

The Ecological and Socio-economic Role of Prosopis juliflora in Eritrea

**An Analytical Assessment within the Context of Rural
Development in the Horn of Africa**

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To my mother.

To my father.

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Mainz, Juli 2008

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I. Foreword

In 1999, during field research the author conducted within her Masters dissertation on desertification and land degradation in Eritrea, *Prosopis* was mentioned as an indicator for degraded land by the local communities in the Western Lowlands (Gash Barka region). Moreover, within a continuous national effort to protect and regenerate the natural resources base and to boost afforestation, the cutting of live trees and shrubs for household or commercial consumption or for unauthorised agricultural land clearance in rural areas has been strictly prohibited. *Prosopis* was the only species excluded from this policy and communities were allowed to continue cutting it. In the view of a widespread need for fuel wood - the main source of rural energy - one would have imagined that *Prosopis* was regarded a saviour or at least a valuable tree among the rural population, particularly poorer households, but the opposite was the case: Eritrean farmers and pastoralists alike made it clear that the plant was a cause for serious concern to their livelihoods and they claimed it was killing their animals. They simply wanted it eradicated.

Two years later - by coincidence - the author came across the issue of *Prosopis* in Eritrea again in the course of her work experience at the Overseas Development Institute (ODI) in London. There, Dr Alan Nicol from the Water Policy Programme (which she had previously met in Asmara during a workshop on the issue of returnees and Eritrea's water policy) asked her to carry out an introductory ten-page desk research study on the issue of *P.juliflora* in Eritrea. Dr Nicol had been puzzled by the varying attitudes and accounts towards *Prosopis* he had come across in Eritrea during his own field work, many of which were rather negative. It was during her short research work at the ODI that the author was soon faced with the "paradox *Prosopis*", a phenomenon discussed in detail in all parts of the world where it could be found: It was praised as a very useful plant in some documents and described as a noxious, harmful weed in others.

However, the data available on *Prosopis* in the Horn of Africa region in general, and Eritrea in particular is very scarce. While there are some research documents and various Msc or Phd theses available on the subject matter in regard to neighbouring Sudan and Ethiopia (many of which have been produced after 2001), hardly any references - published or unpublished - dealing specifically with the issue of *Prosopis*, its introduction, impact, control or management could be tracked down for Eritrea. In fact, except for a brief

workshop presentation (HABTE 2000) and a plant inventory and management plan that was carried out by SOS Sahel UK and the Ministry of Agriculture (MoA) in the riverine forests of the Gash Barka region in Western Eritrea between 1996 and 1999 making a few references to *Prosopis* within a riverine forest management framework, there was no evidence or indication that the ecological or socio-economic role of *Prosopis* in the context of Eritrea had ever been assessed or studied in-depth up to this point.

Although national reports and action plans made various references to its invasive character which was of increasing concern, the issue did not cover more than a couple of lines providing a sense of lacking direction what exactly to do with it.

Eritrea faces increased natural resource shortages. Drought, overuse of fertile land as a consequence of population pressure and inappropriate management, widespread land degradation, and the effect of war are leading to an accelerating cycle of loss in land availability, productivity, and accessibility, ultimately resulting in food insecurity at both national and household level. Under those circumstances - intensified by the government's policy of self-reliance - appropriate, effective and sustainable management practices of Eritrea's natural resources are vital and a detailed knowledge of the existing resource base therefore critical. *Prosopis juliflora* may prove to be a useful tree or a harmful weed in the context of Eritrea's ecosystems (this remains to be assessed within this study). Nevertheless either way it is fundamental to know the actual and potential impact of the species on the natural and social environments so that appropriate management measures can be put in place.

The author commenced her field research on *Prosopis* in Eritrea in June 2002. A month later she was granted a six-month sponsorship from the Deutsch Akademische Auslandshilfe (DAAD) to support her study. The author was based in Eritrea from summer 2003 to summer 2004. However, due to a severe drought and administrative restructuring of the local department of forestry in Akurdet, the author lost the data of the established research plots, which were set up for the research of the plant-soil nutrient correlations and competitiveness between the native *Acacia tortilis* and *Prosopis* and the impact of *Prosopis* on a sorghum crop, for two consecutive years. As a result of this, the ecological aspects of *Prosopis* in Eritrea within this PhD thesis are an analytical assessment based on interviews, observations and related literature reviews.

II. Acknowledgement

I would like to thank a range of people, experts and institutions for their generous assistance and support provided during the undertaking of this study.

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I would also like to thank the various members and officials of the Eritrean Ministry of Agriculture (MoA) at Asmara, zoba Gash Barka and subzoba level (particularly in Akurdet) who have provided me with unpublished research papers and data, interviews, advice, guidance and research permits. Among those Mr Berhane Habte (Head of the Forestry Research Unit, MoA), Mr Estifanos Bein and Mr Dawit Giorgio (Department of Land Resources & Crop Production, MoA, Asmara), and Abraha Garza (Regional Head of MoA Gash Barka). In particular, I would like to thank very much Mr Berhe, former Director of the Forestry Department of the local Ministry of Agriculture branch in Akurdet, who has shown great dedication in setting up and monitoring the research plots and who has been the focal point for my research since 1999 (during my Msc) until his relocation in 2005. I also thank his colleagues who assisted him and particularly the workers at the tree nursery in Akurdet who looked after my research plots.

Furthermore, my appreciation and thanks to a range of local, regional and international experts on *Prosopis* who were prepared to provide me with general assistance, references, research papers, interviews and discussions on the subject matter. These are Professor Phil Harris (University of Coventry, United Kingdom), Mr Nick Pasiecznik (Agroforestry Enterprises, France), Ms Sayeda Khalil (Forest National Cooperation, Khartoum, Sudan), Dr Adil Ahmed Abdallah (Ministry of Science and Technology, Director of Department of Investment, Khartoum, Sudan), Demissew Sertse (Ethiopian Agricultural Research Organization in Addis Ababa, Ethiopia / University of Göttingen, Germany), Dr Jörn Laxén and Kurt Walter (Viiki Tropical Resources Institute, Helsinki, Finland), and Dr Urs Bloesch (SHA, Switzerland).

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Khartoum, Sudan) for discussions on the subject matter in regard to *Prosopis* and fodder production and his willingness and enthusiasm in driving me around Khartoum to attend interviews with experts. Furthermore, I thank Dr Seife Berhe (Global Resources Development Consultancy, Eritrea) who provided me with necessary information and documentation that I required from Asmara in the final stages of my thesis, and Dr Alan Nicol for making some of his *Prosopis*-photographs available for use in this study.

In Asmara and London, my gratitude goes to my dear colleagues Ali Mohamed Ibrahim and Dr Zeremariam Fre from the Pastoral and Environmental Network in the Horn of Africa who provided me with valuable research assistance and access to in-house library resources for which I am very grateful. Furthermore to Kees Maxey, Annette Jardine and Michael Walls, my dear “native” English-speaking colleagues for taking the time in reviewing the final editing of my thesis.

I would like to give my special acknowledgement and gratitude to the many local farmers and agro-pastoralists in Western and Eastern Eritrea who have once again provided great hospitality and were prepared to give their valuable time for interviews and discussions. I hope this research study will be able to give something back to their communities in due course.

My warm thanks go to my parents and my fiancée who have always supported and motivated me throughout. And to my baby boy who spent many hours patiently at the desk with me.

And lastly, my special thanks to my dear professor and tutor Prof (name deleted due to data protection) of the University of Mainz in Germany who has shown great enthusiasm and interest in Eritrea and my work from the start. He has offered me professional support, motivated me in times when I encountered obstacles with my research, and has always believed in my abilities.

III. Introduction : *Prosopis juliflora* in Eritrea within the Global Context of Rural Development and Environmental Sustainability

To ensure environmental sustainability by 2015 is one of the eight Millennium Development Goals (MDGs) of the United Nations alongside the eradication of extreme

hunger and poverty and the combating of HIV/AIDS, malaria and other diseases. They are a blue print of international development to which all countries and leading development institutions agreed. According to the MDGs, environmental sustainability includes the integration of related sustainable development principles into national policies and programmes as well as regeneration efforts regarding environmental resources.

The international development community and policy makers have at last understood the close interlinkages between those goals and have - among other things - acknowledged the importance of tackling environmental degradation and improving ecological management as a vital component in the eradication of global poverty. As a result, many programmes and initiatives in recent years have adopted a more holistic and integrated approach to development. In regard to (natural) environmental sustainability issues such as natural resource management, reforestation, protection of biodiversity, resource based conflict management, and environmental education have all become common aspects in the fight against poverty.

A new major challenge is the integration of the question of climate change, carbon dioxide capture and carbon footprint reduction to which many development organisations and policy makers are only slowly adapting. The ongoing debate on climate change and appropriate measures to mitigate the effects of global warming may be slowing the adaptation process down. Nevertheless the threat is evident and therefore makes the need for the protection and regeneration of natural resources even more immediate.

To achieve this, relevant policy design and widespread mobilisation needs to take place at several levels. Planning, coordination, and implementation of sustainable and effective natural resource management will need to take place at a country cross-cutting level as well as at national, regional and community level. However progress is often undermined by a lack of necessary technologies, capacities, knowledge and research. This often leads to a mismanagement of resources, inappropriate practices or simply a sense of helplessness or ignorance.

The issue of *Prosopis* - at least in the case of Eritrea - seems to fit exactly into this wider picture: Awareness raising about the importance of natural resource management and protection alongside active community mobilisation has been widely and very visibly taking place at all levels and in this regard, Eritrea is ahead of many other Sub-Saharan countries.

In the semi-arid areas of Eritrea however, *Prosopis* is now widely viewed as a threat to those resources and rural livelihoods mainly because of its invasive character at the expense of native species and land size within both range and crop lands.

This research study aims to assess and analyse the impact of *P.juliflora* on Eritrea's ecosystems and its role in terms of both the socio-economic benefits and disadvantages it brings to rural communities. *Prosopis* at the moment seems a continuously spreading element at the expense of Eritrea's native environmental resource base. Therefore, the matter needs to be urgently researched, managed and integrated into related national and community-based development programmes and policies.

Chapter 1 provides a broad overview of *Prosopis juliflora*, including worldwide distribution, plant characteristics and an inside into the still ongoing international debate on *Prosopis* and whether it is a weed or a useful shrub within the world's hot semi-arid and arid lands.

Chapter 2 briefly outlines Eritrea's geographical context covering both physical and anthropogenic factors, such as climate, agro-climatic zones, geology, population and land use, rural livelihoods, natural resource base and ecosystem, land degradation and related legal systems. *Prosopis* spreads within both the Eastern and the Western Lowlands and in a very few locations of the highlands. As these three key geographic regions of Eritrea correspond to the natural habitats of *Prosopis* the study will provide a quick insight into Eritrea as a whole rather than concentrating solely on the outline of the particular sites, in which the survey has taken place. This is an important introduction so the reader who is less familiar with Eritrea is able to understand the geographic context in which the impact of *Prosopis* is being assessed.

Chapter 3 gives a broad insight into the introduction, distribution, invasiveness and trends surrounding *P.juliflora* in Eritrea assessing its impact on native tree species, soil characteristics, ecosystems and rural livelihoods systems among other. Experiences and research findings from other countries in the region as well as India and Pakistan are used to strengthen or discuss certain trends, findings, observations made in the case of Eritrea. This

chapter also provides an assessment as to how the state of local food security and desertification are linked with the continuous spread of *Prosopis*.

Chapter 4 is based on a household survey carried out in four different sites in which *Prosopis* is established. This chapter demonstrates the views and experiences of the rural communities in regards to *Prosopis*. It analyses overall trends and perceptions and seeks to clarify common tendencies and characteristics within communities that are facing the spread of *Prosopis* in Eritrea. It also uses comparative examples from the wider region.

Chapter 5 deals with the issue of past and current management of *P.juliflora* in Eritrea and the question of the appropriate way forward. It also introduces the framework of a potential national action plan on *Prosopis* incorporating outcomes obtained within this research study as well as measures used in other countries which could be potentially adopted in Eritrea.

Chapter 6 is a summary and critical discussion of the findings made in this research study. It also draws a list of concrete recommendations for the way forward in the management of a natural environment, in which *Prosopis* has become a visible element.

Where the study states '*Prosopis*' in the text it refers to *Prosopis juliflora* unless otherwise stated.

IV. Methodology

Data for this study has been collected using a variety of research methodologies from a range of primary and secondary sources. Primary research data has been collected using empirical methods such as observation, rural household survey, mapping, interviews and discussion with experts. Secondary research included data and information obtained from international literature, local (and mostly unpublished) research and policy papers, and newsletters.

Primary research data:

- (1) Personal observations on *Prosopis* and its distribution in Eritrea were made and recorded in the Western Lowlands and the Eastern Lowlands during 2002-2005. The areas visited in the Western Lowlands were Engerne, Akurdet, Mograib, Forto-Sawa, Shambuko, Barentu, Hashenkit, Haikota, Tesseney, and Geluj. Notes from personal observations covered crop areas, open grazing land, riverine forests, road sides, settlement areas, irrigation schemes and wells, horticulture gardens, and tree nurseries. In the Eastern Lowlands open rangelands, road sides and sand dune areas around Gahtelay and Massawa have been observed.
- (2) A questionnaire was designed for the purpose of a small socio-economic household survey. The survey was carried out among pastoralists, agro-pastoralist, farmers and agriculturists in three sites in the Western Lowlands (namely Tesseney, Akurdet, and Engerne) and in one site in the Eastern Lowlands (Gahtelay) covering a total of 37 households. The survey was designed to obtain necessary information on both socio-economic as well as ecological aspects regarding *Prosopis* as perceived by rural inhabitants. The questionnaire included closed-ended as well as open-ended questions. It was pre-tested and then applied in the field. The data processing and statistical analysis was carried out using the statistics programme SPSS 15.0 for Windows. The questionnaire provided a range of quantitative and to qualitative data, which have been used to strengthen, question or dismiss general views and hypotheses on *Prosopis* in relation to the Eritrean case.
- (3) Informal Interviews and discussions on *Prosopis* have been carried out in person (in Eritrea and the Sudan) and via e-mail with a range of officials, administrators and research experts from Eritrea, the Sudan, Ethiopia, France and the UK. They can be considered as informal, as no prior appointments have been made and the interview and discussions were carried out without any particular pre-determined structure (e.g. a questionnaire).
- (4) General vegetation mapping was carried out during the field visits foremost including notes of the distribution and intensity-levels of *Prosopis* in those areas visited. Personal

mapping was complemented by the responses of respondents who were asked during the survey to name localities in which they had come across *Prosopis*, and to some extent by accounts from literature and personal discussions.

Secondary research data:

- (1) International literature was carefully studied and the information and results widely incorporated into the study to strengthen, compare and discuss particular hypotheses and findings for *P.juliflora* in Eritrea. The international and regional information on *P.juliflora* was further used to present a more complete profile of a plant species that had barely been studied in Eritrea. The vast majority of international literature was obtained from the British Library in London, which holds one of the largest scientific collections in Europe. Much of the international literature on *P.juliflora* was based on experiences and research in India and to some extent in Pakistan; however the author tried to retrieve as much information as possible on *P.juliflora* in countries of the Horn of Africa region, which mainly included Sudan, Ethiopia and Kenya.

- (2) Local - and mostly unpublished - research and policy documents were collected in Eritrea mainly from the Ministry of Agriculture and the University of Asmara (College for Agriculture). In Sudan, local research material was obtained from the in-house library of the Sudanese Environmental Conservation Society (SECS). Local documents and newsletters from personal collections as well as the in-house library of the Pastoral and Environmental Network in the Horn of Africa (PENHA) in London were also studied. However, as far as the author and other experts know, except for a brief workshop paper on the issue (HABTE 2000) no specific documentation on the issue of *Prosopis* in Eritrea exists. Related documents on issues such as the environment, desertification, land management etc. were carefully studied and any information on *Prosopis* extracted.

Initial attempts to collect ecological data on *Prosopis* in Eritrea had been made by the author within this PhD study aiming to measure the level of competition between *P.juliflora* and *A.tortilis*, soil-plant nutrient correlations (soil and leaf sampling) and the impact on *Prosopis* on the sorghum harvest (by means of observation and weighing). In cooperation

with the Forestry Department of the Ministry of Agriculture Branch of Akurdet six research plots of the size 5x5 metres were established in Akurdet in 2002, three of which were replicate plots consisting of young *P.juliflora* and *Acacia tortilis* seedlings and three replicate control plots including *A.tortilis* seedlings only. Six further plots of the same size were set up in Engerne, three of which were rain-fed sorghum crops with the presence of thick *Prosopis* shrubs at the edge of the crops and again three plots were replicated control plots containing sorghum only (absence from *Prosopis* in the immediate crop area). However, due to a severe drought during 2002 and 2003 and the administrative restructuring of the local department of forestry resulting into the sudden relocation of the director of forestry in 2004 who supervised the research during the author's absence, the author was unfortunately not able to retrieve the necessary data from the research plots for two consecutive years. After taking a break in her PhD and contemplating a complete subject change, the decision was finally made to continue this important piece of research and to obtain any ecological information from observations, interviews and related research documents only.

V. Problem Statement

An estimated 84% of Eritrea's population derive their food and income from land based subsistence economies. These include mainly small-scale rain-fed farming, mixed farming and pastoralist production systems providing the necessary nutrition and some local trade opportunities to the majority of the rural population. Sustained productivity of the land is therefore vital for their livelihoods and fundamental for food security and local market activities at both household and national level.

The Government of Eritrea has acknowledged the importance of environmental protection and sustainable natural resource management as a basis of national food security and economic self-reliance and has therefore promoted it widely.

However, while some resource management practices such as afforestation and hill terracing have been extensively studied and implemented, other issues have been given less attention. The issue and management of *Prosopis* can be regarded as one of those gaps and the reason for this may well be the lack of expertise and knowledge on a relatively newly

introduced species. It is assumed that *Prosopis* has been introduced to Eritrea from the Sudan only in the 1970s (BEIN *et al.* 1996, p.320) or even in the 1980s (HABTE 2000). It may well have taken one or two decades until the plant invaded so many areas and habitats that it was only recently noticed and regarded as something that required specific attention.

Compared with other countries in the region, for example Ethiopia or the Sudan, the infestation of *Prosopis* in Eritrea is still relatively moderate. While - for example - great parts of open grazing lands in Ethiopia's Afar region have been turned into inaccessible, hostile *Prosopis* thicket and some of Sudan's commercial irrigation schemes have requested millions of dollars to eradicate *Prosopis* from crops and irrigation channels (personal Interview with Sayeda Khalil from the FNC, July 2007), Eritrea at this point seems comparably moderately affected.

