Impact of *Prosopis juliflora* L. (Fabaceae) on Plant Biodiversity at Alledeghi Wildlife Reserve and Surrounding Local Community, Ethiopia

Selamnesh Tesfaye Koyira

Addis Ababa University

Addis Ababa, Ethiopia

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The Department of Plant Biology and Biodiversity Management Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science (Plant Biology and Biodiversity Management)

Selamnesh Tesfaye Koyira

Addis Ababa University

Addis Ababa, Ethiopia

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GRADUATE PROGRAMMES

This is to certify that the thesis prepared by Selamnesh Tesfaye Koyira entitled impact of *Prosopis juliflora* L. (Fabaceae) on Plant Biodiversity at Alledeghi Wildlife Reserve and Surrounding Local Community and submitted in partial fulfillment of the requirements for the Degree of Master of Science (Plant Biology and Biodiversity Management) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Dr. Tamerat Bekele (Advisor)	_____	_____
Prof. Ensermu Kelbessa (Advisor)	_____	_____
_____ (Chairman)	_____	_____

ABSTRACT

Impact of *Prosopis juliflora* L. (Fabaceae) on Plant Biodiversity at Alledeghi Wildlife Reserve and Surrounding Local Community, Ethiopia

Selamnesh Tesfaye Koyira (MSc Thesis)

Addis Ababa University, June 2015

The aim of this study was to assess the impact of Prosopis juliflora on diversity of plant species found in Alledeghi wildlife Reserve and the surrounding local community. Preferential sampling method was used to collect vegetation data. Plots were laid from the main road to inside the reserve following three roads that lead into the reserve. A total of 60 quadrats, each 400 m2, were established along three lines for woody species data collection. Herbaceous species data were collected from 1m2 subplots at the four corners and center of the 60 main plots and 5m2 for shrub. Community perception on invasion and impact of P. juliflora was collected administering questionnaire and semistructured interviews interviewing a total of 80 people. The results showed that P. juliflora affects density, richness, diversity and evenness of other species. Higher proportion of respondents indicated that P. juliflora affects negatively their life because of its low beneficial traits for them. Higher proportion of respondents (87.5 %) put cattle dung as the main disseminating agent of P. juliflora in to the Reserve. Communities attempted to control P. juliflora spread in their land by cutting and applying used motor oil to stumps, burning, hand pulling and both cutting and burning. Nothing was done controlling by utilization in the area; however management strategies were recommended to minimize the ecological and socioeconomic impacts of the invasion and to make use of P. juliflora as a valuable resource to support rural livelihoods in the drylands and at the same time there is a dire need to control the spread of P. juliflora to new areas.

Key words: *Prosopis juliflora*, Impact, Dissemination Utilization, Control, Plant diversity

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Table of Contents

List of Figures

List of Tables

List of Appendices

List of Acronyms

AAU	Addis Ababa University
ANRS	Afar National Regional State
AWR	Allideghi Widlife Reserve
DM	Dry matter (Dry Wight)
EARO	Ethiopian Agricultural Research Organization
EWCA	Ethiopian Wildlife Conservation Authority
FARM-Africa	Food and Agriculture Research Management
FAO	Food and Agricultural Organisation
GISP	Global Invasive Species Program
GPS	Geographic Positioning System
HDRA	Henry Doubleday Research Association
H_2O	Hydrogen dioxide
IAS	Invasive Alien Species
NMSA	National Meteorological Service Agency
WARC	Werer Agricultural Research Centre

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Invasive alien species are those that become established in a new environment, and then proliferate and spread in ways that are destructive to biodiversity and human Interests (GISP, 2004). The spread of invasive alien species (IAS) is now recognized as one of the greatest threats to the ecological and economic wellbeing of the planet. These species are causing enormous damage to biodiversity and on agricultural systems we depend on. Health effects on human beings and animals are increasing and impacts on biodiversity irreversible. Introduced alien species outcompete, infect or transmit diseases, compete, attack, or hybridize with native ones (Wittenberg and Cock, 2001).

Invasive alien species have been introduced deliberately and/or accidentally to countries for various reasons. Some of such species have been proved to be helpful in their new places with regard to their economic importance, biodiversity aspect, ecological merit, or a combination of those factors. On the other hand, there are a lot of exotic plant species, which are found to be harmful after their introduction in different ways. For example: (a) by interfering with rural livelihood activities; (b) impeding land use systems; and (c) incurring extra costs of management to their „new home" due to the fact that they invade a large amount of land within a short period of time (Shakleton *et al.,* 2006). Such plant species, in most cases, are declared to be invasive alien species (IAS) in their new locality.

Ways by which IAS are incorporated into rural livelihoods vary. Shakleton *et al*. (2006) discussed the following four pathways, the first is when the rural community accepts the introduction or they themselves introduce a species because they perceive it as useful. Under this case, initially it is in controlled condition (e.g. within farming land). The species starts affecting non-beneficiaries" livelihoods when it gets out of control and invades much of the landscape. The second possibility is where intentional introduction of IAS into an area takes place and it becomes abundant through time. In this case, the opportunity cost of using scarce resources may invite the rural people to exploit the introduced species. The exploitation is good

for controlling the spread of IAS. The third situation is when the IAS is not introduced on purpose, but local people have already accepted the presence of IAS and try to make use of it. The last condition is the existence of IAS, which has no obvious uses for the community. At initial stage of invasion, the threat may be little. However, the threat becomes more serious when the scale of invasion increases to the extent of affecting the supply of other ecosystem goods and livelihood activities of the community. Ecosystem goods, according to Scoones (1998), are relevant for the sustainability of most rural livelihoods.

Prosopis juliflora is a noxious invasive weed that is native to America ranging from Peru to Mexico. Currently, it occurs as invasive weed in 25 African countries including Ethiopia (GISP, 2004). According to Pacieezuick *et al*. (2001), the earliest introductions to Africa in the 19th century may have been through Senegal, South Africa and Egypt. In Ethiopia, *Prosopis juliflora* was introduced and cultivated for shade, timber, forage, food and medicine (Asfaw Hunde and Thulin, 1989). It escaped cultivation and spread to farmlands, irrigation areas and rangelands. *Prosopis juliflora* has now invaded most of the pastoral areas in Afar Regional State. The success of *P. juliflora* is largely attributed to the high number of seeds produced and their efficient dispersal mechanisms (Hailu Shiferaw *et al*., 2004). Seeds of *P. juliflora* disperse by means of flowing water such as rivers and floods, livestock and wild animals. If the seeds fail to germinate at a particular point in time, they undergo dormancy and remain in the seed bank. With the destruction of the vegetation cover, the soil will be exposed, that promotes the germination (GISP, 2004). Currently, *P. juliflora* poses a threat to indigenous biodiversity whenever it is established in Ethiopia in general, in the Middle Awash area in particular because of its weedy and invasive nature, and its allelopathic effect (Samual Getachew, 2012). In this area, about 30,000 hectares of grasslands, rangelands, water points and croplands are estimated to be occupied by *P. juliflora* (Zeray Mehari, 2008).

Alledeghi Wildlife Reserve is located adjacent to Awash National Park, consisting flat grassland plain with high mountains rising on the eastern border. It is one of few places in Ethiopia where a huge number of wild ungulates (Beisa Oryx and Soemmering‟s gazelle) are observed utilizing the grassland plain (Fanuel Kebede, 2012). This Reserve is very unique not only for supporting substantial number of Soemmering‟s gazelle and Beisa Oryx, but also

harbors remnant endangered equid species Equus grevyi. The Ethiopian biggest isolated population of Grevy‟s zebra occurs in this Reserve (Almaz Kebede, 2009). This wildlife Reserve possesses more than 31 mammals, 140 bird species and an excellent landscape of grassland plain. However in this Reserve human encroachment is most pronounced. Particularly, overgrazing and bush encroachment are being accelerated. Bush encroachment is becoming a common phenomenon, mainly the invasion of alien invasive species (*Prosopis juliflora*).

The invasion by *P. juliflora* reduces grass availability and stocking density by livestock. According to Kahi *et al*. (2009), *P. juliflora* is also affects plant species biodiversity, total biomass production under *P. juliflora* tree shades reduced compared to open areas. This indicates that *P. juliflora* tree canopies inhibit production of understory plant species.

The invasion by *P. juliflora* leads to shrinkage of the rangelands and grasslands and will therefore threaten the existence of the community. This study would help identify the impact of *Prosopis juliflora* over other species and in the Alledeghi Wildlife Reserve. In addition, knowledge about the factors, which promote the spread of *P. juliflora,* will enable the community to apply appropriate management strategy so as to utilize the Reserve resources sustainably.

1.2. Statement of the Problem

In Ethiopia, the aggressive invasion of *Prosopis juliflora* in a pastoral area is displacing native tree species and reducing grazing land (Zeray Mehari, 2008). Alledeghi Wildlife Reserve is located adjacent to Awash National Park; also around the Reserve *P. juliflora* causes a serious threat, which is invading the acacia thickets by well establishing itself in large numbers at the borders of the Reserve. The invasion by *P. juliflora* leads to shrinkage of the rangelands and grasslands and will therefore threaten the existence of the community. This study would help identify the impact of *P. juliflora* over other species and in the Alledeghi Wildlife Reserve. Such knowledge would help have better understanding about the extent of the diversity of the plant and the rate of expansion and the positive and negative impacts of *P. juliflora* in the study local community. In addition, knowledge about the factors, which promote the spread of *P.*

juliflora, will enable the community to apply appropriate conservation strategy so as to utilize the Reserve resources sustainably.

1.3. Significance of the study

The Alledeghi Wildlife Reserve is one of the richest protected areas in Ethiopia with diverse and abundant wild ungulates. This area is close to the capital Addis Ababa, with easy access by a comfortable road, which makes the area high potential for tourism development. *Prosopis juliflora* is negatively affecting the grassland plains and it is further expanding to new sites. This research will generate information regarding how *P. juliflora* is spreading in to the Reserve and to show its impact on plant diversity and the local community in the study area, and to recommend options to control its expansion.

1.4. Objectives of the study

1.4.1. General objective

To assess the impact of *Prosopis juliflora* on diversity of plant species at Alledeghi Wildlife Reserve and surrounding local communities.

1.4.2. Specific objectives

- To assess impact of *Prosopis juliflora* on plant species diversity and their abundance.
- To investigate the introduction of *P. juliflora* in the study area and factors (possible causes) that favors the spread of *P. juliflora* in the Reserve.
- To analyze the benefits and negative impacts of *P. juliflora* in the study local community.
- To assess the attitude of the community about the Reserve and factors which affect the Reserve?
- To fined options that may help for controlling the Reserve from *P. juliflora* invasion and for its effective management.

1.5. Research questions

In order to achieve the stated objectives, the study attempted to answer the following research questions.

1. Is there any impact caused by *P. juliflora* on vegetation species diversity and abundance?
2. How *P. juliflora* was introduced in the study area and what are the factors (possible causes) that promote the spread of *P. juliflora* in Alledeghi Wildlife Reserve?
3. What are the benefits and challenges faced by the Reserve and local community (living around the Reserve) because of *P. juliflora?*
4. Which management options should be employed to control further spreading of *P.juliflora?*
5. Is there any species that grow in *P. juliflora* dominated area?

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Overview of *Prosopis juliflora* in general

Prosopis juliflora (Sw.) DC, one of the 44 species of *Prosopis*, is an evergreen leguminous tree, typical of arid and semi-arid regions belonging to the family Leguminaceae (Fabaceae) and subfamily Mimosoideae. It belongs to the section Algarobia, series Chilenses, which includes ten more species and many varieties (Pascienzk *et al*., 2004). *P. juliflora* is the only *Prosopis* species introduced and recorded in Ethiopia (Lehouerou, 1980). *P. juliflora* is particularly closely connected to *P. pallida*. *P. juliflora* is a woody stemmed, thorned, evergreen fast growing shrub or small tree usually up to about 5m tall but occasionally up to 12m under favorable conditions. It has a deep taproot, growing downwards in search of water tables (down to 40 m depth), with well-developed lateral roots competing with grasses (Pasiecznik *et al*., 2001). The existence of two root systems, a deep tap root to reach ground water and a mat of surface lateral roots to make use of infrequent rainfall events, puts *P. juliflora* species firmly in the category of phreatophytes, but showing a variety of mesophytic and xerophytic characteristics depending on water availability (Mooney *et al*., 1977).

P. juliflora leaves have many adaptations to drought, such as the bipinnate, compound leaves (typical of the Mimosoideae) with 13-25 pairs leaflets arranged on 1 or sometimes 2 pairs of pendulous rachis. Leaflets are oblong (3-16 mm long x 1.5-3 mm broad) (Heuze *et al*, 2015; FAO, 2010). Possession of larger numbers of smaller leaflets is considered to be a response to high temperatures, being a means of dissipating increased heat loads. In the *P. juliflora* - *P. pallida* complex, the action of the pulvinus (is a joint; like thickening at the base of the plant leaf or leaflet that facilitates growth) can cause the leaflets to fold, protecting stomata on the upper leaf surfaces from water loss (Pasiecznik *et al*., 2001).

Flowers are small, 4-6 mm long, gathered densely together on cylindrical, spike-like inflorescences known as racemes. They are generally yellow, straw yellow or yellow-white in color. Flowering may commence in the first or second year under favorable conditions but 3-5 years is common in normal field conditions. Fruits are flattened, curved, indehiscent pods (4

mm thick, 1-1.5 cm wide and 15-20 cm long) (Heuze *et al*., 2015). Pods are straw-colored and contain a fleshy and sugary mesocarp (Gohl, 1982). Pods are made up of an exocarp, a fleshy mesocarp, and endocarp segments each containing a single seed, with up to 30 seeds per pod.

The thorns vary in size between individual trees, from large, thick and strong thorns of up to 7.5 cm in length to small and weak ones of less than 0.5 cm in length. Armature consists of cauline, axillary spines which are geminate and divergent. Spines are straight, multi- or uni- nodal, solitary, paired or solitary and paired on the same branch. Spines are produced on new growth, and tend to be largest on strong basal shoots and prominent on young branches. They become shorter on older stems due to incorporation of spines during wood growth and diameter increments in the stem and branches, and may become absent on older wood. Trees vary in the number and size of thorns, which may be absent or not on all branches. Thorns, when present, can be rare or profuse, long or short, thin or stout, 0.5-7.5 cm long and 2-5 mm in thorn base diameter (Pasiecznik *et al*., 2001).

It grows in very hot, dry climates, with the temperature up to 48 $^{o012.....}$C and annual precipitation from 150 to 750 mm. It is found from sea level to 1500m and it can grow in the variety of soil types including saline and alkaline areas in sandy and rocky soils. The tissue of *P. juliflora* is photosynthetically active throughout the year, presenting a wide spread root system through which the tree fully exploits the available water resources (Pacieezuick *et al.,* 2001). Its low nutritional requirements and resistance to water deficit give *P. juliflora* a great plasticity of response, which allows its wide distribution in arid and semiarid zones in the tropics.

