its nature of terrains. It is normal because at 21% canopy cover, plants count is expected to increase as observed in this case where it has increased 3.3 times in the open areas in hillslopes wooded grassland terrain.

Palatable Trees

In hillslopes wooded grassland, initially there were no palatable trees in the forest of the *Prosopis juliflora* and in the medium area but it increases from the medium canopy cover to the scattered tree area with decrease in canopy cover. This is because this terrain is not a tree forest(shrubland) thus they are few in number hence affected by shading of plants in the forest of *Prosopis juliflora* and at the medium area which minimizes photosynthetic capacity of palatable trees (undergrowth) leading to reduced plant development and eventual reduction in palatable tree counts. From the medium canopy cover to the open area, the palatable tree counts increase with decrease in canopy cover because there is the availability of sunlight thus maximizing its photosynthetic capacity leading to increased plant development and eventual increase in palatable tree counts because of its nature of terrains. It is normal because at 21% canopy cover, plant count is expected to increase as observed in this case where it has increased 0.2 times in the open areas in hillslopes wooded grassland terrain.

Category F: zero count from the forest to the open area with decrease of canopy cover

In Table 4.7 above there was zero count from the forest to the open area with decrease of canopy cover**.**

Medium palatable Grasses

Annual and perennial grasses

In riverine wooded grassland there are no medium palatable grasses from the forest of *prosopis juliflora* to the open grassland. This is because they do not exist. This means all the grasses in this terrain are palatable. It is not normal because in plain wooded grassland we get medium palatable grasses.

In the hillslopes wooded grassland there are no medium palatable grasses from the forest of *prosopis juliflora* to the open grassland. This is because they do not exist and thus they are affected by very dry climate experienced in this terrain where there are severe heat rays in the terrain land that heat hard and also because there is always scarcity of pasture thus the medium palatable grasses are consumed by livestock through out the year and most of the grasses are annuals in this terrain. It is not normal because in the open areas there is zero medium palatable grasses count and we expect them to grow because there is no complete shading. Frost (1990), noted that, the shading effect of the evergreen woody species, such as *Prosopis juliflora* might limit herbage production. Weltzin and Coughenour (1990), observed

that, shading by tree canopy might be the most important factor affecting understorey habit production and composition in African Savanna.

Unpalatable Grasses

Annual and perennial grasses

In riverine wooded grassland there are no unpalatable grasses from the forest of *prosopis juliflora* to the open grassland. This is because they do not exist. This means all the grasses in all the 3 sites are palatable and medium palatable. It is normal because in all the 3 sites we don't get unpalatable grasses.

In plain wooded grassland there are no unpalatable grasses from the forest of *prosopis juliflora* to the open grassland. This is because they do not exist. This means all the grasses in all the 3 sites are palatable and medium palatable. It is normal because in all the 3 sites we don't get unpalatable grasses.

In the hillslopes wooded grassland there are no unpalatable grasses from the forest of *prosopis juliflora* to the open grassland. This is because they do not exist. This means all the grasses in this terrain are palatable and medium palatable. It is normal because in the 3 sites we dont get unpalatable grasses.

Medium Palatable Sedges

Annual and perennial sedges

In the plain wooded grassland there are no medium palatable sedges from the forest of *Prosopis juliflora* to the open grassland. This is because they do not exist and if they were there they were few in numbers and thus they are affected by periodic flooding of the shores of Lake Baringo which chokes plants when River Perkerra (Tikirich River) floods its banks. It is normal because the unpalatable grasses are few in count thus they are killed by flood easily. It is normal because the medium palatable sedges are fragile and floods that kill all the sedges in this site.

Unpalatable Sedges

Annual and perennial

In the riverine wooded grassland; there no unpalatable sedges count from the forest of *Prosopis juliflora* to the open area with decrease in canopy cover. This is because they do

not exist. This means all the sedges in the 3 sites are palatable and medium palatable. It is normal because in the 3 sites we don't get unpalatable sedges.

In the plain wooded grassland there are no unpalatable sedges from the forest of *Prosopis juliflora* to the open grassland. This is because they do not exist. This means all the sedges in the 3 sites are palatable and medium palatable. It is normal because in the 3 sites we don't get unpalatable sedges. In the hillslopes wooded grassland there are no unpalatable sedges from the forest of *Prosopis juliflora* to the open grassland. This is because they do not exist. This means all the sedges in the 3 sites are palatable and medium palatable. It is normal because in the 3 sites we don't get unpalatable sedges.

Unpalatable Shrubs

Dwarf and tall shrubs

In riverine wooded grassland there are no unpalatable shrubs from the forest of *Prosopis juliflora* to the open grassland. This is because they do not exist. This means all the shrubs in the 3 sites are palatable and medium palatable. It is normal because in the 3 sites we don't get unpalatable shrubs.

In plain wooded grassland there are no unpalatable shrubs from the forest of *Prosopis juliflora* to the open grassland. This is because they do not exist. This means all the shrubs in the 3 sites are palatable and medium palatable. It is normal because in the 3 sites we don't get unpalatable shrubs.

In the hillslopes wooded grassland there are no unpalatable shrubs from the forest of *Prosopis juliflora* to the open grassland. This is because they do not exist. This means all the shrubs in the 3 sites are palatable and medium palatable. It is normal because in the 3 sites we don't get unpalatable shrubs.

Palatable Trees

In Riverine wooded grassland there are no palatable trees from the forest of *Prosopis juliflora* to the open grassland. This is because Riverine wooded grassland is grassland and not a tree forest thus palatable tree are few in number hence the probability of finding them growing is low because they are affected by periodic flooding of the shores of Lake Kichirtitt which chokes plants when River Ewasonanyoike (Molo River) floods its banks. However, the only trees available currently in 1982 introduced invasive *Prosopis juliflora.* It is normal because

the trees categorized as palatable are few in count thus they are choked by flooding every year thus the probability of finding them growing is low.

In Plain wooded grassland there are no palatable trees from the forest of *Prosopis juliflora* to the open grassland. This is because Plain wooded grassland is grassland and not a tree forest thus palatable tree are few in number hence the probability of finding them growing is low because they are affected by periodic flooding of the shores of Lake Baringo which chokes plants when River Perkerra (Tikirich River) floods its banks. However, the only trees available currently in 1982 introduced invasive *Prosopis juliflora.* It is normal because the trees categorized as palatable are few in count thus they are choked by flooding every year thus the probability of finding them growing is low.

Unpalatable Trees

In Riverine wooded grassland, Plain wooded grassland and the hillslopes wooded grassland there are no unpalatable trees from the forest of *Prosopis juliflora* to the open grassland. This is because they do not exist. This means all the trees in the 3 sites are palatable and medium palatable. It is normal because in the 3 sites we don't get unpalatable trees. Dregne (1992), observed that, trees utilize deep water tables, improve soil physical conditions, reduce raindrop splash effect and ground level wind speed, and hence, the overall ecosystem productivity.

4.5.2 Interpretation of results on count

Table 4.8, the dry matter in tones per hectare site is not significant ($P \leq 0.05$) at 0.698. Cover is not significant ($P \geq 0.05$) at 0.242. Habit is significant ($P \leq 0.05$) at 0.00 while palatable is not significant ($P \geq 0.05$) at 0.533. The interaction of site and cover is not significant ($P \geq 0.05$) at 0.746. The interaction of site and habit is not significant ($P \geq 0.05$) with a value of 0.157. This means habit is not affected by site irrespective of where it is found.

The interaction of cover and habit is significant ($P<0.05$) at 0.000. This means cover does not affect habit. The interaction of site, cover, and habit is not significant ($P \geq 0.05$) with a value of 0.012. This means site does not affect cover and habit. Site and palatability interaction is not significant ($P \geq 0.05$) with a value of 0.968. This means site does not affect palatability of the grasses, sedges, forbs, shrubs and trees.

Site, cover and palatability interaction is not significant (P≥0.05) with a value of 0.972. This means site does not affect cover and palatability. Site, cover and palatability is not significant (P>0.05) at 0.977 and their confidence interval is 95%. Habit and palatability interaction is not significant (P≥0.05) with a value of 0.972. This means that habit does not affect palatability of the grasses, sedges, forbs.

Table 4.8:Dependent Variable: Count

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	461268.218(a)	53	8703.174	9.586	.000
Intercept	64373.812	1	64373.812	70.900	.000
Site	653.040	2	326.520	.360	.698
Cover	2582.897	2	1291.448	1.422	.242
HABIT	304948.816	6	50824.803	55.978	.000
Palatable	1145.756	2	572.878	.631	.533
Site * Cover	1765.604	4	441.401	.486	.746
Site * HABIT	7291.049	5	1458.210	1.606	.157
Cover * HABIT	29191.251	8	3648.906	4.019	.000
Site * Cover * HABIT	15093.666	6	2515.611	2.771	.012
Site * Palatable	502.036	4	125.509	.138	.968
Site * Cover * Palatable	423.285	4	105.821	.117	.977
HABIT * Palatable	787.091	5	157.418	.173	.972
Site * HABIT * Palatable	.000	0	.	.	.
Cover * HABIT * Palatable	.000	0	.	.	.
Site * Cover * HABIT * Palatable	.000	0	.	.	.
Error	.000	0	.	.	.
Total	361362.941	398	907.947		
Corrected Total	940594.000	452			
	822631.159	451			

a R Squared = .561 (Adjusted R Squared = .502)

Source: Author's findings (2013)

In the ANOVA table 4.8, the dependent variable dry matter in tonnes per hectare site is significantly influenced by cover, habit and palatability (P<0.05). There was a significant interaction between site and cover, site and habit, site and palatability and cover and palatability (P<0.05). This is because the interaction between cover, habit and palatability is significant meaning that habit and cover of *Prosopis juliflora* both affect palatability of plants species at all levels either being in a forest of *Prosopis juliflora* or in the open areas which means something has to be done to mitigate the effects of cover on palatability of undergrowth plants.

4.6 INFLUENCE OF *Prosopis juliflora* DENSITY ON NITROGEN AND FIBRE COMPOSITION ON GRASSES, SEDGES, FORBS, SHRUBS AND TREE LEAVES AND TWIGS HARVESTINGS IN THE 3 SITES

4.6.1 Site 1: Riverine wooded grassland (Lake Kichirtitt)

Table 4.9(a): Nitrogen and fibre content chemical analysis on grasses, sedges, forbs, shrubs and tree leaves and twigs harvestings on Riverine wooded grassland

These chemical results are expressed on DM basis at 105^0C

No.	Habit	Sample name	Sample No	Canopy	DM	NDF %	ADF%	Lignin %	CP %	Palatability
1.	Perennial grass	*Cynodon dactylon*	S1B1C2	C2	93.5959	91.2753	46.2253	9.5998	5.1127	Palatable
2.	Perennial grass	*Cynodon dactylon*	S1B1C3	C3	92.6364	87.7247	40.4970	8.8950	6.0980	Palatable
3.	Perennial grass	*Cynodon dactylon*	S1B2C1	C1	94.0715	82.8307	43.0152	10.3326	7.6252	Palatable
4.	Perennial grass	*Cynodon dactylon*	S1B2C2	C2	91.8849	89.5631	44.8115	11.2206	5.3140	Palatable
5.	Perennial grass	*Cynodon dactylon*	S1B2C3	C3	90.6999	86.8027	40.7608	9.2062	6.0298	Palatable
6.	Perennial grass	*Cynodon dactylon*	S1B3C2	C2	92.3088	84.4936	45.4399	12.6532	5.6507	Palatable
7.	Perennial grass	*Cynodon dactylon*	S1B3C3	C3	92.0558	84.5303	39.7857	7.6910	5.0115	Palatable
8.	Perennial grass	*Cynodon dactylon*	S1B4C1	C1	91.0725	91.7017	44.2614	12.5120	8.3503	Palatable
9.	Perennial grass	*Cynodon dactylon*	S1B4C3	C3	92.6001	81.4200	40.1026	8.1155	6.7839	Palatable
10.	Perennial grass	*Cynodon dactylon*	S1B1C1	C1	93.4293	91.1545	44.2153	9.5527	9.6514	Palatable
11.	Perennial grass	*Panicum coloratum*	S1B4C1	C1	93.7366	88.8341	57.1602	14.4021	5.4527	Palatable
12.	Perennial grass	*Panicum coloratum*	S1B4C2	C2	92.4759	81.3455	50.3320	11.8896	4.4583	Palatable
13.	Perennial grass	*Panicum coloratum*	S1B4C3	C3	92.3365	82.3726	47.4027	12.8118	4.6217	Palatable
14.	Perennial grass	*Panicum coloratum*	S1B2C1	C1	93.8970	85.9293	55.1722	19.1859	5.0523	Palatable
15.	Perennial sedge	*Cyperus papyrus*	S1B1C2	C2	93.3510	87.4763	46.0359	9.1483	3.4190	Palatable
16.	Perennial sedge	*Cyperus rotundus*	S1B2C1	C1	87.3777	86.2405	42.7970	11.6963	8.99108	Palatable
17.	Perennial sedge	*Cyperus rotundus*	S1B3C3	C3	91.0100	84.0787	38.0343	11.2240	6.6169	Palatable
18.	Perennial sedge	*Cyperus rotundus*	S1B4C3	C3	92.6374	81.5329	40.0378	10.7030	4.5151	Palatable
19.	Perennial sedge	*Cyperus papyrus*	S1B1C3	C3	91.4748	79.9892	46.4937	10.7680	3.96251	Palatable
20.	Perennial sedge	*Cyperus papyrus*	S1B2C2	C2	90.9127	86.0331	44.8562	10.0866	4.8952	Palatable