Nevertheless, *Prosopis* is spreading fast and the plant is becoming an increasing concern to local communities. These are both indicators that if the situation were left unmanaged, the infestation could potentially cause soon hazardous damage to local livelihoods. In a country where land productivity and plot size per capita is continuously diminishing and land degradation increasing, a possible loss of vast land areas to a very resistant, alien, and underexploited plant species would indeed be very alarming.

The fundamental challenge in this regard is the lack of locally available information and expertise as well as necessary resources on the genus *Prosopis* in Eritrea resulting in gaps for the development of appropriate management strategies, which are urgently required. Additionally, contradictory existing information and attitudes towards the potential benefits and risks of *Prosopis* in Eritrea and elsewhere may build up to a sense of dilemma or even lack of orientation among local experts as to what exactly to do with this plant. Furthermore, possible benefits of *Prosopis* seem to find little acknowledgement among rural communities in Eritrea. On the other hand, local initiatives to eradicate it have been proven to be too labour intensive, costly and in practice, ineffective: *Prosopis* simply re-grows and continues to spread.

Special consideration in this context will also need to be given to the wide range of agro-climates, ecosystems and customs within Eritrea, as both benefits and risks of *Prosopis* may vary quite substantially depending on different factors within the surrounding environment and climatic conditions.

Graph 1.1: Problem chart: causes for lacking *Prosopis* management in Eritrea

(Source & Design: Author)



According to HABTE (2000) during an annual programme evaluation meeting of the Eritrean Ministry of Agriculture (MoA) in December 1998, it had been recommended that a study on “the attributes, desirability or otherwise” of *Prosopis* should be carried out after “strong differences in opinion were expressed” locally, whether *Prosopis* should be used in community forestry programmes. The findings - which suggested that it was a weed around agriculture, but that it could be of use to pastoralists in the arid and mostly barren drylands of the country - were reportedly presented at the annual meeting of the MoA and at the 4th congress meeting of the Association of Eritreans in Agricultural Sciences at the time. However this first attempt to deal with the issue of *Prosopis* - which is summarised in HABTE (2000) - seems not to have resulted in a broad awareness or action at a policy level, as almost a decade later the issue is insufficiently integrated and acted upon in Eritrea’s rural development programmes.

National action and research papers mentioning the issue of *Prosopis* usually cover it within a few lines. Broad and in-depth studies, surveys and data collections on *P.juliflora* in Eritrea

have so far (or partly since) not taken place. The only references available presenting fair (but brief) insights into the issue are unpublished documents:

- BLOESCH, U. (2001): Evaluation of Domestic Energy in Emergency Situations in Eritrea. Mission Report (21/4 – 6/5/01). Ministry of Local Government/ Swiss Disaster Relief Unit. Biel, Switzerland [*a report on the energy situation in the IDP-camp of Adi Keshi in Western Eritrea including a 4-page outline on the Prosopis problem referring to the species as P.chilensis*]
- HABTE, B. (2000): "Pros and Cons of Growing Mesquite in the Arid and Semi-arid Lowlands of Eritrea." Department of Agricultural Research and Human Resources Development. Ministry of Agriculture, Asmara. [*A 15-page long summary referring to the species present in Eritrea as both P.chilensis and P.juliflora*]
- SOS SAHEL & MoA (1999): Management Plan for the Riverine Forests of the Western Lowlands of Eritrea. London. UK [*including several paragraphs of the status of P.juliflora in the riverine forests*]

This demonstrates the fundamental and urgent need for more research, knowledge dissemination, and a detailed assessment of *Prosopis* in Eritrea, its genus, geographic distribution, and ecological and socio-economic impact within the context of its surrounding local environment. Only on this basis can appropriate management action plans as well as related intervention and skill training modules be developed and finally implemented.

Chapter 1: General Aspects on *Prosopis juliflora*

1.1 Origin and worldwide distribution

Native to Central and South America - spreading from southern Mexico to Panama and from the Caribbean Islands to northern South America (Venezuela and northern Peru) - (HARRIS *et al.* 2003, p.153; PASIECZNIK *et al.* 2001, p.4; WICK and THIESSEN *et al.* 2000, p. 60; NOOR and SALAM 1993, p.83) *P.juliflora* has been introduced globally over the last 200 years. Today, it can be found in various semi-arid and arid climate zones including further parts of Southern America, India and Pakistan, Australia and the Pacific, and several countries in Africa, the Arabic Peninsula, and the Middle East. (PASIECZNIK *et al.* 2001; p.13; WICK and THIESSEN *et al.*, 2000, p. 60; IQBAL and SHAFIQ 1997, p.459).

Also often referred to as *mesquite* or *algaroba* (PASIECZNIK 2001; AL & WARRANG 1998) *P.juliflora* was introduced into India during the late 19th century, possibly from Mexico or Jamaica. Accounts of the exact year of introduction and how the species precisely found its way into India however vary (PASIECZNIK *et al.* 2001, p.15; SHARMA & DAKSHINI 1998, p.63; SHARMA 1984, p.367).

Introduction into Africa is believed to have probably even taken place earlier. According to PASIECZNIK *et al.* (2001) the precise introduction history is not definite, but introductions into Senegal in 1822, South Africa around 1880 and Egypt around 1900 have been documented.

In the case of Sudan, *Prosopis* was introduced by RE Massey from the Egyptian Department of Agriculture at Giza and from South Africa both in 1917 (EL FADL 1997 in PASIECZNIK *et al.* 2001, p.16; MAGID 2007, p.2). Its spread throughout the country has taken place over a period of decades, as it was first confined to small research areas before it was increasingly introduced into rural areas and according to LAXÉN *Prosopis* had established itself in about half of the total 26 states Sudan comprises of by early 2000 (MAGID 2007, p.14; LAXÉN 2005, p.14).¹

¹ Further details on the introduction of *P.juliflora* into the Sudan and Ethiopia can be found under chapter 3.2 within the context of *Prosopis* introduction into Eritrea.

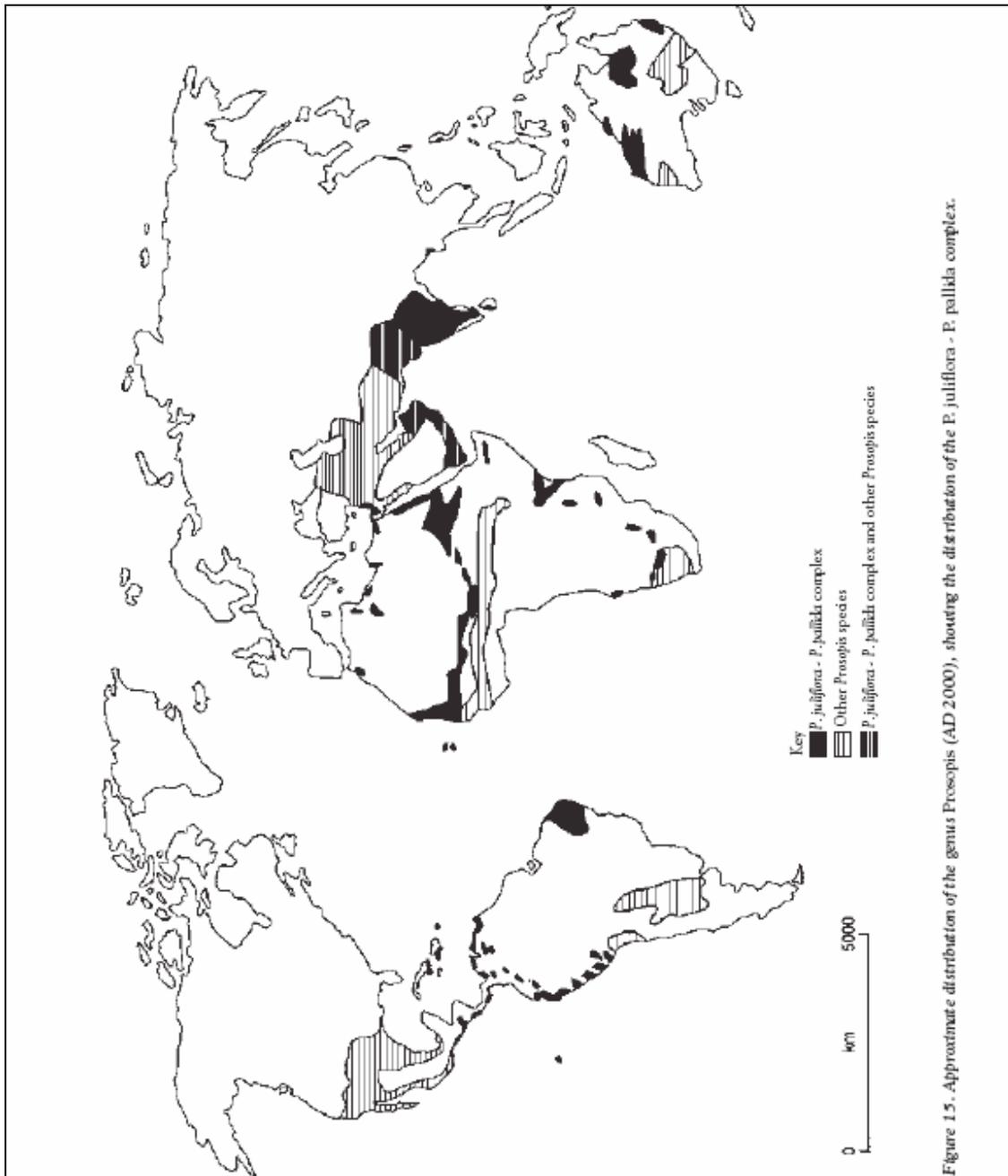
Less clear is the establishment of *P.juliflora* in other countries of Eastern Africa where introduction has taken place much later, mostly during the 1980s, possibly through livestock from the Sudan or southern Africa or by traders, perhaps also coming from India.

Ecologically, the “*P.juliflora* - *P. pallida* complex” is to be found in a wide range of rainfall zones ranging from from less than 100 mm mean annual rainfall in dry coastal zones to more than 1000 mm. Occasionally it can even be located in areas with up to 1500 mm of rainfall, for example in the Andean region where *P.juliflora* can be found at altitudes of up to 1,500 metres (PASIECZNIK *et al.* 2001, p. 59/60; DUKE 1983). Other records suggest even higher elevation tolerance reaching from the coast to up to 1700 m a.s.l (NOOR & SALAM 1995; p.83). In Eritrea, *P.juliflora* can be found around the city of Keren at 1,600 m.

In Yemen, *Prosopis* was introduced in 1974 to combat soil erosion (FAO 2006, p.26)

According to PASIECZNIK *et al.* (2001) the species is not frost tolerant, which is mostly the reason that it hardly spreads into higher altitudes, as compared for example with (the often for it mistaken) *P.chilensis* native to areas up to 2900 m (PASIECZNIK *et al.* 2001, p.59; TEKETAY 1996, p.213)

Map 1.1: Global Distribution of the *P. juliflora* - *P. pallida* complex and other Prosopis Species. (Source: PASIECZNIK *et al.* 2001, p.53)



1.2 *Prosopis juliflora* in Botanical Terms

Prosopis juliflora Swartz (Leguminosae subfam. Mimosoideae) is a perennial, fast-growing, often ever-green and drought resistant plant that grows in semi-arid areas as well as desert like conditions. Worldwide, there are about 44 recognised species of the genus *Prosopis*, which have been identified and listed by BURKHART (1976)² assembling the most extensive taxonomic listing available to this date.

Family: Leguminosae 650 genera, 18,000 species
Sub-family: Mimosoideae 50-60 genera, 650-725 species
Tribe: Mimoseae 5 tribes
Group: *Prosopis* 9 groups
Genus: *Prosopis* 4 genera

Due to continuous hybridisation processes among several *Prosopis* species the list however may be revised in coming years (PASIECZNIK *et al.* 2001, p.2; GOEL & BEHL, 1995, p.17; BURKART 1976)

P.juliflora can grow as a shrub or tree, in which case it can reach up to 12 metres, but it is usually much smaller than that. *P.juliflora* is predominantly xerophilous, aculeate, spiny or rarely unarmed (BURKART 1976). Leaves are bipinnate, often with few pairs of opposite pinnae. The single leaflets of a leaf are many, generally small, mostly opposite, linear, oblong, fusiform and of the same colour on both sides (PASIECZNIK *et al.* 2001, p.29)

P.juliflora usually has thorns with varying thorn size reaching up to 5 cm; some stands are thornless. *Prosopis* thorns however vary much in appearance and can occur either paired or solitary, and even both on the same branch (PASIECZNIK *et al.* 2001, p.36).

P.juliflora is a nitrogen-fixing species and is widely regarded as being potentially useful to people living in desert regions as it can be used as a source of fuel wood, animal fodder, timber for construction and furniture, as living fences and shelterbelts to halt the

² BURKART, A. (1976): A monograph 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.

encroachment of sand dunes, and occasionally even for human nutrition. Other products derived from *P.juliflora* can be honey, gums, fibers and medicines (HARRIS *et al.* 2003, p.153; LAXÉN 2005, p.88).

Photo 1: Dried leaves and pods of *P.juliflora* in Keren, Eritrea



(Photos: author)

P.juliflora is sodic and salt tolerant and has been used successfully for the regeneration and afforestation of sodic wastelands (GARG 1999, p.281; SINGH & SINGH 1998, p.453).

The root system of woody perennials tends to be deeper than that of non-woody perennials, with the shallowest rooting system to be observed in annual herbs (MICHAEL 1986 in SINGH & RAJBAHADUR *et al.* 1996, p.324). Roots of *P.juliflora* can develop rapidly following germination and can reach a depth of 40 cm in eight weeks (PASIECZNIK *et al.* 2001, p.30); they are widely referred to as tap root system (PASIECZNIK *et al.* 2001, p.47; SHARMA & DAKSHINI, 1998; GARG 1998, p.91).

P.juliflora is often flowering throughout the year and is propagated through seed, which sit in a long narrow pod with a high content of viscous, sugary material. When animals eat the pods the seeds are excreted through their droppings. During the rainy season a large number of seeds germinate in the animal droppings (SHIFERAW 2004a, HABTE 2000, p.7).

Yet, one needs to keep in mind that a species not always fits the exact description outlines in research documents. In fact, many *Prosopis* species occur under natural hybridisation. Of particular interest in the regard of this study is the *P.juliflora*-*P.pallida* Complex suggested by PASIECZNIK *et al.* (2001). Both species are generally similar in terms of flower, pods and leaf morphology, as well as tree form. So much so that even most taxonomists would not be able to differentiate between the two, particular in view of continuing hybridisation in areas where overlapping ranges of *P.juliflora* and *P.pallida* exist. It has been suggested that the term *P.juliflora*-*P.pallida* Complex would be more appropriate; hybridisation also occurs where more than one *Prosopis* species are native or have been introduced (PASIECZNIK *et al.* 2001, p.2)

Furthermore conflicting definitions and synonyms have been used for several species throughout history and as a result “discrepancies concerning the generic limits of *Prosopis* and the movement of species from genus to genus were commonplace” (PASIECZNIK *et al.* 2001, p.19).

1.3 Weed or Wondertree? - A Short Insight into the State of International Research on *Prosopis juliflora*

“Weed or wonder tree?”, “friend of foe?”, “devil or saviour?” and the “paradox *Prosopis*” are titles and terminologies used by several experts. This demonstrates not only the division among researchers, practitioners and academics in regard to the role and impact of *Prosopis* within a given rural environment, but also their own desire to shed light into a phenomenon that seems to provide both serious risk and great benefit.

The weediness or invasive character of *P.juliflora* has been widely recorded and acknowledged. But a major part of related research and documentation (probably even the majority) focuses on the benefits that *Prosopis* is (potentially) able to offer rural communities in both socio-economic and ecological terms. Whether *Prosopis* is weedy and invasive is therefore not the real issue of wide-spread discussion. According to PASIECZNIK *et al.* (2001) and BURKART (1976) (who have both produced an extensive monograph on the species commonly quoted by many experts) the majority of *Prosopis* species are indeed weedy or “to some extent weedy” (about 17 species) in their native ranges and the countries

they have been introduced to; only about four are not (PASIECZNIK *et al.* 2001, p.4; BURKART 1976). PASIECZNIK *et al.* further state that “*Prosopis* is now a declared weed over millions of square kilometres of arid and semiarid lands[...]” (PASIECZNIK *et al.* 2001, p.13).

Although experts usually agree on the invasiveness of the species the global discussion that has been continuing for some decades focuses foremost on the impact *Prosopis* has on both the rural livelihoods and the natural environment, and the role it plays within it.

The positive role of *P.juliflora* as a useful, multi-purpose shrub or tree has been extensively promoted. This has challenged those reports outlining the downsides of *Prosopis*. These are the hazards - for example the vast spread of *Prosopis* at the expense of native range lands - that have occurred in many semi-arid and arid lands as a consequence of intensive planting of the species over the last decades and sometimes centuries, extended by the lack of appropriate management and planning. However, many experts remain on a ‘safe boat’: They are simply indecisive whether *P.juliflora* is a threat or an opportunity.

IQBAL and SHAQIF (1997) for example report that “*Prosopis juliflora* Sw. [...] is a common weed in waste lands in Sindh, Punjab and the northern areas up to Kashmir” before continuing to call it a “remarkable shrub” (IQBAL and SHAQIF 1997, p.459), which would appear to be a contradiction to most readers, especially those who are not familiar with the species. The reasons for the approval of a “common weed” lay in its utilisation: *P.juliflora* provides valuable resources to local communities in the form of fuel wood, timber, fodder for livestock such as goats, sheep, and cattle. It can be used as shade in hot climates, as wind breaks or for the stabilisation of sand dunes that threaten to encroach into inhabited land areas. Moreover, *P.juliflora* is extremely tolerant towards a wide range of climatic, soil physical and chemical factors. As a result of those attributes, *P.juliflora* is widely regarded as a useful resource for rural communities which are facing increased natural resources shortages due to population pressure, drought and other climate hazards, as well as armed conflict (LAXÉN 2005; SHIFERAW 2004; PASIECZNIK *et al.* 2001; IQBAL and SHAQIF 1997)

Particular consideration (measured by the many reports of research trials) is given to the ability of *Prosopis* as a source for fuel wood of high quality. Due to its high biomass production, high wood density and low ash and moisture content, the species is broadly regarded as an excellent energy source - including the production of charcoal - and usually outperforms other native and alien tree legumes. Rural communities have to meet their energy needs. In some countries, up to 86% of this comes from cut wood. This has led to serious deforestation and desertification in many parts of the hot dryland regions (GARG 1999; TOMAR *et al.* 1998; GOEL & BEHL 1996), and leads increasingly to resource-based conflict. The continuous spread of *Prosopis* provides rural communities with a rare opportunity: Unrestricted access to fuel wood.

Furthermore of economic importance is the use of timber for construction purposes (SHUKLA & KHANDURI *et al.* 1990). On this basis, many researchers suggest the establishment of *Prosopis* energy plantations to meet the energy shortages of rural communities.