2.2. Introduction and invasion of *Prosopis juliflora* in Ethiopia

P. juliflora has been introduced in many parts of the world (Africa, Asia and Australia) during the last 100-150 years. The species is now established in Africa; including Ethiopia, Kenya, Eritrea and Sudan (Pasiecznik *et al*., 2001; Bokrezion, 2008). The plant has been cultivated for shade, timber, forage, food, and firewood (Pasiecznik *et al*., 2001; Rezene Fessehaie, 2006). There is no precise written document why, when, where, and who introduce *P. juliflora* to Ethiopia, some believe that Ministry of Agriculture introduced the species during the 1970‟s

indiscriminately to both degraded and high quality pastures, including those in the Afar National Regional State (ANRS), to serve as a shade tree and wind break for plantations, and for land reclamation (Dubale Admasu, 2008). On the other hand, the local people of Amibara Wereda of the Afar National Regional State, stated that *P. juliflora* was introduced by an English person from Sudan in 1970s through the Middle Awash Irrigation Project (Hailu Shiferaw *et al*., 2004; Rezene Fessehaie, 2006) and was planted over a large area of the Middle Awash rift valley by local people in 1980 as wind break, shade and shelter around their village. However, contrary to its purpose of introduction, the plant escaped out of control and has invaded farm lands, pasture lands, range lands, irrigation schemes (Rezene Fessehaie , 2006) and became causes for many land use/ land cover changes.

The Amibara Wereda of the Afar National Regional State is thought to be the putative starting point of the spread of *P. juliflora* in Ethiopia. It represents degraded semi-arid ecosystem. Since 1980s the plant has spread rapidly in all land cover in and the spread of *P. juliflora* further continued to Alledeghi Wildlife Reserve.

About half of the seeds, which passed through animal digestive tracts, have the ability to germinate (Hailu Shiferaw *et al*., 2004). According to their findings, the maximum germination percentage was observed on seeds recovered from warthogs (47%) followed by goats (37%). They also observed up to 2833 seeds recovered from a kilogram of cattle dropping. This shows the amount and possibility of *P. juliflora* seeds transportation to far distances within livestock digestive tracts. On top of this, the seeds can germinate under wide ranges of temperature (20 – 40 ^{0}C) and moisture stressed environments (Abiyot Berhanu and Getachew Tesfaye, 2006). Due to these reasons, *P. juliflora* has unchecked expansion in the area, so far, there is no survey made to assess how the invasion is going to the Alledeghi Wildlife Reserve and its impact but the species has also occupied a number of hectares in the area and is still expanding in the Reserve. This land is one of few places in Ethiopia where a huge number of wild ungulates (Beisa Oryx and Soemmering‟s gazelle) are observed utilizing the grassland plain (Fanuel Kebede, 2012). This Reserve is very unique not only for supporting substantial number of Soemmering‟s gazelle and Beisaoryx, but also harbours remnant endangered equid species Equugrevyi. The Ethiopian biggest isolated population of Grevy‟s zebra occurs in this Reserve

(Almaz Kebede, 2009) and ecological goods such as traditional medicines, wild fruits. In addition to Afar and Dire-Dawa regions, currently the species is spreading in arid and semi-arid parts of Somali, Oromia and Amhara regions and the species is declared to be the country‟s no. 1 invasive plant species (EARO and HADRA, 2005).

2.3. Biodiversity and socio-economic impact of *Prosopis juliflora*

2.3.1. Impacts on biodiversity

Study on the impact of *P. juliflora* showed great depressing effect on the number, density and frequency of the other species, particularly on native vegetation (Abdillahi *et al*., 2005). It creates a physical barrier against seedlings of other plant species and make establishment very difficult. Since its branches are many, dense, and have evergreen leaves, sunlight will not reach the ground and plants under canopy of *P. juliflora* will not have enough sunlight that is very crucial for photosynthesis. Reduced numbers of seedlings of native species have been recorded under canopy of non- indigenous invaders (Gordon, 1998). This is due to the conversion of more open stands to closed-canopy systems accompanied by low light, higher humidity, lower temperatures, and other environmental and biological changes (Hobbs and Mooney, 1986). This microclimate adjustment leads to decrease in population number and species composition of the area and also may results in the death of plants under canopy of *Prosopis juliflora* (Pasiecznik, 2001). As Chaturvedi *et al*. (1988) indicated the water use efficiency of *P. juliflora* to be 710 kg H2O/ kg dry matter. With other species, 345 kg H2O/ kg dry matter was estimated for *P. chilensis* (Felker *et al*., 1983). This high level of water use efficiency is related to high evaporation rate of their leaves. This makes the water table to lower and unable to be reached by the roots of native plant species and results in displacement of the native species with *P. juliflora* taking the place. *P. juliflora* also release allelochemical substances into the soil which may disrupt the physiology and mutalistic relations present in the native species (Noor *et al*., 1995; Pasiecznik, 2001). This may help *P. juliflora* to out-compete the local plant species.

2.3.2. Socio-economic impact of *Prosopis juliflora*

The ecological impact of *P. juliflora* has been translated into social, economic and political dimensions in the country. The most important socio-economic impact of *P. juliflora* is

associated with its replacement of pasture lands and native trees of browsing value, which are the sole sources of feed for the livestock of pastoral communities.

The negative features of *P. juliflora* are not limited only to its replacement of pastures and farm lands. It has harmed the wellbeing of local people directly through damages on human and animal health .Pods contain cytotoxic alkaloids that may cause intoxications to cattle, horses, sheep and goats in diets containing high levels of pods (>50 %). Problems have been reported in the USA, Peru and Brazil (Tabosa *et al*., 2006; Silva *et al*., 2007; Camera *et al*., 2009; Assis *et al*., 2010). Goats and cattle fed with diets containing 60-90 % and 50-75 % *P. juliflora* pods respectively suffered mandibular tremors during chewing due to toxicity to neurons of certain cranial nerve nuclei (Tabosa *et al*., 2000; Tabosa *et al*., 2006). In another series of outbreaks in Brazil, the main clinical signs were progressive weight loss, dropped jaw, tongue protrusion, salivation and impaired swallowing (Camara *et al*., 2009). Neuronal lesions result in difficulties in chewing; it subsequently causes animal death (Tabosa *et al.*, 2006).

The thorn of *P. juliflora* causes inflammation when injuries occur. The injury does not heal easily despite intensive medical treatment (Abiyot Berhanu and Getachew Tesfaye, 2006). According to Duck (1983), the wood is also known to cause dermatitis when it burns. The thick *P. juliflora* thickets have also constrained the mobility of people and blocked access to land, roads and watering points (Abiyot Berhanu and Getachew Tesfaye, 2006).

2.4. Uses of *Prosopis juliflora*

Prosopis juliflora has documented merits like improving soil fertility, controlling soil erosion, stabilizing sand dunes, providing fuel wood and feed/forage for livestock, fencing and for construction timber and furniture wood (Zeila *et al*., 2004; Esther and Brent, 2005; Stefen, 2005). However, there are also research findings, which contrast some of the described benefits.

P. juliflora is able to improve the soil in which it is growing by means of biological nitrogen fixation, leaf litter accumulation, nutrient pumping from deeper soil layers, loosening of a hard soil structure, stabilizing of loose sands, and an increase of the fauna above and below the

ground (Kaushik and Kumar 2003, Kahi *et al*. (2009), However, Zainal *et al*. (1988), noted that litter of *P. juliflora* reduces soil fertility.

P. juliflora has also been used to shelter agricultural crops from wind and to reduce the movement of soil and sand. Its leaves contain various chemicals known to affect palability to livestock, but also suppress the germination and growth of crops, weeds and other trees (Esther and Brent, 2005).

P. juliflora is reported to produce good quality firewood and charcoal because wood is hard, burns slowly and has excellent heating properties (Dubale Admasu, 2008 Pasiecznik, 2001). The mature timber is resistant to pest attack and weathering and thus can be used for furniture making and other useful purposes especially housing (Pasiecznik, 2001). However, there are conflicting reports on the quality of the fuel wood. According to Esther and Brent (2005) the fuel wood is of good quality with high calorific value, whereas report from Kenya claimed that the fuel wood produced poisonous smoke. They also complained that the wood is soft and easily attacked by insects, which make the tree unfit for fuel wood and house construction (Nabori *et al*., 2007).

P. juliflora pods have been said having high nutritional value and being palatable for livestock (Paseicznik *et al*., 2004; Esther and Brent, 2005). Pods have a relatively high nutritional value.

They contain about 10-15 % DM of crude protein, 20-30 % DM (dray mater, dray weight) of crude fiber and 16-41 % of total sugars (75 % saccharose) (Sawal *et al*., 2004). Pod composition is quite variable and pods from India and Africa appear to have lower levels of desirable carbohydrates and higher levels of unwanted fibre than pods from Peru and Brazil (Pasiecznik *et al*., 2001). The sugar content makes them palatable to ruminants, pigs, poultry, equines and other animals. As Sawal *et al*. (2004), studies show that cattle rations containing less than 50% *P. juliflora* pods lead to no adverse effects on consumption, digestibility, nutrient balance and animal health (Pasiecznik *et al*., 2001). But goats and cattle fed with diets containing 60-90% and 50-75% mesquite pods suffered mandibular tremors during chewing, due to toxicity to neurons of certain cranial nerve nuclei (Tabosa *et al*., 2000; Tabosa *et al*., 2006). In another

series of outbreaks in Brazil, the main clinical signs were progressive weight loss, atrophy of the masseter muscles, dropped jaw, tongue protrusion, difficulties in prehending food, tilting the head during mastication or rumination, salivation, impaired swallowing, and decreased tone of the tongue (Camara *et al*., 2009). Neuronal lesions resulted in difficulties in prehending and chewing; it subsequently caused feed wastage and death of the animal (Tabosa *et al*., 2006) Lower inclusion rates of 15-25 % are recommended in sheep and goats. In all ruminants‟ species, inclusion rates higher than 50-60 % may cause toxicity problems (Silva *et al.*, 2007; Tabosa *et al*., 2006; Camara *et al*., 2009; Assis *et al*., 2010).

2.5. Cause for invasion of *Prosopis juliflora*

The success of *P. juliflora* is largely attributed to the high number of seeds produced and their efficient dispersal mechanisms (Hailu Shiferaw *et al*., 2004). In addition, its fast growing ability, dormant seeds, attractive pods, seeds resistance to browsing, incredible ability of re-sprouting and fast coppice growth (Hailu Shiferaw *et al*., 2004), also reported that the life style of the nomadic local people has helped, seed maintaining viability in the dropping of livestock and wild animals as the animals eat the pods and travel long distances, disseminating seeds to new areas through droppings and high water use efficiency contribute to its invasion (Felker *et al.,* 1983).

2.6. Different *Prosopis juliflora* controlling and management methods

There are Different methods are studied to control spread *P. juliflora* According to Pacieezuick *et al*. (2001); Belton (2008), there are four kinds of controlling mechanism: mechanical, chemical, Fire and biological).

2.6.1. Physical/Mechanical methods

Hand pulling - Effective on seedlings and plants up to 20cm or so tall, in light or sandy soil where the taproot can be completely removed.

Cutting – before seed production will prevent further dispersal, but the plants will resprout from the stump. Cutting is a necessary step when working with large plants, to remove the above ground portion. Application of herbicide to the freshly cut stump will prevent resprouting. Methods of cutting include chainsaw for large stemmed plants, or a clearing saw, handsaw, or loppers, for smaller plants.

Hand-digging – Effective on small infestations, provided all roots can be removed.

Mechanical – control methods such as bulldozing have been used on Mexican thorn in some countries, however this method creates significant unnecessary ground disturbance and is not considered appropriate for Ascension.

2.6.2. Chemical methods

Chemical control has supremacy over other control methods due to its quick action and time saving. Larger trees and shrubs are killed by cutting the stem at ground level and spraying or painting the freshly cut stumps with suitable herbicide. In India, ammonium sulphamate was successful in killing *P. juliflora* trees and as a stump treatment (Panchal and Prabhakar, 1977). However this method is very expensive and largely unsuccessful in the long term. It has been accepted that using herbicides, eradication of vegetation‟s are possible but the potential environmental damage (non-Glycophosphate based herbicides) from widespread use of some herbicide must also be taken into consideration.

2.6.3. Biological control

Predators or pathogens are used to control the *P. juliflora* reproduction. In the native range, bruchid beetles can destroy substantial amounts of *P. juliflora* seed produced, thus severely limiting the potential for invasion. For example, according to Lima (1994), the twig girdler Oncideres limpida attack *P. juliflora* in Brazil. Biological control also involves animals besides insects to eat and kill seeds. *Prosopis* species seeds when passed through the gut of cattle, they would germinate better. According to Pacieezuick *et al*. (2001), replacing these livestock with

others such as sheep and pigs can prevent the expansion of *P. juliflora* this is because of the seeds lose their viability during passing through the gut of these animals.

2.6.4. Fire

Young seedlings are sensitive to fire the slow burning dung generates heat to shrivel up the stem and damage the stem, which ultimately result in the death of the plant, but older trees become increasingly protected by thick bark as they mature and will re-sprout rapidly after fire.

2.6.5. Control through utilization

Experiences from America, Asia and Australia have shown that eradication of *P. juliflora*, by the different methods, especially the mechanical and chemical ones are highly expensive and mostly ineffective (HDRA, 2005). Hence, management strategies were recommended to minimize the ecological and socioeconomic impacts of the invasion and to make use of *P. juliflora* as a valuable resource to support rural livelihoods in the dry lands (HDRA, 2005; Mwangi and Swallow, 2005). At the same time there is a dire need to control the spread of *P. juliflora* to new areas. In the regional consultation workshop organized by FARM-Africa in (2004), on *P. juliflora* control, charcoal production and pod crushing for livestock feeding were two options endorsed by the stakeholders. Utilization of *P. juliflora* tree for charcoal by clearing the stumps is assumed to restore the land, and the collection and crushing of the pods will also prevent further spread of the invasion to new locations.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the study area

The Alledeghi Wildlife Reserve was established in the 1960s when most of Ethiopia"s Wildlife Protected Areas were designated according to Hillman, (1993). It covers an area of 1,832 km^2 and it is located in the Great Rift Valley in the north eastern region of the country between Longitudes $39^0$30' to $40^0$30' E and Latitudes $8^0$30' to $9^0$30' N. The reserve is about 280 km east of Addis Ababa. The altitude of the study area is between 800 m and 2400 m above sea level (WCMC, 1991). The Reserve lies in two regional states namely Afar and Oromia (From the Afar side is the major wildlife concentration plain called the Alledeghi plain and it is found within the Amibara Wereda of the Afar Region). The southern and south western mountain part lies in the Mieso Wereda (District) of the Oromia Region. The boundary, name and the size of the Reserve areas have changed and there is no recent published (gazette) map.