No.	Habit	Sample name	Sample No	Canopy	DM	NDF %	ADF%	Lignin %	CP %	Palatability
21.	Perennial sedge	*Cyperus papyrus*	S1B3C2	C2	91.6383	89.7223	47.3601	9.5539	4.8258	Palatable
22.	Perennial sedge	*Cyperus papyrus*	S1B1C2	C2	92.7108	88.0804	46.3538	9.2114	3.44264	Palatable
23.	Annual forb	*Commelina benghalensis*	S1B1C1	C1	90.6242	76.8890	39.7631	10.1960	8.9206	Palatable
24.	Annual forb	*Hygrophilla auriculata*	S1B1C1	C1	90.0215	69.3057	30.1389	18.5436	10.1915	Palatable
25.	Annual forb	*Hygrophilla auriculata*	S1B4C1	C1	91.5354	91.6694	39.3454	12.1046	9.5339	Palatable
26.	Annual forb	*Hygrophilla auriculata*	S1B1C2	C2	91.7954	76.6324	48.4447	16.6130	4.9160	Palatable
27.	Annual forb	*Hygrophilla auriculata*	S1B1C3	C3	91.0673	84.2674	39.7454	11.3817	5.4591	Palatable
28.	Annual forb	*Hygrophilla auriculata*	S1B2C2	C2	89.7936	76.6369	35.4702	14.6948	4.3294	Palatable
29.	Annual forb	*Satureia abyssinica*	S1B3C3	C3	91.5963	86.7939	51.7488	28.9422	5.0049	Palatable
30.	Annual forb	*Xanthium pungens*	S1B3C3	C3	89.6515	43.6133	21.2991	16.1905	7.7753	Unpalatable
31.	Annual forb	*Xanthium pungens*	S1B4C3	C3	91.2133	41.5510	23.6972	18.2594	11.1970	Unpalatable
32.	Annual forb	*Indigofera schimperi*	S1B2C3	C3	92.6402	78.4810	51.1603	15.4091	7.14355	Palatable
33.	Annual forb	*Commelina benghalensis*	S1B4C1	C1	85.9454	79.9287	40.8922	17.6915	10.7706	Palatable
34.	Shrub	*Acacia mellifera*	S1B2C1	C1	91.1681	65.8454	31.5352	10.0364	14.1498	Palatable
35.	Shrub	*Acacia mellifera*	S1B2C3	C3	89.7749	47.0243	26.9421	9.7689	19.7737	Palatable
36.	Shrub	*Acacia nubica*	S1B3C3	C3	89.5914	31.9506	20.2642	14.5047	11.6882	Unpalatable
37.	Shrub	*Acacia reficiens*	S1B2C1	C1	92.4673	54.7599	30.8217	15.6217	11.7366	Palatable
38.	Shrub	*Acacia reficiens*	S1B3C3	C3	91.8700	41.1886	24.6490	9.0563	11.0602	Palatable
39.	Shrub	*Acacia reficiens*	S1B4C3	C3	89.7834	49.8700	35.2849	21.3013	13.1502	Palatable
40.	Shrub	*Acalypha fruticosa*	S1B3C3	C3	91.0994	43.6666	16.9211	3.8145	11.9502	Palatable
41.	Shrub	*Acacia mellifera*	S1B2C3	C3	89.9354	41.6744	21.6711	9.4123	19.7384	Palatable
42.	Shrub	*Acacia mellifera*	S1B4C1	C1	91.6225	63.9035	31.1878	10.5978	15.295	Palatable
43.	Tree	*Acacia tortilis*	S1B2C3	C3	91.4314	49.8242	34.6981	13.2066	11.7689	Palatable
44.	Tree	*Acacia tortilis*	S1B3C3	C3	91.4454	45.5627	22.5763	10.8808	12.2172	Palatable
45.	Tree	*Acacia tortilis*	S1B4C1	C1	91.8021	47.0686	29.8849	15.3482	15.2651	Palatable
46.	Tree	*Acacia tortilis*	S1B4C3	C3	91.7765	45.1586	22.6420	10.2205	11.0403	Palatable
47.	Tree	*Balanites aegyptiaca*	S1B1C3	C3	91.1516	49.7687	24.2728	15.6991	9.1020	Palatable
48.	Tree	*Prosopis juliflora*	S1B1C1	C1	92.3308	49.8696	24.8130	10.9498	16.1958	Palatable
49.	Tree	*Prosopis juliflora*	S1B1C2	C2	93.0604	48.9843	26.3431	11.2132	15.0395	Palatable
50.	Tree	*Prosopis juliflora*	S1B2C2	C2	89.7055	49.5789	24.8814	11.1197	13.3211	Palatable
51.	Tree	*Prosopis juliflora*	S1B3C2	C2	90.0865	49.0029	23.9825	11.9663	14.6715	Palatable
52.	Tree	*Prosopis juliflora*	S1B4C1	C1	91.9420	49.7379	28.7899	14.0523	14.7659	Palatable

No.	Habit	Sample name	Sample No	Canopy	DM	NDF %	ADF%	Lignin %	CP %	Palatability
53.	Tree	*Prosopis juliflora*	S1B1C3	C3	91.6314	50.8068	25.7990	10.6950	15.0373	Palatable
54.	Tree	*Prosopis juliflora*	S1B2C3	C3	91.6191	51.9815	26.3864	10.9748	13.8961	Palatable
55.	Tree	*Prosopis juliflora*	S1B3C3	C3	92.2390	56.1910	28.6321	21.3034	13.3696	Palatable
56.	Tree	*Prosopis juliflora*	S1B4C2	C2	91.8066	54.6802	28.2823	11.2955	15.8331	Palatable
57.	Tree	*Prosopis juliflora*	S1B4C3	C3	91.5927	50.6154	24.9256	14.7719	12.1495	Palatable
58.	Tree	*Salvadora persica*	S1B2C1	C1	86.6880	56.8245	13.5198	5.9639	14.5623	Palatable
59.	Tree	*Salvadora persica*	S1B2C2	C2	89.0806	51.9455	15.8995	6.3313	10.1305	Palatable
60.	Tree	*Salvadora persica*	S1B2C3	C3	88.2526	53.0013	12.9005	5.2293	9.0765	Palatable
61.	Tree	*Salvadora persica*	S1B3C2	C2	88.1474	19.4901	13.8461	4.6002	13.9993	Palatable
62.	Tree	*Salvadora persica*	S1B4C3	C3	89.3447	56.3268	12.7204	5.8593	13.8117	Palatable

Key:
C1 = 65-100% Prosopis canopy cover - 83% - High.
C2 = 31-64% Prosopis canopy cover – 54% - Medium.
C3 = 0-30% Prosopis canopy cover – 21% - Low.

Source: Author's findings (2013)

Site 1: Effects of *Prosopis juliflora* cover on percentage CP, NDF, ADF, Lignin and DM of different pasture species in Riverine wooded grassland of Marigat District

Crude Protein

Crude protein is the amount of protein contained in plant species. The interactions between percentage *Prosopis juliflora* cover and pasture species significantly ($P \leq 0.05$) determined the crude protein content (Table 4.9 (a)). *Salvadora persica* growing under 83% *Prosopis juliflora* cover, had the highest crude protein content compared to the rest of the plant species. Generally, plants growing under 83% cover of *Prosopis juliflora* had the highest crude protein content.

Neutral Detergent Fibre

Neutral detergent fibre is the amount of fibre contained in a plant species. *Prosopis juliflora* cover and plant species interaction significantly ($P \leq 0.05$) determined the NDF of plant species in this study site (Table 4.9(a)). *Panicum coloratum* had the highest NDF at 83% and 21% *Prosopis juliflora* canopy covers, similar to *Cynodon dactylon* (at all canopy covers of *Prosopis juliflora*) and *Hygrophylla auriculata* (at 21% *Prosopis juliflora* canopy cover) The least NDF was recorded in *Salvadora persica* plants that were collected from 54% canopy cover of *Prosopis juliflora.*

Acid Detergent Fibre

There was a significant ($P \leq 0.05$) interaction between canopy cover of *Prosopis juliflora* and pasture plant species in determination of ADF in this site (Table 4.9(a)). *Panicum coloratum* had the highest ADF compared to other pasture plant species where the *Prosopis juliflora* canopy covers were 83% and 54%, and *Salvadora persica* had the least ADF under all canopy covers of *Prosopis juliflora*. Plants growing under 54% cover of *Prosopis juliflora* generally had a higher ADF compared to those growing under 21% cover of *Prosopis juliflora*.

Acid Detergent Lignin

Plant species and percentage *Prosopis juliflora* cover had significant ($P \leq 0.05$) interactive effects on ADL in this site (Table 4.9(a)). *Panicum coloratum* growing under 83% *Prosopis*

juliflora cover, had the highest ADL compared to the rest of the pasture plant species while *Salvadora persica* had the least ADL under all the 3 *Prosopis juliflora* covers. Generally, pasture plant species growing under 83% *Prosopis juliflora* cover had the highest ADL.

Lignin

There were significant (P≤0.05) interactive effects of *Prosopis juliflora* cover and plant species in determination of lignin content of various pasture plant species (Table 4.9(a)). *Hygrophylla auriculata* had the highest lignin content under 54% and 83% cover of *Prosopis juliflora,* while *Salvadora persica* had the least lignin content compared to other plant species under the 3 canopy covers of *Prosopis juliflora*.

Dry Matter

Prosopis juliflora cover and plant species interaction significantly (P≤0.05) determined the dry matter content of different plants in this site (Table 4.9(a)). *Panicum coloratum* and *Cynodon dactylon* had significantly higher dry matter content at 83% *Prosopis juliflora* cover, compared to other treatment combinations. *Salvadora persica* had the least dry matter content at 83% cover of *Prosopis juliflora* generally over all canopy covers of *Prosopis juliflora.*

Prosopis juliflora cover had significant (P≤0.05) effects on ADF, ADL, CP, NDF, but had no effect on lignin content and dry matter of *Cyperus rotundus*. *Cyperus rotundus* plants growing under 83% *Prosopis juliflora* canopy cover had significantly higher contents of ADF, ADL, CP and NDF compared to those growing under 21% canopy cover of *Prosopis juliflora*.

4.6.2 Site 2: Plain wooded grassland (Ng`ambo)

Table 4.9 (b): Nitrogen and fibre content chemical analysis on grasses, sedges, forbs, shrubs and tree leaves and twigs harvestingss on Plain wooded grassland

These chemical results are expressed on DM basis at 105^0C

No.	HABIT	SAMPLE NAME	No	CANOPY	DM%	%NDF	%ADF	%Lignin	CP%	Palatability
1.	Annual forb	*Alternanthera pungens*	S2B2C1	C1	91.659	53.634	31.563	12.257	12.625	Palatable
2.	Annual forb	*Alternanthera pungens*	S2B1C2	C2	91.382	47.362	29.366	10.686	14.592	Palatable
3.	Annual forb	*Alternanthera pungens*	S2B2C2	C2	91.593	54.671	29.713	10.017	11.343	Palatable
4.	Annual forb	*Alternanthera pungens*	S2B3C2	C2	91.310	30.134	30.134	8.893	11.378	Palatable
5.	Annual forb	*Alternanthera pungens*	S2B4C2	C2	90.686	47.196	24.083	20.389	10.138	Palatable
6.	Annual forb	*Alternanthera pungens*	S2B3C3	C3	92.063	58.791	35.617	21.002	12.654	Palatable
7.	Annual forb	*Alternanthera pungens*	S2B2C3	C3	91.686	42.597	19.403	11.005	8.933	Palatable
8.	Annual forb	*Bidens ugandensis*	S2B2C1	C1	88.589	52.574	31.110	11.220	16.368	Palatable
9.	Annual forb	*Bidens ugandensis*	S2B1C3	C3	89.983	59.278	32.578	20.559	14.454	Palatable
10.	Annual forb	*Chenopodium fasiculosum*	S2B4C1	C1	90.099	69.474	37.009	10.644	16.447	Unpalatable
11.	Annual forb	*Chenopodium opulifolium*	S2B2C1	C1	89.125	69.217	38.367	11.276	13.352	Palatable
12.	Annual forb	*Chenopodium opulifolium*	S2B2C2	C2	91.542	62.359	38.627	9.597	11.250	Palatable
13.	Annual forb	*Chenopodium opulifolium*	S2B3C2	C2	91.730	57.560	19.754	17.165	11.227	Palatable
14.	Annual forb	*Chenopodium opulifolium*	S2B2C3	C3	90.914	71.150	36.975	12.996	9.813	Palatable
15.	Annual forb	*Justicia exigua*	S2B2C1	C1	90.010	57.407	32.108	10.117	12.564	Palatable
16.	Annual forb	*Sida ovata*	S2B1C2	C2	90.116	59.718	34.494	18.858	15.027	Palatable
17.	Annual forb	*Sida ovata*	S2B3C2	C2	91.384	48.318	19.511	7.961	9.292	Palatable
18.	Annual forb	*Sida ovata*	S2B4C2	C2	91.560	51.737	30.854	9.573	10.051	Palatable
19.	Annual forb	*Sida ovata*	S2B1C3	C3	91.399	46.658	17.030	11.379	9.782	Palatable
20.	Annual forb	*Sida ovata*	S2B1C1	C1	91.214	72.532	39.966	13.101	9.535	Palatable
21.	Annual forb	*Sida ovata*	S2B2C1	C1	89.436	50.606	26.539	16.721	9.741	Palatable
22.	Annual forb	*Sida ovata*	S2B4C1	C1	91.005	73.611	40.179	12.400	14.275	Palatable
23.	Annual forb	*Sida ovata*	S2B3C3	C3	88.379	68.540	38.986	20.904	9.281	Palatable
24.	Annual forb	*Solanum nigrum*	S2B4C3	C3	88.870	70.519	37.229	39.035	18.566	Palatable