Another area that has attracted great interest is the potential ability of *Prosopis* to regenerate sodic wastelands, due to its high survival rate and relatively good tolerance towards soil salinity, low pH and water logging. This would increase the productivity of these degraded lands (GARG 1998; SHARMA & DAKSHINI 1998; BHATIA 1998; BHOJVAID 1997; WARRANG 1994).

Focus has also been given to the research of *P.juliflora* as a browse for livestock and a processed fodder resource. Pastoralists, the poor and those living in hot arid desert zones are believed to benefit the most, particularly during the dry season when feed resources are becoming scarce. In particular, the high protein content of the pods has been referred to. The leaves, which are only relatively palatable, are still a potentially valuable browse when everything has dried out. These are also of importance to animal production. Many researchers feel that it is foremost the rural poor or landless that profit from *Prosopis*, as it provides “income safety nets for the survival” (LAXÉN 2005; SHIFERAW 2004; PASIECZNIK *et al.* 2001)

On the contrary, there are also (if seemingly not as many) research trials and studies available that present in more details the negative impacts of *Prosopis*. These sources view *P.juliflora* foremost as “an aggressive invader”. Of particular discussion is the loss of grazing land, native plant species and general biodiversity as well as the reduction of harvest under the presence of *Prosopis*, which quickly becomes dominant within many of the native ecosystems.

Some international research has been carried out on the allelopathic effects of *P.juliflora*, which have an inhibitory effect on the germination and seedling of other species growing in the surrounding (AL & WARRAG 1998; NOOR and SALAM 1995). However, the amount of research and supporting documentation on the allelopathic effects of *P.juliflora* are rather scarce and mostly based on laboratory methods, such as the soaking of plant seeds in *Prosopis* leaf or fruit extract.

Another related aspect of *P.juliflora* on which research experts seem to disagree upon is its impact on local soils under land management efforts. While higher microbial biomass, C and N contents were measured beneath and around *P.juliflora* canopies by some researchers (WICK and THIESSEN *et al.* 2000, p.65) others present in contrast findings demonstrating that *P.juliflora* clearly reduces soil nutrient availability. “It [*P.juliflora*] has become aggressive and has not only successfully invaded several habitats but has also caused substratum degradation in these by causing loss of finer soil particles...and increased [...] salt content of soils in dry conditions.” (SHARMA & DAKSHINI 1998, p.63)

To add to the ‘state of confusion’ as to how *Prosopis* should be best perceived, there is another reason that could have contributed to the outcome of contradictory research results in some cases: the failure to precisely identify a plant as *P.juliflora*. PASIECZNIK *et al.* (2001) and HARRIS *et al.* (2003) state that *P.juliflora* and *P.pallida* for example “are still frequently misidentified in the field”, which is due to their adaptation to the same environment and rather similar morphological characteristics. Misidentification has also taken place in Eastern Africa and other countries where *P.juliflora* has been widely identified as *P.chilensis* (PASIECZNIK *et al.* 200, p.22; HARRIS *et al.* 2003)

The global discussion on *Prosopis* is continuing. Many research trials and studies have been carried out and published, usually strengthening a pro or contra standpoint on *Prosopis* that has been previously made.

A visible gap in the international research on *Prosopis* however clearly exists: the lack of objective socio-economic surveys that take the concerns, views and perceptions of the very communities on board that are affected by *Prosopis*. While some studies do incorporate an outline of socio-economic benefits including the costing of *Prosopis* by-products, no study has been found that costs the losses. Generally, it can be said that the negative ‘findings’ made by rural communities themselves are rarely sufficiently covered or referred to - and in much of the scientific research material on *Prosopis* barely mentioned at all. An important source of community views is currently the press, some development reports, or local workshop proceedings. However these views often lack the necessary expertise on the subject.

Chapter 2: Physical and Anthropologic Geographical Summary and Regional *Prosopis* Habitats in Eritrea

2.1 Land Area and Climate in Eritrea

Eritrea covers a total land area of 123,324 square kilometres (IGAD 2004). It shares borders with Sudan in the West and North, Djibouti in the South East, Ethiopia in the South and has a coastal line of 1,200 km along the East bordered by the Red Sea. Administratively, Eritrea is divided into six regions (*zoba*) and 56 sub-regions (*sub-zoba*).

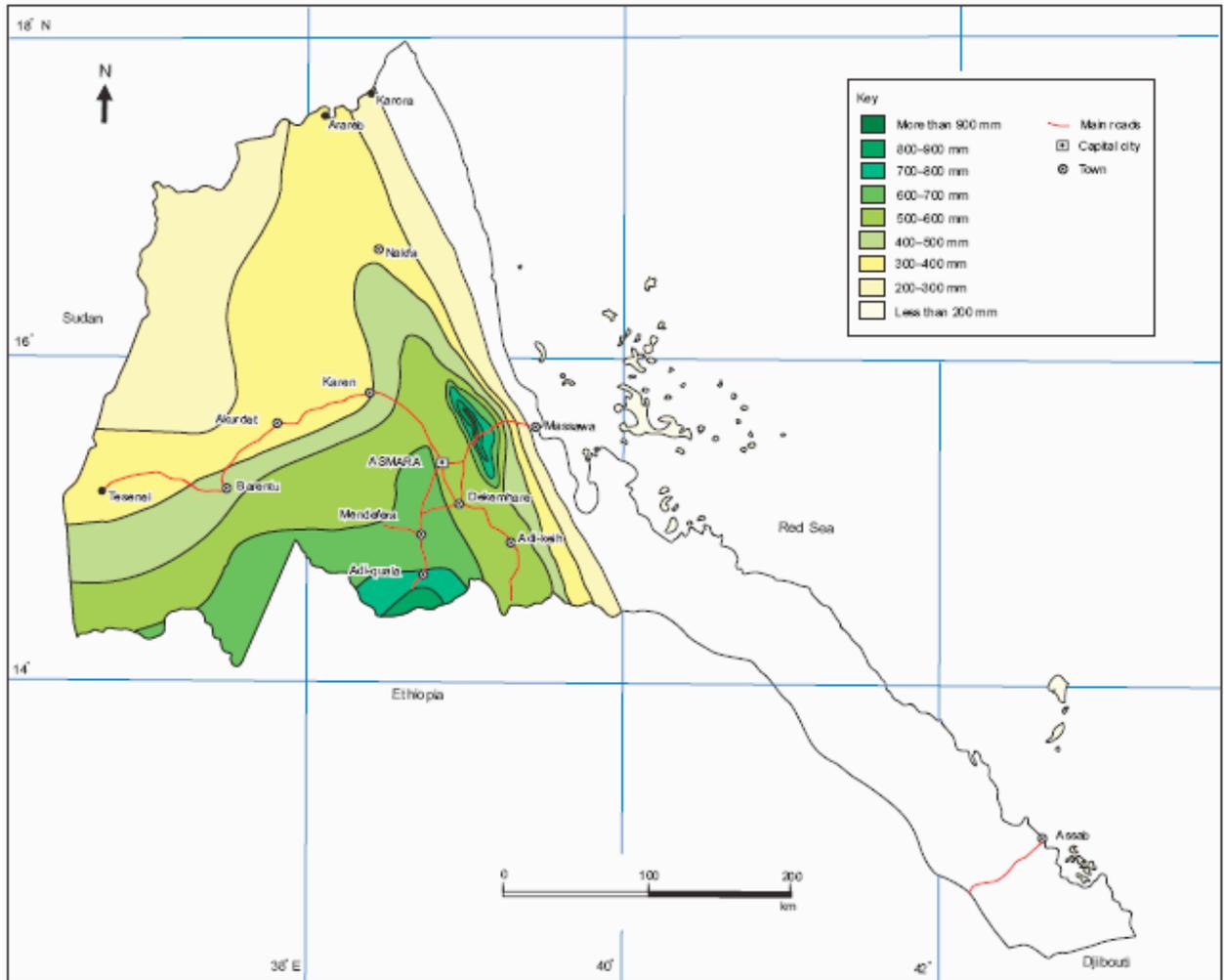
Eritrea's climate is highly influenced by the topographic set up of the country with Southern highlands reaching over 3,000 m above sea level whereas the eastern edge of that plateau drops below sea level creating depressions along the south eastern coast in *Danakil*.

While the highlands and Western Lowlands receive a very large amount of rainfall during the main rainy season from June to August (arriving with South West winds from the Atlantic Ocean), the Eastern Lowlands in contrast, are in the middle of their dry season at this time. There, small amounts of rainfall arrive with gentle East Winds developing over the Red Sea between November and March.

The Central Highlands receive an annual precipitation between 400 mm and 700 mm, rising up to over 1000 mm towards the South. Temperatures in the highlands are generally mild, and climate is often described as Mediterranean. Maximum temperatures reach 26 °C during the day, while minimum temperatures can drop to 0 °C during the night, especially during November to January. The Western Lowlands are predominantly semi-arid and fairly hot, with precipitation ranging from 200 - 400 mm towards the South and around 200 mm towards the North. Hot and arid desert conditions are prevalent in the Eastern Lowlands where precipitation is usually below 200 mm and temperatures along the coast reach 45 °C - 50 °C during the day and above 20 °C during the night (IGAD 2004).

Graph 2.1: Mean annual rainfall in Eritrea

(Source: www.worldagroforestry.org)



Generally speaking Eritrea lies under the influence of the South West monsoon, which develops over the Atlantic Ocean and moves over the Congo and parts of Central Africa towards northeast. Low pressure zones arrive in Eritrea usually around April and May and occasionally bring small rainfall events. Main precipitation however occurs with the air masses arriving with the monsoon during the summer months. The high altitudes of the Eritrean and Ethiopian highlands act like a natural barrier forcing the air to rise up which results usually in intense rainfall. Eastern Eritrea in the contrary lies under the influence of North East winds, which occur during the winter months bringing moisture from the Red Sea.

2.2 Agro-climatic Zones

In broad physiographical terms, Eritrea can be divided into just three major zones: These are the Highlands, the Western Lowlands and the Eastern Lowlands, which vary in climate, vegetation, and socio-economic set-up.

However, using additional parameters such as primary agricultural production and livelihood systems as well as more distinct elevation and vegetation factors, a division into five or sometimes even six zones is common. These are (from east to west):

- the Coastal Plains (Eastern Lowlands)
- the Eastern Escarpments including the “green belt zone”
- the Highlands (consisting of Southern, Central and Northern Highlands)
- the Western Escarpments
- the Western Lowlands

The Western Lowlands are sometimes subdivided into the North-western Lowlands Zone (NWLZ) and the South-western Lowlands Zone (SWLZ).

P.juliflora can be found in all five of these zones. However, the arid Coastal Plains (Eastern Lowlands) and the semi-arid Western Lowlands are undoubtedly its prime habitats, with a higher level of infestation in the latter. *Prosopis* can also be found to some extent in higher elevations of the escarpment zones (above 1,000 m) e.g. around Ginda in the Eastern Escarpments, which will however be considered within the context of the lowlands.

Its occurrence in the Highland zone is very limited. *Prosopis* does grow around Keren in the western parts of the Central Highlands. The semi-humid Southern Highlands and semi-arid to arid Northern Highlands are free of *Prosopis*.

The Coastal Plains (Eastern Lowlands)

The Coastal Plains stretch along the Red Sea coastal area for a length of approximately 1,200 km (IGAD 2004, p.61). The area can reach up to 600 m towards the West and includes the depression in the *Bada* area which is known as the Danakil depression at 80 m below sea level with a mean annual rainfall of 100-200mm. The coastal plains have a hot desert climate with precipitation below 200 mm and a high potential evapo-transpiration of over 2,000 mm. The rainy season in the Coastal Plains and the Eastern Escarpments occurs during November to March when it arrives with North East winds from the Red Sea. The

area is dry and predominantly sandy with sketchy dryland vegetation, such as *Acacia* shrubs and desert grasses while some parts especially towards the southern coastal area show hardly any vegetation at all. The landscape near the coast is mostly flat with low hills, which increase in height and density towards the west. *Prosopis* is mainly found in the central parts of the coastal plains, and a few ranges can be found towards the north. The species is only rarely found towards the very arid south.

The main production systems in the area are pastoralism, agro-pastoralism and fishing. However, although components of agricultural crop production can be found, crop fertility is poor and only possible with supplementary spate irrigation where the landscape allows. Irrigation by the means of boreholes also exists in a few areas, especially in the central parts of the region, but is very limited. After the rainy season in the coastal plains (November - March) and before the start of the main rainy season in the highlands (July) many people migrate towards the highlands around April in the search for water and grazing land (BEIN *et al.* 1996, p. xvii)

The Eastern Escarpments and the “green belt” zone

The Eastern Escarpments is the region between the coastal plains and the highlands, stretching slightly from northeast to southwest. It has an altitude between 600 m and 1,600 m, but according to some records reaches up to 2,000 m at its highest peak, although altitudes far over 1,500 m should strictly speaking belong to the highland area. Like the Coastal Plains the Eastern Escarpments obtain rainfalls during November to March, however due to its high altitudes, air masses are forced steeply up resulting in a much higher mean annual precipitation of over 1,000 mm. This amount of precipitation has led to the fact that most of the Eastern Escarpments stay in vast contrast to the dry desert climate of the Eastern Coast: The Escarpments cover various micro-ecological zones, furthermore determined by topography, exposure and soils. Although the climate is generally semi-arid, some of the slopes become very lush and green during the rainy season.

Of particular importance is the so called “green belt” (*Bahri*), which is a unique area in Eritrea with a sub-humid to humid tropical climate, and which reaches with an elevation of 900-2400 m, far into the highlands. It contains a substantial portion (approx. 53,000 ha) of thick coniferous forest that once covered wide parts of the highlands, but which is very

rare and scattered today. Within this green belt lays the Semenawi Bahri National Park, which is protected due to its unique climate and biodiversity. Due to very steep slopes and relative inaccessibility the green belt area has remained widely untouched and mixed farming and livestock rearing is only practiced moderately. The area also has vital importance in view of natural conservation and tourism. (BEIN *et al.* 1996, p.xix, NASTASI 1993, p.22).

Although *Prosopis* is occasionally found on greater altitudes - e.g. in Keren at around 1,600 m - and in areas with high precipitation of around 1,000 mm the high elevation of the green-belt, rainfall of over 1,000 mm and significant air moisture (cloud forests) throughout the year result into a low risk infestation by *Prosopis*.

Some *Prosopis* stands however can be found in the arid northern parts of the Eastern Escarpments around Karora and Mahmimet near the highland zone.

The Highlands

The Highlands (*Kebesa*) comprise of the central, the northern and the southern highlands with altitudes over 1,500 m. The average altitude is 2,300 m and the highest peak at (Mount) Amba Soira in the eastern part of the south 3013 m. The main rainy season lasts for about three months starting in June or July and ending in early September. However, occasionally a small additional rainy season occurs during end of March / April and May. Precipitation within the highlands varies and at more than 700 mm is usually highest in the semi-arid to widely semi-humid south and with around 400 mm lowest in the north. This northern area (together with parts of the NWLZ) lies within Africa's Sahel belt. The Central Highlands are sub-humid semi-arid and receive around 500 - 600 mm rainfall; they are often described as having a Mediterranean climate.

Prosopis can be found in very limited areas within the western parts of the highlands around the city of Keren, which is the second largest in Eritrea. There, small ranges have been observed alongside the De'arit and Anseba rivers. A couple of single trees have also established themselves east of the city near the road that connects the city with the capital Asmara.

Alongside the Eastern Escarpments the main rainy season in the eastern parts of the highlands is often marked by a period of mist and fog creating a specific micro environment suitable for the late cultivation of cereals. Those parts are also under the influence of two

major regional wind and precipitation systems: The south-western summer monsoons originating over the Atlantic Ocean and the North East winds, which bring some rainfall from the Red Sea during the winter months.

The highlands with their moderate climate and fertile soils are the most densely populated region in the country (the capital Asmara with well over half a million habitants and most of Eritrea's bigger cities and towns are situated there). However, a long history of settlement, cultivation and overexploitation of natural resources, particularly timber, has resulted in high levels of land degradation (NAP 2002, p.33; BEIN *et al.* 1996, p. xx)

Small-scale farming and mixed farming (including animal husbandry) are the main production systems in the highlands with an increased livestock component towards the north. According to BEIN (1996) the classification of production systems can also be made based on a "rainfed-cereals/pulses-based system" and an "irrigated-horticulture-based system" cultivating a range of vegetables (BEIN *et al.* 1996, p.xx). However, this could wrongly imply that irrigated horticulture is well represented within highland livelihoods whereas it is really just a very small and recent minority that practices irrigated and mostly commercial horticulture in the highlands, for example, at Ilaber'id.

The arable land available for farming is steadily decreasing and varies between 0.5 and 2 ha with an average of about 1 ha per capita. Barley, wheat, *taff* (millet), finger millet, sorghum and maize are the main cereal crops. Farmers are heavily dependent on the power of animals for ploughing due to the steep and rocky terrain.

The Western Escarpments

The Western Escarpments are the zones between the highlands and the Western Lowlands, ranging in altitude from 600 - 1,500 m. They are mostly semi-arid with precipitation ranging from around 300 - 400 mm. They are a transition zone between the highlands and lowlands in terms of population, topography and livelihood systems.

The dominant production system is agro-pastoral and average farm sizes are with 2-3 ha larger than in the highlands. The main crops consist of sorghum, finger millet, maize, sesame and chickpeas (BEIN *et al.* 1996, p.xx). There is also an increased trend in recent

years for irrigated large-scale horticulture and plantations, e.g. around Keren with fruit and vegetables or around Af'abet with cotton and ground nut.