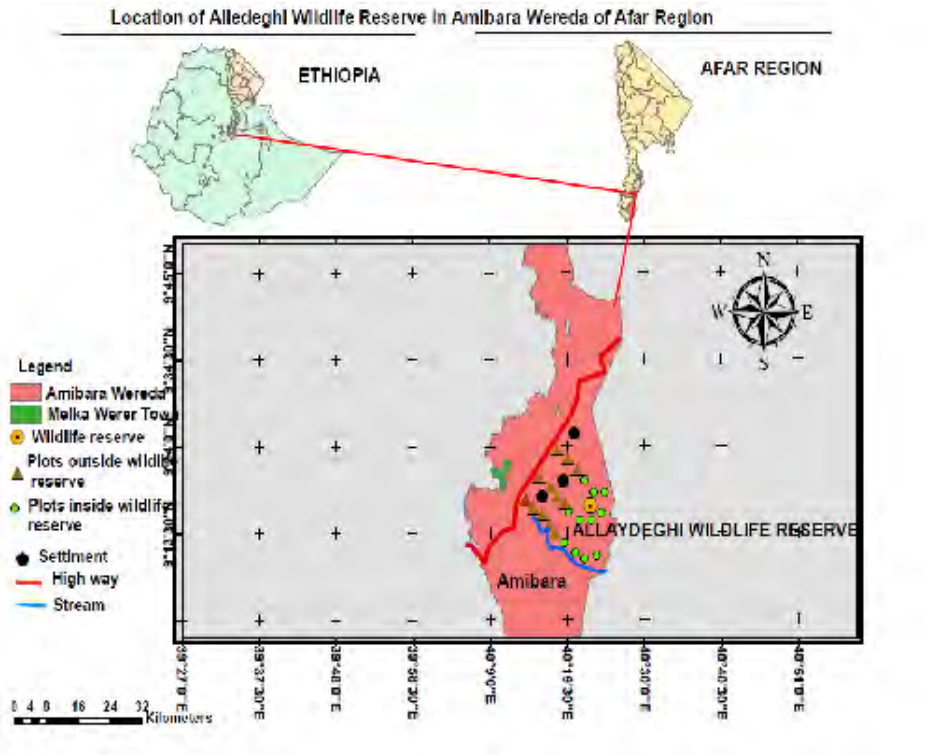


Figure 1: Map of Ethiopia showing Regional states and the study area

3.1.1. Climate

According to WCMC (1991), Alledeghi Wildlife Reserve is a semi-arid ecosystem with annual rainfall ranging between 400 and 700mm. As recorded from a10year period data the mean annual rainfall is 442 mm. July-September is a rainy period (Figure 2), and the mean seasonal temperature ranges from 14.1 to 39.2^{o}C (NMSA, 2014). Average monthly rainfall recorded in the area showed that the highest amount of rainfall is received in September. The driest month in the study area is October with less than 2 mm rainfall.

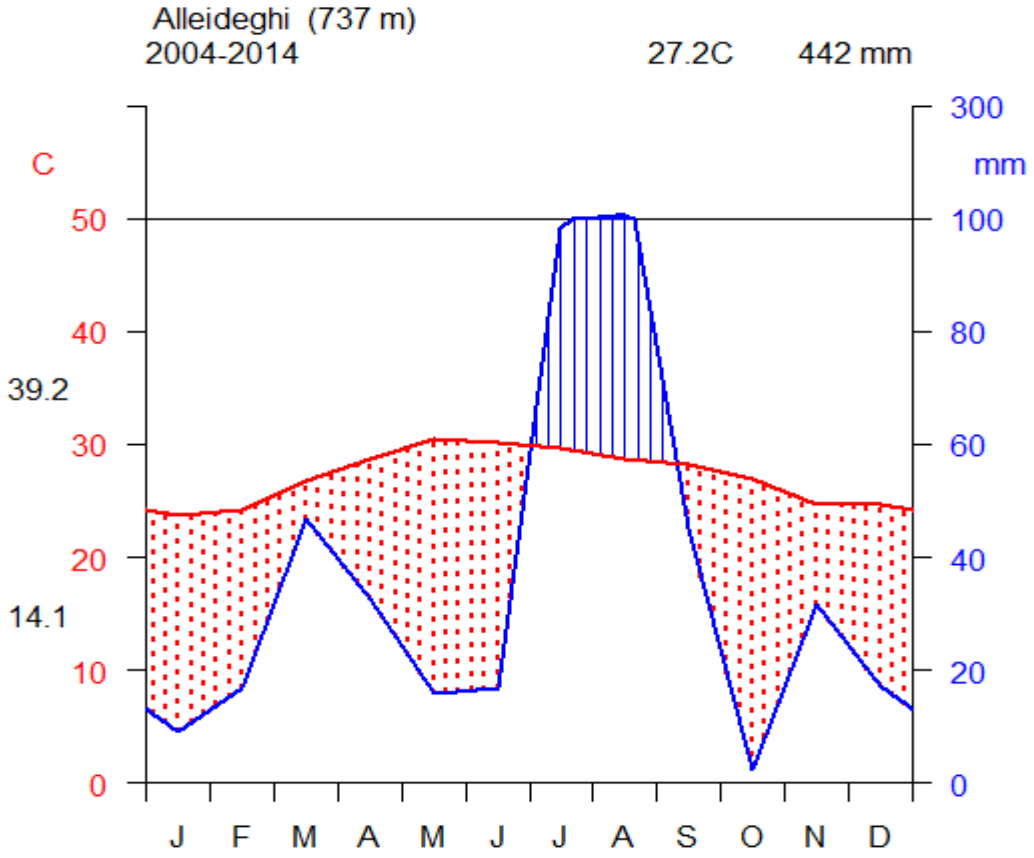


Figure 2: Climate diagram of the study area showing mean annual temperature and rainfall. (Source of data: NMSA, 2014)

3.1.2. Soil

According to WARC (2003/2004), there are two soil types and based on FAO/UNESCO classification they belong to Vertic cambisols and Calcic Cambisol. The pH of the soil is alkaline and ranges from 8.1 to 9.1. The organic matter (OM) content is low and ranges from 0.5 - 1.9%.

3.1.3. Vegetation

The major vegetation types in and around the Reserve include grasslands, bushland, shrubland, wooded grassland, shrub grassland, riverine forest and highland forest (Almaz Kebede, 2009). *Chrysopogon plumulosus* and *Sporobus lusiocladus* comprise a relatively high percentage of herbaceous vegetation on the plains (Almaz Kebede, 2009). The southern, northern, and western edges of the Reserve are bush-grasslands or shrublands, with *Acacia Senegal* being the dominant species and in some parts of the grassland; *P. juliflora* is becoming the dominant woody species. The woody plant species in the plains of this Reserve includes *Acacia senegal*, *A.tortilis*, *A.mellifera*, *Balanitis aegyptiaca*, *Cadaba* spp. and *Grewia* spp. The highland forest of Mount Asebot include *Cordia africana*, *Croton macrostachyus*, *Erythrina abyssinica*, *Juniperus procera*, *Olea europaea*, *Podocarpus falcatus*, *Rhsu vulgaris* and many others. (Almaz Kebede, 2009).

3.1.4. Fauna

Thirty-one species of mammals have been observed at AWR and the surrounding areas. Most common large herbivores in the AWR include Oryx, Soemmering‟s Gazelle, Gerenuk, Cheetah, leopard, lion, Lesser Kudu, Ostrich and many others and (Almaz Kebede, 2009).

3.2. Data source and materials

Different kinds of data have been collected to conduct this study. The data from primary sources include field data and information using questionnaire from members of the surrounding community on the other hand, secondary data were obtained from the study area, topographic maps besides, the published materials including books, journals, research articles and census reports were reviewed. For sampling plot layout and vegetation data collections plant press, secateurs, plastic bags, flimsies, clinometers, altimeter, GPS, digital camera were materials used.

3.3. Sampling design and methods of data collection

3.3.1. Reconnaissance survey

Before actual field data collection was started, a reconnaissance survey was made in September 12-15/2014 in order to obtain an impression on the distribution of *P. juliflora*.

3.3.2. Sampling design

After reconnaissance survey, the vegetation data collection was made between September 15-October 15, 2014. The diversity, density and distribution of woody and herbaceous plants in the study area were investigated by using preferential sampling technique. The extended Braun-Blanquet and Domain Cover Scales as stated in Kent and Cocker (1992) were used to calculate the cover abundance values. Species abundance values were converted following the Braun-Blanquet 1-9 scale as modified by Van der Maarel (2005). In the study area plots were preferentially laid based on visually observed heterogeneous vegetation. That is, plots were laid from the main road to the reserve following three roads that lead into the reserve. For each road followed, twenty plots were taken preferentially. A square quadrat of 20m x 20m ($400m^2$) was used to sample the vegetation and sub quadrates of and 5mx5m for shrubs and 1mx1m for herbs were established to calculate respective cover abundance values. A total of 60 plots were taken for the whole study. In each sample plot, type of species present, and count of saplings and seedlings were carefully recorded. Plant species in the plots were recorded and the abundance of

each species was determined by counting individual members in the plots. Cover /-abundance values in the large quadrat (one from each corner of the large square quadrate and one at the center). Both woody plants and herbaceous species were collected, pressed, dried, labeled and identified using the different volumes of Flora of Ethiopia and Eritrea at the National Herbarium (ETH), Addis Ababa University.

3.3.3. Community perception on invasion and impact of *Prosopis juliflora*

In order to acquire information on the trend of *P. juliflora* invasion with respect to causes of the invasion and its impact, data were collected by administering questionnaire and semi structured interviews. Both quantitative and qualitative approaches were used for data collection in the survey. These included researcher-administered household questionnaire (Appendix 1) with both open-ended and closed questions. The techniques include semi- structured interviews (individual and group discussion) and field observation (Martin 1995, Cotton 1996). Interviews and focal group discussions were held with local community living around the Reserve, Reserve scouts and key informants regarding introduction, potential problems and beneficial use, possible causes of encroachment in the study area, trend of livestock introduction to the Reserve, factors affecting the Reserve and eradication mechanisms. Translators assisted in data collection. Key informants were selected based on comments and recommendations from elders and authorities. From key stakeholders such as the Reserve, community members lives around the reserve (from nearby three kebeles), Wereda (district) Agriculture and FARM-Africa offices a total of 80 people 60 from kebele or community members and 20 from Reserve, Agriculture and FARM-Africa offices were selected using systematic random sampling technique. The focal group discussion was performed with one group. Control measures were evaluated by observing of previously any practice done in the area.

Figure 3: Semi-structured interview and discussion with informants

The quantitative data collected through the household surveys were analyzed using simple descriptive statistics, such as percentages, frequencies, and means, in the Statistical Package for Social Science version 13.

3.4. Data analysis

Based on the collected ecological data the status of *P. juliflora* was examined by computing density, abundance and frequency using the following equations.

Frequency: the percentage of sampling plots (vegetation registrations) on which a particular plant species is found.

$$\text{Frequency} = \frac{\text{Number of plots in which a species occurs}}{\text{Total number of plot}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of species}}{\text{Frequency of all encountered species}} \times 100$$

Density: number of individual species per unit area.

$$\text{Density} = \frac{\text{Number of individuals of species in all sampling unit}}{\text{Sampled area in hectare}} \times 100$$

$$\text{Relative density} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

Abundance: population density of plant species expressed as the number of individuals of a species per unit area.

$$\text{Abundance} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

3.4.1. Diversity and similarity indices

Program for R statistical Software version 3.0.2 (R Core Development Team, 2013) following (Zerihun Woldu, 2012) was used for plant community type and distribution analysis. In the identification of plant species richness and evenness Shannon Wiener diversity index was taken in to account to compute following R statistical Software.

3.4.2. Species diversity analysis

Shannon - Wiener (1949) index of species diversity was applied to quantify species diversity and richness.

$H = -\sum(pi \ln pi)$,

Where H is the Shannon- Wiener diversity index, pi is the ratio of a species average to the total species average, ln the natural logarism to base e (loge)

$J = H/Hmax$

Where J is the species evenness H Shannon and wiener diversity index and Hmax is lnS, Where S is the number of species.

Equitability or evenness (J) = H/ ln ( )‟‟S or = H/ max'H

Where:

- H‟‟=Shannon-Wiener Diversity Index
- H‟‟max=InS
- S=total number of species in the sample.
- In S= the natural logarithm of the number of species

3.4.3. Plant community analysis

Agglomerative Hierarchical cluster analysis (classification) was made using R statistical software version 3.0.2. (R Core Development Team, 2013) following (Zerihun Woldu, 2012). The analysis was based on the abundance of the species (number of individuals).The data matrix contained 60 plots and 89 plant species collected from the sample plots. The plant community types were named after two or three dominant species selected using the relative magnitude of their Synaptic values.

CHAPTER FOUR

4. RESULTS

4.1. Plant Community types of the study area

Four plant community types were identified from the hierarchical cluster analysis (Figure 4). The four communities identified were; *Prosopis juliflora* - *Acacia nilotica* (Community type 1), *Xanthium strumarium* - *Eriochloa fatmensis* (Community type 2), *Setaria verticillata* - *Prosopis juliflora* (Community type 3) and *Blepharis boranensis* - *Tribulus cistoides* (Community type 4)

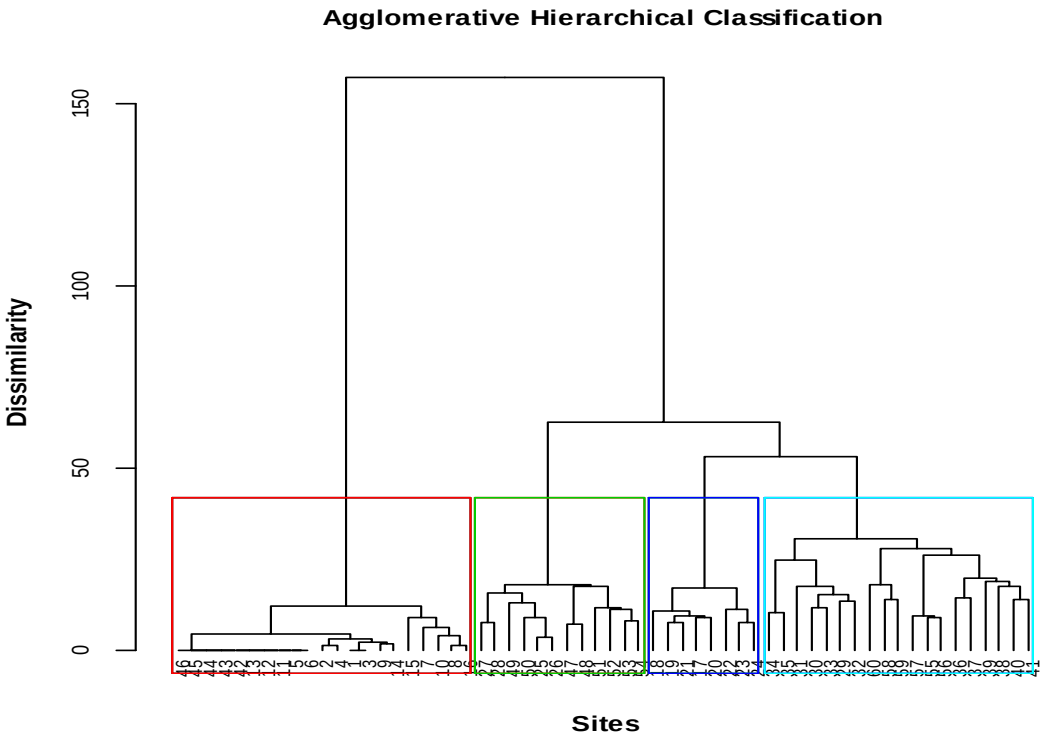


Figure 4 . Agglomerative Hierarchical Clustering using Euclidean distance

Assigning the Cluster IDs as labels

Table 1: Synoptic table of species with synoptic value ≥1 in at least one community type.