No.	HABIT	SAMPLE NAME	No	CANOPY	DM%	%NDF	%ADF	%Lignin	CP%	Palatability
25.	Annual forb	*Solanum dubium*	S2B3C2	C2	91.185	55.936	28.782	10.353	15.082	Palatable
26.	Annual forb	*Solanum dubium*	S2B4C2	C2	91.656	66.362	20.752	12.945	14.391	Palatable
27.	Annual forb	*Solanum dubium*	S2B1C3	C3	91.850	72.586	35.809	10.838	15.007	Palatable
28.	Annual forb	*Solanum dubium*	S2B3C3	C3	89.480	62.679	30.945	9.209	16.222	Palatable
29.	Annual forb	*Withania somnifera*	S2B2C1	C1	90.835	38.318	20.537	7.410	15.370	Unpalatable
30.	Annual forb	*Withania somnifera*	S2B4C1	C1	90.721	49.558	23.038	11.083	20.882	Unpalatable
31.	Annual forb	*Withania somnifera*	S2B4C2	C2	89.910	33.383	17.451	13.786	12.268	Unpalatable
32.	Annual forb	*Withania somnifera*	S2B2C2	C2	88.972	38.638	17.329	7.258	12.398	Unpalatable
33.	Annual forb	*Withania somnifera*	S2B2C3	C3	91.594	49.954	31.880	17.872	17.474	Unpalatable
34.	Annual forb	*Withania somnifera*	S2B3C3	C3	86.902	44.360	32.376	20.581	19.931	Unpalatable
35.	Annual forb	*Xanthium pungens*	S2B1C1	C1	90.101	51.348	21.820	9.828	17.080	Unpalatable
36.	Annual forb	*Xanthium pungens*	S2B4C3	C3	89.664	99.995	21.943	10.461	10.123	Unpalatable
37.	Annual forb	*Xanthium pungens*	S2B2C3	C3	90.301	47.835	28.278	11.584	11.658	Unpalatable
38.	Annual grass	*Eleusine indica*	S2B4C3	C3	90.425	83.434	40.249	13.453	6.417	Medium palatable
39.	Perennial grass	*Cynodon dactylon*	S2B1C1	C1	92.885	87.382	49.303	13.436	8.787	Palatable
40.	Perennial grass	*Cynodon dactylon*	S2B2C1	C1	91.512	84.562	47.731	10.119	9.630	Palatable
41.	Perennial grass	*Cynodon dactylon*	S2B3C2	C2	93.921	84.885	34.699	18.750	8.201	Palatable
42.	Perennial grass	*Cynodon dactylon*	S2B4C2	C2	91.325	72.981	32.499	11.125	3.694	Palatable
43.	Perennial grass	*Cynodon dactylon*	S2B2C2	C2	93.103	83.311	39.859	18.066	10.438	Palatable
44.	Perennial grass	*Cynodon dactylon*	S2B2C3	C3	92.947	81.789	35.859	21.894	7.117	Palatable
45.	Perennial grass	*Cynodon dactylon*	S2B1C3	C3	92.700	85.868	45.939	11.392	7.136	Palatable
46.	Perennial grass	*Cynodon dactylon*	S2B4C3	C3	90.359	80.999	42.580	10.829	7.379	Palatable
47.	Perennial sedge	*Cyperus rotundus*	S2B1C1	C1	92.382	83.918	38.990	11.371	10.658	Palatable
48.	Perennial sedge	*Cyperus rotundus*	S2B3C1	C1	92.005	80.686	37.286	10.918	9.310	Palatable
49.	Perennial sedge	*Cyperus rotundus*	S2B1C2	C2	91.355	82.765	39.866	10.393	11.196	Palatable
50.	Perennial sedge	*Cyperus rotundus*	S2B2C2	C2	88.542	78.177	34.684	7.070	12.407	Palatable
51.	Perennial sedge	*Cyperus rotundus*	S2B4C2	C2	91.334	40.117	27.356	3.498	10.785	Palatable
52.	Perennial sedge	*Cyperus rotundus*	S2B4C3	C3	92.498	43.915	27.471	18.087	10.265	Palatable
53.	Perennial sedge	*Cyperus rotundus*	S2B3C3	C3	90.618	74.422	43.970	11.973	4.585	Palatable
54.	Shrub	*Acalypha fruticosa*	S2B3C1	C1	89.112	50.800	22.922	15.195	18.633	Palatable
55.	Shrub	*Acalypha fruticosa*	S2B1C3	C3	91.488	54.251	23.036	17.871	15.258	Palatable
56.	Tree	*Balanites aegyptiaca*	S2B4C3	C3	90.929	64.644	24.514	21.995	10.546	Palatable
57.	Tree	*Cordia sinesis*	S2B1C1	C1	90.500	78.823	49.895	18.127	15.385	Palatable

No.	HABIT	SAMPLE NAME	No	CANOPY	DM%	%NDF	%ADF	%Lignin	CP%	Palatability
58.	Tree	*Prosopis juliflora*	S2B1C1	C1	89.579	52.719	25.419	11.415	17.302	Medium palatable
59.	Tree	*Prosopis juliflora*	S2B2C1	C1	90.824	54.468	30.042	14.842	17.486	Medium palatable
60.	Tree	*Prosopis juliflora*	S2B3C1	C1	91.455	57.077	25.821	12.536	16.468	Medium palatable
61.	Tree	*Prosopis juliflora*	S2B4C1	C1	90.288	50.726	27.700	8.423	10.019	Medium palatable
62.	Tree	*Prosopis juliflora*	S2B1C2	C2	91.181	56.289	25.691	12.574	17.436	Medium palatable
63.	Tree	*Prosopis juliflora*	S2B3C2	C2	91.631	54.381	20.779	15.235	15.246	Medium palatable
64.	Tree	*Prosopis juliflora*	S2B4C2	C2	91.397	50.379	24.590	13.026	17.034	Medium palatable
65.	Tree	*Prosopis juliflora*	S2B2C2	C2	92.262	46.449	26.208	7.305	15.307	Medium palatable
66.	Tree	*Prosopis juliflora*	S2B3C3	C3	92.056	52.838	26.685	13.285	17.205	Medium palatable
67.	Tree	*Prosopis juliflora*	S2B1C3	C3	92.069	52.162	26.855	10.709	17.280	Medium palatable
68.	Tree	*Prosopis juliflora*	S2B1C3	C3	92.069	50.011	25.720	10.726	17.280	Medium palatable
69.	Tree	*Prosopis juliflora*	S2B2C3	C3	91.283	54.681	29.398	11.245	16.289	Medium palatable
70.	Tree	*Prosopis juliflora*	S2B4C3	C3	89.384	54.433	28.523	15.288	17.124	Medium palatable

Key:
C1 = 65-100% Prosopis canopy cover - 83% - High.
C2 = 31-64% Prosopis canopy cover – 54% - Medium.
C3 = 0-30% Prosopis canopy cover – 21% - Low.

Source: Author's findings (2013)

Site 2: Effects of *Prosopis juliflora* cover on percentage CP, NDF, ADF, Lignin and DM of different plant species in Plain wooded grassland (Ng'ambo)

Crude Protein

Crude protein is the amount of protein contained in a plant species. There were significant (P≤0.05) plant species and *Prosopis juliflora* cover interactions in determination of crude protein content of different plant species in this site (Table 4.9 (b)). *Withania somnifera* had the highest crude protein content at 21% and 83% cover of *Prosopis juliflora*, while *Cynodon dactylon* (at 21% and 54% canopy cover of *Prosopis juliflora*), *Cyperus rotundus* and *Sida ovata* (both at 21% canopy cover of *Prosopis juliflora*) had significantly lower crude protein contents compared to most plant species. Generally, plants growing under 83% canopy cover of *Prosopis juliflora* had the highest crude protein content.

The interaction between canopy and plant species had a significant (P≤ 0.05) effect on crude protein in site 2. *Withania somnifera* had the highest crude protein in canopy 21% and 83% followed by *Chenopodium opulifolium* and *Alternanthera pungens* under (83%) canopy cover, *Withania somnifera*, *Sida ovata* and *Cyperus rotundus* (54%). Generally, plants in 83% had the highest crude protein compared to those under canopy 21% and 54%.

Neutral Detergent Fibre

Neutral detergent fibre is the amount of fibre contained in grasses, sedges, forbs. There were significant (P≤0.05) NDF differences among *Prosopis juliflora* covers and plant species in this site (Table 4.9(b)). Plants growing under 83% canopy cover of *Prosopis juliflora* had the highest NDF, followed by those growing under 21% and 54% covers of *Prosopis juliflora* respectively. Among the plant species, *Cynodon dactylon* had the highest NDF compared to the other plants, while *Withania somnifera* had the least NDF.

In site 2, the *Prosopis juliflora* canopy cover had a significant (P≤0.05) effect on NDF of plant species. Similarly, NDF variations between different plant species were significant (P≤ 0.05), but the interaction between the two were not significant. Plant in canopy 83% had the highest NDF compared to those in other canopy covers (21%, 54%). Among the plant species *Cynodon dactylon* (Perennial grass) had a significantly higher NDF followed by *Cyperus rotundus* and *Chenopodium opulifolium. Withania somnifera* had the least NDF.

Acid Detergent Fibre

There were significant (P≤0.05) *Prosopis juliflora* cover and plant species interactions in determination of ADF content of different plants in this site (Table 4.9 (b)). Tissue analysis showed that *Cynodon dactylon* had a significantly higher ADF (48.52%) at 83% *Prosopis juliflora* cover compared to any other plant species rasses. On the other hand, *Withania somnifera* had the least ADF compared to other plant species at 54% and 83% canopy cover of *Prosopis juliflora*. Generally, plant species growing under 83% and 21% cover of *Prosopis juliflora* had the highest ADF.

Prosopis juliflora canopy covers and plant species interactions were significant (P≤0.05). *Cynodon dactylon* had the highest ADF where we had *Prosopis juliflora* canopy cover 83%. *Withania somnifera* had the lowest ADF where we had canopy cover of 54% and 83%.

Acid Detergent Lignin

There were significant (P≤0.05) *Prosopis juliflora* cover and plant species interactions in determination of ADL content of different plants in this site (Table 4.9 (b)). Among the plant species, *Sida ovata* had the highest ADL at 21% cover of *Prosopis juliflora.* Generally, plants growing under 21% cover of *Prosopis juliflora* had the highest ADL.

Dry Matter

The interactions between canopy covers of *Prosopis juliflora* and different plant species in dry matter content determination were significant (P≤0.05) (Table 4.9(b)). *Cynodon dactylon* had a higher dry matter content at 83% cover of *Prosopis juliflora* compared to *Alternanthera pungens* (at 21% cover of *Prosopis juliflora*), *Chenopodium opulifolium* (at 83% cover of *Prosopis juliflora*), *Cyperus rotundus* (at 83% cover of *Prosopis juliflora*) and both *Sida ovata* and *Withania somnifera* (at all covers of *Prosopis juliflora*).

4.6.3 Site 3: Hillslopes wooded grassland (Kampi Samaki)

Table 4.9(c) Nitrogen and fibre content chemical analysis on grasses, sedges, forbs, shrubs and tree leaves and twigs harvestings on Hillslope wooded grassland

These chemical results are expressed on DM basis at 105^0C.