The Western Lowlands

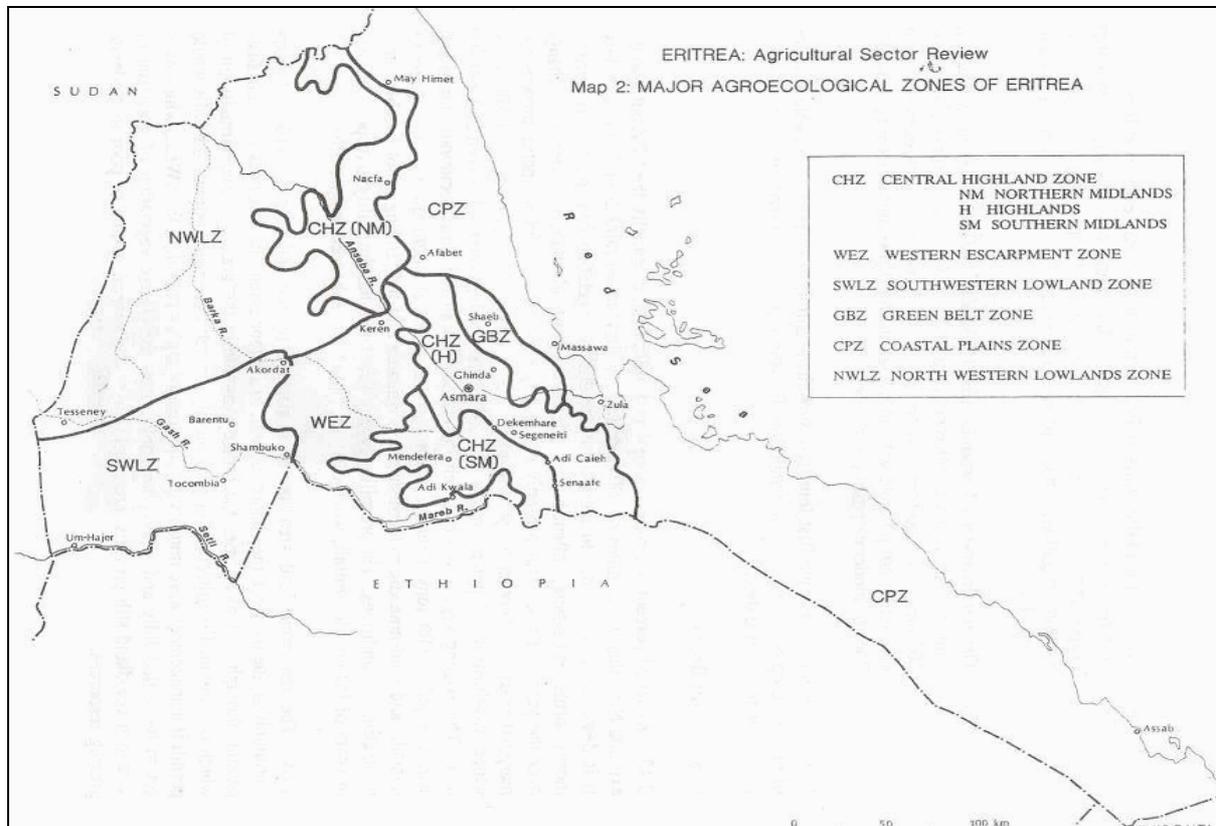
The Western Lowlands are sometimes subdivided into the South Western Lowland Zone (SWLZ) and the North Western Lowland Zone (NWLZ). Altitudes for this area vary widely from around 300 - 600 m within the flat plains (NAP 2002, p.33) and up to 1,000 m towards the escarpments zone.

The climate is moderate semi-arid to hot semi-arid with aridity levels increasing towards the north. Rainfall in the southern Western Lowlands ranges from 400 - 600 mm, but decreases towards the north to an annual average of 200 - 300 mm (BEIN *et al.* 1996, p.xxii; NAP 2002, p.33)

The Gash Barka Region, which is situated in the southern and central Western Lowlands and which covers the majority of this zone, is often referred to as the “bread-basket” of the country. Eritrea’s main river systems and drainage basins, such as the Mereb, Setit, Barka and Gash rivers are based here providing water, good micro climate, and fertile land strips for rain-fed farming, cash-crops, horticulture and livestock herding. The proximity of this area to neighbouring Sudan and Ethiopia have also lead to the development of a variety of local and regional markets and trade routes and is a key area for nomadic and refugee migration making it probably the most dynamic region in Eritrea (BOKREZION *et al.* 2006, p. 39)

Map 2.1: Eritrea's agro-ecological zones

(Source: MoLWE, 2001, p. 13)



2.3 Geology, Water Resources and Soils

Geology

The Pre-cambrian rocks occurring in Eritrea have been involved in the Pan-African orogeny and are the oldest rocks forming a crystalline basement of intensively folded volcanic as well as metamorphosed sediments and igneous intrusions. They surface to large extent in the north-western and Eastern Lowlands of Eritrea. Among the Pre-cambrian rocks are Andesite lavas and tuffs, tuffaceous slates, greywacks, limestone dolomites, phyllites, chloritic and seritic shists and others which have been formed during the upper Proterozoic formations (SPRINGER VERLAG 2006; YOHANNES 1991, p. 23; TEKLAY 1997, p.12).

Mesozoic rocks were subject to severe deformations as a result of massive epeirogenic (continent forming) movements which lead to the gradual sinking and later uplift of land masses in the Horn of Africa. Severe sediment deformations are present in the

Danakil and Aysha horsts. The Mesozoic sedimentary rocks were deposited in three layers, which are known as the Sandstones of the Adigrat Series, limestones and marls of the Antola series and the Sandstones of the Amba Aradam Series.

Cenozoic rocks were subject to extensive fracturing with the major uplifting of the Horn of Africa in the early Cenozoic era (Miocene), which continued to some extent during the early Pleistocene (Pleistocene-Miocene). This resulted in a range of faulting and rifting (particularly east and west of the Central Highlands, but also east of the Southern Highlands, in the Danakil depression in south-east Eritrea, which is part of the Red Sea, Gulf of Aden and East African Rift System). These fractures and rifts lead to widespread volcanic activity and the eruption of vast quantities of basaltic lava accompanied by large amounts of ash and fragmental material, which together form the Trap Series, the earliest volcanic rocks. This was followed by the Dogali Formation of the Red Sea coast with marine and continental sedimentation processes, consisting of sandstones, gypsiferous marls, and limestone, as well as the Red Series of Afar (Miocene-Pliocene) with similar sedimentary make-up. The Afar Depression commenced during this miocenic era. A thick salt formation sits on the top of the Red Series and fills the basin in the centre of the Danakil Depression, which reaches 80 m below sea level³. Sediments include among other halite, gypsum, anhydrite, and potash salts. The most recent formation is the one of the Pleistocene-Holocene-Deposits including continental sediments of alluvium and aeolian nature, such as conglomerate, sand, silt, clay, reef limestone and the White Series (Enkafla Beds) of the Afar Depression (Pleistocene deposits). Holocene deposits include marine sediments of coral limestone and some of the dunes on the coastal plains of Afar are from this age, which followed the last known marine transgression in the region (SPRINGER VERLAG 2006; YOHANNES 1991, p. 24-26)

Water

Surface water and drainage systems

Eritrea has five major river streams mainly to be found in the West of the country. These are the Mereb, Gash, Barka, and Anseba rivers, which are seasonal containing only water

³ Personal communication with Dr Seife Berhe, Senior Eritrean Geologist, in 2008. Depression includes Lake Asal in Northern Ethiopia at 155m below sea level, which is the lowest point in Africa.

during and shortly after the rainy season. The Setit is the only perennial river in the country forming the south-west border with neighbouring Ethiopia where it is known as the Tekeze River. The Setit River has an estimated catchment area of 7,300 km² and is draining into the Nile River in the Sudan. Also draining into the Nile is the Mereb-Gash drainage system in south-western Eritrea with an estimated catchment area of 17,400 km². The Barka-Anseba drainage system with the largest catchment area of 41,200 km² among the river streams is to be found further north (NAP 2002, p.33; FAO Information Systems 2005, www.fao.org/nr/water/aquastat/countries/eritrea/index.stm). Both rivers have their springs in the Central Highlands and while the Barka soon makes its way through the Western Lowlands, the Anseba River is the only major river stream to be found within the highlands. The Barka and Anseba also flow into the Sudan and drain there into the Red Sea. There are several other small rivers in Eritrea flowing into the Sudan in the West and many more running from the Eastern slopes of the highlands into the Red Sea. The Red Sea has according to the NAP (2002) an estimated catchment area of 44,690 km². The Danakil Depression in the arid-hot south east is another drainage basin with an estimated 10,532 km² catchment area.

There are no other natural surface water bodies, such as lakes, in the country. Only artificially constructed dammed water bodies can be found, mainly within the highlands. Further dam construction can be expected in the near future, mainly for agricultural production (irrigation and livestock) and household use purposes. According to the FAO (2005), there are 187 dams with a holding capacity of over 50,000 m³ each and a total capacity of 94 million m³. Furthermore during a recent water point inventory 5,365 water points (including traditional and motorised wells) were counted.

Boreholes are usually 20-70 m deep (FAO Information Systems 2005). The majority of boreholes are to be found in the Western Lowlands alongside or near the seasonal river streams where they are widely used for irrigation. Locals claim that *Prosopis* stands flourishing around the wells contribute to the decrease of the water table and irrigation systems are often obstructed by the species.

Traditional dug and widely unprotected wells can be found in large numbers alongside the banks and valleys of major and small rivers or within river beds. They are mostly used for household consumption and as water points for animals.

Groundwater resources

Groundwater can be tapped in almost all parts of the country, however desired water quantity and quality may be poor. In broader terms, there are no reliable measurements and data sources available for Eritrea's water-resources potential, ground water resources in particular, as no up to date comprehensive studies have taken place in the country in this regard. However, based on different geological and hydro-geological units and characteristics, as well as recharge and water quality patterns three to four main types of aquifers can so far be identified:

- a. *Granular or inter-granular aquifers*: These cover large areas in the Western and Eastern Lowlands, mainly associated with river valleys and floodplains consisting of alluvial and colluvial sediments. Ephemeral streams and hot springs within the Eastern Lowlands (e.g. around May Wu'uy) also belong to this category.
- b. *Fractured (or fissured) and jointed volcanic aquifers*: These are mainly associated with seasonal streams and wells in the southern parts of the Central Highlands (e.g. southeast of Asmara).
- c. *Fissured and karstic aquifers*: Found within sedimentary rock formations, such as limestones and coral reefs, as well as within evaporate deposits and metamorphic assemblages.
- d. *Fissured aquifers of crystalline metamorphic basement rocks*⁴, including intrusive rocks, alongside weathered and fractured zones. They often act as groundwater barriers and therefore have limited groundwater resources.

(NAP 2002, p.34; FAO Information Systems 2005)

⁴ The category 'industry' has been identified within the FAO Information System 2005. However it was not listed by the NAP 2002.

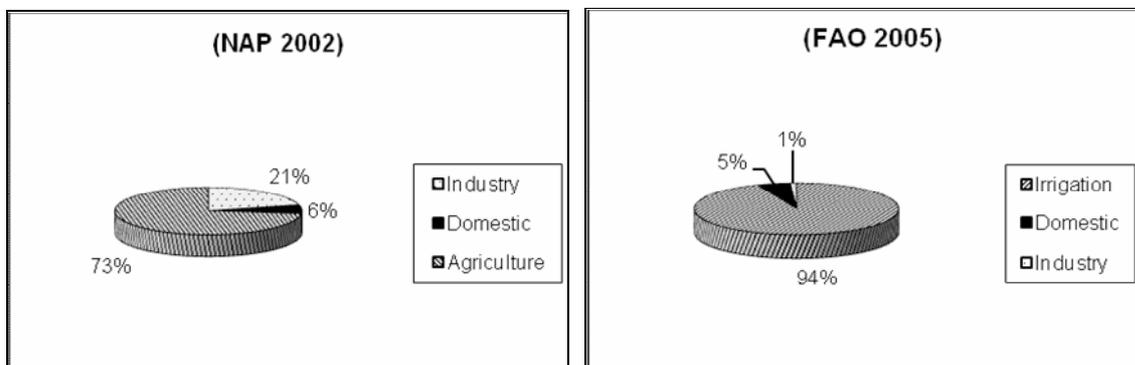
Water consumption

According to the FAO Information Systems (2005) water consumption in Eritrea is predominantly based on agricultural (including commercial agriculture) and domestic consumption. Only little is demanded by other commercial or industrial sectors. Groundwater is the basis for any kind of water consumption in Eritrea. In 2004 total water withdrawal was estimated at 550 million m³ for agricultural production (94.5%) - mainly crop irrigation- and only 31 million m³ for domestic consumption (5.3%), while about 1% was used for industrial purposes.

However, the FAO data report on national water consumption fails to state the water demand and consumption of livestock, which according to the NAP 2002 is estimated to be 43.1 million m³. In general, water consumption by sector as per NAP 2002 states slightly different figures (73% agricultural, 21% industrial and 6% domestic) as compared with the FAO figures stated above.

Graph 2.2: Water Use by Sector: Comparison of NAP and FAO Data Sources

(Data sources: NAP 2002, FAO 2005; Design: Author)



The above data show that experts agree on the amounts for domestic water consumption, which according to the NAP (2002) are 13 l/capita/day (national average) while overall water consumption per head (including all sectors) is estimated to be 32 l/capita/day (NAP 2002, p.35). However, much more obvious should be how the agricultural sector is subdivided in terms of water consumption by irrigation (small-scale and commercial), livestock, and commercial trading. A discrepancy of twenty times the proportion of water

consumption stated for the industrial sector is quite unsatisfactory making it apparent that more detailed data or a clearer subdivision of water consuming sectors needs to be obtained.

Eritrea up to this date has no official national water policy.

Soils in *Prosopis* habitat regions

In the Western Lowlands, fluvisols, luvisols, vertisols, and cambisols are the leading soil types. However the latter two exist particularly in the southern parts of the Western Lowlands which is only invaded by *Prosopis* to a limited extent. Therefore, fluvisols around the Gash and Barka river system in the central parts of the lowlands and luvisols in the very west (around Tesseney) are the soils predominantly infested by *Prosopis*.

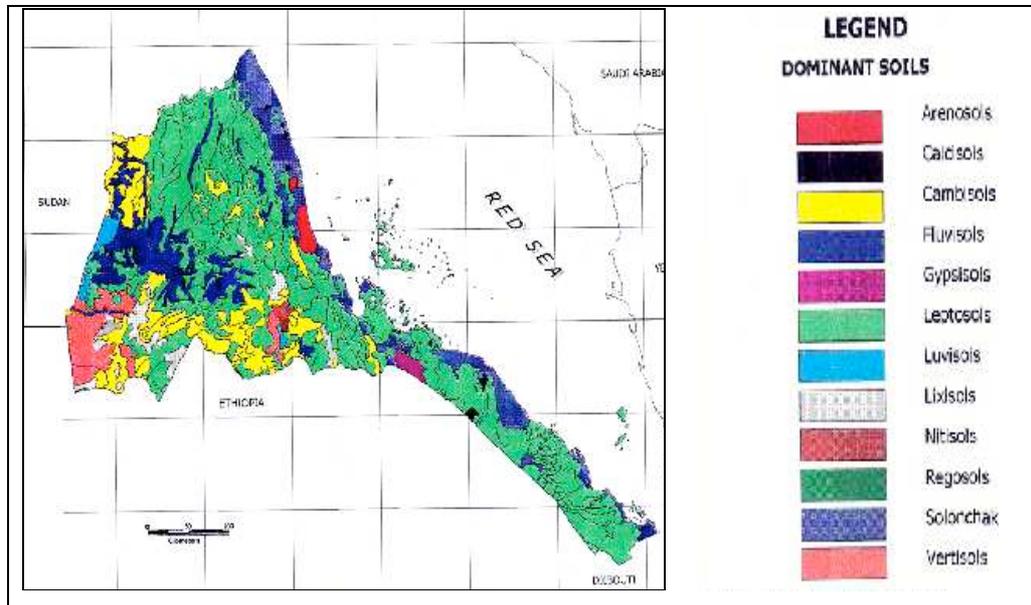
In the Western Escarpment zone - the topographic entity between the Western Lowlands and the highlands - where *Prosopis* is also present to some extent, the makeup of soils changes and is more similar to that of the highlands with cambisols being the predominant soil type.

Cambisols of a brown or reddish colour are in addition widely found in the Southern Highlands consisting usually of colluvial soils. Although these soils often have a low organic matter and phosphorus content, they are generally quite deep (1-1.5m) with a considerable silt content making them suitable for agriculture (BEIN *et al.*1996, p.xix; MOA 1999, 1).

Vertisols - often of a dark brown colour - do have a high clay content, which leads to high water storage capacity, but these soils have a rather low permeability increasing surface run-off. Although vertisols are often hard to plough, farmers generally prefer them to other soils due to a relative good nutrient content. It has however been observed that due to land overuse and erosion nutrients in vertisols are much more depleted in the highlands than in the lowlands resulting in better millet harvest outcomes in the latter (MOA 1999, p.2,5)

Map 2.2: Eritrea's soil classification

(Source : FAO 2002)



In the desert climate of the Eastern Lowlands - the second regional *Prosopis* key habitat after the Western Lowlands - the species is particularly found in the central parts reaching from the Eastern Escarpment zone around Ginda up to the port of Massawa. Here, regosols and near the coast also solonchaks, and to a very limited amount fluvisols are the predominant soil types. Solonchaks have a high salt content, low nutrient content and pH value reaches up to 9. However, due to its relative tolerance towards soil salinity and high pH value, *Prosopis* establishes well on these soils, e.g. around the city of Massawa.

Lithosols⁵ and eutric regosols followed by eutric cambisols cover the main land area of the highlands (YOHANNES 1991, appendix p.18). Lithosols and regosols are a result of the dry climate in the region where chemical weathering in particular is slowed down. Additionally, soil erosion as a product of both natural and anthropogenic processes has led to limited soil formation with low to medium organic matter content.

⁵ Other sources refer to Leptosols rather than Lithosols.

2.4 Population

Eritrea's population is estimated at about 3.5 million, and is growing at a rate of 2.9% per annum (IGAD 2004 after FAO 1997). Besides natural growth, Eritrea has also seen a considerable growth in population following the migration of several hundred thousand returnees from the Sudan who mainly resettled in the western parts of the country. Furthermore, many more were deported into Eritrea from Ethiopia during the Ethio-Eritrean border war from 1998-2000. On the other hand, Eritrea faced a great loss of human life in the recent war and many have left the country in the last few years, leading to a general population estimate of 3.5 to 4.0 million among experts.

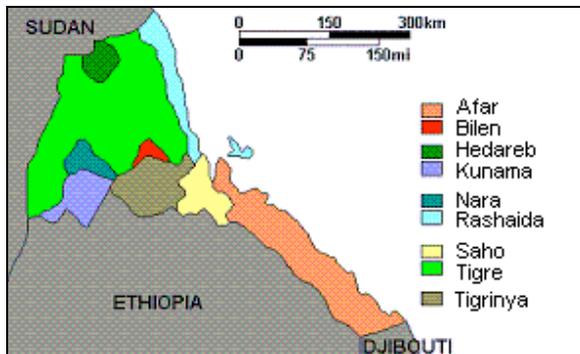
According to IGAD (2004), approximately half of the population is below the age of 18 (IGAD 2004, p. 61)

About 65% of the population live in the semi-arid to semi-humid Central and Southern Highlands, which form only 16% of the total land area. High population density has led to visible overuse of natural resources and land degradation in the highlands. The decrease in land productivity and land size per capita has resulted in an increased trend in migration not only from rural areas into the towns and cities, but also from the highlands into the less densely populated and relatively fertile Western Lowlands in the Southwest.