Species	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Abutilon figarianum	0.09	2.30	0.91	2.10
Acacia nilotica	0.42	2.60	0.16	0.05
Acacia oerfota	0.04	0.12	0.08	1.20
Acacia Senegal	0	0.25	0	1.10
Acacia tortilis	0.14	0.25	1.25	0.40
Blepharis boranensis	0	0.12	0.58	3.68
Cadaba rotundifolia	0	0.25	0	1.68
Celosia argentea	0	1.00	0	0
Chrysopogon plumiilosus	0.04	0.25	1.70	2.40
Crotalaria pycnostachya	0	2.60	0.08	0
Dactyloctenium scindicum	0	1.10	0	1.00
Echinochloa colona	0	0	0	1.00
Eriochloa fatmensis	0	4.50	0	0.20
Ipomoea sinensis	0	0.87	2.30	0.80
Justicia.caerulea	0	2.75	2.50	1.26
Leucas stachydiformis	0	1.87	0.08	0
Ocimum forskolei	0.14	1.25	2.17	1.70
Paspalidium geminatum	0	0	1.00	1.26
Prosopis juliflora	8.70	2.60	4.25	0.47
Rostraria cristata	0	1.60	0	0
Ruellia patula	0.09	1.10	0.08	1.00
Setaria verticillata	0	0	6.75	0.89
Solanum dennekense	0.23	0.62	3.58	0.21
Sporobolus festivus	0	0.12	0.25	1.40
Sporobolus nervosus	0	0	0	1.70
Tephrosia linearis	0	1.00	0.08	1.10
Tetrapogon tenellus	0	0	0	2.20
Tragus berteronianusn	0.14	0.62	1.08	2.00
Tribulus cistoides	0	1.50	0.50	2.50
Urochloa trichopus	0	0	0.17	1.30
Xanthium strumarium	0	4.60	0	0

Cluster	Plots	Size	%
Community1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,42,43,44,45,46	21	35
Community 2	25,26,27,28,47,48,49,50,51,52,53,54	12	20
Community 3	17,18,19,20,21,22,23,24	8	13.3
Community 4	29,30,31,32,33,34,35,36,37,38,39,40,41,55,56,57,58,59,60	19	31.6

From the cluster analysis, four community types were identified. One or a combination of species with relatively higher synoptic values was used to name each community type in the cluster. Accordingly, the following is a description of the community types identified

4.1.1. *Prosopis juliflora - Acacia nilotica* Community type

This Community type consisted of 13 species and occurs in areas of high anthropogenic disturbances such as overgrazing and the areas highly dominated by *P.juliflora*. The dominant species (relatively higher synoptic values.) in this community type are *P. juliflora and Acacia nilotica*. Even though this community was named as *P. juliflora- Acacia nilotic* synoptic values of *P. juliflora* very high compared to that of *Acacia nilotica* .The top six dominant species in community 1 in terms of their synoptic values are listed in Table 3. The cover-abundance values of other associated species to this community are listed in Appendix 2

Table 2: The top six dominant species of community 1 in terms of relatively higher synoptic values.

Species	Synoptic values
Prosopis juliflora	8.76
Solanum dennekense	0.23
Acacia nilotica	0.42
Acacia tortilis	0.14
Ocimum forskolei	0.14
Tragus berteronianus	0.14

4.1.2. *Xanthium strumarium - Eriochloa fatmensis* Community Type

This Community is composed of 35 species and also this community occurs in areas of anthropogenic disturbances such as overgrazing .The top six dominant species in Community 2 in terms of their synoptic values are listed in Table 4. The mean cover-abundance values of other associated species to this Community are listed in Appendix **2.**

Table 3: The top six dominant species of Community 2 in terms of relatively higher synoptic values.

Species	**Synoptic values**
Xanthium strumarium	4.6
Eriochloa fatmensis	4.5
Justicia caerulea	2.7
Acacia nilotica	2.6
Crotalaria pycnostachya	2.6
Prosopis juliflora	2.6

4.1.3. *Setaria verticillata - Prosopis juliflora* Community Type

This community consists of 36 species. In this community *Setaria verticillata and Prosopis juliflora* are the most dominant. The top six dominant species in community 3 in terms of their mean cover-abundance values are listed in Table 5. The mean cover abundance values of other associated species to this community are listed in Appendix 2.

Table 4: The top six dominant species of Community 3 in terms of relatively higher synoptic values.

Species	**Synoptic values**
Setaria verticillata	6.7
Prosopis juliflora	4.2
Solanum dennekense	3.5
Justicia caerulea	2.5
Ipomoea sinensis	2.3
Ocimum forskolei	2.1

4.1.4. *Blepharis boranensis - Tribulus cistoides* Community Type

This community is composed of 59 species. The top six dominant species in Community in terms of their mean cover-abundance value are listed in Table 6. The mean cover abundance values of other associated species to this Community are listed in Appendix 2.

Table 5: The top six dominant species of Community 3 in terms of relatively higher synoptic values.

Species	**Synoptic values**
Blepharis boranensis	3.68
Tribulus cistoides	2.52
Chrysopogon plumulosus	2.42
Tetrapogon tenellus	2.21
Abutilon figarianum	2.15
Tragus berteronianus	2.05

The four communities, besides differing in their characteristics species composition, also differ in diversity measures. Table 7 gives diversity indeces values of the different communities.

Table 6: Diversity indeces values of the different communities.

Community	Richness	Diversity Index (H‘)	Evenness
1	13	2.38	0.89
2	35	3.48	0.93
3	36	3.47	0.97
4	59	4.07	0.96

4.2. Impact of *Prosopis juliflora* on plant species diversity and their density

4.2.1. Impact of *P. juliflora* on density, diversity, richness and evenness of other plant species

The study assessed the advance of *P. juliflora* in to the Reserve and its impact on plant species diversity, density, richness and evenness. The study had three road lines that lead into the reserve and each contained 20 plots. Each road line was divided in to four groups and each group contained five plots. Group one contains the first 5 plots, hence group 2 contained the next five plots and group 3 & 4 placed in five plots interval consecutively. A total of 60 plots were used to show the advance of *P. juliflora* in to the Reserve and its impacts on plant species diversity, density and richness.

(Fig. 5) The first group, which was 9,500m far from the Reserve contained *P. juliflora* and 26 other plant species and the relative density of *P. juliflora* is (60.4%) in 0.6 hectares and (45.6 %) for that of all 26 other plant species. The 2nd group was 5,500 m far from the Reserve and contained *P. juliflora* and 29 other plant species. In this group the relative density of *P. juliflora* is (55.6%) in 0.6 hectares and (49.5 %) for 31 other plant species. The 3rd group was 2,500m far from Reserve also contained 41 other plant species and the relative density of *P. juliflora* is (34.08%) in 0.6 hectare and (65.9%) for the 41 other plant species. The last group comprised plots inside the Reserve, which contained *P. juliflora* and 58 other species and the relative density of *P. juliflora* is (3.4%) and (96.5 %) for 31 other plant species in 0.6 hectare. (All other plant species are listed in Table 8). Richness, diversity and evenness increased from outside towards the Reserve (Fig.6)

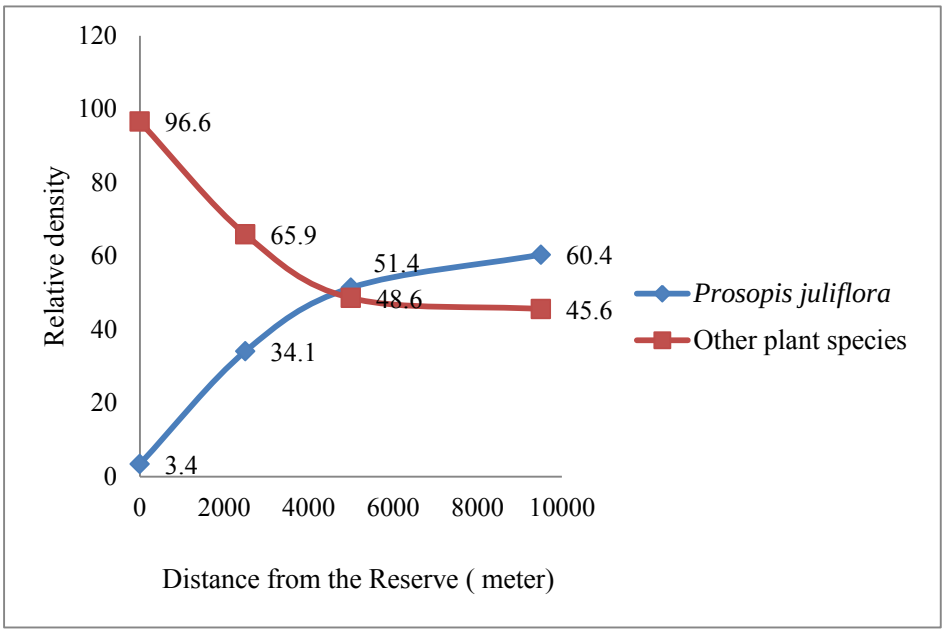


Figure 5: Impact of *P.julifora* on plant species density

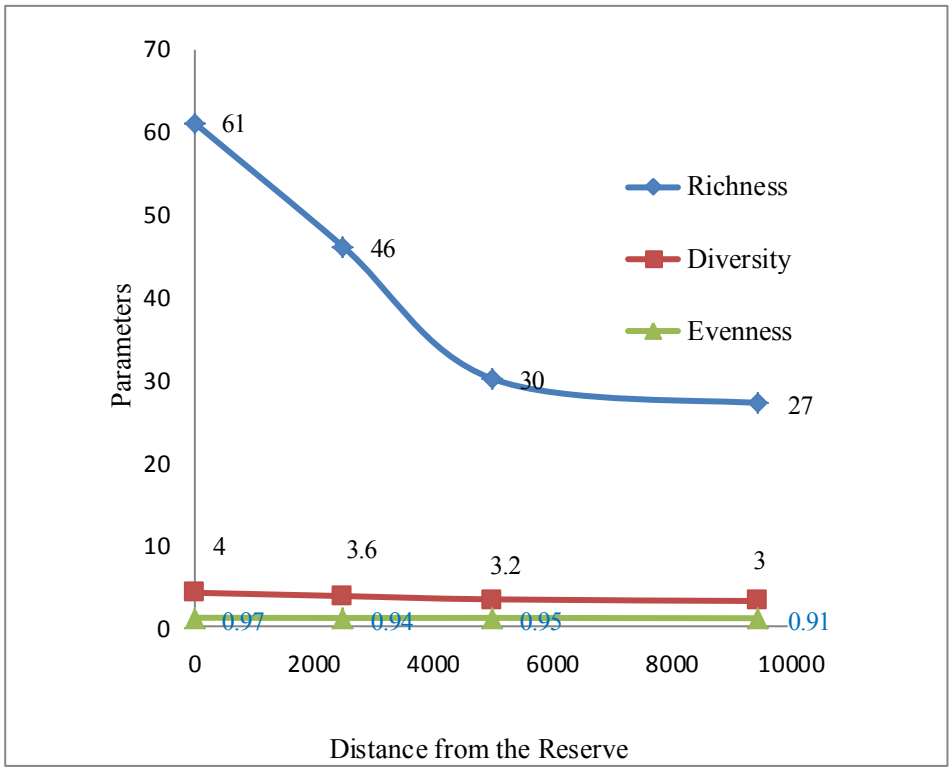


Figure 6: Impact of *P. juliflora* on species diversity, richness and evenness

Table 7: List of other plant species for each plot

NO	Other species	Plot 9500 m far from the Reserve	Plot 5000 m far from the Reserve	Plot 2500 m far from the Reserve	Plot comprised inside the Reserve
1	*Balantis aegyptiaca*	√		√	
2	*Acacia tortilis*	√	√	√	√
3	*Acacia mellifera*			√	
4	*Acacia nilotica*	√	√	√	√
5	*Acacia senegal*			√	√
6	*Setaria verticillata*	√	√	√	
7	*Abutilon figarianum*	√	√	√	√
8	*Ocimum forskolei*	√	√	√	√
9	*Sporobolus ioclados*		√		
10	*Dactyloctenium geminatum*		√		
11	*Kedrostis leloja*	√			
12	*Urochloa trichopus*	√	√		√
13	*Solanum dennekense*	√	√	√	√
14	*Ruellia patula*	√		√	√
15	*Paspalidium geminatum*	√		√	√
16	*Crotalaria pycnostachya*	√			√
17	*Justicia caerulea*	√	√	√	√
18	*Hibiscus macranthus*	√		√	√
19	*Ipomoea sinensis*	√	√	√	√
20	*Tribulus cistoides*	√	√	√	√
21	*Blepharis boranensis*	√	√	√	√
22	*Eragrostis aspera*	√			√
23	*Tragus berteronianus*	√	√	√	√
24	*Sporobolus festivus*	√	√	√	√
25	*Chrysopogon plumulosus*	√	√	√	√
26	*Tephrosia linearis*	√		√	√
27	*Boerhavia repens*	√		√	
28	*Seddera bagshawei*	√		√	√
29	*Acacia oerfota*	√	√	√	√
30	*Cadaba rotundifolia*			√	√
31	*Cordia sinensis*				√
32	*Tetrapogon tenellus*			√	√
33	*Dactyloctenium scindicum*			√	√

NO	Other species	Plot 9500 m far from the Reserve	Plot 5000 m far from the Reserve	Plot 2500 m far from the Reserve	Plot comprised inside the Reserve
34	*Euclasta condylotricha*		√	√	√
35	*Cynodon dactylon*			√	√
36	*Coelachyrum poiflorum*			√	
37	*Grewia tenax*			√	√
38	*Amaranthus caudatus*				
39	*Sporobolus nervosus*			√	√
40	*Achyranthes aspera*				√
41	*Ocimum basilicum*		√	√	√
42	*Phyllanthus ovalifolius*			√	
43	*Echinochloa colona*				√
44	*Dactyloctenium aegyptium*		√		
45	*Leucas stachydiformis*		√		√
46	*Phyllanthus oblongiglans*		√		
47	*Amaranthus sparganiocephalus*		√		√
48	*Parthenium hysterophorus*		√		
49	*Murdannia simplex*		√		√
50	*Eriochloa fatmensis*		√		
51	*Aeschynomene abyssinica*		√		
52	*Rostraria cristata*				√
53	*Celosia argentea*				
54	*Meineckia phyllanthoides*				√
55	*Polygala obtusissima*				
56	*Kohautia grandiflora*				
57	*Xanthium strumarium*				√
58	*Heliotropium zeylanicum*				√
59	*Brachiria deflexa*				√
60	*Zaleya pentandra*				√
61	*Tetrapogon cenchriformis*				√
62	*Farsetia stenoptera*				√
63	*Brachiaria leersioides*				√
64	*Indigofera colutea*				√
65	*Chloris gayana*				√
66	*Grewia villosa*				√
67	*Lantana camara*				√
68	*Solanum somalense*				√
69	*Solanum melastomoides*				√

NO	Other species	Plot 9500 m far from the Reserve	Plot 5000 m far from the Reserve	Plot 2500 m far from the Reserve	Plot comprised inside the Reserve
70	*Oreosyce africana*			√	
71	*Panicum atrosanguineum*			√	
72	*Celosia schweinfurthiana*				√
73	*Prosopis juliflora*	√	√	√	√

4.2.2. Relation of *P. juliflora* and *Setaria verticillata*

Contrary to other plant species *Setaria verticillata* showed correlation relation with *P. juliflora*. As relative frequency and abundance of *P .juliflora* increase at the same time relative frequancy and abundance of *Setaria verticillata* increased.