NO	HABIT	SAMPLE NAME	No	CANOPY	DM	%NDF	%ADF	%Lignin	%CP	Palability
1.	Annual forb	*Alternthera pungens*	S3B1C2	C2	91.7421	64.6432	38.0578	15.3801	10.2429	Palatable
2.	Annual forb	*Justicia exigua*	S3B1C1	C1	90.9504	53.4082	25.4534	16.9653	12.7669	Palatable
3.	Annual forb	*Justicia exigua*	S3B2C1	C1	90.7615	43.2122	17.1604	6.0268	13.6493	Palatable
4.	Annual forb	*Solanum dubium*	S3B1C1	C1	91.4488	57.0046	33.5543	26.0583	14.0870	Palatable
5.	Annual grass	*Digitaria velutina*	S3B1C1	C1	91.7146	69.0785	28.4906	16.9602	10.1419	Palatable
6.	Annual grass	*Digitaria velutina*	S3B4C1	C1	90.3458	74.1872	37.8379	8.2904	10.2629	Palatable
7.	Annual grass	*Digitaria velutina*	S3B2C2	C2	90.1000	85.8713	34.6115	18.2908	7.2691	Palatable
8.	Annual grass	*Digitaria velutina*	S3B3C2	C2	91.5600	72.5699	38.4939	10.5122	5.5919	Palatable
9.	Perennial grass	*Cynodon dactylon*	S3B1C2	C2	91.2342	86.9356	43.3500	8.2973	8.2881	Palatable
10.	Shrub	*Acalypha fruticosa*	S3B2C1	C1	88.8579	35.4161	16.6277	16.4814	16.6640	Palatable
11.	Shrub	*Baleria acanthoides*	S3B2C2	C2	92.4000	73.9502	47.9004	17.7976	22.5108	Palatable
12.	Shrub	*Baleria acanthoides*	S3B1C3	C3	91.9532	66.2674	46.0669	19.7492	6.3022	Palatable
13.	Shrub	*Baleria acanthoides*	S3B2C3	C3	92.4500	66.2574	45.9816	19.3672	6.7799	Palatable
14.	Shrub	*Baleria acanthoides*	S3B3C3	C3	92.5510	64.3321	44.4728	17.6227	7.2835	Palatable
15.	Shrub	*Barleria diffusa*	S3B1C1	C1	92.3085	61.8090	33.5614	18.7415	8.9016	Palatable
16.	Shrub	*Barleria diffusa*	S3B2C1	C1	90.6303	54.6672	30.3155	23.2262	10.8379	Palatable
17.	Shrub	*Barleria diffusa*	S3B3C1	C1	90.3660	53.9971	33.8346	22.7630	10.3667	Palatable
18.	Shrub	*Barleria diffusa*	S3B4C1	C1	90.9597	56.9043	32.8442	10.7575	10.4073	Palatable
19.	Shrub	*Barleria diffusa*	S3B3C2	C2	91.0969	61.9560	40.1880	17.5198	6.0595	Palatable
20.	Shrub	*Barleria diffusa*	S3B3C2	C2	89.9000	68.1535	43.4928	13.2759	4.3874	Palatable
21.	Shrub	*Barleria diffusa*	S3B1C3	C3	90.0934	71.2816	45.6693	11.0219	3.7454	Palatable
22.	Shrub	*Barleria diffusa*	S3B2C3	C3	90.7401	57.2514	35.7670	19.4236	9.5382	Palatable
23.	Shrub	*Barleria diffusa*	S3B3C3	C3	91.2692	67.8158	43.9469	14.7750	4.0429	Palatable
24.	Shrub	*Barleria diffusa*	S3B4C3	C3	90.0589	67.4559	44.7763	14.9624	4.8198	Palatable
25.	Shrub	*Indigofera cliffordiana*	S3B1C3	C3	92.0118	75.7620	50.0208	24.7686	8.1181	Palatable
26.	Shrub	*Indigofera cliffordiana*	S3B3C3	C3	91.8838	37.1665	25.6193	11.6071	5.0090	Palatable

NO	HABIT	SAMPLE NAME	No	CANOPY	DM	%NDF	%ADF	%Lignin	%CP	Palability
27.	Shrub	*Sericocomopsis pallida*	S3B1C2	C2	92.9838	78.5728	52.0843	20.9606	5.2760	Palatable
28.	Shrub	*Sericocomopsis pallida*	S3B1C2	C2	92.9800	80.6733	54.6838	25.1398	5.2762	Palatable
29.	Shrub	*Sericocomopsis pallida*	S3B3C2	C2	92.5042	73.9263	49.1707	28.9500	6.9985	Palatable
30.	Shrub	*Sericocomopsis pallida*	S3B4C2	C2	91.9655	77.8444	52.8459	28.1301	5.8633	Palatable
31.	Shrub	*Sericocomopsis pallida*	S3B1C3	C3	92.4330	79.3926	53.2764	22.0863	5.4299	Palatable
32.	Shrub	*Sericocomopsis pallida*	S3B4C3	C3	92.2974	77.5645	77.5645	22.0483	6.5442	Palatable
33.	Shrub	*Sericocomopsis pallida*	S3B2C3	C3	92.2218	81.9600	60.2623	30.3019	5.0736	Palatable
34.	Tree	*Acacia tortilis*	S3B2C1	C1	90.5670	77.7215	46.7720	23.4633	11.7631	Palatable
35.	Tree	*Acacia tortilis*	S3B4C1	C1	90.2978	50.4165	33.0573	20.7979	11.7774	Palatable
36.	Tree	*Acacia tortilis*	S3B3C2	C2	91.1935	63.1734	41.0281	16.5692	12.8073	Palatable
37.	Tree	*Maerua pubescence*	S3B1C1	C1	91.2175	29.2543	9.0114	5.0539	9.3134	Palatable
38.	Tree	*Maerua pubescence*	S3B2C2	C2	89.2519	23.3385	8.3864	7.4396	11.0124	Palatable
39.	Tree	*Prosopis juliflora*	S3B1C1	C1	91.3678	48.6550	27.8216	23.2467	12.1318	Medium palatable
40.	Tree	*Prosopis juliflora*	S3B2C1	C1	89.8719	50.3828	21.7699	10.4093	15.3627	Medium palatable
41.	Tree	*Prosopis juliflora*	S3B3C1	C1	89.8719	52.7028	30.3766	13.9309	13.1599	Medium palatable
42.	Tree	*Prosopis juliflora*	S3B4C1	C1	91.0932	50.4264	29.5082	14.6389	13.8389	Medium palatable
43.	Tree	*Prosopis juliflora*	S3B3C2	C2	92.2192	55.4114	29.8853	22.4411	11.5100	Medium palatable
44.	Tree	*Prosopis juliflora*	S3B4C2	C2	90.0550	49.6197	27.1945	15.3850	12.6474	Medium palatable
45.	Tree	*Prosopis juliflora*	S3B2C2	C2	92.1566	46.0846	25.0823	13.1136	12.5980	Medium palatable
46.	Tree	*Prosopis juliflora*	S3B1C3	C3	89.8742	38.2257	23.8111	12.9570	15.5469	Medium palatable
47.	Tree	*Prosopis juliflora*	S3B2C3	C3	89.8700	47.4547	35.7461	15.9230	16.5055	Medium palatable
48.	Tree	*Prosopis juliflora*	S3B4C3	C3	91.8604	55.6061	29.9803	22.5287	12.3174	Medium palatable

Key:
C1 = 65-100% Prosopis canopy cover - 83% - High.
C2 = 31-64% Prosopis canopy cover – 54% - Medium.
C3 = 0-30% Prosopis canopy cover – 21% - Low.

Source: Author's findings (2013)

Site 3: Effects of *Prosopis juliflora* cover on percentage CP, NDF, ADF and Lignin of different plant species in Hillslopes wooded grassland North Baringo District

Crude Protein

There were significant (P≤0.05) *Prosopis juliflora* cover and plant species interactions in determination of crude protein of different plants in this study site (Table 4.9 (c)). *Acacia tortilis* had the highest crude protein content at both canopy covers compared to other plants, while *Digitaria velutina* had significantly lower crude protein content at 54% cover of *Prosopis juliflora*. Generally, plants growing under 83% cover of *Prosopis juliflora* had higher crude protein percentage than those growing on 54% cover of *Prosopis juliflora*.

Neutral Detergent Fibre

There were significant (P≤0.05) *Prosopis juliflora* cover and plant species interactions in determination of NDF content of different plants at this site (Table 4.9 (c)). *Digitaria velutina* (at both canopy covers of *Prosopis juliflora*) and *Acacia tortilis* (at 83% cover of *Prosopis juliflora)* had significantly higher NDF content compared to the rest of the treatment combinations. In contrast, *Maerua pubescence* had significantly lower NDF content at both covers of *Prosopis juliflora* compared to other plants.

Acid Detergent Fibre

Plant species variation in ADF content was significant (P≤0.05) in this site (Table 4.9 (c)). *Acacia tortilis* had the highest ADF followed by *Alternanthera pungens* and *Digitaria velutina*, while *Maerua pubescence* had the least ADF.

Acid Detergent Lignin

Prosopis juliflora cover and plant species interaction significantly (P≤0.05) determined ADL of different plants in this site (Table 4.19 (c)). *Alternanthera pungens* had a significantly higher ADL at 83% cover of *Prosopis juliflora*, followed by *Acacia tortilis* at the same cover of *Prosopis juliflora*. *Maerua pubescence* had the least ADL under both covers of *Prosopis juliflora* compared to the other plants.

Lignin

There were significant (P≤0.05) *Prosopis juliflora* cover and plant species interactions in determination of lignin content of different plants at this site (Table 4.9 (c)). *Alternanthera*

pungens had significantly higher lignin content (43.72%) at 83% cover of *Prosopis juliflora* compared to any other plant growing under either cover of *Prosopis juliflora*. On the other hand, *Maerua pubescence* had significantly lower lignin content at both covers of *Prosopis juliflora* compared to other plants (Table 4.9 (c)).

Table 4.10: Effects of *Prosopis juliflora* on percentage DM,CP,NDF,ADF and ADL of different plant species in the 3 sites of Marigat and North Baringo Districts

Site	Canopy (%)	Species	DM	CP	NDF	ADF	ADL
Riverine wooded grassland (Site 1)	83	*Cynodon dactylon*	92.86	8.54	88.56	43.83	15.79
	54		92.60	5.36	88.44	45.49	13.60
	21		92.00	5.98	85.12	40.29	11.64
	83	*Hygrophylla auriculata*	90.78	9.86	80.49	34.74	15.81
	54		90.80	4.62	76.63	41.96	15.78
	21		91.07	5.46	84.27	39.75	11.80
	83	*Panicum coloratum*	93.74	5.45	88.83	57.16	19.28
	54		92.48	4.46	81.35	50.33	13.93
	21		92.34	4.62	82.37	47.40	14.66
	83	*Salvadora persica*	86.69	14.56	56.82	13.52	5.89
	54		88.61	12.06	35.72	14.87	5.88
	21		88.80	11.44	54.66	12.81	5.59
Plain wooded grassland (Site 2)	83	*Alternthera pungens*	91.66	12.62	53.63	31.56	13.04
	54		91.24	11.86	44.84	28.32	13.09
	21		91.87	10.79	50.69	27.51	15.32
	83	*Chenopodium opulifolium*	89.13	13.35	69.22	38.37	11.74
	54		91.64	11.24	59.96	29.19	14.79
	21		90.91	9.81	71.15	36.98	12.67
	83	*Cynodon dactylon*	92.20	9.21	85.97	48.52	15.22
	54		92.78	7.44	80.39	35.69	17.36
	21		92.00	7.21	82.89	41.46	17.69
	83	*Cyperus rotundus*	92.19	9.98	82.30	38.14	14.09
	54		90.41	11.46	67.02	33.97	9.28
	21		91.56	7.42	59.17	35.72	17.42
	83	*Sida ovata*	90.55	11.18	65.58	35.56	14.69
	54		91.02	11.46	53.26	28.29	13.14
	21		90.94	9.03	62.60	32.08	30.61
	83	*Withania somnifera*	90.78	18.13	43.94	21.79	9.87
	54		89.44	12.33	36.01	17.39	6.88
	21		89.25	18.70	47.16	32.13	19.82
Hillslopes wooded grassland (Site 3)	83	*Acacia tortilis*		12.40	72.0	49.78	30.4
	54			12.81	63.2	41.03	16.4
	83	*Alternanthera pungens*		10.51	60.1	36.04	45.4
	54			10.24	64.6	38.06	16.5
	83	*Digitaria velutina*		10.20	71.6	33.16	12.9
	54			6.43	79.2	36.55	15.6
	83	*Maerua pubescence*		9.31	29.3	9.01	4.5
	54			11.01	23.3	8.39	7.6

Source: Author's findings (2013)

4.6.4 General discussion on CP, NDF, ADF, ADL DM

Nutritional Value of Plants

Plants and plant products form the animal diet and thus animals depend upon plants for their existence. Plants are able to synthesize complex materials from simple substance such as carbon dioxide, water and inorganic elements from the soil. Sunlight energy is used in the photosynthesis process. The chemical energy produced by plants, is stored in them and it is this energy that animals use for maintenance and growth of tissues (McDonald *et al.,* 1995). Pastures provide the basic pasture for livestock providing the energy, vitamins, minerals and some proteins. However, these animals face great variability in supply of pasture and nutrients throughout the year (Juarez *et al.,* 2004).

Despite this constraint in the same areas, trees and shrubs are the prominent sources of pasture for range ruminants (Bhatta *et al.,* 2004) and are mostly used as protein supplements in the arid and semi arid lands (Makkar, 2003). It is also reported that leguminous browse plants, such as *Prosopis* species, generally contain higher levels of crude protein than other shrub families (Wilson, 1969) and are often good sources of pasture reserves. The major value of browse, trees and shrubs is that they provide protein, vitamin and mineral elements which are lacking in grassland pasture during the dry or cold seasons. They also enable standing feed reserves to be build up so that herds are able to survive critical periods of shortfall or prolonged drought without losses. In addition, browse species are an effective means of utilizing marginal lands on which normal crop production is ineffectual owing to climatic, topographic or edaphic constraints (Le Houėrou *et al.,* 1980).

Effects of *Prosopis juliflora* on physical and chemical characteristics of different plant species in 3 sites of Marigat and North Baringo Districts

It was observed that plants growing under a dense canopy of *Prosopis juliflora* (83%) had high ADF and NDF in 2 sites (Riverine wooded grassland and Plain wooded grassland); high crude protein content in the 3 sites and high lignin content in 2 sites (Riverine wooded grassland and Hillslopes wooded grassland).