There are nine ethno-linguistic groups in Eritrea. The Tigre and Hidareb are mainly agro-pastoralists who live in the Anseba and Gash Barka regions. Together with the Kunama, who are mainly settled farmers and hunter-gatherers they occupy most of the Western Escarpments and Lowlands. The Bilen and Nara are also mostly settled farmers or agro-pastoralists who live in the higher altitudes of the escarpments around the central and northern highlands. The Tigrinya are mainly settled in the Central and Southern Highlands where they derive their livelihoods from small-scale farming although considerable numbers have migrated to all parts of the country, particularly into the Western Lowlands. The Nara, Afar and Rashaida inhabit the Eastern Lowlands and escarpments. While the Nara are mostly settled farmers and herders, the Afar and Rashaida are pastoralists.

Map 2.3: Ethnic groups in Eritrea

Source: www.geschichteinchronologie.ch



The fact that the Western and Eastern Lowlands are the regional habitats of *Prosopis* the ethnic rural communities which most often (in absolute numbers) encounter the species' invasion are the Tigre. They typically live in the Western Lowlands but also in the escarpment zone of the Eastern Lowlands and are the second biggest group in Eritrea⁶. Also within highly infested *Prosopis* areas live the Nara. On the edge of this regional *Prosopis* habitat with severe to limited infestation live the Kunama (e.g. area around Barentu and west of Shambuko).

In the central Eastern Lowlands, the Tigre, Rashaida and Saho are mostly living within *Prosopis* affected areas. The Afar do face some *Prosopis* infestation in the central parts of the lowlands, but are usually less affected, as the species' spread was reported by several people to be minimal towards the south except for a few stands for example in Ti'o town situated at the north-central coast within the Afar area (Southern Red Sea zone).

2.5 Land Use and Rural Livelihood Systems

About 80% of the population derive their livelihoods from subsistence economies, such as rain-fed farming, mixed farming or (agro-) pastoralism and are highly dependent on the productivity of the land for survival. According to the MoA (NAP 2002) 26% of the

⁶ The Tigrinya are the biggest group living typically in the densely populated areas of the Central and Southern Highlands.

country's GDP is derived from agriculture with 15% of that being contributed by the livestock sector.

Land use and land tenure systems are dependent on several factors, such as climatic and edaphic conditions, topography, and cultural heritage. In the semi-arid and semi-humid Central and Southern Highlands of the country small scale rain-fed farming and mixed farming are the main land use practices among the rural communities.

The highlands are fairly homogenous in its land use systems. In the Western Lowlands agro-pastoralism, rain-fed and mixed farming, irrigated farming, cash crop agriculture, and horticulture (especially alongside the fertile riverine areas) can be considered as major land use practices with increased livestock based household economies towards the drier North. In terms of production systems the Western Lowlands can clearly be regarded as the 'melting pot' of the country and the most dynamic region in Eritrea. *Prosopis* infestation is therefore equally encountered by all production systems.

The arid Eastern Lowlands are mostly inhabited by pastoralist communities with fishery being an important supplementary livelihood source.

Livestock population is particularly high in the regional *Prosopis* habitats of the Western and Eastern Lowlands contributing significantly to the distribution of the species. These two regions are largely inhabited by agro-pastoralists and pastoralists who can be regarded as the main stakeholders of Eritrea's livestock sector.

At the same time, a considerable number of animals can also be found within mixed farming systems in the highlands. The livestock population is estimated at 6.75 million, comprising 1.25 million cattle, 5.0 million sheep and goats, 0.3 million donkeys, and 0.2 million camels. Sheep and goat are undoubtedly the main livestock and are owned by poor, better off, and wealthy households.

Livestock is predominantly kept for household use and for trading of both live animals and livestock-based products at local markets. Some livestock is traded regionally (e.g. in Eastern Sudan) adding to the seed distribution of *Prosopis* across the border in both directions due to continuous livestock movements between the two countries. Only small amounts of livestock and by-products are currently being exported from Eritrea.

2.6 Natural Resources, Vegetation and Ecosystems

Eritrea is a relatively small country, but its distinct topography and long stretching land mass from North to South have created a wide variety of climatic conditions, landscapes and natural ecosystems with distinctive vegetation. These include sand and rock deserts, semi-arid grassland and bush savanna, and montane mist forests.

Forest resources in Eritrea are currently on the increase, following intense afforestation efforts by the government and local communities. However, forests have been subject to deforestation throughout the last century. Vast degradation of forests started with the Italian colonisation at the end of the 19th century when wood was cut for domestic and industrial use and export. Throughout the next century forest resources (excluding the riverine forests) are reported to have declined from 30% of the total area at the beginning of the century to just 0.4% in 1994. In recent years, closed forest cover is believed to have risen to 2-3% (IGAD 2004, p. 52) and afforestation projects can be witnessed throughout the country.

Table 2.1: Eritrea's vegetation types and estimated covered land area

Source: FAO 1997 (amended)

Vegetation type	Area (ha)	Percentage of total area	<i>Prosopis</i> infestation
Closed to medium-closed forest	51,520	0.42	-
Closed forest	40,790	0.33	-
Closed to medium-closed woodland	452,730	3.68	-
Open woodland	1,112,760	9.05	√
Riverine forest	185,480	1.51	√
Mangrove	11,330	0.09	√
Bushland and shrubland	5,309,560	43.19	√
Grassland and wooded grassland	2,326,260	18.93	√
Bare land	1,879,190	15.28	√
Arable/cropped land	685,040	5.57	√
Other and non-classified land	240,320	1.95	√
Total	12,294,980		

The main tree species to be found throughout the savannas and woodlands of the Western Lowlands are *Acacia* species, such as *A. mellifera*, *A. tortilis*, *A. senegal*, *A. oefarta*, *A. asak*, and *A. seyal*, which are widely found alongside *Prosopis* where the species has invaded open grass and shrubland.

Other tree species can also be observed, but are often limited to a certain area or specific ecosystem within the western escarpments and lowlands. These are *Adansonia digitata*, *Boscia angustifolia*, *B. senegalensis*, *Balanites aegyptiaca*, *Delonix elata*, *Cadaba rotundifolia*, *Boswellia popurifera*, *Albizia amara*, and *Hyphaene thebaica* (Doum palm). Some of the tree species such as *Balanites aegyptiaca* and *Hyphaene thebaica* are found in ecosystems increasingly infested by *Prosopis*, e.g. the riverine forests.

The natural highland forests consist mainly of *Juniperus procera* and *Olea africana* (IGAD, 2004, p. 61)

The riverine forests, which can be mainly found alongside the Barka and Gash rivers, but also along the Anseba, Mogoraib and Lukaib are often referred to as the most biodiverse and socio-economical valuable ecosystems in the country. The reason for this is that the forests are highly heterogeneous comprising a wide range of fauna and flora.

Their unique ecology within the semi-arid lowlands is of considerable social-economic importance to various local rural communities, particularly during the rainy season. The main plant species to be found in the riverine forests are the characteristic Doum palm, *Balanites aegyptiaca*, *Ziziphus spina-christi* and various *Acacia* species. The riverine forests are a prime habitat for *Prosopis* within the Western Lowlands.

Mangrove vegetation is very rare and can be found in the hot Eastern drylands at the Red Sea coast around Massawa, Ti'o, and Assab and some of the islands. The dominant mangrove species is *Avicennia marina*, followed by *Rhizophora mucronata*, *Bruguiera gymnorrhiza* and *Ceriops tegal* (IGAD, 2004, p. 63). During field visits, *Prosopis* was found to have invaded mangrove vegetation under the influence of sea water in Massawa. Small stands of *Prosopis* reportedly also exist in Ti'o.

Chapter 3: *Prosopis juliflora* in Eritrea

3.1 Brief Assessment of Invasive and Endangered Tree Species in Eritrea

The invasive character of *Prosopis* in Eritrea is well known to local experts, yet it seems that this has only become commonly apparent in recent years. This is indicated by the fact that earlier research documents and national policy papers such as the National Environmental Management Plan for Eritrea (NEMP-E) of 1995 do not include the species *Prosopis* alongside other species that have been listed as “undesirable” as they endanger indigenous plant species. The NEMP-E for example only emphasises the spread of the alien species *Opuntia vulgaris* (*cactus*) and *Nicotinea* spp. (*tree tobacco*).

There is no concrete evidence as to when *cactus* was introduced into Eritrea, but it is believed to have been planted in the southern parts of the highlands (within the former province of Akuleguzai) by a French Catholic missionary as early as 1839 and was brought to the Central Highlands (within the former province of Hamasien) later on during the railway construction under the Italians (NEMP-E 1995, p. 72). Other sources however state that it was an Italian missionary by the name of Padre Stella who introduced the species to Eritrea in 1910 (BEIN 1996, p. 288). Although there is a big gap between the suggested dates of introduction, the fact is that the *cactus* was introduced to Eritrea many decades before *Prosopis*, which is believed to have come from the Sudan not earlier than the 1970s (BEIN 1996, p.320) and possibly only in the 80s (HABTE 2000). Hence, the continued spread of *Prosopis* over a wider land area may only have become apparent in recent years. The time factor (the period during which the spread of *Prosopis* has taken place) may be a reason for the lack of information or statements on *Prosopis* in earlier research and policy papers.

The fruit of the *cactus*, called *beles* locally, is a sweet and popular food and *cactus* seeds were quickly spread by people, livestock, and wild animals, especially monkeys. A century later *cactus* was a common sight in the highlands and estimated to cover about 10,000 hectares of the land. Of particular concern however, was its negative impact on native species such as *Olea africana* and *Juniperus procera* (NEMP-E 1995, p. 72; NASTASI 1993, p.23), which often appear alongside each other and are found throughout Eritrea,

particularly in the highlands and the Eastern Escarpments (BEIN 1996, p.284). There, cactus reportedly even competes with those native species found within the rare remnant forest area of Eritrea's "green belt" (*Semenawi Bahri*) zone (NEMP-E 1995, p.77).

Nicotiana glauca has also been given earlier attention within related research. The small tree is said to have achieved "tremendous multiplication" during the last few decades. It is also not palatable to livestock, as it contains alkaloid nicotine.

Another tree species that is widely discussed among experts is *Eucaplyptus*. It has been a prominent species for the use in energy plantations and afforestation projects and is estimated to cover a total area of about 10,000 hectares. However, *Eucaplyptus* plantations have caused much debate in Eritrea due to their undesirable environmental effects such as excessive water and soil nutrient requirements. They are also believed to have allelopathic effects on adjacent crops (NEMP-E 1995, p. 72). The ongoing discussion in the country about the risks and benefits of *Eucaplyptus* could be compared to some degree with the global discussion on *Prosopis*, which has only recently swept into Eritrea.

Related research papers and policy documents such as the NEMP-E 1995 or even more recent documents such as the "State of Forest Genetic Resources in Eritrea" (EMAN 2001) co-published by FAO/IPGRI/ICRAF in 2001 are treating the issue of *Prosopis* with a lack of urgency. This could be linked to the lack of available data information. The FAO/IPGRI/ICRAF states: "*Prosopis chilensis* and/or *P.juliflora* are making an appearance in the Tesseney area of the riverine forest, and this exotic tree is likely to spread, causing considerable difficulties to cultivators and herders" (EMAN 2001, p.9). The research paper on forest genetic resources fails to acknowledge the fact that *Prosopis* had already widely spread into many areas of the Western and Eastern Lowlands, not only endangering crops and grazing land, but also local biodiversity including the forest genetic resources the paper is seeking to address.

However, most of the related documents do agree on the various threats to the flora and fauna in Eritrea. The NEMP-E identifies the loss of habitat "as the single most important factor affecting [native] species", which is a result of "agricultural expansion, overuse of natural resources, war and drought". It continued by observing that the introduction of exotic species "can also have devastating effects on [native] species and ecosystems", acknowledging the threat that lies in the invasive character of species that are not indigenous to Eritrea (NEMP-E 1995, p.83). A list of factors threatening the indigenous

flora and fauna, as well as an inventory of those plant species regarded most at risk can be viewed in table 3.1 and 3.2.

Table 3.1: Threat factors to Eritrea’s flora and fauna

(Source: NEMP-E 1995; amended by author)

Habitat destruction by	Specific contributing threats	Consequences	Social and administrative threats
Expansion of agriculture, industry, xerophytes etc.	Introduction and spread of exotic species	Loss of habitat	<ul style="list-style-type: none"> • Lack of specific legislation & land use classification • Lack of data and research
Conversion of undervalued land for construction (e.g. wetlands, coral reefs)	Commercial agriculture, cash crops, and settlement expansion	Loss of habitat	Lack of protected area systems
Overuse of resources and resource depletion (e.g. timber extraction, harvest of <i>Doum palms</i>)	Population growth, poverty, conflict, migration	Destruction of habitat leading to population fragmentation	Local reluctance to cooperate due to low availability of alternatives
Overgrazing	Primary and secondary population growth	Loss of nesting sites for birds and loss of fauna. Soil erosion.	<ul style="list-style-type: none"> • Unplanned and uncontrolled development and population growth • Lack of awareness how to exploit natural resources sustainably

Table 3.2: List of endangered plant species in Eritrea

(Source: EMAN 2001, NEMP-E 1995, BEIN *et al.* 1996; design: author)

Endangered Tree Species	Listed by
<i>Albizia anthelmintica</i>	Eman (MoA 1997)
<i>Adansonia digitata</i>	NEMP, Eman (MoA 1997), Bein <i>et al.</i> 1996
<i>Balanites aegyptiaca</i>	NEMP, Eman (MoA 1997)
<i>Boscia angostifolia</i>	NEMP, Eman (MoA 1997)
<i>Boscia salicifolia</i>	NEMP, Eman (MoA 1997)
<i>Boswellia papyrifera</i>	NEMP, Eman (MoA 1997), Bein <i>et al.</i> 1996
<i>Buddleja polystachya</i>	NEMP, Eman (MoA 1997)
<i>Commiphora africana</i>	NEMP, Eman (MoA 1997)

<i>Cordia africana</i>	NEMP, Eman (MoA 1997)
<i>Croton macrostachys</i>	NEMP, Eman (MoA 1997)
<i>Diospyros abyssinica</i>	Eman (MoA 1997)
<i>Diospyros mespiliiformis</i>	NEMP, Eman (MoA 1997)
<i>Dobera glabra</i>	NEMP, Eman (MoA 1997), Bein <i>et al.</i> 1996
<i>Entada abyssinica</i>	Eman (MoA 1997)
<i>Erythrina abyssinica</i>	NEMP, Eman (MoA 1997)
<i>Ficus sycomorus</i>	NEMP, Eman (MoA 1997)
<i>Ficus vasta</i>	NEMP, Eman (MoA 1997)
<i>Juniperus procera</i>	NEMP, Eman (MoA 1997)
<i>Kigelia africana</i>	Eman (MoA 1997)
<i>Maesa lanceolata</i>	Eman (MoA 1997)
<i>Maerus crassifolia</i>	Eman (MoA 1997), Bein 1996
<i>Mimusops kummel</i>	NEMP, Eman (MoA 1997)
<i>Nuxia congesta</i>	Eman (MoA 1997)
<i>Oncoba spinosa</i>	Eman (MoA 1997)
<i>Ozoroa insignis</i>	Eman (MoA 1997)
<i>Pappea capensis</i>	Eman (MoA 1997)
<i>Piliostigma thonningii</i>	Eman (MoA 1997)
<i>Pygeum africanum (Prunus africana)</i>	NEMP, Eman (MoA 1997)
<i>Rhus natalensis</i>	NEMP, Eman (MoA 1997)
<i>Rhus abyssinica</i>	NEMP, Eman (MoA 1997)
<i>Securidaca longipedunculata</i>	Eman (MoA 1997)
<i>Syzygium guineanse</i>	NEMP, Eman (MoA 1997)
<i>Tamarindus indica</i>	NEMP, Eman (MoA 1997), Bein <i>et al.</i> 1996
<i>Ximenia americana</i>	NEMP, Eman (MoA 1997), Bein <i>et al.</i> 1996

The direct impact of *Prosopis* on particularly endangered tree species in Eritrea can at present be generally regarded as low. The main reason for this is that a majority of the endangered tree species is widely found in the southern Western Escarpments and the Eastern Escarpments as well as the highlands all areas where *Prosopis* invasion is very scattered and in some parts non existent. The above table of endangered species can however act as a basis for future management, by exactly describing the habitats and geographical occurrence of those species and matching them with *Prosopis* habitats outlined within this study.

3.2 Introduction, Geographic Distribution and Local Nomenclature of *P.juliflora*

According to BEIN *et al.* (1996) *Prosopis*⁷ was introduced into Eritrea from the Sudan in the 1970s (BEIN *et al.* 1996, p.320). A slightly later date is given by HABTE (2000) who states

⁷ The species referred to was *Prosopis chilensis*, however as explained in chapter 3.1 this was a common misidentification for *P.juliflora*

that it was introduced into Eritrea in the early 80s, with Sudan also being mentioned as the country of origin.

It has been reported that “*Prosopis* was introduced into Sudan by RE Massey from the Egyptian Department of Agriculture at Giza and from South Africa both in 1917” (BROUN & MASSEY 1929 in EL FADL 1997 in PASIECZNIK *et al.* 2001, p.16). According to MAGID (2007) the purpose was “to find exotic fast growing tree species resistant to drought and grazing” that are valuable “for conservation of ecological balance”, and which can be used as a “source of fuel wood and fodder and other economical values”. MAGID further states that the plants had been planted at the time within a small agricultural research farm in the outskirts of Khartoum, and that first field trials planting *Prosopis* outside the city took place in 1928 (MAGID 2007, p.14). According to LAXÉN (2005) the species is fast spreading in the Sudan stating that “in the early 2000s *Prosopis* had been introduced in about half of the total of 26 states which constitute Sudan” (LAXÉN 2005, p.11)

Of particular importance would be the introduction of *Prosopis* into Eastern Sudan, particularly Kassala State, as this is the region that borders the Western Lowlands of Eritrea, the prime habitat region for *Prosopis* in Eritrea. Unfortunately, accounts of the introduction into Eastern Sudan and Kassala State vary quite significantly. The earliest introduction is being reported by MAGID (2007) who states that “by 1948 plantations were established in Kassala, Gash Delta and Northern Regions” and along the Red Sea Coast near Port Sudan and the “sandy unstable edges of the Gezira irrigated scheme” (MAGID 2007, p.14). LAXÉN (2005) on the other hand - also not particularly referring to Kassala State - suggests that “in the 1960s Sudanese foresters were introducing the locally adapted *Prosopis* tree to many densely populated rural areas in various parts of Sudan, such as the agricultural irrigation schemes [two of the well-known are located in Eastern Sudan]⁸ and the suburban areas of major towns.” (ELSIDDIG 1998 in LAXÉN 2007, p.11).

In an article of the Sudan Vision Daily (1st of March 2008 edition) early introduction from Egypt and South Africa to Sudan in 1917 by a British government botanist is confirmed, however regarding the introduction of *Prosopis* into Eastern Sudan it states that “it was then deliberately introduced on a large scale into northern and eastern parts of the

⁸ E.g. The New Halfa Agricultural Irrigation Scheme and the Gash Irrigation scheme are located in Kassala State in Eastern Sudan.