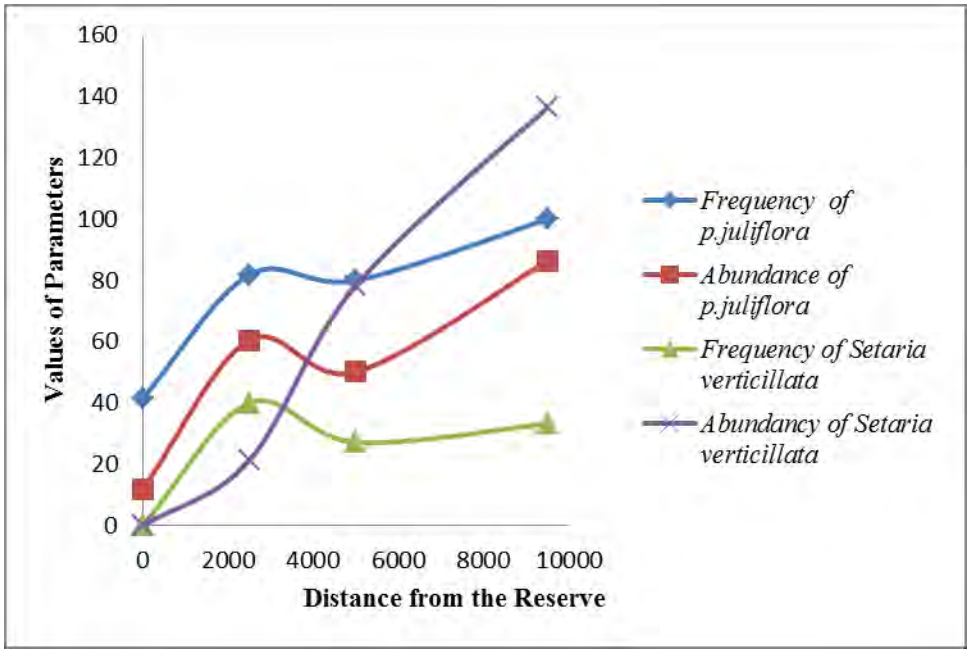


Figure 7: Relative frequency and abundance of *P. juliflora* and *Setaria verticillata*

4.3. Communities' perception on *P. juliflora* invasion and impact

4.3.1. Socio-demographic characteristics

In total, 80 respondents from which 60 were interviewed from the community members and 20 from government and non-government offices. Out of these 87.5% were males while 12.5% were females. From the community members of 66% the occupation was mainly livestock rearing while 8.7% of them participate in charcoal and other small trade. A small proportion of the respondents were below the age of 25 years with an overall mean age of 37.5 years and mean household size was found to be eight (8).

Table 8: Socio-economic and demographic characteristics of the respondents

Characteristic	Description	Frequency	Mean
Sex n=80	Female	10	12.50
	Male	70	87.50
Age	16-24	12	15.00
	25-34	18	22.50
	35-44	20	25.00
	>45	30	37.50
Occupation n=80	Livestock rearing	53	66.25
	Trading	7	8.75
	Government employer	20	25.00
House hold size	Mean house hold size		8.00
No. of camel owned	None	20	25.00
	1-10	11	13.75
	11-20	15	18.75
	Above 20	34	42.50
No. of cattle owned	None	20	25.00
	1-10	9	11.25
	11-20	15	18.75
	Above 20	35	43.75

4.3.2. Introduction of *P. juliflora* and its disseminating agents

In the study area most of the respondents agreed that *P. juliflora* was observed in the area in 1970 while some suggested 1983 as a year when invasion was started. Higher proportion of the respondent from local people stated that *P. juliflora* was introduced by an English person to combat desertification. On the other hand, respondents from agricultural and FARM- Africa offices believe that the Ministry of Agriculture introduced the species during the 1970ʿs indiscriminately to rehabilitate both degraded land and for its high quality pastures to serve as a shade tree and wind break for plantations, and also for land reclamation. Regarding the dissemination status of the species in to the Reserve, the survey results indicated that 87.5% of the respondents put cattle dung, 6.25% flood, 3.75 % wind then 2.5 % human in decreasing sequence as agent of introduction respectively.

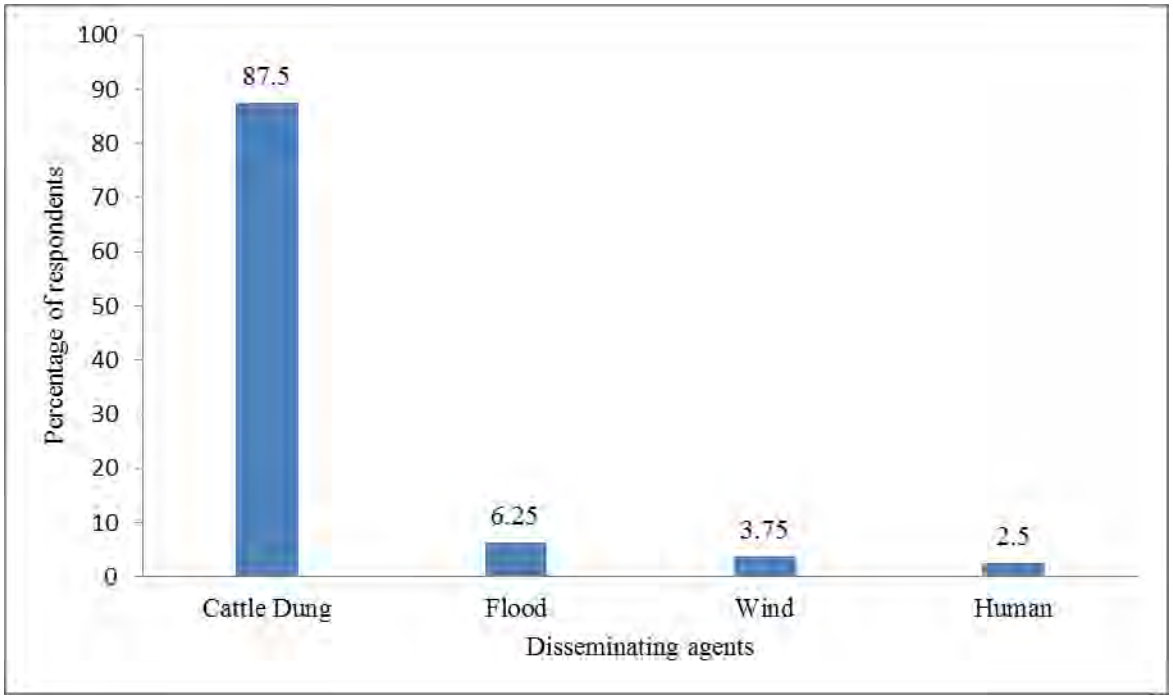


Figure 8: Agents facilitating dissemination of *P. juliflora* in the study area

4.3.3. Negative impacts of *P. juliflora* in the study community

The study assessed problems of *P. juliflora* and identified highly mentioned problems which are: - reduction of grass lands and grazing lands, health impacts on human and animals, decreasing biodiversity, invade settlement area, narrowing of footpath and roadside. Respondents from local community bitter about the nature *P. juliflora* and they tried to express its natures like tolerance of arid condition and impressiveness over other plant species as:-

"Whenever there is Dergahria (*Prosopis juliflora*), grasses will never grow Dergharia grows by avoiding the growth of the others". "It does not choose a place to grow, it grow even in concrete". (Fig 5, A & B)

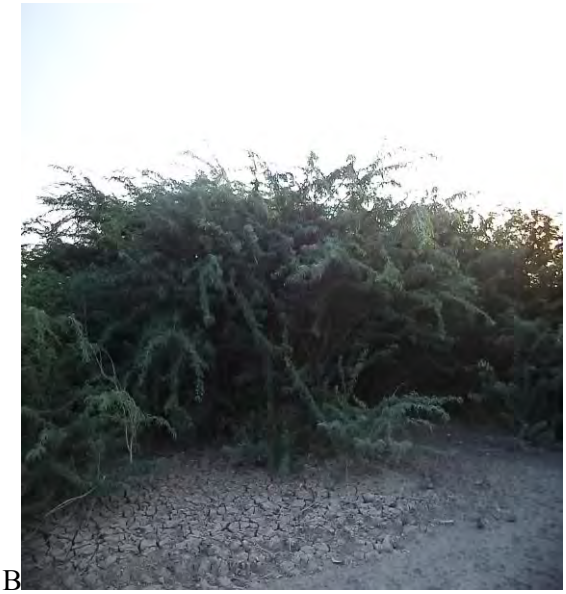
A  B 

Figure 9: (A): Picture showing that *P. juliflora* could grow in extreme adverse condition which could be impossible to other plant species. (B) *P. juliflora* dominated areas it is impressive over other species. (Photo by Selamnesh, 2014)

4.3.4. Benefits of *Prosopis juliflora*

The socio economic survey identified the following data of uses of *P. juliflora* in study the area. 66.25 % of respondent‟s puts *P. juliflora* as harmful, 20% both beneficial and harmful and 13.75 % beneficial. A respondent from the local community totally agreed on its harmfulness and respondents from agricultural and FARM-African office agreed on its both beneficial and harmful.

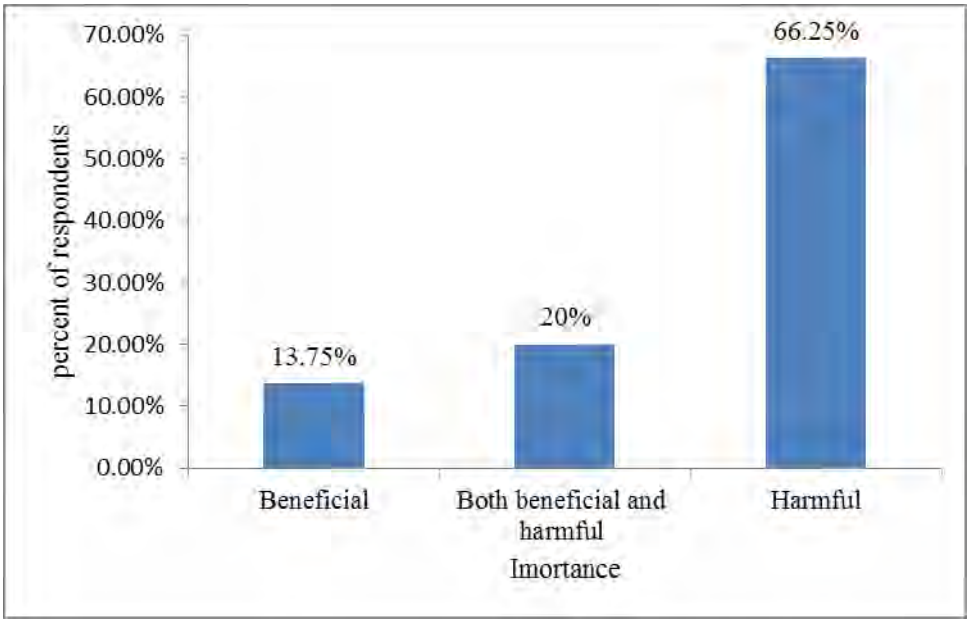


Figure 10: Importance of *Prosopis juliflora* by respondent

4.3.5. Attitude of individuals about Reserve and affecting factors

The study also served to assess the attitude of the community about the benefit, protection and factors which are affecting the reserve. Almost all of respondents agreed about the benefit of the Reserve. But respondents from the local community explained the benefit with respect to their livestock, it is the only place less invaded by *P. juliflora* hence it is their future hope for their livestock grazing land.

Factors which are severely affecting the reserve, 66.25% of respondents put encroachment of *P. juliflora,* 25% and 9 % of respondents put competition for grazing land and fire wood collection consecutively.

The respondents have high willingness to protect the Reserve from the invasion of *P. juliflora* like other part of the land and mentioned the need of external help as a solution for minimizing the expansion. Respondents from Agricultural and other offices strongly mentioned immediate action should have to be taken especially protect the Reserve from entrance of livestock.

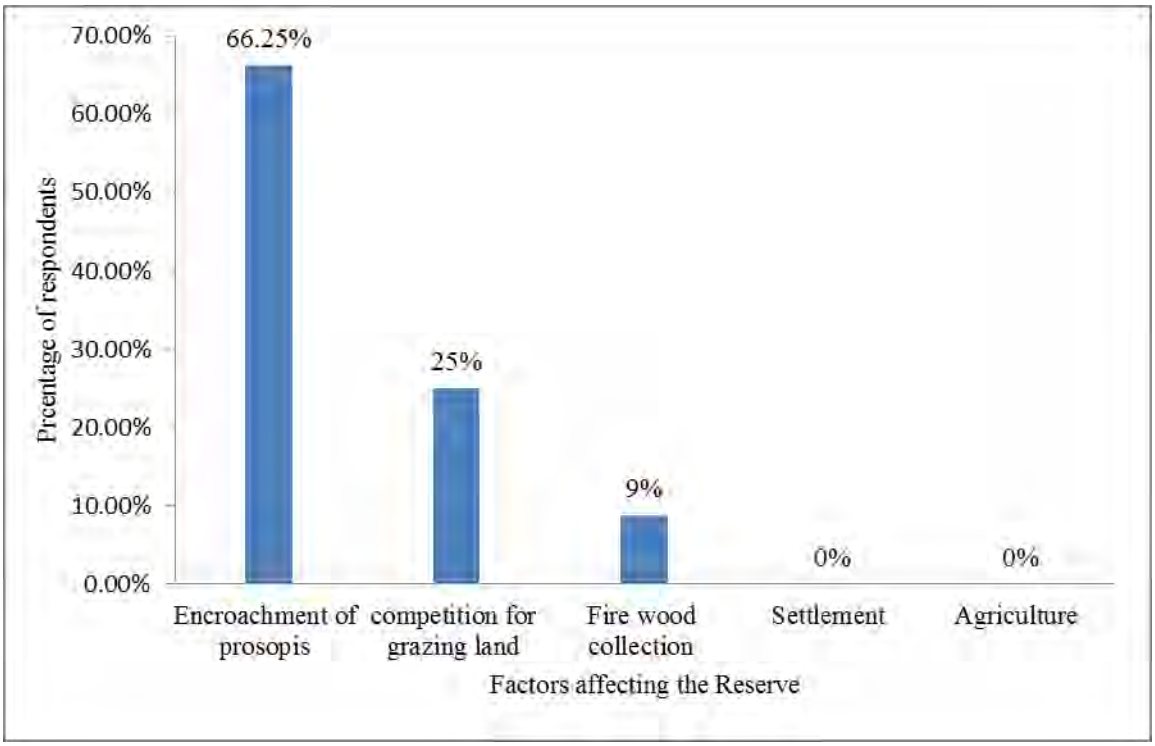


Figure 11: Factors severely affecting the health of the Reserve

4.3.6. Methods used to control *P. juliflora* by the community

Even if the quantity varies, *P. juliflora* has been found in almost all parts of the study area. Even though communities could not pull themselves out from the problems they have taken different measures to secure their livelihoods due to the situation where sole dependency on pastoralism. The study found out that (37.5%) of the respondents attempted to control *P. juliflora* spread in their land by cutting and applying used motor oil to stumps. Both cutting and burning were the

next most commonly used techniques reported by 28.75. Burning and hand pulling were reported by 17.5% and 16.25% of the respondents respectively.