Tissue analysis showed that at 83% canopy cover of *Prosopis juliflora, Panicum coloratum* had the highest ADF, ADL and NDF in Riverine wooded grassland, while *Cynodon dactylon* had the highest ADF in Plain wooded grassland. *Acacia tortilis* had the highest ADF in

Hillslopes wooded grassland and also high NDF in the same site at 83% canopy cover of *Prosopis juliflora*. Similarly, *Alternanthera pungens* had the highest ADL at 83% cover of *Prosopis juliflora* in Hillslopes wooded grassland but in contrast, *Sida ovata* had the highest ADL at 21% cover of *Prosopis juliflora* in Plain wooded grassland. NDF content was the highest in *Cyperus rotundus* growing in Plain wooded grassland.

In Riverine wooded grassland, *Salvadora persica* had the highest crude protein content at 83% cover of *Prosopis juliflora.* It was further observed that, *Acacia tortilis* had the highest crude protein content at *Prosopis juliflora* canopy cover over 54% in Hillslopes wooded grassland while *Withania somnifera* had the highest crude protein in Plain wooded grassland with *Prosopis juliflora* canopy covers of 21% and 83%.

Salvadora persica had the least lignin content under all canopy covers of *Prosopis juliflora* in Riverine wooded grassland, while *Maerua pubescence* had the least lignin content at *Prosopis juliflora* canopy covers over 54% in Hillslopes wooded grassland. *Cyperus rotundus* had the least lignin content in Plain wooded grassland.

Dry matter content was highest in *Cynodon dactylon* growing in Riverine wooded grassland (at 83% cover of *Prosopis juliflora*), and at 54% cover of *Prosopis juliflora* in Plain wooded grassland.

Crude protein

Gohl, (1981) reported that crude protein of 11.7% and 7.8% at the age of 4 to 8 weeks respectively compared to the current study where samples were cut at the age of 14 weeks. Nabi, *et al.,* (2006) reported that working with five sorghum varities showed a decrease in crude protein contents as plant matures with higher content at early blooming stage.

NDF AND ADF

Matlebyane, *et al.,* (2009) reported that environmental differences could influence chemical composition and digestibility of pasture grown in different areas and harvested at the same age of maturity.

Dry matter

McDowell, (1972), in his study reported that all the varieties recorded higher (In Vitro Dry Matter Digestibility) IVDMD than 45% to be acceptable level to maintain weight and 55% dry matter digestibility to gain 0.5 to 0.6 kg a day for cattle in the tropics.

Lignin

Grenet and Besle, (1991) postulated that the cell wall carbohydrates are little degraded in the rumen due to a high extent of lignifications. Ramirez, *et al.*,, (1995) reported that lambs selected diets that were never lower than 10% CP and a variable NDF during the year. The high cell wall levels in pasture consumed by ruminants may be a limiting factor reducing animal intake and digestibility by microbes in the rumen and may depress the animal`s performance. Nagadi, *et al.*, (2000), Ahmad and Wilman, (2001) reported that, incomplete degradation of cell walls is a major factor limiting the value of pastures and straws for animals. Traxler *et al.,* (1998) and Agbagla-Dohnani *et al.,* (2001) reported that, lignin is generally accepted as the primary component responsible for limiting the digestion of pastures.

4.7 OBSERVATIONS AND CURRENT STATE OF *Prosopis juliflora* INVASION AROUND THE STUDY AREA

The communities who inhabit the shores of the 3 large water bodies in Ilchamus flat are: Aror, Endorois, Ilchamus, and Pokot. Aror occupy the hilly western part, Pokot occupy the north and Ilchamus occupy the southeastern plains near Lake Baringo and Endorois occupy Loboi plains around Lake Bogoria (Meyerhoff, 1991). The Aror inhabitants call *Prosopis juliflora* “Kipsamis” meaning a bad tree. The Ilchamus call it “Ildalami” because its pods are yellow in colour like that of *Acacia nilotica (ilkiloriti)* flowers. The Endorois call it “pestus”. The 4 communities are pastoralists who graze their livestock around the lakes in the dry season and on Laikipia and Tugen escarpments during wet season. The pasture land has been on the decline, due to the invasion of *Prosopis juliflora*, which was initially introduced with a view to reduce the negative impact of environmental degradation (Pasiecznick, 1999), has contributed to the decline of herbaceous plants, shrubs and trees. Ellison and Houston, (1958) noted an inverse relationship between the tree canopy and herbaceous understorey and Weltzin and Coughenour, (1990) observed that shading by tree canopy might be the most important factor affecting understorey habit production and composition in African Savanna.

In the local term, *Prosopis juliflora* has been nicknamed “dryland demon”, because of its serious negative effects.

Locations with medium invasion of *Prosopis juliflora* are Kiserian, Rugus, Noosuguro, Mukutani and Komolion in Riverine wooded grassland (Site 1), Ng`ambo, Salabani, Marigat town and Ilig’arua in Plain wooded grassland (Site 2), Endao, Taimon, Rondinin, Loruk and Chepilat in Hillslopes wooded grassland (Site 3), Eldume, Longewan, Perkerra, Leseki and Ildepe around the river banks of river Perkerra and Ewasonanyoike, Sandai, Mbechot, Loboi, Maji ndege, Kapkuikui and Kaptombes around the shores of Lake Bogoria.

In the next 10 years, locations which will be under threat are; Arabal, Chemorongion and Kasiela to the east and Tangulbei to the North in Riverine wooded grassland (Site 1), Katiorin, Ossen, Ngoron, Putero, Amaya, Korossi, Loyamorok and Kositei in Hillslopes wooded grassland (Site 3), Maoi, Koriema, Sabor, Kimorok and Ketamwo around the river banks of river Perkerra and Ewasonanyoike, Mochongoi, Kimoriot and Chebinyiny around the shores of Lake Bogoria.

Streams and lakes are known to be one of the factors which have contributed to the spread of the seeds of *Prosopis juliflora* to various parts which later germinate resulting to its spread. This spread had been noted to be very fast due to existence of several rivers in these areas which carries away the seeds to different places and to lakes like Lake Tilam and Turkana which is already invaded. These are regions adjoining the areas under threat or the areas affected by *Prosopis juliflora*. Counties that adjoin the areas invaded are more prone to experience its invasion. During the study, the natives of the area already invaded pointed out that cattle rustling is also another major factor leading to widespread of *Prosopis juliflora.* According to the observation, cattle rustling from Marigat District by Pokot rustlers have led to its spread to East Pokot District. This is because as the cattle feed on its pods in Marigat District, once they are stolen to East Pokot, they excrete the seeds along the route to East Pokot which later germinate resulting to its encroachment into areas like Churo, Kolowa, Nginyang and Tangulbei Divisions. These are findings during the study while administering the questionnaires of perception of inhabitants regarding *Prosopis juliflora* and questionnaires of livestock census in 14 locations).

The majority of the inhabitants felt that the leaves of *Prosopis juliflora* are Unpalatable to livestock and pointed out that its invasion has led to reduction of grass cover and indigenous vegetation in the invaded area. The ASAL areas are most affected because of their fragile

ecology. *Acacia* is by far the most frequently treated genus (22.5% of condensed ha) with *Prosopis* (tree) (11.6%) and *Chromolaena* (shrub) (10.4%) also being important species (Mwangi and Swallow, 2008).

4.8 SITUATION AND THE SPREAD OF *Prosopis juliflora* IN BARINGO COUNTY

Baringo County has 6 Districts which happens to be 6 Constituencies moving from Nakuru County to the South towards Turkana County to the North namely; Mogotio, Eldama Ravine, Baringo South, Baringo Central, North Baringo and Baringo East. The observation below concentrated on 5 Districts namely; Mogotio, Baringo South, Baringo Central, North Baringo and Baringo East because all of them border Baringo Valley (Ilchamus Flat).

During the study, the following 15 Divisions out of 24 Divisions in Baringo County neighbouring the initial planting area were investigated to find out whether *Prosopis juliflora* had been sighted or not: namely Marigat, Mukutani, Mochongoi, Kisanana, Mogotio, Emining Kabartonjo, Kipsaraman, Bartabwa, Barwesa, Salawa, Nginyany (Loiyamorok), Kollowa, Churo and Tangulbei (DC Baringo County, 2009).

From the initial Marigat Division where *Prosopis juliflora* was introduced it has spread to other Divisions. Its spread has been facilitated by several factors which include cattle rustling and nomadic pastoralism. As pastoralist move with their livestock in search of water and pasture, the animal waste results to germination of *Prosopis juliflora* leading to its widespread. Livestock also eat *Prosopis juliflora* pods while drinking water in Lake Baringo and Lake Kichirtitt. The invasive mathenge weed has covered over 300 acres of grazing natural pasture land suppressing plant species and leading to livestock death since its introduction in 1982.

Prosopis juliflora spread to Marigat, Mukutani, Mochongoi, Mogotio, Kisanana, Emining, Kabartonjo, Kipsaraman, Nginyang and Tangulbei divisions. Apendix 16 is a map of Baringo County showing main divisions.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 GENERAL CONCLUSION

5.1.1 Objective 1: Effects of *Prosopis juliflora* density on the yields (biomass production under various *Prosopis juliflora* percentage cover) of grasses, sedges, forbs, shrubs, tree leaves and twigs in Marigat

From this study the following conclusions were made:

i. There was an increase in palatable plants biomass production with decrease in canopy cover from the *Prosopis juliflora* forest to the open grassland in the 3 sites. Thus the canopy cover of *Prosopis juliflora* affected the total biomass production by reducing the palatable species significantly.

ii. There was an increase in biomass production of medium palatable plants with increase in canopy cover of *Prosopis juliflora* as one moved into the forest in the 3 sites i.e. Riverine wooded grassland, Plain wooded grassland and Hillslope wooded grassland.

iii. There was a decrease in unpalatable plant biomass production in the Riverine wooded grassland with decrease in *Prosopis juliflora* canopy cover. In contrast, there was an increase in biomass production with decrease in *Prosopis juliflora* canopy cover in the Plain wooded grassland and Hillslopes wooded grasslands. The canopy cover in the two areas assisted in moisture conservation in the soil and reduced transpiration promoting higher plant growth.

5.1.2 Objective 2: Influence of *Prosopis juliflora* densities on the distribution and composition counts of grasses, sedges, forbs, shrubs and trees in Marigat

i. Known unpalatable grasses, sedges, shrubs and trees were not observed in the three sites.

ii. There was a decrease in medium palatable trees count with decrease in canopy cover from the *Prosopis juliflora* forest to the open grassland in the 3 sites. Thus, the canopy cover of *Prosopis juliflora* affected the total count by reducing the medium palatable species significantly. *Prosopis juliflora* tree was classified as medium palatable.

5.1.3 Objective 3: Influence of *Prosopis juliflora* density on nitrogen and fibre composition of grasses, sedges, forbs, shrubs and trees leaves and twigs in Marigat

Prosopis juliflora cover had variable inconsistent effect on nutrient composition with exception of protein that appeared to decrease with decreasing canopy cover.

5.2 RECOMMENDATIONS

From this study the following recommendations were made:

i. Immediate measures should be undertaken to prevent *Prosopis juliflora* spread into new area.
ii. Pruning and thinning the *Prosopis juliflora* trees and sowing of grass on the cleared areas can increase pasture production.
iii. Animals be fed on ground pods, so that the seeds are completely destroyed in order to prevent the spread of *Prosopis juliflora*.

5.3 SCOPE FOR FURTHER WORK

The communities in Baringo County view *Prosopis juliflora* as a threat to their livelihood as it interferes with pasture for livestock production. Efforts to address its control and management will therefore be a very big relief and welcome move to the affected communities and has not come at a better time.

i. A study should be carried out by use of questionnaire to evaluate the inhabitants' perception on the effects of *Prosopis juliflora* on their livestock since its introduction in the study area in 1982.
ii. A local livestock census should be carried out in the entire Baringo county and the area between Lake Bogoria and Lake Baringo which covers about 14 locations invaded by *Prosopis juliflora.* This is to determine the actual stocking rate of cattle, goats, sheep, donkeys, and ostriches which graze and browse in the area and to establish the effect of *Prosopis juliflora* on livestock population in Marigat District.
iii. There is need to conduct a similar study during the wet season in the study area. Results are expected to be different and more accurate because all the plant species shrubs and trees will have grown in varieties, count, biomass and adequate representation.