Sudan in the 1970s and 1980s, for the purposes of dune stabilisation. It has since spread in an “uncontrolled manner”.

While those references provide three very different years of introduction of the species into Eastern Sudan ranging from 1948 to the 1980s, BABIKER (2006) suggests that the first *P.juliflora* introduction into Kassala State was in fact made as early as late in 1947, and that several further introduction efforts (planting programmes) were made in 1965 and again widely in 1974. He states: “Late in 1947 and subsequently in 1965 mesquite was re-introduced into eastern Sudan, where it was planted in a green belt around Kassala (Abdel Barie, 1986). In New Halfa mesquite was introduced to protect the research farm at inception in 1966 (El Tayeb, *et al.*, 2001). The prevailing drought in the 1970s rejuvenated the interest in mesquite and further introductions, into eastern Sudan, were made to protect residential and cultivated areas. In 1974 mesquite seeds were broadcast by airplanes in around Kassala and further planted in protected forests (Elsidig, Abdelsalam and Abdelmagid, 1998). In the period 1978-1981 the tree was planted as shelterbelts at Portsudan and Tokar.” (BABIKER 2006, p.2)

It took only a few years for it to spread into the north of Eritrea. During 1984, *P.juliflora* was already flourishing in and around the border town of Karora (Eritrean side) (Personal communication with a senior Eritrean livestock specialist who during the liberation struggle visited Karora in 1984 for his PhD study research), so introduction must have taken place via the Tokar delta or possibly also from Port Sudan immediately after its introduction there.

The upcoming chapter 4.3 (Perceptions about occurrence and level of spread) within this study looks into the accounts made by farmers and pastoralists during the survey regarding the introduction of Prosopis in Eritrea. Ideally, their statements would be presented in detail at this point, it was however equally important to keep their reports and perceptions within the context of the survey analysis which takes place under chapter 4. Nevertheless a few references to the views of farmers and pastoralists on the introduction of *Prosopis* in Eritrea shall be made at this point:

The wide span of dates (ranging over 30 years) suggested for the consecutive introduction of *Prosopis* into Eastern Sudan is repeated when looking at the accounts made by rural respondents in Western Eritrea about the introduction of *Prosopis* into their region. The span ranges from 1970-2001, however a clear majority (63.7%) of respondents in all

three sites claimed it was between 1980-1989 (a slightly higher number of whom believed it was in the later 80s).

One can now also reverse the link and make conclusions about the significant appearance and spread of *Prosopis* in Eastern Sudan (particularly Kassala State) by looking at the accounts collected in Western Eritrea. The accounts presented by BABIKER (2006) and MAGID (2007) stating that *Prosopis* was introduced into Kassala state as early as 1947 and 1948, respectively must - in view of the outcomes in Western Eritrea - have been a introduction at very small scale. Unless *Prosopis* was planted in an enclosed site (for example a research site) that was not accessible to browsing livestock, it would be unlikely that the dissemination of seeds by livestock and the spread of a highly invasive species had taken as long as 30-40 years. All respondents agreed that *Prosopis* was introduced into Eritrea by livestock coming from the Sudan and considering active livestock migration between the two countries one would have imagined an earlier appearance in Eritrea if *Prosopis* had been visibly present in Kassala since the 1940s.

The accounts presented by BABIKER (2006) and LAXÉN (2005) that introduction around the area took (also) place during the 60s would suggest that it had taken around 15-20 years for *Prosopis* to appear in Western Eritrea. While movements from Sudan into Eritrea were highly affected by the Eritrean war for independence and the on-off-occupation of several towns during the 70s and 80s a 15-20 year span is still a noticeably long time considering the fact that *Prosopis* is being described as a major browse to animals. However, the possibility still remains that introduction into Eritrea slowly followed the planting in Kassala during the 1960s, as migration into Eritrea was significantly decreased and times completely halted. Respondents in Eritrea could potentially have also reported slightly later years for the introduction, simply because they did not take immediate notice of a newly introduced species during the difficult times of war.

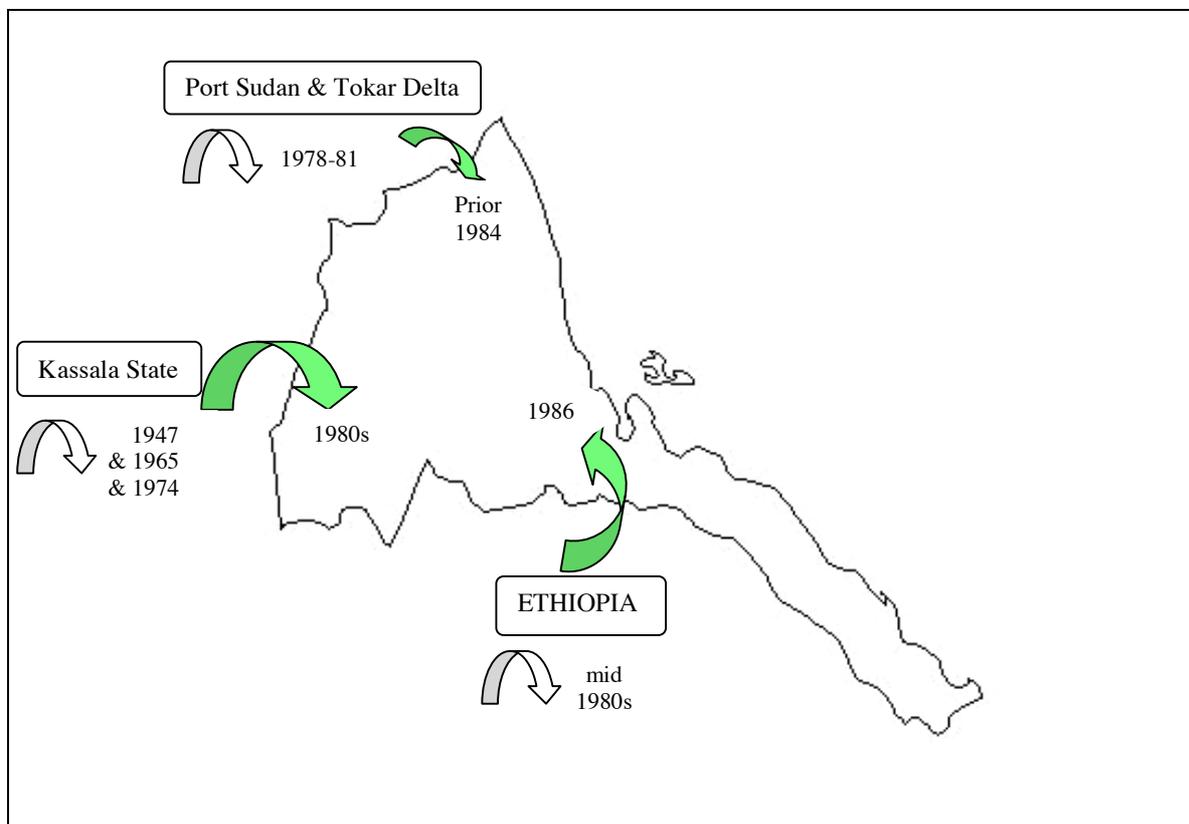
However, the strongest case makes the wide-spread re-introduction into the Kassala area by airplanes in 1974 suggested in BABIKER (2006). It is very likely that *Prosopis* introduction into Eritrea was only taken place significantly during that time.

In contrast, general consensus was reached during the survey by respondents in the Eastern Lowlands of Eritrea, where a majority (57%) claimed that the year of introduction was exactly 1986 (the rest still similarly claiming it was during 1987 and 1988) when *Prosopis* was introduced by the Ethiopian authorities (Ethiopian *derg* army), probably as a

source of wood for fire and construction purposes. It can therefore be assumed that *Prosopis* introduction into Eritrea most probably happened from two countries and as independent events: *Prosopis* entered into western and northern Eritrea from the Sudan, probably during the early 80s, and was introduced by livestock (which is also a possibility for northern Eritrea), while it came into eastern Eritrea from Ethiopia where it had been deliberately planted by the Ethiopians, for example around Gahtelay, in 1986.

Map 3.1: *Prosopis juliflora* introduction into Eritrea

(Source: own survey; BABIKER 2006; Design: author)



The following is a list of those areas within the Western and Eastern Lowlands in which *Prosopis* is found at the point of this study (2008). The areas - including towns/big villages + surrounding area (equivalent to sub-districts including several smaller villages that are not listed) or sometimes just villages + surrounding area within a subdistrict - have been identified as *Prosopis* habitats by the respondents during the survey interviews (which is

presented in detail in chapter 4), through personal observation during field trips, and in a few cases through literature (HABTE 2000, p.12).

Prosopis is currently found in the following areas (in alphabetical order)⁹:

Western Lowlands (including escarpment zone):

Abugemel, Adebera, Aderde, Adi Keshi, Ad-Omer, Ad-Simbira, Alebu, Akurdet, Alighider, Awad, Begos, Darotay, Diger, Dirsas, Edey, Engerne, Fadadab, Geluj, Gergef, Gersay, Girmayka, Hagaz, Haikota, Hilet Sidi, Himbol, Kambo 10, Karobete river area, Mensura, Molober, Numra 8, 10, 13 & 14, Qurokel, Sheterge, Shingirbit, Sinkatkinab, Sitmo, Tebeldiya, Tadalay, Talatasher, Tekreret, Temarat, Tesseney.

Eastern Lowlands/escarpment zone:

Ad-Shuma, Agrae, Demas, Felket, Gahtelay, Ginda, Maihimet, Mitsuwa (Massawa), Sheeb, Ti'o, Karora

western Central Highlands

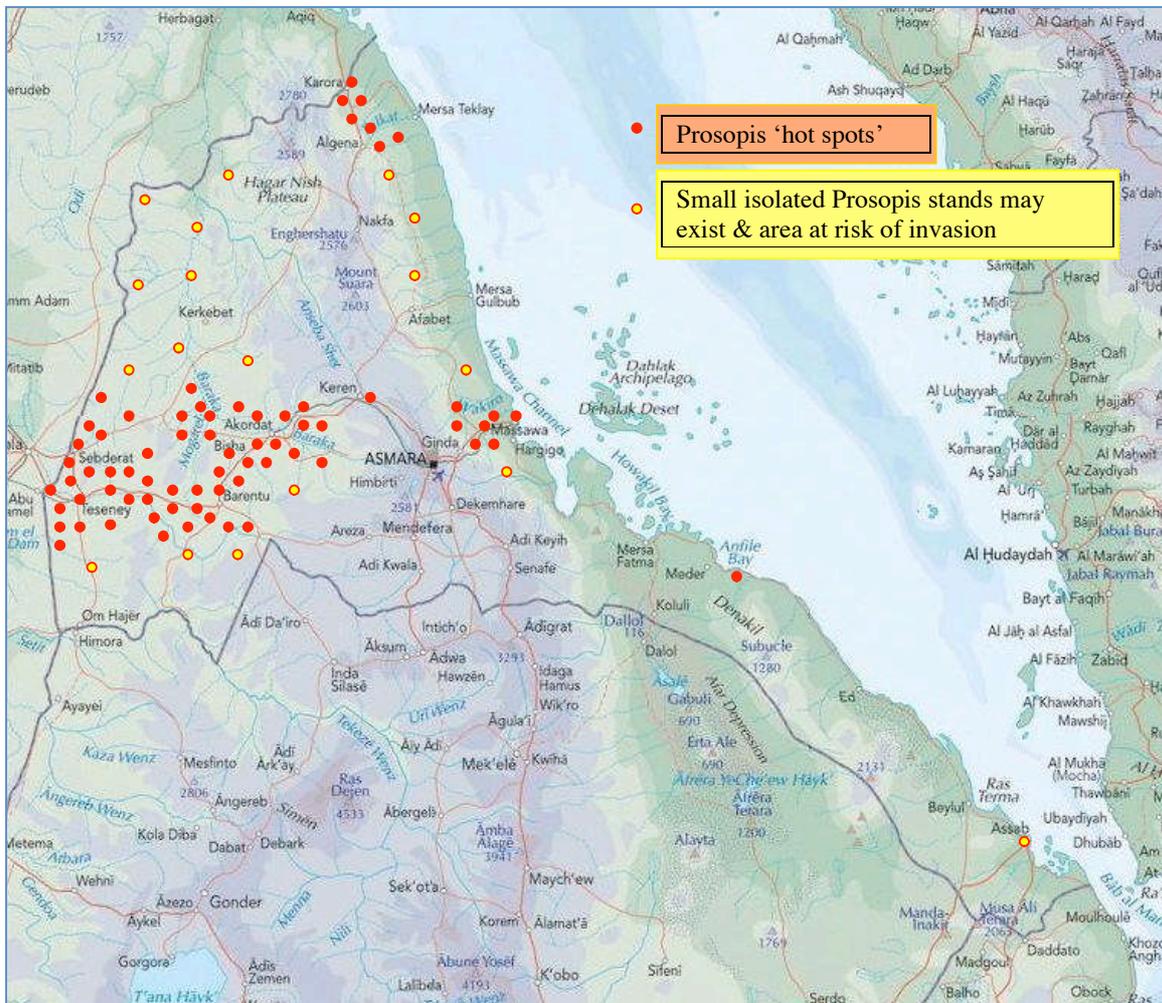
Keren

The highland zone acts like a natural border or protection zone preventing the re-inforced spread of *Prosopis* from east to west or the other way around through the means of wind, water and livestock. Although some pastoralists travel with their herds from the lowlands to the highlands during the dry season (transhumance or *sabek sagm*), they usually remain in the highlands where they empty their bowls and where at certain height *Prosopis* seed germination is halted due to high rainfall, low temperatures and occasional frost.

However, *Prosopis* does grow in Keren at 1,590 m in small stands around the De'arit and Anseba rivers and a couple of trees have been observed outside the city on the route to Asmara.

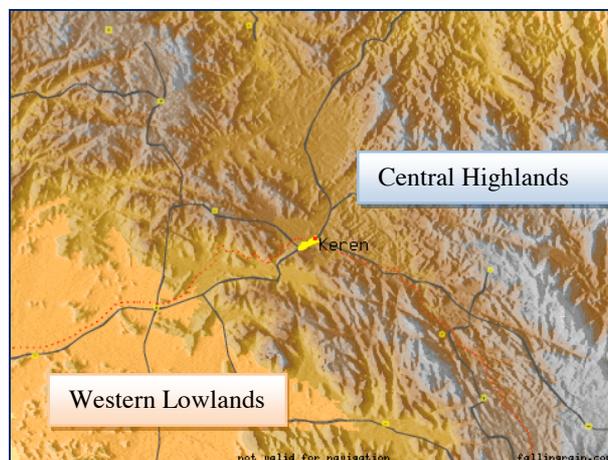
⁹ Records based on interviews and personal observations. More areas may exist however most of the villages that have not been named are included in the sub-district area of bigger villages and towns

Map 3.2: Distribution of *P. juliflora* in Eritrea (Mapping: author)



Map 3.3: Keren - rare highland habitat of *Prosopis*

Source: www.fallingrain.com (amended)



Prosopis in Eritrea is widely known locally as *temer musa* (Tigre & Arabic) or *temri musa* (Tigrinya) and *sesban* (or *sesman*). The former is widely used in the Western Lowlands and in northern Eritrea in the Karora area, although some do refer to it as *sesban*. It has been reported by respondents that inhabitants of Karora, which has an Eritrean and a Sudanese side, also call it *temer musa* on the Sudanese side, however HABTE (2000) states that people in Karora and Maihimet call it “sesaman” (HABTE 2000, p.3). Interestingly, locals in the Eastern Lowlands of Eritrea call *Prosopis sesban* with some knowing the term *temer musa* and others being less aware of it. Where the names come from and what their original meaning is could not be entirely established. The following is a possibility: ‘*temer*’ means ‘date’ (the fruit of the date palm) while ‘*musa*’ in Arabic can either refer to one of the genera for the family Musaceae to which the banana belongs or it the Arabic name for Moses. Hence, *temer musa* would either mean ‘the banana date’ or ‘the date of Musa (Moses)’. While the former could refer to the sweet, long, banana-shaped and often yellow (when dry) *Prosopis* pods, it is somewhat more difficult to interpret the latter. Local Tigre speakers suggested that *temer musa* would more likely refer to the ‘date of Musa’. Keeping in mind that *Prosopis* was widely regarded as a saviour in the region (Sudan) during its early introduction the name may derive from a positive perception that regarded *Prosopis* as a gift from Moses.

The origin of the term *sesban* is somewhat harder to assess. In fact the name *Sesbania sesban* (Egyptian river hemp) exists in botany, but refers to a different species of the family Leguminosae. However to a non-expert the species has clear similarities with *Prosopis* particularly in regard to its leaves, which have several opposite bipinnate leaflets with single leaves being many and small, and to its long pods. There may be a chance that it has been ‘mis-identified’ at one point (e.g. in Sudan) and that the name *sesban* has since been used for *Prosopis* among locals.

Local experts and practitioners in Eritrea refer to the species mainly as *Prosopis* or as *mesquite*.

3.3 Ecological Aspects of *Prosopis juliflora* in Eritrea

3.3.1 An Overview of *P. juliflora* within Eritrea's Ecosystems

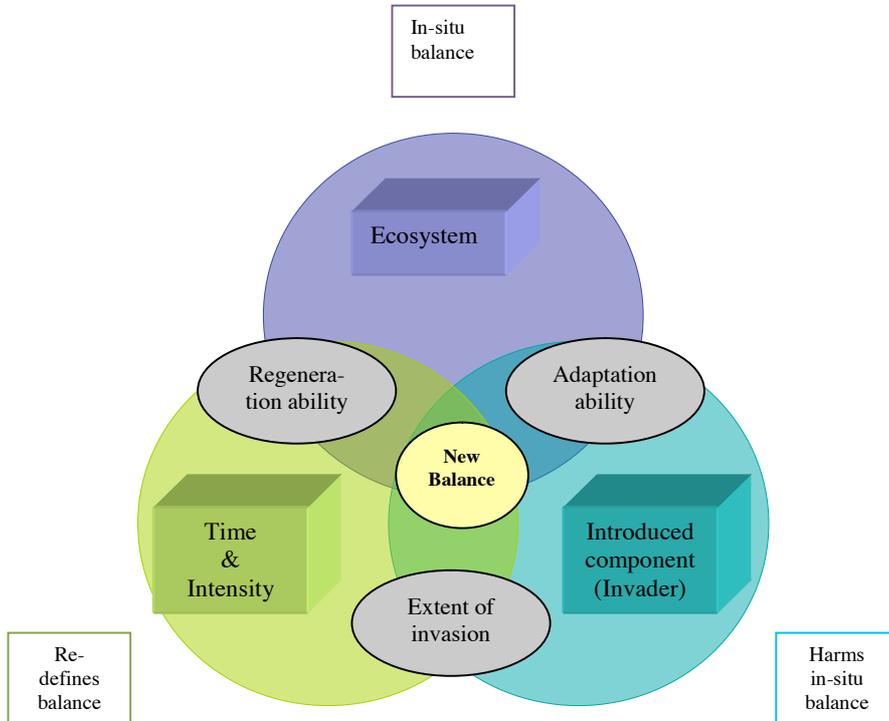
Ecosystems define an area, in which an ecological community or group of living organisms builds a unit (e.g. in form of a more or less self-contained synergy) with its surrounding environment. Therefore, over time abiotic or anthropogenic factors can be part of this unit, although they will have most probably to some extent disturbed or transformed the system that was previously in place.