Table 9: *P. juliflora* control measures practiced by pastoral households

Methods used to control	Respondents practiced control measures	Respondents in %
Cutting	30	37.5
Both cutting and burning	23	28.75
Burning	14	17.5
Hand pulling	13	16.25

Respondent; I cut Dergahria (*P. juliflora* trees) from my homestead and burned it continuously and if he /she stooped burning the stump starts to regenerate, so kept on burning it until it died and at this time other specie start to grow .

Figure 12: Practiced measure taken by pastoral household to eradicate *P. juliflora* (This *P. juliflora* was cut and scorched by fire) (Photo by Selamnesh, 2014)

CHAPTER FIVE

5. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. Discussion

5.1.1. Plant community types of the study area

In all observed communities, species with higher synoptic values are those easily observed repeating themselves in associations. *P. juliflora* has with higher synoptic values and observed repeating itself in associations. Community 1 named as *Prosopis juliflora- Acacia nilotica* but there is a big difference in synoptic values between *P. juliflora* and other species belong to this community. Plots included in Community 1 are those with high anthropogenic disturbances like overgrazing, and this community covers 35% of plot size and plots in Community 4 have low disturbance. Of the four community types, community 4 has highest species diversity and richness with less synoptic values of *P. juliflora.* Contrary, Community 1 has low diversity and richness with high synoptic values of *P. juliflora.* As we go from Community 4 to Community 1 synoptic values of *P. juliflora* increasing and diversity decreased (Table 6).

5.1.2. Assessing impact of *Prosopis juliflora* on plant species diversity and their density

5.1.2.1. Impact of *P. juliflora* on density, diversity, richness and evenness of other plant species

The relative density of *P. juliflora* decreased from outside towards the Reserve and that of other species contrarily increased (Fig. 10). In areas where *P. juliflora* was dominant other species diversity was very low, as comparative study conducted by Keblawy and Rawai (2007), had also shown the relatively high density of *P. juliflora* was associated with fewer number of other plant species. Low plant diversity and its high density indicated its high competitiveness and its threat to other plant species in the area.

Within the Reserve the density of other species was high, which was, because the density of *P. juliflora* is less. The number and frequency of other species decreased in plots having high number of *P. juliflora.* A study on the impact of *P. juliflora* showed great depressing effect on the number, density and frequency of the associated species, particularly on native vegetation (Abdillahi *et al*., 2005).

The first fifteen plots were highly dominated by *P. juliflora* and forming bush. In this area the probability of finding other species was very low. The last fifteen plots were less density of *P. juliflora.* According to Singh *et al*. (2008), forage grass species have not been observed in *P. juliflora* dominated lands, this is because *P. juliflora* starts branching closer to the ground and high canopy closure resulted in interference with light and hence the death of under story vegetation. Also this may be one of the reasons for low plant diversity observed under the *P. juliflora* fields

Species richness increased and plots were more even in the Reserve means abundance of species is less but when we go out from the reserve richness, evenness and diversity decreased (Fig. 11). And greater evenness is considered to have greater species diversity. Also study conducted by Singh *et al.* (2008) showed *P. juliflora* has a negative impact on plant diversity

5.1.2.2. Correlation of *P. juliflora* and *Setaria verticillata*

As the result showed, abundance and frequency of *P. juliflora and Setaria verticilata* almost corresponded with each other (Fig 8). *Setaria verticillata* was recorded in areas where *P. juliflora* was dominant. Abundance and frequency decreased at the same time when moving in to the Reserve and increased towards the outside of the Reserve. This shows that there is correlation between them. According to Samuel Getachew *et al.,* (2012) *P. juliflora* contains allelo-chemicals in its organ parts in various amounts and types. Leaves seem to have greater inhibitory effects than roots and barks. The effect is also species specific. It could be the reason why *Setaria verticillata* is found at higher density under canopy of *P. juliflora* than other plant species. Also *P. juliflora* is able to improve the soil in which it is growing by means of biological nitrogen fixation, leaf litter accumulation, nutrient pumping from deeper soil layers,

loosening of a hard soil structure, stabilizing of loose sands, and an increase of the fauna above and below the ground (Kaushik and Kumar, 2003).

5.1.3. Socio-demographic and economic characteristics

From the result the majority of respondents are elders this is because they have knowledge and close contact from the beginning about *P. juliflora* introduction. The community rely heavily on livestock as their main source of livelihood (Table 2). Being a pastoral community, there is heavy dependence on livestock and around 91% of Afar people in Ethiopia are estimated to be herders (Tadesse Berhe and Yonas Adaye, 2007).

5.1.4. Assessing the introduction and disseminating agents of *P. juliflora* in the study area

There is no precise written document why, when, where, and who introduced *P. juliflora* to the study area. Different respondents had different perception regarding the origin and introduction of the species into their environment. Peoples‟ perceptions of invasive species are determined by whether the species meets their socio-economic needs (Pasiecznik, 2001). Elder respondents believed that the aim of *P. juliflora* introduction in to their area was to combat desertification. Contrary to that belief nowadays in the study area *P. juliflora* has been observed along roadsides, bare lands, waterways, grasslands and settlement areas and it is expanding into the Reserve. Also study by Rezene Fessahaie (2006), indicated that in contrary to its purpose of introduction, the plant escaped out of control and has invaded farm lands, pasture lands, range lands, irrigation schemes and caused several land use/ land cover changes.

From the results, cattle dung is the main disseminating agent of *P. juliflora* into the Reserve (Fig. 11). The cattle feed on the pods (which is palatable and tasty) and the seeds were distributing all over the places through their dung. According to Pasiecznik *et al*. (2001), animals, both domestic and wild, feed on *P. juliflora* pods. These animals and flood water are the major dispersal agents of *P. juliflora*. Moreover, birds, bats, reptiles and ants that feed on *P. juliflora* pods are also expected to contribute for dispersal of the seeds

As shown by the socioeconomic data the community almost sole depend on livestock and this forced them to have high number of livestock, but their pasture land has been invaded by P. *juliflora* as a result of which they started to graze their livestock in the Reserve.

5.1.5. Assessing negative impacts of *Prosopis juliflora* in the study community

Problems associated with *P. juliflora* were assessed and all of the respondents indicated that *P. juliflora* affects negatively their life in different ways. According to Anderson (2005), invasive species are usually associated with economic, environmental and social losses in introduced areas and the common problems are reduction of pasturelands, decline in crop yield, loss of biodiversity, changing water flow, injuries and poisons to livestock and humans and the formation of impenetrable thickets

All of the respondents claimed that the forage/fodder cover of grazing areas has been reduced in the past fifteen to twenty years. Due to prolific growth and invasion of *P. juliflora* on communal grazing lands that is located around the settlement area, which reduced the amount of pastures available for local livestock. *P. juliflora* totally dominated settlement areas, and no grass is found there and it grew in any kind of soil. It grows on concert, does not need favorable condition (Fig 9, A &B). This result coincides with previous studies that reported *P. juliflora* can grow in a variety of soil types including saline and alkaline areas in sandy and rocky soils (Pacieezuick *et al*., 2001). Because of its deep rooting system that consumes much moisture as well as shading under its thick canopies, *P. juliflora* discourages grass growth (Esther *et al.*, 2005). Because of little or no grass on communal land livestock are now more frequently driven to pastures further in Alledeghi Wildlife Reserve because of this *P. juliflora* is spreading there as well. Also a study in Kenya, Maundu *et al*. (2009), reported that pastoralists move away from *P. juliflora* infested areas to seek pastures in distant areas including protected areas, such as national parks and national reserves, thus spreading *P. juliflora* through animal droppings.

Killing, injuring and poisoning animals were other mentioned problems by respondents. The hard seeds of *P. juliflora* lodge between gums and teeth, leading to inflammation; livestock jaws are eventually disfigured. According to respondents this plant decreases the quality and quantity of livestock causing diseases such as twisting of necks, wounds on their skins and hooves and

preventing their movement in searching of food and causing death. According to a comparative study conducted by (Tabosa *et al*., 2006 ;Maundu *et al*.,2009),while showed goats and cattle fed with diets containing 60-90 % and 50-75 % *P. juliflora* pods respectively suffered mandibular tremors during chewing due to toxicity to neurons of certain cranial nerve nuclei and neuronal lesions result in difficulties in chewing ; it subsequently causes animal death .

P. juliflora also injures humans due to strong and poisonous thorns which was cited as a major problem by respondents. The thorn of *P. juliflora* causes inflammation when injuries occur. *P. juliflora* thorn causes problems on humans ranging from minor infection to hospitalization and even death in a few cases (Maundu *et al.,* 2009), which confirms what has been observed by the local people. According to respondents romanced the spines penetrate any type of shoes, and it is difficult to walk even around their home since thorns cause serious inflammation that may take a week to subside.

Moreover, most of respondents indicated the negative impacts of *P. juliflora* invasion on the biodiversity. Several plant species such as Adado (*Balanites aegyiptiaca)*,Kasalto (*Acacia nilotica*) , Mederto (*Cordia sinensis*) and *Acasia senegal*, were frequently mentioned among the indigenous trees, to have been affected by *P. juliflora* invasion and many useful grass species that were once found in the area , including Durfu (*Chrysopogon plumulosus*) and Isisu (*Cymbopogon schoenan*), Malif (*Andropogon canaliculatus* are now on the verge of extinction.

Respondents also mentioned that *P. juliflora* invasion of settlement areas and footpaths were mentioned as a major problem. *P. juliflora* invasion is very fast and it blocked key paths and roads used by both humans and livestock, requiring longer walking times to get to a desired destination similar problems were also faced in *P. juliflora* dominated areas elsewhere (Esther and Brent, 2005).

5.1.6. Benefits of *Prosopis juliflora*

Prosopis juliflora has documented merits like improving soil fertility, controlling soil erosion, stabilizing sand dunes, providing fuel wood and feed/forage for livestock, fencing and for construction timber and furniture wood (Zeila *et al*., 2004; Esther and Brent, 2005). Despite

these facts, the proportion of respondents who put *P. juliflora* as harmful is high (Fig 10.), the aggregate loss due to *P. juliflora* far outweighs its benefits for this reason local community members in the study area can‟t realize even its little use and they are bitter about the introduction of *P. juliflora* and they ended their comment by saying ″ it has no benefit”. This may be because nothing is done to minimize the spread of the species by utilization it in this area and very small proportion of respondents who participated in charcoal production and other respondents from the Reserve and Agricultural offices mentioned some of its benefits as source of wood for charcoal, local house construction, for fence construction and fuel wood.

5.1.7. Assessing the attitude of individuals about Reserve and affecting factors

Perception of the community about the benefit of the Reserve vary, the local community believed that because their communal land invaded by *P. juliflora,* the Reserve is as the reserve area for their livestock. On the other hand, respondents from Agricultural and Reserve offices believed it has economic, social and environmental benefits.

Higher proportion of respondents from local community put encroachment of *P. juliflora* is severely affecting the Reserve. On the other hand, respondents from Agricultural and Reserve offices indicated that nowadays encroachment of *P. juliflora* is not the major problem of the Reserve but competition for grazing land is the most severe problem. This is because pastoral land is highly invaded by *P. juliflora* and higher number of livestock grazes in the Reserve further facilitating the spread of *P. juliflora* and aggravating the problem and also may even put the sustainability of the Reserve under question mark.

5.1.8. Methods used to control *P. juliflora* by the community

Cutting and applying used motor oil to stumps which was reported by respondents as an effective means to control its regeneration. The community of Alfora Kebele tried to remove *P. juliflora* by cutting from parts of their area. They successfully cleared it but they could not control livestock movement and *P. juliflora* has re-colonized the area. Burning is one of the methods that have been frequently used by the local people to control the plant but they could

not solve the problem as indicated in a study conducted by Abiyot Berhanu and Getachew Tesfaye (2006), which showed Burning of *P. juliflora* may kill very small seedlings but it encourages the copying ability of big stems of *P. juliflora*. Therefore, it should not be implemented for all ages of this plant. According to the respondents after cutting continuous burning would help to discourage the growth of *P. juliflora.*

The study found out that nothing was done to control the spread of *P. juliflora* by utilization in the area. However, experiences from America, Asia and Australia have shown that eradication of *P. juliflora* species by the different methods, especially the mechanical and chemical ones are highly expensive and mostly ineffective (HDRA, 2005). Hence, management strategies were recommended to minimize the ecological and socioeconomic impacts of the invasion and to make use of species as a valuable resource to support rural livelihoods in the area and at the same time, control the spread of *Prosopis juliflora* to new areas. For instance, charcoal production and crushing pods for animal feed. *P. juliflora* is a good fodder for livestock during drought seasons and has no adverse effect on animals if it is used together with other types of forages (Alder, 1949; Zeraye Mehari, 2008). Utilization of *P. juliflora* tree for charcoal by clearing the stumps is assumed to restore the land and become source of income generation for the local people, and the collection and crushing of the pods will also prevent further spread of the invasion to new locations. This method becomes so effective if and only if the charcoal makers remove the plant at least 10cm below the ground (HDRA, 2005; Mwangi and Swallow, 2005).

5.2. Conclusion

Thirty eight years after *Prosopis juliflora* was introduced into the rangelands of the Amibara Wereda it has now well established along roadsides, bare lands, waterways, grasslands and settlement areas and Alledeghi Wildlife Reserve. The present study showed that of *P. juliflora* is a strong competitive bush with low beneficial traits for Afar pastoralists and the most threatening factor hampering the livestock‟s and may be the sustainability of Alledeghi Wildlife Reserve.

The study result indicated that the major income source for the communities of the study area is livestock rearing and they have sole dependence on livestock, on the other hand *P. juliflora* invaded their communal land. Less invaded area is Alledeghi Wildlife Reserve but nowadays lack of grass on communal land of the communities forced them to graze their livestock in the Reserve. As determined thought the study, the main disseminating agents for *P. juliflora* in Alledeghi Wildlife Reserve include cattle dung, flood, wind and human.

The invasion of *P. juliflora* has affected the livelihood of the pastoral community in many ways. Such as: by reducing pasture availability; invasion of settlement area; poisonous thorn for both the people and their livestock and posing health hazard on livestock due to the pod; These effects were found interacting to one another and have become complex to have magnified the negatives of *P. juliflora* invasion against the pastoral livelihoods.

The study result indicated that *P. juliflora* affects the diversity, density and richness of other species. Low plant diversity and its high density show it‟s highly competitiveness and threatening other plant species in the area .When comparing plant diversity inside the Reserve , border and outside the Reserve, in the outside there is high anthropogenic disturbances including overgrazing ,besides cattle are the main disseminating agents of *P. juliflora* and peculiar features of this species such as tolerance of arid conditions and saline soils, fast growing, nitrogen-fixing ,rooting abilities, coppicing abilities, ability to stay dormant for longer time in a media (e.g soil) and germinating during favorable conditions, number of seeds/pod, sweetness of pods, etc made it grow tremendously and to dominate the area .But inside the Reserve the density of *P. juliflora* is less which favors to increase other species diversity. The

evidence from this study suggests that *P. juliflora* invaded parts of the study area, which are under severe threat of disappearance of other plant species.