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APPENDICES

Appendix 1: Field data form

Woody Plant species

I. GPS Reading (Latitude) _____Date_____

(Longitude) _____

II. Site identity :(S1, S2, S3) _____

III. Terrain: Riverine wooded grassland, Plain wooded grassland and Hillslopes wooded grassland)_____

IV. *Prosopis juliflora* canopy cover %_____(100-65, 64-31, 30-0)

V. 20 x 20 plot number _____(1; 2; 3; 4)

or 10X10 plot number _____(1; 2; 3; 4)

VI. Quadrant number (Q1, Q2, Q3)) _____ (a; b; c)

VII. Diameter. (D1, D2)

Field woody Plant species

Snr No.	**Block No.**	**Species Name**	**Species count No.**	**Field fresh wt**	**Dry 60^0 Wt**	**Total biomass**	**Remarks**
1							
2							
3							
4							

Source authors survey (2009)

Appendix 2: Field data form

Herbaceous (grasses, sedges, forbs)

I. GPS Reading (Latitude) _____Date_____

   i. (Longitude) _____

II. Site identity :(S1, S2, S3) _____

III. Terrain: Riverine, Plain wooded grassland and Hillslopes wooded grassland)

   a. _____

IV. *Prosopis juliflora* canopy cover %_____(100-65, 64-31, 30-0)

V. 20 x 20 plot number _____(1; 2; 3; 4)

   or 10X10 plot number _____(1; 2; 3; 4)

VI. Quadrant number (Q1, Q2, Q3) _____ (a; b; c)

VII. Diameter. (D1,D2)

Field data table form- Herbaceous

No species	**Species**	**Replicate quadrants**	**Number of individual species Count**	**Raw Wt**	**Dry 60^0 Wt**	**Remarks**
1		A				
		B				
		C				
2		A				

Source authors survey (2009)

Appendix 3: Field data form- woody species canopy cover

I. GPS Reading (Latitude) _____Date_____

   i. (Longitude) _____

II. Site identity :(S1, S2, S3) _____

III. Terrain: Riverine wooded grassland, Plain wooded grassland and Hillslopes wooded grassland)

   a. _____

IV. *Prosopis juliflora* canopy cover %_____(100-65, 64-31, 30-0)

V. 20 x 20 plot number _____(1; 2; 3; 4)

or 10X10 plot number _____(1; 2; 3; 4)

VI. Quadrant number (Q1, Q2, Q3) _____ (a; b; c)

VII. Diameter. (D1, D2)

Field woody species canopy cover data table form

Block No	**Species Name**	**D1**	**D2**	**Remarks**

Key- D – Measurement of distance.

Source authors survey (2009)

Appendix 4: Formulae for ease of reference

The frequency, density and biomass of the above species of pastures were calculated.

I. (a) Frequency = $\frac{\text{Number of species}}{\text{Number of plots species occurred}} \times 100$

(b) Density is defined **as the number of individuals in a given unit of area, or the reciprocal of the mean area of space per individual.** For example.If mean area per individual=25m^2, then Density=1/25=4 individuals m^{-2}

There are various specific types of density:

i. **Crude density** is the number of individuals of a species per unit total space.

ii. **Ecological (specific) density** is the number of individuals of a species per unit of habitat space (available area or volume that can actually be colonized by the population).

iii. **Relative density** is the Density of a given species expressed as a proportion of the total density of all species in an area. This was used in this study.

Other types of density include **security density, subsistence density and tolerance density.**

(c) Biomass estimation

The units for biomass production are in tonnes/hectare. Dry weights at 60^{o}C for the different plant species were used in calculating biomass production. The biomass production formulae is as shown below

$$\text{Biomass production} = \frac{\text{Mass}}{\text{Area (20m x 20m)} \times 10{,}000\text{m}^2} = \text{ton/ha}$$

II. Canopy cover estimation= $\frac{\text{Diameter D1+D2/2}}{\text{Full length of the plot}} \times 100$

D1 is the distance from one end of a tree canopy to the opposite end of the canopy of the same tree.

D2 is the distance from one end of a tree canopy to the opposite end of the canopy of the same tree perpendicular to D1 measurement.

III. A complete randomized block design was followed with sites serving as blocks and 20m x 20m quadrats serving as random sampling sites and experimental units.

IV. % moisture at 60^{0}C = $\frac{\text{weight of wet sample - weight of air dried sample}}{\text{Weight of wet sample}} \times 100$

V. Percentage Moisture

$$= \frac{\text{Weight of sample at } 60^0\text{C} + \text{weight of sample after 12hrs in oven}}{\text{Weight of wet sample at } 60^0\text{C}} \times 100$$

VI. Calculation of protein was done as follows:

$$\text{x protein is } \% N = \frac{(B-T) \times n \times 14.007 \times 100}{\text{Weight of sample in mg}}$$

Where: % N is Nitrogen

N = Normality of acid

T = Tritration volume for sample (m's)

B = Titration volume for blank

F = Conversion factor for Nitrogen to protein

Weight of sample in grams

% Protein = % N x F

VII. Neutral Detergent Fibre (NDF) was calculated as shown below:

$$\% NDF = \frac{(\text{Weight of oven dried crucible including fibre} - \text{wt of empty crucible}) \times 100}{\text{Weight of sample x DM content of sample}}$$

VIII. Acid Detergent Fibre (ADF) was calculated as shown below:

$$\% ADF = \frac{(\text{Weight of oven dry crucible including fibre} - \text{wt of empty crucible}) \times 100}{\text{Weight of sample x DM content of sample}}$$

IX. The calculation of lignin was done as shown below:

The acid detergent lignin was then calculated.

$$= \frac{L \times 100}{S \times DM \text{ content}} = \% \text{ lignin}$$

The same calculation was done for site 2 - Plain wooded grassland and site 3 - Hillslopes wooded grassland

X. The mean of quadrat $\frac{a+b+c}{3} = d$ was used to calculate the count of each individual species in individual plots.

XI. The total number of individual plant species in *Prosopis juliflora* canopy cover in site 1 - Riverine wooded grassland for 21%

$= B_1 + B_2 + B_3 + B_4$

For site 2, *Prosopis juliflora* canopy cover of 54% = $B_1 + B_2 + B_3 + B_4$

For site 3, *Prosopis juliflora* canopy cover of 83% = $B_1 + B_2 + B_3 + B_4$

Of the above calculations are seen in the result table 4.2, 4.3, 4.4, 4.5, 4.6 in chapter 4.

Appendix 5: Key Summary for Plants that Form the Vegetation in the Study Area (Ilchamus Flat)

A. GRASSES

Longevity - Annual grasses

No	Botanical name	Ilchamus	Tugen	Ranking S1	S2	S3	Palatability
1.	*Aristida mutabilis*	Ilkujita leldonyo	Cheluwoyon	1	0	2	Palatable
2.	*Aristida keniensis*	Lonyokwe	Chebirsongol	2	0	2	Palatable
3.	*Eragrostis cilianesis*					3	Palatable
4.	*Eragrostis tuneifolia*					2	Palatable
5.	*Eleusine indica*					3	Unpalatable
6.	*Digitaria velutina*			3		1	Palatable
7.	*Tetrapogon spathecious*					7	Palatable
8.	*Sporobolus marginatus*					6	Palatable
9.	*Dactyloctenium aegyptiaca*			2			Palatable
10.	*Echinochloa colonum*			1			Palatable
11.		Loipuup	Ngeiwan	1	1	1	Palatable
12.			Chemulpal	1		3	Palatable
13.			Chepkotiwo	1	1	3	Palatable
14.			Chemuryan	2	0	2	Palatable
15.		Loreprepe	Sokorkor	1	1	1	Palatable
16.			Kapcheptilil	1	1	1	Palatable
17.			Chepngwanian				Palatable
18.			Ng'ekchan				Palatable
19.			Cherurwen				Palatable
20.			Kiptoborwo				Palatable

Longevity - Perennial grasses

No	Botanical name	Ilchamus	Tugen	Ranking S1	S2	S3	Palatability
1.	*Cynodon dactylon* (Bermuda grass)	Long'eri	Seretion	1	1	1	Palatable
2.	*Panicum coloratum* (klein grass/blue panic grass/white buffel grass)	Ilkerei	Kelelwee	3	0	2	Palatable
3.	*Cenchrus ciliaris* (Buffel grass)	Ilperesi	Peresion	1	1	1	Palatable
4.	*Leersia hexandra*	Sapongwa	Sapongwa	2	1	2	Palatable
5.	*Echinochloa haploclada*	Ndokwe	Cheruron	4			Palatable
6.	*Echinochloa pyramidalis*	Laamara	Lomara	1	2	2	Palatable
7.		Larau	Argution	1	1	0	Palatable
8.		Ntorkose	Senetwet	1	1	1	Unpalatable
9.	*Alternthera pungens*	Nterep	Kapsekei	1	1	1	Palatable
10.	*Chloris roxburghiana*						Palatable

B. SEDGES

Longevity - Annual sedge

No	Botanical name	Ilchamus	Tugen	Ranking S1	S2	S3	Palatability
1.	*Cyperus species*	Lapirriai	Moigutie/Solel	1	1	1	Palatable

Habit-Perennial sedges

No	Botanical name	Ilchamus	Tugen	Ranking S1	S2	S3	Palatability
1.	*Cyperus rotundus* (coco-grass,purple nut sedge,red nut sedge)	Seyai	Chepkik	1	1	1	Palatable
2.	*Cyperus papyrus* (papyrus sedge,paper weed,mile grass)						Palatable
3.	*Cyperus articulatus*	Lomejicho	Kiptobor	2	0	1	Medium palatable

C. FORBS

Longevity - Annual forbs

No	Botanical name	Ilchamus	Tugen	Ranking S1	S2	S3	Palatability
1.	*Amaranthus spinosa* (thorny amaranth)	Ilkamasei	Chepkatee Konesyan	5	5	4	Palatable
2.	*Solanum dubium*	Iltulelei	Lobotwo	9	12	7	Medium palatable
3.	*Solanum nigrum*	Ilmoomoi	Isochot	12	14	12	Medium palatable
4.	*Commelina benghalensis* (wondering jew)	Ngaiteteyai	Chepchutpei	3	17	8	Palatable
5.	*Abutilon mauritianum* (khaki weed)	Sulubei	Kipkabuwo	1	0	3	Palatable
6.	*Xanthium pungens*	Pampa	Kapinguron	4	8	0	Unpalatable
7.	*Chenopodium opulifolium*				17		Unpalatable
8.	*Withania somnifera* (winter cherry)	Lesayet	Kipararie	0	9	0	Medium palatable
9.	*Hygrophilla auriculata*			1	0	0	Palatable
10.	*Ocimum bacilicum*			2	0	0	Palatable
11.	*Celosia anthelmintica*			5	0	0	Palatable
12.	*Satureia abyssinica*						Palatable
13.	*Indigofera schimperi*			7	0	4	Palatable
14.	*Amaranthus spinosus*	Nterere	Cheptoktokan	4	5	1	Palatable
15.			Kamoskoi/ Kap inguron	4	8	2	Unpalatable
16.	*Solanum Nigrum*	Saipadei	Sochot	1	1	1	Medium palatable
17.		Loberikine	Nderemiat	1	1	1	Palatable
18.	*Amaranthus spp.*		Mboroch	0	1	1	Palatable
19.		Lote	Kilotee	1	1	2	Palatable

No	Botanical name	Ilchamus	Tugen	Ranking			Palatability
				S1	S2	S3	
20.	*Lycoperscon esculatum* (tomato)	Ilnyanyai	Nyanyat	1	1	2	Palatable
21.	*Borreria stricta*			10	0	0	Palatable
22.	*Justicia striata*			11	0	0	Palatable
23.	*Glinus lotoides*			12	7	0	Palatable
24.	*Nothosaerva brachiata*			13	0	0	unpalatable
25.	*Portulaca foliosa*			14	0	1	Palatable
26.	*Sida ovata*			0	1	0	Palatable
27.	*Bidens ugandensis*			0	3	0	Palatable
28.	*Ageratum conyzoides*			0	6	0	Unpalatable
29.	*Conyza floribunda*			0	10	0	Unpalatable
30.	*Cassia occidentalis*			8	0	0	Unpalatable
31.	*Sida rhombifolia*			0	17	0	Palatable
32.	*Amaranthus hybrindus*			0	16	0	Palatable
33.	*Tribulus cistoides*	Lomerirwaki	Nornor	1	1	1	Palatable
34.	*Heliotropium subulatum*			0	17	0	unpalatable
35.	*Chenopodium fasiculosum*			0	17	0	unpalatable
36.	*Justicia exigua*			0	0	1	palatable
37.	*Euphorbia crotonoides*			0	0	2	unpalatable
38.	*Trianthema triquetra*			0	0	9	Palatable
39.	*commicarpus helenae*			0	0	5	
40.	*Kalanchoe denseflora*			0	0	6	Unpalatable
41.	*Crotalaria incana*	Kideu	Kipkurkurie	1	1	1	Unpalatable
42.			Chepkotiwe	2	4	4	Palatable
43.			Chelelmet	3	1	3	Palatable
44.			Chemintilil	1	2	1	Palatable
45.			Kipkobuo	1	1	1	Palatable
46.			Ling'ok	1	1	2	Palatable
47.			Kiptoruru	0	1	1	Palatable
48.			Kipnamkwe	1	1	1	Palatable
49.			Ketkurak		1	4	Palatable
50.			Tamnapkwe	1	0	5	Palatable
51.		Kisowou	Chepkoit	1	1	1	Palatable
52.			Kipsinos	1	1	9	Palatable
53.			Sakyande	1	1	1	Palatable
54.			Sitaki	1	2	3	Palatable
55.			Sotopcheptuke		2	4	Palatable
56.		Lolei					Palatable
57.		Ntilitan	Kimaruru	1	0	3	Palatable
58.		Longudai					Palatable
59.		Nchelengei					Unpalatable
60.		Lorongoti					Unpalatable
61.		Ilmateengei					Palatable