It is without a doubt difficult to always foresee to which extent biotic or abiotic components that are reasonably newly introduced to an ecosystem have the ability to either harm the system or to adjust to it. *Time* and *intensity* are most likely factors that play a significant role in the long-term outcome of any kind of intrusion into an existing ecosystem. The factor 'time' may decide over the ability to adapt over a period of time to achieve balance within the ecosystem; and adaptation in this regard could take place on a multi-track basis: Firstly, the ability of the newly introduced component (or species) to adapt itself to the ecosystem it has 'invaded' and/or secondly, the ability of several existing organisms within the ecosystem to adapt themselves to the newly introduced component (species). The factor 'intensity' will with certainty also decide over the stability of an ecosystem 'invaded' by an alien component. Again, intensity may refer to the ecosystem itself, for example regarding its level of stability, fragility, and ability to adapt or to regenerate. Of much greater impact may be the factor 'intensity' in relation to the intruding component in terms of the extent and continuity of intrusion, as well as the range of harming characteristics the intruding component brings along (see graph 3.1).

With the total land area comprising of around 123,324 km² Eritrea is relatively speaking a small country. But because of its unique topography and geomorphology, its far-stretching north-south shape and its geographic position at the Red Sea the country entails a wide range of climatic conditions and natural ecosystems within a small land area.

Graph 3.1: Factors deciding over new balance development in invaded ecosystems.

(Source & Design: Author)



To carry out an impact assessment regarding the invasion of *P.juliflora* into Eritrea’s ecosystems one needs to take into consideration not only the botanic characteristics of the invading species and the intensity in which the invasion takes place, but also the in-situ conditions such as ecology, climate, level of local degradation, native vegetation, and topography of those ecosystems that are being invaded by *P.juliflora*. At a macro level, *P.juliflora* can be found in two major regional ecosystems of Eritrea, which are equivalent to two climate-ecological land regions:

- **Semi-arid Lowland Ecosystems** within the Western Lowland and the Western Escarpments Zones
- **Lowland Desert Ecosystems** within the Eastern Lowland (Costal Plains) Zone and at lower altitudes also the Eastern Escarpment Zone

Map 3.4: Satellite images of semi-arid lowland ecosystems (Western Lowlands) and lowland desert ecosystems (Coastal Plains)



River Gash, riverine forests and irrigated agriculture east of Tesseney (Western Lowlands) (Source: Google Earth, 2007)



Road north of Massawa city (Eastern Plains) ; (Source: Google Earth, 2007)

The satellite pictures clearly show the difference in climate, vegetation cover and ecological habitats that are to be found in those two regions, where *P.juliflora* has invaded a number of local key areas and ecosystems.

Within this study the following local ecosystems have been identified as prime habitats for *P.juliflora* in Eritrea.

- Riverine forests and river banks
- Irrigated crop land
- Road sides
- Immediate settlement areas

Except for the riverine forests all four ecosystems and *Prosopis* habitats can be found in both the Western and the Eastern Lowlands. While the riverine forests and irrigated crop land are habitats foremost infested by *Prosopis* in the Western Lowlands, in the Eastern Lowlands the species is densely spread primarily along road sides, in settlements, and alongside various dry river banks and beds. It is to be noted that the riverine forests and river beds are the only natural ecosystems identified among the prime habitats stated, whereas irrigated crop land, road sides and immediate settlement areas are anthropogenic ecosystems.

Riverine Forests / river beds

The riverine forests are one of the most biodiverse natural ecosystems to be found in the country. They can be mainly found in the southern and central parts of the Western Lowlands where they are situated alongside riverbeds and within some hillside valleys. Those forests host an enormously wide range of distinct flora and fauna, but it is probably the *Doum palm (Hyphaene thebaica)*, which is the most distinctive and characteristic feature.

Riverine forests have dwindled rapidly during the last century, as the land was cleared for agricultural expansion, horticulture, wood production and widely neglected during decades of war and reoccurring drought cycles. The forests, which are said to have covered vast areas alongside the river streams, but also on higher elevations along hillside valleys within the western escarpment zone a century ago (SANDER 1929, p.39) have been reduced to patches during the 20th century.

Photo 2: Riverine forest: mature *Doum palm* trees and juvenile stocks



(Photo: author)

The riverine forests are highly valued locally and are of significant socio-economic importance to rural communities in those areas, as they provide sources of food, fodder and shelter, and the *Doum palm* leaves in particular are used to make mats, ropes, and crafts generating an income at local and national markets. Although according to SOS Sahel and MoA (1999) their inventory results showed that the forests were “relatively healthy and undegraded” (SOS Sahel & MoA 1999, p.10), this statement relates primarily to those patches that have remained, as significant areas of prime forest have been cleared for agriculture and horticulture in the past. This has not been acknowledged enough by the inventory. GHEBRESLASSIE (2005) on the contrary states that health of Eritrea’s riverine forests is severely declining indexed by absence of various plant height classes, serious recruitment failure and sex composition imbalance (GHEBRESLASSIE 2005, p.103).

Riverine forests are increasingly invaded by *P.juliflora* threatening indigenous species. According to SOS Sahel & MoA (1999) *Prosopis* actually - “contrary to popular opinion” - “does not invade closed riverine forests as it is not shade tolerant [but] spreads into clear or partially clear areas [...]”. Similarly, GHEBRESLASSIE (2005) states on Eritrea’s riverine forests that “in some areas, due to the clearance of forests for agriculture, the opening encourages colonization of the undesirable and invasive *Prosopis* [...] tree

species” (GHEBRESLASSIE 2005, p.10). This is an important finding and if correct would give a sense of hope for those forest spots that have remained dense and intact as well as for future forest regeneration efforts. However the finding is somewhat questionable: the fact that *P.juliflora* infestation can be easily observed throughout riverine forest habitats and that the invasion of *Prosopis* into riverine forests is one of the main concerns to local communities would suggest that it is taking place on a rather large-scale. In fact, the alarming level of *Prosopis* invasion into the riverine forest has been demonstrated by the very same inventory report and the necessity for *Prosopis* control or eradication has been acknowledged throughout the document. On this basis, it can be assumed that invasion is not confined to cleared forest spots, but is taking place all over the riverine forests. This would be somewhat supported by a statement to be found in the Indian Workshop Papers (1986) where it has been stated that “*Prosopis juliflora* can tolerate fairly heavy amount of shade [...]”.

The inventory, which was jointly carried out by SOS Sahel and the MOA from 1996-1999 provides a more detailed view of the extent to which this invasion is taking place. It has remained the first documentation of its kind in Eritrea and has produced a valuable insight into the ecological status of the riverine forests.

The inventory identified 55 original vegetation types in the riverine forests consisting of different species mixes. Following the *Doum palm* with a leading presence in 17 of those vegetation types, and a range of “mixed” or “other species” in 12 vegetation types, it was in fact *P.juliflora*, which appeared as the single most available species in seven of the original vegetation types, while mixed *Acacia* woodland was leading in six and *Acacia nilotica* in four of the vegetation types.

The original *Prosopis* vegetation types identified are:

- *Acacia seyal/Prosopis juliflora*
- *Acacia tortilis/Prosopis juliflora*
- *Prosopis juliflora*
- *P.juliflora* + few scrubs¹⁰
- *P.juliflora/Tamarix aphylla*

¹⁰ Few scrubs were defined as 500-1,500 scrubs per ha (SOS Sahel & MoA 1999, p.47)

- *P.juliflora/Zizyphus spina-christi*
- Mixed – *P.juliflora* + no scrub¹¹

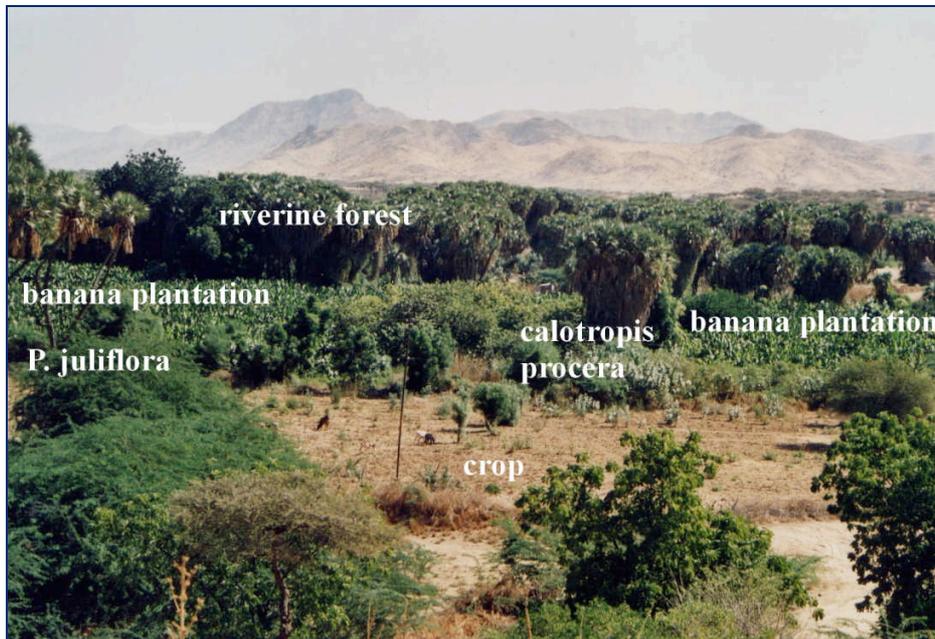
(SOS Sahel & MoA 1999, p. 45-47)

The 55 original vegetation types of the inventory were then reduced to just 14 “revised vegetation types (RVT)” for general planning purposes with *Prosopis* making up RVT 12 in the inventory and management plan report. This demonstrates once more that *Prosopis* has invaded the riverine forests to such an extent that it has very much become a characteristic feature of it or - as one may be tempted to put it - has become a vegetation type in its own right.

The inventory states that, while natural regeneration of the forest resources is “very patchy” and in many areas even “non-existent”, *P.juliflora* is the only species that “shows excellent regeneration from seed” which causes “great concern” (SOS Sahel and MoA 1999, p.14). The level of germination of *P.juliflora* within the riverine forests in comparison to the ability of natural regeneration of other forest species is a very important finding to be used for future management and conservation plans of the forests. Furthermore it demonstrates the urgent need for a management plan specifically designed for *P.juliflora*. While seed germination of *P.juliflora* can be restricted by a lack of moisture availability to break the hard coat of the seeds, the riverine forests are based on highly nutritious alluvial soils with relatively high soil moisture content due to low water table levels. These conditions are ideal for *P.juliflora* seed germination, which is - according to SOS Sahel and the MoA (1999) - with up to 50,000 seedlings/ha significantly greater than those of the native forest species suggesting that *P.juliflora* has the upper hand. This will undoubtedly affect proportional species mix and vegetation type classes of the forests in the long-run and could cause major harm to the natural balance of this valuable ecosystem.

¹¹ No scrubs were defined as <500 scrubs per ha (SOS Sahel & MoA 1999, p.47)

Photo 3: External threats to the riverine forest ecosystem



(Photo: author)

According to SOS Sahel & MoA (1999) data for the land area covered by riverine forests had been widely derived from the Land Use and Land Cover Map of the FAO 1997 and stated to be around 195,024 ha. Although the number varies slightly in related references (compare land area in above table 2.1) the figures do not show major discrepancies in relation to percentage of riverine forests to total land area. During the course of the inventory it was found that the above estimates were likely to include all forms of vegetation near the riverine systems, and that the actual land area covered by forests around the key rivers was found to be only about 21,455 ha. SOS Sahel and MoA calculated that if one was to include some of the smaller rivers that had not been mapped the total area of riverine forests in the Western Lowlands would cover approximately 40,735 ha (SOS Sahel & MoA 1999, p.9). This is significant, as the new figure is almost a fifth of what has been believed to be an available riverine forest resource suggesting that those forests are even more scarce and fragile than previously indicated. According to most recent figures in the NAP (2002) the figure drops even further to about 5 000 ha, which is less than 0.1 % of the total land area of the country. According to GHEBRESLASSIE (2005) land clearance, local overexploitation, resettlement, livestock and the invasion of *Prosopis* pose the main threats

to the riverine forests (GHEBRESLASSIE 2005, p.9). It is for those reasons - the rich biodiversity, the serious level of degradation, and the small areas of the riverine forests - that the riverine habitats have become a priority of conservation (NAP 2002, p. 59). The issue of *Prosopis* however has so far not been addressed with specific control measures.

Irrigated crop land

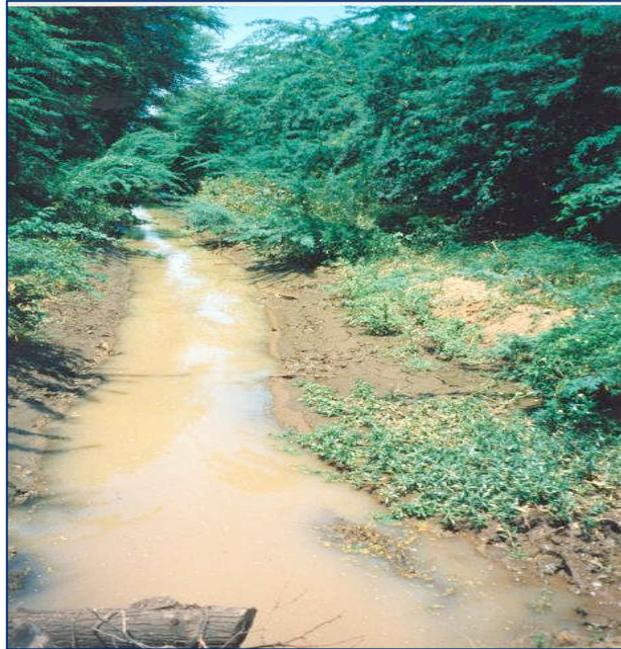
Irrigated cropland areas are anthropogenic ecosystems, which, in the case of Eritrea, consist of both perennial and seasonal irrigation systems. In the mid 1990s about 22 thousand ha were under irrigation, which is about 0.2% of the total land area (NAP 2002, p.1 and p.22). The figure may have risen slightly over the past years, as irrigation has been promoted by the government as a means for increased agricultural production. About 18 thousand ha is under seasonal irrigation, such as spate irrigation, where surface water e.g. occurring after rainfall, is diverted onto the crops. This method is particularly used in the Eastern Escarpment zone, but also elsewhere.

The remaining four thousand ha is under perennial irrigation (NAP 2002, p.22). It is highly dependent on the availability of and access to surface water or groundwater and uses diversion channels, pipes, pumps and motor equipment to regulate irrigation onto crops.

Due to the relative high water availability in areas surrounding irrigation systems, *Prosopis* is flourishing. Not only does it obstruct the diversion channels, but it invades vast areas of irrigated crop land making it labour-intensive and costive to remove seedlings and shrubs from the fields in both the Western and the Eastern Lowlands.

Photo 4: *Prosopis* either side of a diversion channel, Gash-Barka region

(Photo: Dr Alan Nicol, ODI, made available for this study)



In the Western Lowlands, big irrigated land areas are established alongside the riverbanks of the major river streams often set in proximity of or within riverine forests. Although riverine forests are generally protected from clearance the government has

established vast hectares of cash crops (e.g. banana plantations around the Akurdet area) for national production alongside the rivers to meet the water requirements of these crops. The infestation of these crops with *Prosopis* therefore increases the risk of further invasion into the riverine forests.

Irrigation is promoted highly by the government to boost agricultural production within its policy of self-reliance and national development. It is expected that irrigated areas will see a significant increase during 2008 and the coming years with emphasis on banana, sorghum, wheat, and sugarcane.

To meet water requirements the government focuses on the construction of new dams such as the major construction project of the Gerset dam (National Union of Eritrean Youth and Students' Interview with Eritrea's Minister of Agriculture in March 2008, www.eriyoung.org). Some of these dams will be situated within open savannah land, which is so far relatively low infested by *Prosopis*. Increased water availability around dam areas, may lead to new *Prosopis* habitat development within open grass and shrub land.

Road sides

Road sides often form local micro-depression zones either because the road is situated within a valley giving it a lower position compared to the surrounding land, or simply

because the road is constructed on an artificial rampage creating a ‘micro-depression belt’ in the immediate area between the street and the surrounding field. In both cases water can more easily accumulate and relative water or moisture content alongside these edges is usually higher. Typical manifestation of *P.juliflora* along road sides (compared to thin or no *P.juliflora* vegetation in the surrounding open area) can be observed on the route from Gahtelay to Massawa and from Massawa city to Gourgusum Beach in the Eastern Lowlands, or between Engerne and Akurdet and in the area of Hashenkit in the Western Lowlands.

Additionally, roads are also used occasionally and temporarily as livestock routes probably to assist the herders coming from other areas with orientation or because it is convenient to walk alongside them for a certain fraction of a herder’s journey. This leads to increased livestock accumulation on road sides and animals can increase seed germination in those areas through their droppings.

Photo 5: *Prosopis* thicket on the main road to Tesseney



(Photo: author)

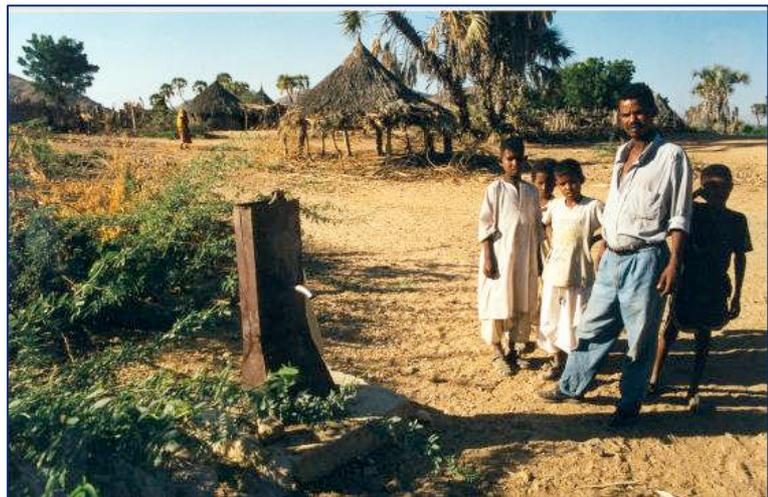
Generally, *Prosopis* infestation around road sides can be regarded as causing low threat, as these mirco-ecosystems do not play a particular role within the region’s biodiversity and cause little disruption to local production systems. Problems, can however occur where *Prosopis* along road sides has formed into inaccessible thicket (e.g. around

Tesseney or Gahtelay), as this restricts accessibility for livestock and people to the road as well as the area ‘behind’ the thicket.