The dilemma on the benefit and adverse impact of *P. juliflora* can be solved by enhancing the benefits and implementing proper management options. Complete eradication of *P. juliflora* is virtually impossible at the current state of management options but it is possible to reduce further spreading with proper and efficient utilization of the plant.

5.3. Recommendations

In summary, it can be stated that Allidegi Wildlife Reserve is confronted with a serious threat of habitat conversion due to expansion of *P. juliflora* problem. The impact of this would be far-reaching from deterioration of the population of grazing wildlife to total habitat alteration. This calls for taking appropriate management measures without a significant delay, and in light of this the following recommendations are made.

- Hand clearing and uprooting of the plants from grazing lands, around the villages, and from protected lands should be carried out individually or in group.
- Livestock introduction to the Reserve should be controlled so as to preventing further invasion to new areas.
- The pastoralists should appreciate the system of control by utilization of *P. juliflora* hence invasion can be reduced by using crushed pods as a fodder for livestock and source of income from charcoal production.
- Methods like repeated burning and bush clearing avoiding the usage of mature plants for fencing, otherwise by removing the ripe pods, should be employed to control the invading woody species.
- Remove *P. juliflora* seedlings at the early stage (<1.5 yrs.) and/or apply prescribed fire under controlled conditions.
- Avoid cutting the plant randomly as it has strong copying ability if proper management such as repeated clearance is lacking.
- Further study needs to be conducted on the relation between *P. juliflora* and *Setaria verticillata.*
- There is also a need for research on the detailed physiological mechanisms which makes *P. juliflora* out-compete over other indigenous species.

REFERENCES

Abdillahi A., Aboud P., Kisoyan K. and Coppock D.L. (2005). Agro-pastoralists‟ wrath for the *P. juliflora* Tree: The case of the II chamus of baringo district. pastoral risk management project, Kenya.

Abiyot Berhanu and Getachew Tesfaye (2006). The Prosopis dilemma, Impacts on dry land biodiversity and some controlling methods. *Journal of the Dry lands* **2**: 158-164.

Alder A.E. (1949). Indigestion from unbalanced Kiawe (Mesquite) and bean diet. *Journal of the American Veterinary Medical Association* **153**: 263.

Almaz Kebede (2009**)**. Sustaining the Allideghi grassland of Ethiopia: influence of pastoralism and vegetation change. Phd Dissertations, Utah University.

Andersson S. (2005). Spread of the introduced tree species *Prosopis* (Sw.) C in the Lake Baringo area, Kenya.

Asfaw Hunde and Thulin M. (1989). *Mimosoideae*. In: Hedberg, I. and Edwards, S. (eds.) Flora of Ethiopia: *Pittosporaceae*to *Araliaceae*, **3**. Addis Ababa University, Addis Ababa and Uppsala University, Sweden.

Assis T.S., Medeiros R.M.T., Riet-Correa F., Galiza G.J.N Dantas A.F.M., Oliveira D.M. (2010). Plant poisoning diagnosed in ruminants and horses and estimation of the economical losses in Paraiba. *Pesq. Vet. Bras.* **30** (1): 13-20.

Belton.T. (2008), Management Strategy for Mexican Thorn (Prosopis juliflora) on Ascension Island: SAIS Project, RSPB

Bokrezion H. (2008). The ecological and socio-economic role of *Prosopis juliflora* in Eritrea. Academic Dissertation, Johannes Gutenberg-Universität Mainz, Germany. (PhD report).

Burkhart A. (1976). A mongraph of the genus Prosopis (Leguminosae subfam. Mimosoideae). (Part 1 and 2). Catalogue of the recognized species of *Prosopis*. *Journal of the Arnold Arboretum* **57**: 219-249 and 450-525.

Camara A.C.L., Costa N. de A., Riet Correa F., Afonso J.A.B., Dantas A.F.M., Mendonca C.L. and Souza M.I. (2009). Spontaneous poisoning in cattle by mesquite beans,Prosopis juliflora (Leg.Mimosoideae) in Pernambuco. *Pesq. Vet. Bras.* **29** (3): 233-240.

Chaturvedi A. N., Sharma S. C. Andsrivastava R. (1988). Water consumption and biomass production of some forest tree species. *International Tree Crops Journal* **5:** 71-76.

Cotton C.M. (1996): Ethnobotany: principles and applications. Wiley, J and Sons (eds.) Chichester, New York: 399.

Dubale Aadmasu. (2008). Invasive Plants and Food Security: the case of *Prosopis juliflora* in the Afar region of Ethiopia (Publication, from IUCN.

Duke J.A. (1983). *P. juliflora* DC. Handbook of energy crops, Unpublished.

EARO and HADRA (2005). Controlling the spread of *Prosopis* in Ethiopia by its utilisation. Addis Ababa: Agricultural Research Organization (EARO) and Henry Doubleday Research Association (HADRA).

EL-Keblawy A. and AL-Rawai A. (2007). Impacts of the invasive exotic *Prosopis juliflora* (Sw.) DC. on the native flora and soils of the UAE. *Plant Ecol*. **190:** 23-35.

Esther M. and Brent, S. (2005). Invasion of *Prosopis juliflora* and local livelihoods: Case study from the lake Baringo area of Kenya,: World Agroforestry Center: *ICRAF Working paper* **3.** Nairobi: 66.

Fanuel Kebede (2012). Ecology and Community Based Conservation of the Grevy‟s Zebra (*Equus grevyi*) and the African Wild Ass (*Equus africanus*) in the Afar Region, Ethiopia. PhD Thesis, Addis Ababa University, Addis Ababa: 203.

FAO (2010). Grassland Index. A searchable catalogue of grass and forage legumes. FAO.

Felker P., Cannell G. H., Osborn J. F., Clark P. R. and Nash P. (1983). Effects of irrigation on biomass production of 32 *Prosopis* (mesquite) accessions. Experimental Agriculture **19:**187-198.

GISP (2004). Africa invaded: The growing danger of invasive alien species. Global invasive species program, Cape Town.

Gohl B. (1982). Les aliments du betail sous les tropiques. FAO, Division de production etsanté animale, Roma, Italy.

Gordon D. R. (1998). Effects of invasive, non-indigenous plant species on ecosystem processes: lessons from Florida. *Ecol. Appl.* **8:** 975-89.

Hailu Shiferaw, Demel Teketaye., Sileshi Nemomissa and Fassil Assefa. (2004). Some biological characteristics that foster the invasion of *Prosopis juliflora* (Sw.) DC. at Middle Awash Rift Valley Area, north-eastern Ethiopia. *Journal of Arid environments* **58:**134-153.

HDRA (2005). Realistic approaches to the management of *Prosopis* species in South Africa: Policy brief.

Heuze V., Tran G., Boval M., Renaudeau D., 2015. *Mesquite (Prosopis juliflora)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/554

Hillman J.C. (1993). A wildlife compendium for Ethiopia. Ethiopian Wildlife Conservation Organization (EWCO), Addis Ababa, Ethiopia: 786.

Hobbs R. J. and Mooney H. A. (1986). Community changes following shrub invasion of grassland *Oecologica* **70:** 508-513.

Kahi C.H., Ngugi R.K., Mureithi S.M., Ng‟ethe J.C., (2009). The Canopy Effects Of *Prosopis Juliflora* (Dc.) And *Acacia Tortilis*(Hayne) Trees On Herbaceous Plants Species And Soilphysico-Chemical Properties In Njemps Flats, Kenya Tropical And Subtropical Agroecosystems, 441 – 449.

Kaushik N. and Kumar V. (2003). Khejri (*Prosopis cineraria*)-based agroforestry system for arid Haryana, India. *Journal of Arid Environments*.

Kent, M. and Coker, P. (1992). Vegetation Discription and Analysis: A Practical Approach. John Willey and Sons. CRC Press, USA and Belhaven Press, London.

Lehouerou, H. (1980). Agroforestry Techniques for Conservation and Improvement of soil fertility in Arid and Semi-arid Zones.

Lima P. C. F. (1994) .Comportamento silvicultural de especies de *Prosopis*, em Petrolina-PE, Região Semi-Arida Brasileira. PhD Thesis, Universidade Federal do Parana, Brazil.

Martin G.J. (1995): Ethnobotany: method manual. World wide fund for nature, chapman and hall, London: 268.

Maundu. P , Kibet.S , Morimoto.Y , Imbumi.M & Adeka.R (2009) Impact of *Prosopis juliflora* on Kenya's semi-arid and arid ecosystems and local livelihoods, Biodiversity, 10:2-3, 33-50, DOI: 10.1080/14888386.2009.9712842

Mooney H.A., Simpson B.B. and Solbrig O.T. (1977). Phenology, morphology, physiology. In: Mesquite, Its biology in two desert ecosystems. (Ed.)B. B. Simpson. Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pennsylvania, USA: 26-43.

Mwangi E. and Swallow B. (2005). Invasion of *Prosopis* and local livelihoods: Case study from the lake Baringo area of Kenya. ICRAF Working Paper **3**. Nairobi, World Agroforestry Centre.

Nabori.L.C., Saaya.O.J., Nashuru.C., Kakimon.W., Tamar.E., Lemeiguran.R.N., Meiguran.L.S., Kakimon.L.S., Lengiyaa.S.S. (2007). Kenya law, in the high court of Kenya At nairobi (nairobi law courts), Petition 466; 34.

NMSA (2014): National Meteorological Service Agency, ten years mimeographed weather report, Addis Ababa.

Noor M., Salam U., and Khan M.A. (1995). Allopathic effects of *Prosopis juliflora* (Swartz). *J Arid Environ*. **31:** 83–90.

Panchal Y. C. and Shetty P. (1977). Chemical control of *Prosopis juliflora* (Sw) DC. Paper No. 153. Program and abstracts of papers, weed science conference, Delhi, India.

Pasicznik, NM., PJC, Harris & SJ, Smith. (2004). *Tropical Prosopis Species*: *A Feld Guide*. *HDRA*, *Coventry*, *UK*. *ISBN 0 905343 34 4*. Kenilworth, UK: HDRA.

Pasiecznik N. M., Felker P., Harris P. J. C., Harsh L. N., Cruz G., Tewari J. C., Cadorer K., and Maldonado L.J. (2001). The *Prosopis juliflora-Prosopis Pallida* Complex: A Monograph. HADRA, Coventry: 172.

R Core Development Team (2013).http://www.cran.r- project.org/bin/windows/base/old/3.0.2.

Research Programme. HDRA – the organic organisation. Funded and published by DFID: 162.

Rezene Fessehaie (2006). Challenges and potential of *P. juliflora*. In: *Alien invasive weed and insect pest*: Management and control option (Rezene Fessehaie, Aberra Tekelemariam, Kemal Ali Mohammed Dawd and Seid Ahemed, eds.). Second National Workshop on Alien Invasive Weeds and Insect Pest: 53-63.

Samuel Getachew, Sebsebe Demissew and Tadesse Woldemariam (2012). **A**llelopathic effects of the invasive *prosopis juliflora* (sw.) dc. on selected native plant species in middle awash, southern afar rift of Ethiopia. *Management of Biological Invasions* **3** (2): 105–114.

Sawal R. K., Ratan R., Yadav S.B.S. (2004). Mesquite (Prosopis juliflora) pods as a feed resource for livestock - A review. *Asian-Aust. J. Anim. Sci*. **17** (5): 719-725.

Scoones I. (1998). Sustainable rural livelihoods. A framework for analysis, *IDS Working* Institute of Development Studies, University of Sussex. *Paper **72:*** 22.

Shackleton C.M., McGarry D., Fourie S., Gambiza J., Shackleton S.E. and Fabricius C. (2006). Assessing the effects of invasive alien species on rural livelihoods: Caseexample and a framework from South Africa. *Human ecology an interdisciplinary Journal*.

Silva A. M. M., Silva, A. R., Pinheiro A.M., Freitas S.R.V.B., Silva V.D.A., Souza C.S., Hughes J.B., El-Bacha R.S., Costa M.F.D., Velozo E.S., Tardy M., Costa S.L., (2007). Alkaloids from Prosopis juliflora leaves induce glial activation, cytotoxicity and simulate NO production. *Toxicon* **49** (5): 601-614.

Singh G. Rathod T.R., Mutha S., Upadhyaya S.and Bala N. (2008). Impact of different tree species canopy on diversity and production of under storey vegetation in Indian desert. *Tropical Ecology* **49** (1): 13–23.

Tabosa I. M., Riet-Correa F., Baross S. S., Summers B. A., Simoes S. V., Medeiros R. M. T. and Nobre V.M.T. (2006). Neurohistologic and ultrastructural lesions in cattle experimentally intoxicated with the plant *Prosopis juliflora*. *Vet pathol* **43**: 695-701.

Tabosa I. M., Souza J. C., Graca D. L., Barbosa-Filho J. M., Almeida R. N., Rie Correa F. (2000). Neuronal vacuolation of the trigeminal nuclei in goats caused by ingestion of *Prosopis juliflora* pods. *Vet. Hum. Toxic*. **42** (3): 155-158.

Tadesse Berhe. and Yonas Adaye. (2007). Afar: The impact of local conflict on regional stability Pretoria: Institute for security studies: 16.

USFS (2006). Technical Trip Report to EFDR Government.

Van der Maarel (2005). Vegetation Ecology. Blackwell Publishing, Padstow, UK.

Werer Agricultural Research Centre (WARC). 2003. Annual Report 2003/04. WARC, Werer, Ethiopia.

Wittenberg R. and Cock M.J.W. (2001). Invasive alien species. How to address one of the greatest threats to biodiversity: A toolkit of best prevention and Management practices. CAB International, Wallingford.

World Conservation Monitoring Centre (WCMC) (1991). Biodiversity guide to Ethiopia.A report for the commission of the European Communities, Cambridge.

Zainal A.S., Abdel-Rahim A.M., Abu-Ali R.M., and Radwan S.S. (1988). Antimicrobial substance(s) in the leaf litter of the xerophyte Prosopis juliflora. *Zentralblatt Fur Mikrobiologie* **143**: 375-381.

Zeila A. A., Mwangi E., and Swallew B. (2004). *Prosopis juliflora: Boon or bane for dryland agroforestry?* A quarterly publication of Eastern and Central Africa Region of the World Agroforestry Center **1**.

Zeray Mehari (2008). Invasion of *Prosopis juliflora* (SW.) DC and rural livelihoods. The Case of Afar pastoralists at middle Awash area of Ethiopia.MSc. Thesis, Norwegian University of Life Science, Oslo.

Zerihun Woldu (2012), Environmental and Ecological Data Analysis Basic, Concepts and Methods. Lambert Academic Publishing.

APPENDICES

Appendix 1 Questionnaire

Semi-structured interview concerning *Prosopis juliflora* in Allideghi wildlife Reserve, Ethiopia. This questionnaire is prepared to access information for M.Sc. thesis entitled "impact of *Prosopis Juliflora* L. (Fabaceae) on Plant Biodiversity and Surrounding Communities: The case of Allideghi Reserve. The objective of this study is only for research purpose for partial fulfillment of the degree of Master of Science.

1. Personal information

Age □ Sex □ Occupation ..... family size □

1.1. If your occupation is farmer what kinds of crops are you cultivated

1.2. If you are cattle rancher no of cattle and goats?

2. What is history of vegetation change looks like in the Reserve from the very beginning you know?

3. Which of the following factors severely affect the health of the Reserve?

Fire wood collection □ - Settlement -□ Agricultural – encroachment of *P. juliflora* Others□-

If others, list them.....