Perennial Forbs							
No	**Botanical name**	**Ilchamus**	**Tugen**	**Ranking**			**Palatability**
				S1	**S2**	**S3**	
1.	*Ipomoea cairica*						Palatable
2.	*Aerva persica*			0	0	0	Unpalatable
D. Longevity **Shrubs**							
No	**Botanical name**	**Ilchamus**	**Tugen**	**Ranking**			**Palatability**
				S1	**S2**	**S3**	
1.	*Barleria diffusa*	Loliyo		0	0	1	Palatable
2.	*Barleria acanthoides*		Kataprel	0	0	4	Palatable
3.	*Sericocomopsis pallida*						Palatable
4.	*Acacia mellifera*	Ilchurai	Barsol	3	3	3	Palatable
5.	*Acacia nubica*	Ildepe	Sepeiwe	2	2	2	Unpalatable
6.	*Acacia reficiens*	Iti	Ng`oror	2	0	5	Palatable
7.	*Lantana camara*	Ilmakirkiriani	Kipserem	0	2	0	Medium palatable
8.	*Datura stramonium*	Longu	Kamalile				Unpalatable
9.	*Acalypha fruticosa*	Lekuru	Lokuru	3	1	3	Palatable
10.	*Maerua subcordata*		Monogw`e	4	0	0	Unpalatable
11.	*Opuntia stricta* (Cactus)	Kaktas	Kures	1	1	1	Unpalatable
12.	*Ludwigia stolonifera* (yellow flower)	Rara		0	0	0	Unpalatable
13.	*Elvolvulus alsinoides*	Nesirore	Chepchutpei	0	1	2	
14.	*Cadaba farinosa*	Lamarngwenyi	Parkelat	1	2	1	Palatable
15.	*Gynodropsis synadra* (Spider flower)	Loborkwe	Chelelmet	1	1	1	Palatable
16.	*Euphorbia gossypina*	Lolii		0	0	0	Poisonous
17.	*Grewia bicolor*	Siteti	Sitewee	0	0	0	palatable
18.	*Grewia tenax*	Ilgogomi	Toronwee	1	1	1	Palatable
19.	*Indigofera cliffordiana*			0	0	6	Palatable
20.	*Maerua crassifolia*	lamayoki					Palatable
21.		Loirabraba					Palatable
22.		Ntorkose					Unpalatable
23.		Raprapa					Palatable
24.		Lomlomi	Momoniat	2	1	2	Palatable
25.		Rapai	Kilembe	2	1	4	Palatable
26.			Mpirikwo	2	1	2	Palatable
27.			Kamoskoi	2	1	2	Palatable
28.			Kipyambatai	1	1	1	Palatable
29.			Chebuluswo	2	3	2	Palatable
30.			Kornees	3	1	4	Palatable
31.			Chepchoiwo	3	1	4	Palatable
No	**Botanical name**	**Ilchamus**	**Tugen**	**Ranking**			**Palatability**
				S1	**S2**	**S3**	

32.		Lemanara	Keketch	2	1	2	Palatable
33.			Katapleiyan	2	2	2	Palatable
34.			Chokorwo	1	1	1	Palatable
35.			Koiwe				Palatable
36.		Ilchokorei					Palatable
37.		Nadonger					Palatable
38.		Senetoi					Unpalatable
39.			Kipsuskutuch				Unpalatable
40.			Many Koyang				Palatable
41.			Kolowo				Palatable
42.			Chepkoyan				Palatable
43.			Barkuntui				Palatable
43.	*Senna bicapsularis*	Daa	Osenwe				Palatable
44.	*Cadaba farinosa*	Latacha	Eldumeyon	2	3	1	Palatable
45.	*Lycium europeaum*	Lokii					Palatable

E. TREES

Longevity - Trees

No	**Botanical name**	**Ilchamus**	**Tugen**	**Ranking**			**Palatability**
				S1	**S2**	**S3**	
1.	*Balanites aegyptiaca*	Lowei	Ng`oswe	3	2	3	Palatable
2.	*Cordia sinesis*	Saapani	Salabani	1	2	1	Palatable
3.	*Salvadora persica*	Sokotei	Sokotewe	2	3	2	palatable
4.	*Prosopis juliflora*	Ildalami	Kipsamis	1	1	1	Palatable
5.	*Acacia xanthophloea*	Lerai					Palatable
6.	*Maerua pubescence*			0	0	3	Palatable
7.	*Acacia seyal*	Luwai	Lengnee	1	2	1	Palatable
8.	*Acacia clavigera* (*robusta*)	Sesiai	Tiryon	2	3	4	Palatable
9.			Ngororo	3	2	2	Palatable
10.	*Acacia Senegal*	Ilderkesi	Jemanga	3	1	3	Palatable
11.	*Ficus sycomorus*	Ilng'aboli	Lokoiwe	2	3	2	Moderate palatable
12.	*Boscia coriacea*	Sorichoi	Sirikwo	3	2	3	Palatable
13.	*Acacia tortilis*-(Forsk)	Iltepes	Sesia	2	0	2	Palatable
14.			Chepkoryande				Palatable
15.			Burkuntu				Palatable
16.			Chepyakwai				Unpalatable
17.			kokchan				Palatable
18.	*Terminalia orbicularis*	Lebokich					Unpalatable
19.		Iltukumei					
20.		Ilmurgusian	Kibulwo				Unpalatable
21.			Barkuntui	1	1	1	Palatable
22.		Reteti	Masyan				
23.		Ilgurme					Palatable
24.		Langudai					
25.		Ilturle					Palatable

No	Botanical name	Ilchamus	Tugen	Ranking S1	S2	S3	Palatability
26.		Longortomia	Parkelat				Palatable
27.		Lorupakani					Palatable
28.		Lomudong'o					Palatable
29.		Ilmachiktai					Unpalatable
30.		Singirpilei	Chemul Barsul	1	2	2	Unpalatable
31.		Sokoni	Sokee	1	1	1	Unpalatable
32.		Ilgirigiri					Unpalatable
33.		Lororoi	Likwon	2	2	2	Unpalatable
34.			Tiriyon	2	2	2	Palatable
35.		Ilbukoi	Koloswe	2	1	2	Palatable
36.		Losichoi	Aruwe	2	1	2	Palatable
37.			Muchukwe	1	2	2	Palatable
38.		Ilgotoi	Tuwet	2	0	2	Palatable
39.			Rironde				Palatable
40.		Lororoi	Likwon	2	2	2	Palatable
41.			Noiwe	1	2	2	Palatable
42.			Chapyakwai				Unpalatable
43.		Nkayamai	Mpikirwo	1	1	3	Unpalatable
44.		Ncheni Ngiroo					Palatable
45.		Ilmejoi					Palatable
46.		Ilmedimu Koon					Palatable
47.		Ildencha					
48.		Lokorosho					
49.		Lomanira					
50.		Dorkoi					
51.		Lemunyi					
52.		Ilngirman					
53.		Ilparsukuti					
54.		Ilturkan					

Appendix 6: Definition of terms / operational terms

Annual grasses – These are grasses whose longevity is one season.

Arid shrubs and tree savanna – This refers to vegetations mixture of shrubs and trees with grass underneath.

Biomass – It refers to all the dry weight of a plant per unit area.

Canopy – Is the cover formed by tree branches at the top.

Climax – The kind of community capable of perpetuation under the prevailing climate and edaphic conditions; the terminal stage of a sere under the prevailing conditions (Hanson, 1966).

Colonize other species – This is where *Prosopis* rapid growth rate suppresses the growth of other plant species which cannot survive in shady conditions. i.e. grasses and dwarf,shrubs forbs and trees.

Cover – The proportion of the ground surface underlive aerial parts of plants or the combined aerial parts of plant and much. Also it means shelter and protection for animals and birds.

Cultivated grassland - either temporally or permanent pastures either single species or mixture of relatively small numbers of species.

Deciduous trees-These are trees that shed their leaves during dry season.

Desirable plant species – species of moderate to high palatability that are preferred by animals. Also, species that are beneficial with respect to soil and water conservation.

Dry weight – Is defined as a weight of a substance after all the moisture has been removed either by sun-drying or using any other dehydrating method.

Ecology – That branch of the biological sciences that is concerned with living things in relation to one another and to their physical environment. The reciprocal relations of organisms and their environment.

Ecotone – A transition between two or more communities.

Environment – The sum of all physical, chemical and biotic factors in a given location.

Evergreen tree-It is a tree which is growing and green in all seasons whether dry or wet.

Pasture is a grass and other plants that are eaten by animals such as cattle.

Forbs –are broad leaved herbaceous plant species other than grasses.

Forest type – A sub-division of a forest are a characterized by predominance of certain general or species of trees regardless of stage of succession.

Grazing – Consumption of range artificial pasture pasture by animals.

Grazing pasture - is the consumption of range artificial pasture by animal.

Grazing capacity – The maximum stocking rate possible without inducing damage to vegetation or related resources.

Grazing preference – selection of certain plants over others by grazing animals.

Habit – Is a growth form of plants

Habitat – Is the actual location where a plant species is commonly found e.g understorey, open land etc.

Herb – Any flowering plant except those developing persistent woody stems above the ground

Herbaceous –This is a plant with many leaves and twigs and very short on the ground.

Herbage – Herbs taken collectively, usually used in the same sense as pasture, except that it may include material not acceptable to animals

Ilchamus flat – Refers to the lowlands around Lake Baringo and Lake Bogoria that is inhabited by the Ilchamus communities

Ildalami - Refers to *Prosopis juliflora* tree in "Ilchamus" community.

Indicator – An organism, species or community that shows the presence of certain environmental conditions syns, indicator plant, indicator species and plant indicator

Inhabitants – This refers to the people who have settled in the area invaded by *Prosopis juliflora* in Baringo

Invader plant species – plant species that were absent in undisturbed portions of the original vegetation and invad under disturbance or continued overuse commonly termed invaders

Invasion - Refers to the place where the *Prosopis juliflora* grow and overtake the original grasses, sedges, forbs, shrubs and trees

Kipsamis –Refers to *Prosopis juliflora* tree in "Aror" community

Lake Kichirtitt – Refers to a Lake that formed at the end before it enters in Ilngarua swamp of river Molo (Ewasonayokie). Also called Lake 94

Livestock management – Application of business method and technical principles to livestock production

Management plant – A programme of action designed to reach a given set of objects. Similar to grazing management plan

Marginal land – land of questionable economic capabilities for specific purpose.

Mathenge – Is a local name referring to *Prosopis juliflora* tree in Kenya

Medium palatable- These are plants that are rarely consumed by grazing and browsing livestock in the free range and do not form the bulk of feed to ruminants. They are medium palatable because of tannins which have a propensity to form insoluble complexes with proteins which reduces the digestibility of pastures by inhibiting digestive enzymes as well as causing a decrease in protein availability to the animal (McLeod, 1974)

Methodology – This refers to the methods used to collect data. These are: sampling, interviews, filling in questionnaires, line transects and also belt transect

Mudomo bend – This is a dental condition in goats, which the Ilchamus nicknamed meaning bend jaws as a result of chewing very hard *Prosopis juliflora* seeds

Natural grassland – include rough and hill grazing

Palatability – The relish that an animal shows for a particular plant species, plant, or plant part

Palatable-These are plants that are consumed by grazing and browsing livestock in the free range and form the bulk of feed to ruminants

Pasture is the plant species eaten by grazing livestock

Pasture herbage – is the natural food for herbivorous domestic animals

Pasture land – is a track of land that supports grass and other vegetation eaten by domestic animals

Perennial grasses – These are grasses whose longevity is more than one year

Pestus - Refers to *Prosopis juliflora* tree in "Endoroise" community

Physiognomy is a vegetation classification e.g. wooded grassland, shrubland, open grasslands, scattered tree grasslands, bush thicket or bushland, bushed grasslands, forest

Plant classification – This refers to the process of grouping plants according to their similarities and differences in structure

Plant retrogression – The process of vegetational deterioration whereby the same area becomes successively occupied by different communities of lower ecological order

Plant succession – The process of vegetational development whereby an area becomes successively occupied by different plant communities of higher order.

Plant vigour – plant health

Plastic is a change in form e.g. from tree to shrub depending on terrain and water availability or perennial grasses changing to annual e.g *Cenchrus ciliaris* in North Eastern

Plot - is defined as a square of 20m by 20m. (20m x 20m)

Poisonous plant – A plant containing or producing substances that cause sickness, death or deviation from normal state of health of animals.

Prosopis juliflora – Refers to invasive species of *Prosopis leguminous* trees introduced in 1982 in Baringo County

Quadrat –is defined as a sampling unit or plot

Range plants can be classified as: grasses, sedges, forbs, shrubs and trees: Sedges are further subdivided into annual sedges and perennial sedges. This system of classification also applies to forbs and grasses found in rangelands

Range Site – is a certain place or region identified for a specific function or because of a specific feature.It also means a section in the study area which is identified for a specific function or because of certain unique characteristic. In our study; sites were Lake Kichirtitt, Kiserian Location, Ng`ambo Location and Kampi ya Samaki, Akoroyan Location

Re-vegetation – The re-establishment or improvement of vegetation through either a natural or mechanical means

Sample – is defined as a portion representative of all the population

Savannah – A grassland with scattered trees, either as individuals or clumps; often a transitional type between a true grassland and forest

Sedges – are grass like plants that grow on moist soils

Shrubland – Refers to an area dominated by shrubs

Shrubs – Are multi-stem from ground level, from 0.7m to 8m.They can be evergreen semidecidous or deciduous. The giant shrubs are 8m and more, medium shrubs are 4m and more, short shrubs are less than 2m and dwarf shrubs are less than 70 cm

Site – The combined physical and biotic environment of forest area including soil, climate, exposure and biota. Expressed either in terms of quality (based on height of trees in a given time, usually 50 years) or interms of valuable trees species to which it is suited or both

Site 1 - Represented the Riverine wooded grassland (Lake Kichirtitt, Kiserian Location) which is the area of study between Lake Kichirtitt and Lake Bogori

Site 2 - Represented the plain wooded grassland (Ng'ambo Location) which is the area of study between Lake Kichirtitt and the Marigat- Kabarnet road

Site 3 - Represented the wooded grasslands on hillslopes (Kampi Samaki, Akoroyan Location) which is the area of study between Lake Baringo and Lake Tilam

Site 1, 2, 3 –Are typical vegetations represented which are likely to be observed in areas where *Prosopis* occurs in Kenya

Species composition – The relative proportions of various plant species in the total cover on a given area. It may be expressed in the terms of cover, density weight etc.

Stocking rate – Actual number of animals expressed in either animals units or animals months on a specific area at a specific time

Stubble – The basal portion of herbaceous plants either artificially or by grazing animals.

Study area – Refer to a large area in which data is collected during the research period. Study area is further sub-divided into small sections called study sites. In our research our study area is the region between and around Lake Bogoria and Lake Baringo in Baringo County.

Study site – Refers to the actual location where the ecology and livestock data was collected. Our study sites are; Ng`ambo, Lake Kichirtitt and Kampi Samaki.

Succession – The sequence of changes that occurs in the course of development of environments. The various stages are usually designated by names of characteristic plants

Tolerance – The capacity of a plant to ensure crown and root competition (in a restricted sense frequently used in forestry, the capacity of a plant to ensure shading).

Topography - Refers to the landscaping in the lowlands, ranges, hills, rivers, streams, swamps and Lakes of Baringo

Toxic plant species – A plant containing toxin formed as a product of metabolism

Tree/shrub leaves and twigs – This is the process of plucking off leaves from twigs of a tree/shrub

Trees– Are clearly divided into one or few stems and crown (canopy). The canopy may be cylindrical, umbrella shaped and also dense or open. They can be evergreen, semi-deciduous or deciduous. They are differentiated by height, giant is 40m and above, tall is 20m and above, short is less than 5m and dwarf trees are less than 2m.

Undesirable species – Species that are not desirable because they are unpalatable or low palatability, injurious to animals, poisonous, poor stabilizers of soil and water

Unpalatable-These are plants that are not consumed by grazing and browsing livestock in the free range and do not form the bulk of feed to ruminants. They are unpalatable because of Tannins which have a propensity to form insoluble

complexes with proteins which reduces the digestibility of pastures by inhibiting digestive enzymes as well as causing a decrease in protein availability to the animal (McLeod, 1974)

Weather – The sum of all meteorological factors averaged over a long period.

Wooded grasslands – Refers to grassland dominated by trees and grass

Appendix 7 (a): Showing plant habit woodland – forest of *Prosopis juliflora* site 1

		Canopy Cover (%)				
Habit	**Plant species**	**21**	**54**	**83**	**Total**	**Rank**
Annual grasses	*Echinochloa colonum*		8		8	1
	Dactyloctenium aegyptiaca	3			3	2
	Digitaria velutina	2			2	3
	Total	**5**	**8**		**13**	
Perennial grasses	*Cynodon dactylon*	517	427	94	1038	1
	Leersia hexandra		24	66	90	2
	Panicum coloratum	6	4	23	33	3
	Echinochloa haploclada		6		6	4
	Total	**523**	**461**	**183**	**1167**	
	Grand total	**528**	**469**	**183**	**1180**	
Perennial sedges	*Cyperus rotundus*	297	21	146	464	1
	Cyperus articulatus		1	1	2	2
	Grand Total	**297**	**22**	**147**	**466**	
Annual forbs	*Hygrophilla auriculata*	32	33	9	74	1
	Ocimum bacilicum	29			29	2
	Commelina benghalensis			24	24	3
	Xanthium pungens	19		5	24	4
	Celosia anthelmintica			21	21	5
	Satureia abyssinica	5	2	5	12	6
	Indigofera schimperi	9	1		10	7
	Cassia occidentalis			6	6	8
	Solanum dubium	4			4	9
	Borreria stricta		3		3	10
	Justicia striata	2			2	11
	Glinus lotoides		1		1	12
	Nothosaerva brachiata			1	1	13
	Portulaca foliosa	1			1	14
	Alternanthera pungens	1			1	14
	Total	**102**	**40**	**71**	**213**	
Perennial forbs	*Ipomoea cairica*			2	2	
	Grand Total	**102**	**40**	**73**		
Shrubs	*Grewia tenax*	6		4	10	1
	Acacia nubica	6			6	2
	Acacia reficiens	5		1	6	2
	Acalypha fruticosa	4			4	3
	Acacia mellifera	1		3	4	3
	Maerua subcodata	1			1	4
	Grand Total	**23**		**8**	**31**	
Trees	*Prosopis juliflora*	23	76	132	231	1
	Salvadora persica	1	2	1	4	2
	Acacia tortilis	3		1	4	2
	Balanites aegyptiaca	2			2	3
	Grand Total	**29**	**78**	**134**	**241**	

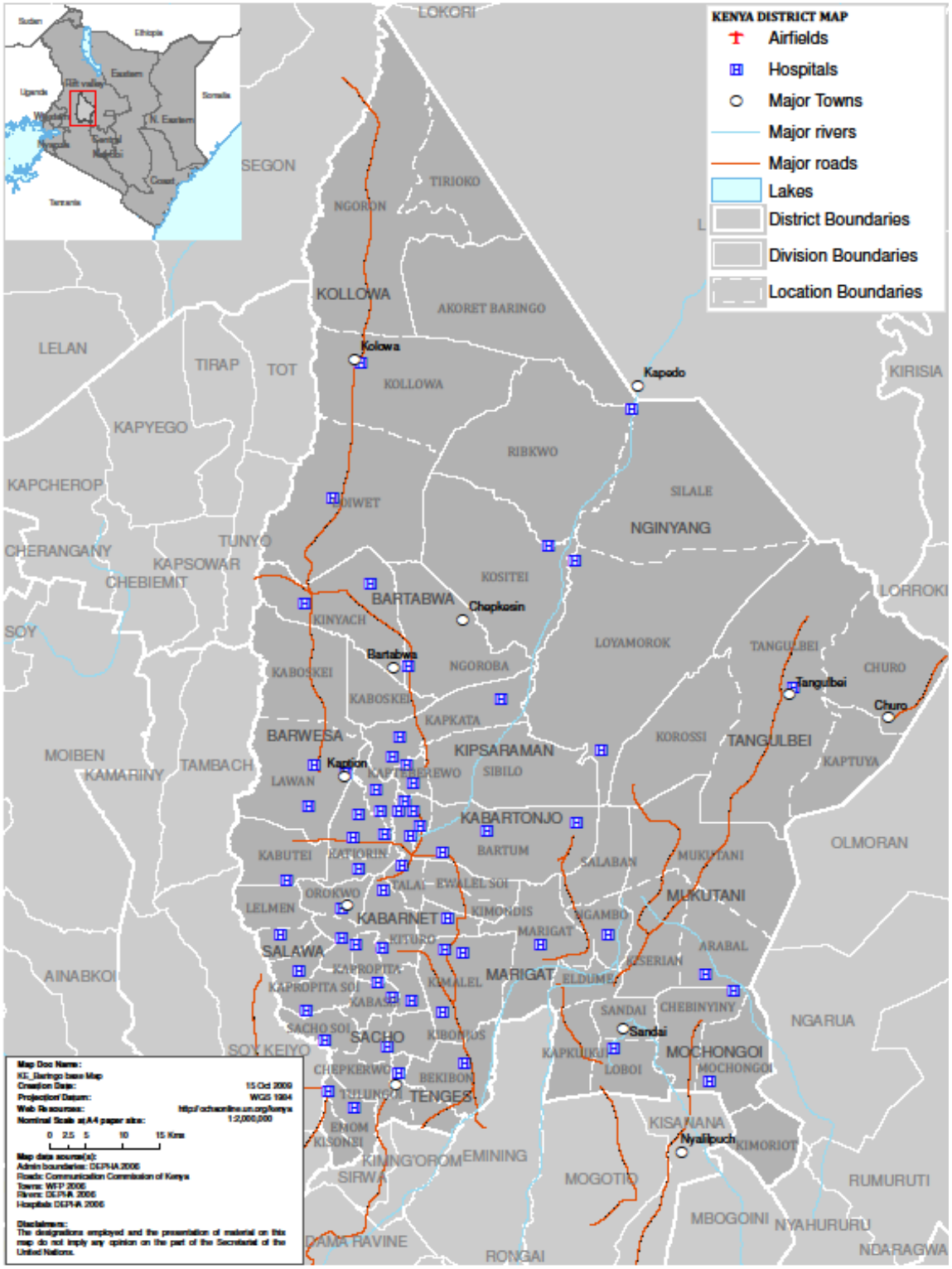
Appendix 7(b): Showing plant habit woodland – forest of *Prosopis juliflora* site 2.

Habit	Plant Species	Canopy Cover (%)			Total	Rank
		21	**54**	**83**		
Annual grass	*Eleusine indica*	7	2	0	9	
	Cynodon dactylon	0	45	4	49	1
Perennial grasses	*Echinocloa pyramidalis*	35	0	8	43	2
	Grand Total	**42**	**47**	**12**	**101**	
Annual sedge		0	0	0	0	
Perennial sedges	*Cyperus rotundus*	0	147	255	402	1
	Grand Total	**0**	**147**	**255**	**402**	
	Sida ovata	50	317	142	509	1
	Alternthera pungens	120	127	8	255	2
	Bidens ugandensis	10	0	107	117	3
	Chenopodium opulifolium	12	24	6	42	4
	Amaranthus spinosus	38	2	0	40	5
	Ageratum conyzoides	0	0	21	21	6
	Glinus lotoides	18	1	0	19	7
	Xanthium pungens	4	0	14	18	8
	Withania somnifera	8	6	3	17	9
	Conyza floribunda	0	0	15	15	10
	Cassia occidentalis	1	0	11	12	11
	Solanum dubium	8	3	1	12	12
	Satureia abyssinica	8	1	0	9	13
	Solanum nigrum	7	0	0	7	14
	Indigofera schimperi	3	0	0	3	15
	Amaranthus hybridus	0	0	2	2	16
	Heliotropium subulatum	0	1	0	1	17
	Chenopodium fasiculosum	0	0	1	1	17
	Commelina benghalensis	0	0	1	1	17
	Ocimum bacilicum	1	0	0	1	17
Annual forbs	*Sida rhombifolia*	0	1	0	1	17
Perennial forbs		0	0	0	0	
	Grand Total	**288**	**482**	**330**	**1103**	
	Acalypha fruticosa	6	0	6	12	1
Shrubs	*Lantana camara*	2	0	5	7	2
	Grand Total	**8**	**0**	**11**	**19**	
	Prosopis juliflora	18	59	68	145	1
	Balanites aegyptiaca	1	0	0	1	2
Trees	*Cordia sinensis*	0	0	1	1	2
	Total	**19**	**59**	**69**	**147**	

Appendix 7(c): Showing plant habit woodland – forest of *Prosopis juliflora* site 3.

		Canopy Cover (%)				
Habit	**Plant Species**	**21**	**54**	**83**	**Total**	**Rank**
Annual grasses	*Digitaria velutina*	83	160	86	329	1
	Eragrostis tuneifolia	18	37	5	60	2
	Eragrostis cilianesis	2	37	0	39	3
	Aristida keniensis	10	3	0	13	4
	Aristida mutabilis	0	7	0	7	5
	Sporobolus marginatus	0	1	5	6	6
	Tetrapogon spathecious	0	2	0	2	7
Perennial grasses	*Cynodon dactylon*	0	8	2	10	
	Grand Total	**113**	**255**	**98**	**466**	
Annual sedges	*Cyperus spp.*	0	6	0	6	
Perennial sedges	*Cyperus rotundus*	182	0	0	182	
	Grand Total	**182**	**6**	**0**	**188**	
Annual forbs	*Justicia exigua*	2	0	57	59	1
	Euphorbia crotonoides	1	53	0	54	2
	Alternanthera pungens	0	14	31	45	3
	Indigofera schimperi	0	14	1	15	4
	Commicarpus helenae	0	13	0	13	5
	Kalanchoe denseflora	8	0	0	8	6
	Solanum dubium	1	0	4	5	7
	Commelina benghalensis	0	0	4	4	8
	Trianthema triquetra	0	0	4	4	9
	Abutilon mauritianum	0	0	2	2	10
	Portulaca foliosa	0	1	1	2	1
Perennial forb	*Aerva persica*	1	0	0	1	
	Grand Total	**13**	**95**	**104**	**212**	
Shrubs	*Barleria diffusa*	137	202	283	622	1
	Acacia mellifera	37	2	0	39	2
	Acalypha fruticosa	26	3	7	36	3
	Barleria acanthoides	7	8	0	15	4
	Sericocomopsis pallida	4	11	0	15	4
	Acacia reficiens	11	0	0	11	5
	Indigofera cliffordiana	5	0	0	5	6
	Grand Total	**227**	**226**	**290**	**743**	
Trees	*Prosopis juliflora*	65	238	254	557	1
	Acacia tortilis	36	1	3	40	2
	Maerua pubescence	0	2	1	3	3
	Grand Total	**101**	**241**	**258**	**600**	

Appendix 8: Map of Baringo County showing main divisions and locations.



Source: Survey of Kenya (2009)