If possible try to put from the most severe factor to less one?

4. Is the area where you are living in is the Reserve area?

Yes □ ☐ No □ ☐

If yes, is it being expanding or limited?

5. Is there cultivation activity inside or around the Reserve?

Yes ☐ No ☐

If yes, is it expanding or halted?

6. Is there any livestock introduction to the Reserve?

Yes ☐ No ☐

6.1. If yes, could you guess the number and trend being increasing and decreasing from time to time?

6.2. What is its intensity from past to present?

6.3. Are the domestic animals mainly grazers or browsers?

7. What types of plant is dominant in the Reserve?

8. Is there grazing land problem for your livestock? Why?

Yes ☐ No ☐

If yes, what are the reasons.....?

8.1. Do you think that the grazing land in the Reserve is enough for both livestock and wild animals?

8.2. Don't you think that there is a sort of competition b/n the two?

9. Have you ever noticed the plant species disappeared due to the effect of *Prosopis juliflora*

Yes ☐ No ☐

If yes, mention them.....

10. What is the local name of *P. juliflora?*

11. When was *P. juliflora* introduced? By who and for what purpose? Do you have any records of this? Please share with us.

12. Please describe the habitat in which much of this species is found, and why you think this is so.

13. What are the advantage (benefit) and disadvantage of this species?

14. What are the possible causes of the spread of *prosopis juliflora* in the Reserve?

15. What impacts do these species have on the Reserve?

16. Among the following which one do you think is the most common dispersal mechanism of encroaching species?

Wind ☐ Animals ☐ Humans ☐ Others ☐

If possible try to put from the most to less common?

17. What are the problems faced by the grazing animals due to encroaching species?

18. Is there a change in plant species composition due to *Prosopis juliflora* in the Reserve?

Yes ☐ No ☐

If yes, what it looks like.....

19. Has the density/cover of the ground cover around *Prosopis juliflora* i.e. grasses and forbs increased or decreased in the past 5-10 years?

20. What are the most serious problems you are facing with this species today? Please quantify any losses.

21. How did it come to be there? Was it planted? By whom? When? Why? Were you involved?

22. What are your main sources of income? How has the increase/decrease in *P. juliflora* affected this income? Please quantify.

23. Has the incidence of *P. juliflora* affected the availability of other resources that you

Have been using? How?

24. What would you like to be done with regard to the *P. juliflora* problem?

25. Who do you think should do it? Why?

26. What is you‟re feeling about the importance of the Reserve?

27. What is the benefit you obtain from the Reserve?

28. Is there any eradication mechanism to these encroaching woody species?

Yes ☐ No ☐

If yes, list them.....

29. What are the possible mechanisms to prevent the spread of *P. juliflora* in the Reserve?

30. What do you say about the present status of the reserve regarding encroachment?

31. What should be done to manage good manifestations of the Reserve?

Thank you!!!

Appendix 2 Synoptic Table

Species	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
Abutilon figarianum	0.09	2.37	0.91	2.10
Acacia melifera	0.09	0.12	0.41	0.26
Acacia nilotica	0.42	2.62	0.16	0.05
Acacia oerfota	0.04	0.12	0.08	1.20
Acacia Senegal	0	0.25	0.08	1.40
Acacia tortilis	0.14	0.25	1.25	0.40
Achyranthes aspera	0	0	0	0.94
Aeschynomene abyssinica	0	0	0	0.15
Amaranthus caudatus	0	0	0	0.15
Amaranthus sparganiocephalus	0	0.62	0.16	0.15
Balantis aegyptiaca	0.09	0	0	0.36
Balaria proxima	0	0	0	0.05
Blepharis boranensis	0	0.12	0.75	4.20
Boerhavia repens	0	0	0	0.10
Brachiaria leersioides	0	0	0	0.21
Brachiria deflexa	0	0	0	0.89
Cadaba rotundifolia	0	0.25	0	1.68
Celosia argentea	0	1.00	0	0
Celosia schweinfurthiana	0	0	0	0.15
Chloris gayana	0	0	0	0.10
Chrysopogon plumulosus	0.04	0.25	1.66	3.10
Coeuchyrum poiflorum	0	0	0	0.47
Cordia sinensis	0	0	0	0.21
Crotalaria pycnostachya	0	2.62	0.08	0
Cynodon dactylon	0	0	0	0.21
Dactyloctenium aegyptium	0	0	0.33	0
Dactyloctenium geminatum	0	0	0	0.15

Dactyloctenium scindicum	0	1.12	0	1.00
Echinochloa colona	0	0	0	1.00
Eragrostis aspera	0	0	0.33	0.89
Eriochloa fatmensis	0	4.50	0	0.21
Euclasta condylotricha	0	0.50	0	0.89
Farsetia stenoptera	0	0	0	0.15
Grewia tenax	0	0	0	0.05
Grewia villosa	0	0	0	0.73
Heliotropium zeylanicum	0	0.12	0	0.47
Hibiscus macranthus	0	0	0.08	0.21
Indigofera colutea	0	0	0	0.15
Ipomoea sinensis	0.09	0.87	2.60	0.84
Justicia.caerulea	0	2.75	2.50	1.26
Kedrostis leloja	0	0	0.08	0
Kohautia grandiflora	0	0.62	0	0
Lantana camara	0	0	0	0.05
Leucas stachydiformis	0	1.87	0.08	0
Meineckia phyllanthoides	0	0.75	0	0
Murdannia simplex	0	0.25	0	0.05
Ocimum basilicum	0	0.62	0.16	0.21
Ocimum forskolei	0.14	1.25	2.16	1.70
Oreosyce africana	0	0	0.50	0
Panicum atrosanguineum	0	0	0.08	0
Parthenium hysterophorus	0	0	0.25	0
Paspalidium geminatum	0	0	1.00	1.26
Phyllanthus oblongiglans	0	0	0.08	0
Phyllanthus ovalifolius	0	0	0.08	0.15
Polygala obtusissima	0	0.25	0	0
Prosopis juliflora	8.76	2.87	4.80	0.47

Rostraria.cristata	0	1.62	0	0
Ruellia patula	0.09	1.12	0.08	1.05
Setaria verticillata	0	0	6.75	1.21
Seddera bagshawei	0	0	0.16	0.57
Solanum dennekense	0.23	0.62	3.50	0.21
Solanum melastomoides	0	0	0	0.21
Solanum somalense	0	0	0	0.47
Sporobolus festivus	0	0.12	0.25	1.42
Sporobolus iodados	0	0	0.50	0
Sporobolus nervosus	0	0	0	1.70
Tephrosia linearis	0	1.00	0.08	1.10
Tetrapogon cenchriformis	0	0.62	0	1.10
Tetrapogon tenellus	0	0	0	2.20
Tragus berteronianus	0.14	0.62	1.00	2.30
Tribulus cistoides	0	1.50	0.50	2.50
Urochloa trichopus	0	0	0.25	1.57
Xanthium strumarium	0	4.62	0	0
Zaleya pentandra	0	0	0	0.05

Appendix 3: List of plant species in the study area

No	Scientific name	Family	Growth habit	Collection code
1	*Tragus berteronianus* Schult.	Poaceae	Grass	S1
2	*Paspalidium geminatum* (Forssk)	Poaceae	Grass	S2
3	*Eriochloa fatmensis* (Hochst. & Steud.) W. D. Clayton	Poaceae	Grass	S3
4	*Echinochloa colona* (L.) Li n k	Poaceae	Grass	S4
5	*Brachiaria leersioides* (Hochst.) Stapf	Poaceae	Grass	S5
6	*Urochloa trichopus* (Hochat.) Stapf	Poaceae	Grass	S6
7	*Brachiria deflexa* (Schumach.) Robyns	Poaceae	Grass	S7
8	*Panicum atrosanguineum* A. Rich.	Poaceae	Grass	S8
9	*Euclasta condylotricha* (Hochst. ex St eud.) Stapf	Poaceae	Grass	S9
10	*Tetrapogon tenellus* (*Roxb.) Chiov.*	Poaceae	Grass	S10
11	*Tetrapogon cenchriformis.* (A .Rich.) Clayton	Poaceae	Grass	S11
12	*Chloris gayana* Kunth	Poaceae	Grass	S12
13	*Lintonia nutans* Stapf	Poaceae	Grass	S13
14	*Eragrostis cilianensis* (All.) Vign. ex Janchen	Poaceae	Grass	S14
17	*Eragrostis aspera* (Jacq.) Nees	Poaceae	Grass	S15
18	*Eriochloa fatmensis* (Hochst. & Steud.) W.D. Clayton	Poaceae	Grass	S16
19	*Setaria verticillata* (L.) P. Beauv.	Poaceae	Grass	S17
20	*Sporobolus iodados* (Trin.) Nees	Poaceae	Grass	S18
21	*Rostraria cristata* (L.) Tzvel ev	Poaceae	Grass	S19
22	*Dactyloctenium scindicum* Boiss.	Poaceae	Grass	S20
23	*Dactyloctenium geminatum* Hack.	Poaceae	Grass	S21

24	*Dactyloctenium aegyptium*. (L.) Willd.	Poaceae	Grass	S22
25	*Chrysopogon plumiilosus Hochst.*	Poaceae	Grass	S23
26	*Chloris pycnothrix* Trin.	Poaceae	Grass	S24
27	*Tetrapogon.* Cenchriformis (A.Rich.) Clayton	Poaceae	Grass	S25
28	*Sporobolus nervosus* Hoehst	Poaceae	Grass	S26
29	*Sporobolus festivus* Hochst. ex A. Rich.	Poaceae	Grass	S27
30	*Paspalidium geminatum* (Forssk.) Stapf	Poaceae	Grass	S28
31	*Coeuchyrum poiflorum* Chiov.	Poaceae	Grass	S29
32	*Urocbloa Trichopus (*Hochat.) Stapf	Poaceae	Grass	S30
33	*Justicia ladanoides* Lam .	Acantaceae	Herb	S31
34	*Blepharis boranensis* vollesen	Acantaceae	Herb	S32
35	*Dicliptera verticillata*	Acanthaceae	Herb	S33
36	*Balaria proxima*	Acanthaceae	Shrub	B3
37	*Justicia caerulea* Forssk.	Acanthaceae	Herb	S34
38	*Ruellia patula Jacq* .	Acanthaceae	Herb	S35
39	*Crotalaria pycnostachya* Benth.	Fabaceae	Herb	S36
40	*Aeschynomene abyssinica* (A. Rich.) Vatke	Fabaceae	Herb	S37
41	*Tephrosia linearis* (Willd.) Pen.	Fabaceae	Herb	S38
42	*Acacia tortilis* (Forssk.) Bayne	Fabaceae	Tree	S39
43	*Acacia melifera* (Vahl) Benth.	Fabaceae	Tree	S40
44	*Acacia senegal* (L) Willd.	Fabaceae	Tree	S41
45	*Acacia nilotica* (L.) Willd. ex Del.	Fabaceae	Tree	S42
46	*Acacia oerfota* (Forssk.) Schweinf.	Fabaceae	Tree	S43

47	*Indigofera colutea* (Burm. f) Merr.	Fabaceae	Tree	S44
48	*Prosopis Juliflora* (Sw.)'DC.	Fabaceae	Tree/Shrub	S45
49	*Cadaba rotundifolia* Forssk.	Capparidaceae		S46
50	*Dobera glabra* (Forssk.) Poir.	Salvadoraceae	Tree	S47
51	*Balantis aegyptiaca (L.) Del.*	Balanitaceae	Tree	S48
52	*Cordia sinensis* Lam.	Boraginacea	Tree	S49
53	*Ipomoea sinensis* Choisy	convolvulaceae	Herb	S50
54	*Ipomoea aquatica* . forssk.	convolvulaceae	Herb	S51
55	*Seddera bagashawei* Rendle	convolvulaceae	Shrub	S52
56	*Oreosyce Africana* Forssk.	Cucurbitaceae	Climbing herb	B2
57	*Kedrostis leloja* (forssk.) C. Jeffrey	Cucurbitaceae	Climbing herb	S53
58	*Cucumis ficifolius* . A. Rich.	cucurbitaceae	Herb	S54
59	*Leucas stachydiformis* (Hochst. ex Benth.) Briq.	Lamiaceae	Herb	S55
60	*Ocimum forskolei* Benth.	Lamiaceae	Herb	S56
61	*Ocimum basilicum.* L.	Lamiaceae	Herb	S57
62	*Murdannia simplex* (Vahl) Brenan	Commelinaceae	Herb	S58
63	*Phyllanthus ovalifolius* Forssk.	Euphorbeacea	Shrub	S59
64	*Meineckia phyllanthoides* Bail.	Euphorbiaceae	Herb	S60
65	*Phyllanthus oblongiglans* M Gilbert	Euphorbiaceae	Herb	S61
66	*Hibiscus macranthus* Hochst. exA. Rich.	Malvaceae	Shrub	S62
67	*Abutilon figarianum* Webb	Malvaceae	Shrub	S63
68	*Tribulus cistoides* L.	Zygophyllaceae	Herb	S64
69	*Grewia tenax* (Forssk.) Fiori	Tilliaceae	Shrub	S65

70	*Grewia villosa* Willd.	Tilliaceae	Shrub	S66
71	*Heliotropium zeylanicum* (Bur m f.) Lam.	boraginaceae	Herb	S67
72	*Lantana camara* L.	Verbenaceae	Shrub	S68
73	*Solanum dennekense* Dammer	Solanaceae	Shrub	S69
74	*Solanum somalense* Franchet .	Solanaceae	Shrub	S70
75	*Solanum melastomoides* c.u. Wright	Solanaceae	Shrub	S71
76	*Conyza aegyptiaca* (L.) Dry and ex Ait.	Asteraceae	Herb	S72
77	*Xanthium strumarium* L.	Asteracea	Shrub	S73
78	*Achyranthes aspera* L.	Amaranthaceae	Herb	S74
79	*Celosia schweinfurthiana* Schinz	Amaranthaceae	Herb	S75
80	*Pupalia lappaceae (*L.) A. Juss.	Amarantaceae	Herb	S76
81	*Amaranthus sparganiocephalus* TheIl.	Amarantaceae	Herb	S77
82	*Celosia. argentea* L.	Amaranthaceae	Herb	S78
83	*Amaranthus caudatus L.*	Amaranthaceae	Herb	S79
84	*Zaleya pentandra* (L.) Jeffrey	Aizoaceae	Herb	S80
85	*Kohautia grandiflora* DC.	Rubiaceae	Herb	S81
86	*Farsetia stnoptera* Hochst.	Brassicaceae	Herb	S82
87	*Boerhavia repens* L.	Nyctoginaceae	Herb	S83
88	*Polygala obtusissima* Chod.	Polygonaceae	Herb	S84
89	*Parthenium hysterophorus* L.	Asteraceae	Herb	B1

Declaration

I, the undersigned declare that this Thesis is my original work and it has not been presented in other universities, colleges or institutes for a degree or other purpose. All sources of the materials used have been duly acknowledged.

Name: Selamnesh Tesfaye Signature: _____ Date: _____

This work has been done under my supervision.

Name: _____ Signature: _____ Date: _____

_____ Signature: _____ Date: _____