It has also been reported from Rajasthan in India that *Prosopis* thorns are a hazardous to bicycles (IUCN 2001, p.149), which does not create a problem in Eritrea where bicycles are not a typical form of transport.

Immediate settlement areas

Photo 6: *Prosopis* around an abandoned well in a village in Gash Barka (Photo: Dr Alan Nicol, ODI, made available for this study)



Prosopis has established itself in many settlement areas in both the Western and Eastern

Lowlands. Particularly affected seem smaller settlements and villages, which are less built on and where the settlement area is more or less an extension of human and livestock activity within the natural setting.

But bigger towns such as Tesseney or Akurdet are also infested by *Prosopis*, particularly on the outskirts of the town where the ground is less compacted. These towns are major market places and herders frequently visit with their herds.

Prosopis is also a particular problem in settlements near the main rivers in Gash Barka where irrigation takes place to large extent. The village of Engerne for example is highly infested and inhabitants have complained about increased health hazards and risks due to thorns and risen numbers of snakes and hyenas hiding in the thickets and attacking people and livestock. *Prosopis* also obstructs wells and pathways.

“*Temer mussa* [*Prosopis*] grows fast along the riverine forests. With increasing distance from the forests its speed decreases becoming very slow on the mountains. As a result of this the Gash and Barka river areas are full of *temer mussa*. Other rivers like the Korobel and Kealay rivers are also hugely infested by it. But *temer mussa* numbers are only a few on the mountains and in remote villages away from the streams.”

Source: Interview with an agro-pastoralist in Gash Barka during the survey

It should be said at this point that *P.juliflora* can also be found in several other ecosystems, such as the savannahs covering large areas of the Western Lowlands and to a lesser extent the Eastern Lowlands. These are dry ecosystems with patches of mixed herbaceous, shrub and tree species with variation in their abundance and distribution across the landscape (KAARAKKA 1996, p.9). Patchiness in savannahs is usually attributed to climate seasonality, but can also occur as a result of ecological tension when trees are frequently under climate, water and nutrient stress and where successful regeneration is therefore infrequent (COUGHENOUR & ELLIS 1992 in KAARAKKA 1996, p.9). The relative dry conditions make seed germination and seedling survival of *Prosopis* in dryland savannah less successful as compared with the riverine areas. Degradation of savannahs however may make them more vulnerable where *Prosopis* has established itself.

Prosopis can also be found on rain-fed crops located away from the rivers. However, the level of infestation onto those ecosystems is less intense, whereas riverine forests, irrigated crop land areas, road sides and immediate settlement areas experience higher levels of infestation and therefore have been identified as prime habitats within this study. This should not imply that infestation in other areas is less important, as a farmer owning rain-fed crops away from the rivers may still face the same challenges.

According to NOOR & SALAM (1995), *P.juliflora* is so aggressive that it can be found in various habitats, such as coastal marshes and deserts, sand dunes, flat plains, hilly areas, dry stream beds, inland saline flats, and degraded and disturbed areas. However, in their assessment flat plains with a shallow water table appear to be the best suited habitat (NOOR & SALAM 1995, p.83)

3.3.2 Assessment of *P.juliflora*'s Invasiveness and its Impact on Native Plant Species

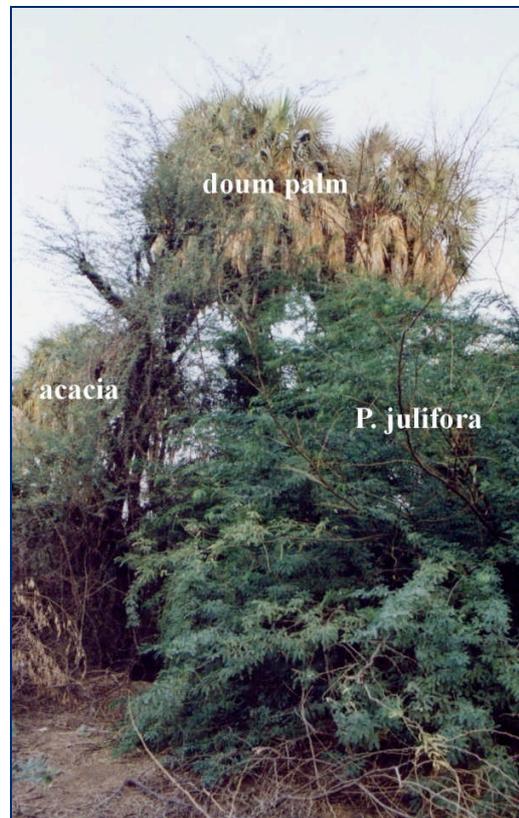
In general, trees are contributing to a positive micro-climate under their canopies and the immediate surrounding area, primarily by intercepting rain and solar radiation (KAARAKKA 1996, p. 10). In natural ecosystems trees and herbaceous plants are therefore usually not competitors; in fact trees often positively contribute to soil nutrient and moisture availability e.g. through shading and litter composition. Herbaceous layers in the contrary hardly affect the growth of mature trees, however they do have a strong impact on the survival and growth rate of tree seedlings, therefore acting as a natural control on the rate of recruitment of mature trees in savanna areas (KAARAKKA 1996, p.10).

In Gash Barka, detailed research into the coexistence and competition of *P.juliflora* with native plant species, including detailed chemical analysis of leaf-soil nutrient and moisture correlations in *Prosopis* and any native tree species have not been carried out until this point in time. First attempts in this regard had been made within this PhD study and research plots - aiming to measure the level of moisture and nutrient competition between *P.juliflora* and *A.tortilis* - had been established in Akurdet 2002 and again in 2003 in cooperation with the Forestry Department of the local Ministry of Agriculture Branch. In Engerne, research plots were set up to measure the impact of *Prosopis* on Sorghum harvests. However in 2003, the research plots - using *Acacia tortilis* seedlings from the local tree nursery - were destroyed by a severe drought. Reconstruction of the research plots in 2003 failed yet again, when the cooperating experts in the Forestry Department were relocated at short notice by a major restructuring of the ministry. As a result of these circumstances the research efforts were halted.

The assessment of the impact of *P.juliflora* on native plant species in Eritrea therefore remains mainly subject to observation and reports of individuals within rural communities supported by research findings in other parts of the world. Generally, the degree of invasion at the expense of indigenous plant species is at this stage not very severe. Compared with certain sites in neighbouring countries such as in Kassala State of Eastern Sudan or some of the pastoral range lands in Northeastern Ethiopia, where thick inaccessible *P.juliflora* forest has completely destroyed vast areas of valuable grazing land, levels of *Prosopis* infestation in Western Eritrea could be overall assessed as a 'medium risk area' but nevertheless serious.

Thick and high growing, inaccessible *P.juliflora* vegetation can so far only be witnessed in patches, and usually near road sides, for example near Tesseney (Barentu-Tesseney Road) in Western Eritrea where it has overgrown *Acacia* trees and *Doum palms* and destroyed the herbaceous ground layers, or around the settlements area of Gahtelay (particularly also alongside the road to Massawa). Infestation levels within the local semi-arid grassland savanna (away from roads) are generally not severe, but still significant due to the potential of *Prosopis* to spread considerably fast.

Photo 7: *Prosopis* competing with native species



(Photo: author)

Slightly more serious is the situation in areas with higher moisture availability such as agricultural land, especially irrigated schemes, and alongside river streams, where *P.juliflora* poses much more of an immediate problem. The riverine forests along the main streams are one of the most diverse ecosystems in the country. A high level of biodiversity consisting of a countless number of plants and rare wildlife have given the riverine forests a

special status in the inventory of Eritrea's natural environment in general, and the semi-arid drylands of the Western Lowlands in particular.

Native species that can be found in the riverine forests and that are under increasing threat from fast spreading *Prosopis* infestation are (among other): *Hyphaene tebaica* (Doum palm), *A.tortilis*, *A.nilotica*, *A.seyal*, *A.laeta*, *A.mellifera*, *A sieberiana*, *Zizyphus spina-christi*, *Boscia*, and *Tamarix aphylla* (SOS Sahel & MoA 1999; BEIN *et al.* 1996).

The loss of native species is of great concern to the rural communities who have expressed that *Prosopis* is destroying the vegetation they know. *Tamarix aphylla* - which is locally generally known as *Ubel* - has also been reported to spread alongside *Prosopis* on the river banks of small seasonal rivers in the Eastern Lowlands. Some people have however claimed that even *Ubel*, which is eaten by some camels due to its salt content, is starting to disappear although it is regarded by locals as being rather resistant.

In regard to the riverine forests, *P.juliflora* infestation poses not only a risk to native plant species, but also to wildlife that loses its indigenous habitat, and seemingly to the local communities who are depending highly on the productivity of the forests for the survival of their families and livestock.

What are the factors that make *P.juliflora* highly competitive and invasive, enabling it to spread at the cost of native species? There are several factors: One factor is the characteristic deep tap type root system of *P.juliflora* (SHARMA & DAKSHINI, 1998). Due to the structure of its root system, *P.juliflora* would appear to obtain the vast amount of its water intake from deeper soil levels giving it the upper hand compared with some of the native species that may have a shallower or lateral root system. Another finding during a sand dune stabilisation project in India strengthens this suggestion. There, GUPTA & SINGH (1997) stated that *P.juliflora*'s survival rate did not significantly change under mulch treatment, which helps to contain soil moisture, while other plants (except for *A.tortilis*) showed considerable improvement (GUPTA & SINGH 1997, p. 207). This may suggest that *P.juliflora* has the "upper hand" in surviving in hot dryland climates, as it is not depending on the availability of moisture in upper soil layers.

However, in regard to successful seed germination, *P.juliflora* seems much more reliant on soil moisture availability than widely believed and some experts suggest that it shares this reliance with native species. It has for example been widely observed that

trees become repeatedly established in depressions with general increase in moisture and organic matter content (KENNENNI 1990 and GIJSBERS *et al.* 1994 in KAARAKKA 1996, p.10), as it helps the germination process. Distribution of *P.juliflora* in Eritrea makes it evident that the species clearly shares this preference in regard to successful seed germination with other tree species. There, *P.juliflora* can be found widely, and in some areas predominantly along roadsides in both the semi-arid Western Lowlands and the mostly arid Eastern Lowlands, which form a long-stretched local 'micro-depression belt'.

P.juliflora also flourishes in the riverine forests of the Western Lowlands where - alongside river banks - local soil moisture availability is again higher. Higher plant density and predominant distribution of *P.juliflora* in Eritrea in areas with increased local levels of soil moisture availability may therefore suggest that, although *P.juliflora* has a deep tap root system that enables it to survive in drier areas and compete with native plants, successful seed germination (and maybe seedling growth) of *P.juliflora* is in fact depending highly on increased moisture availability. The assumption would then be that *P.juliflora* has a much higher potential of seed germination and seedling survival rate under ideal conditions compared with native plant species. This would mean that germination ability is a crucial factor in the competitiveness and invasiveness of *P.juliflora*.

The need for increased water availability for seed germination and seedling growth has also been mentioned by PASIECZNIK *et al.* (2001), who suggested that short rainy seasons often offer insufficient time for seedling establishment before the start of the dry season (PASIECZNIK *et al.* 2001, p.114). He further confirms that "all *Prosopis* species are able to survive in areas with exceptionally low annual rainfall or very lengthy dry periods, but only if roots are able to tap ground water or another permanent water sources within the first few years". It is further stated that high air moisture - for example in coastal areas - reduces the need for underground water (PASIECZNIK *et al.* 2001, p.74)

Another affirming finding in this regard can be made in Ethiopia. According to SHIFERAW (2004) vast invasion of *P.juliflora* in Ethiopia is taking place in the Afar region where the Awash River can be found. He states that the species is particularly invading zone 1 and 3 of Afar Region (SHIFERAW 2004, p.1). Interestingly, an independent UNDP report from the Emergency Unit Ethiopia (UNDP-EUE) in 1999 states exactly those two zones (out of five zones in the Afar region) as those that are frequently flooded. In fact, the area around Dubti, which has also been named by SHIFERAW as a *P.juliflora* invasion 'hot spot'

is been reported by UNDP-EUE to be so recurrently flooded that it has become marshland (<http://www.africa.upenn.edu/Hornet/afar0999.html>, 1999). This again demonstrates that although rivers and irrigation systems do act as a seed disperser, *P.juliflora* clearly establishes itself predominantly there and thrives in semi-arid ecosystems with an unusual or relative high local level of water availability.

Vegetation cycles in the Sahel after dry seasons, including natural regeneration after drought years depend on a number of critical stages such as seed dispersal (of existing plants), predation and germination as well as seedling growth (TYBIRK 1991 in KAARAKKA 1996, p. 10). Soil moisture has been regarded as the main limiting factor for plant regeneration (KAARAKKA 1996, p.11), while low water as well as soil nutrient availability have been considered to be the main factors limiting primary production (BREMEN & DE WIT 1983, BELSKY *et al.* 1993 in KAARAKKA 1996). Other experts consider however that under extreme arid conditions or in areas with severe degradation the (lack of) available vegetation becomes the main limitation to biomass production (BREMEN & KESSLER 1995 in KAARAKKA 1996). These observations can be easily made in arid Eastern Eritrea: There, mature *Prosopis* shrubs and trees can be found throughout the dry season with high photosynthetic productivity, even on very hot-arid sandy sites near the coast in Massawa where hardly anything else survives the high level of aridity. This would strengthen the theory that *Prosopis* in desert climates has a greater quantitative advantage of primary production over native species due to the higher availability of mature trees for seed production. However, although the theory seems sensible it lacks to acknowledge that in the very beginning soil moisture and nutrients - and not the lack of available vegetation for seed production - seem to be the primary limitation also in very arid conditions, as *P.juliflora* manifested itself under those unfavourable conditions while other local plants did not.

According to SHARMA & DAKSHINI (1998) a specific lack of ecological integration of *P.juliflora* is yet another factor that leads to its competitiveness. Their experiments found that while the native *P.cineraria* showed numerous correlations amongst plant and soil characteristics this was not the case for *P.juliflora*. This lack of integration and its ability to meet its nutrient requirements in various climatic conditions could be the basis for its invasive character and broad spread. In their experiment there were significantly higher

concentrations of K in *P.juliflora* compared with *P.cineraria* implying a higher requirement of it in the alien *P.juliflora*. However, more interestingly this K uptake was in no correlation with the amount available in the substratum. Furthermore, there was an almost “negligible inter-relatedness” of leaf K with other leaf variables whereas the native *P.cineraria* showed a close link of its K uptake in regard to substratum availability and also with several other leaf characteristics. This “independence” of *P.juliflora* in regard to soil conditions and “minimal level of integration within itself” coupled with its rapid seed germination could be the reason for its ability to establish in any kind of habitat with a high maintenance of photosynthetic efficiency. However, this may come along with a change in soil substrate characteristics and actual physical deterioration of the soil (SHARMA & DAKSHINI 1998, p.63-67).

Similar findings were made by SHARMA (1984): while potassium and phosphorus contents of the soil only fairly related to their foliar concentration in *P.juliflora* (with a correlation coefficient $r=0.74$ and 0.61 respectively) there were no significant correlations in the foliar and soil contents for the other nutrient elements calcium, magnesium, sodium, and nitrogen. There was a very low plant uptake of available soil magnesium, while plant sodium and nitrogen uptakes were very high (SHARMA 1984, p. 371/372).

It has been speculated that the positive correlation characteristics of a plant are a sign of its stable integration within the ecological conditions of the local habitat. It may appear that this is rather restrictive to its spread, however on the contrary the ability of some alien species to spread easily in terms of locality and time has been at a cost: the drastic ecological alteration of the local area (EL-GHONEMY 1978 and SOLBRIG 1979 in SHARMA & DAKSHINI 1998, p. 68).

However, findings in a slightly different light have been made by ALARCON & DIAZ (1993) who measured water relations and nutrient dynamics. They found that osmotic adjustments were made in *P.juliflora* during the driest periods. All measured leaf macronutrients had higher values during the dry season. They concluded that “the ecophysiological” plasticity of *P.juliflora*, regarding nutrient and water requirements have permitted the ample distribution of this species (...)” (ALARCON & DIAZ 1993, p. 433).

Another factor that may play a role in *P.juliflora* high level of competitiveness may be its allelopathic potential. NOOR and SALAM (1995) even note that “the exceptional success of *P.juliflora* [in its invasiveness] could be attributed to allelopathy”. They found

that extracts from fruit and seed of *P.juliflora* in Pakistan considerably delayed and reduced germination, root, shoot and seedling growth of cultivars such as *Zea mays* (maize), *Triticum aestivum* (common wheat), and *Albizia lebbek*. However, they also noted that there was an absence of inhibitors in the soil, which may be attributed to heavy rainfall just days before the soil samples were taken (NOOR and SALAM 1995, p. 89).

PANDIT *et al.* (1995) also found that although shoot rate of cultivated *Bajra* (pearl-millet) was significantly inhibited by stem and root extracts of *P.juliflora* rather than leaf extract, he also was not able to provide a strong conclusion in regard to concentrations released into the open soil. References are however provided that suggest concentration of inhibitory substances found in agricultural soils may be low due to rain and continuous irrigation (PANDIT *et al.*, 1995, p. 145-148).

Statements about *P.juliflora* allelochemicals hindering the germination and seedling growth of native species have been made by a series of research experts: AL & WARRAG (1998) for example discovered that seed germination and seedling growth of the native *bermudagrass* was restricted by the allelopathic effects of *P.juliflora* foliage. (AL & WARRAG 1998, p.239-241).

DHAWAN (1995) also reports a considerable impact of *P.juliflora* allelochemicals on seed germination. He tested the inhibitory effect of foliar aqueous leachates of *P.juliflora* on *Parthenium hysterophorus* Linn, which he describes as a “deadly, noxious weed” and “agriculture and health hazard”. DHAWAN observed that *Parthenium* usually does not grow in the proximity of *Prosopis* and later found that foliar aqueous leachates of *P.juliflora* inhibited 78% of seed germination of *Parthenium*, while *P.juliflora* foliar extracts even inhibited 92.65% of seed germination. Also seedling growth was decreased by more than half of the seedling length in the control. Based on these findings DHAWAN suggests that the allelopathic potential of *P.juliflora* could be exploited regarding the spread of weeds such as *Parthenium* and even recommends that *Prosopis* be planted “alongside roadsides and vacant plots, as a preliminary step towards the containment of this weed...” (DHAWAN, 1995, p. 289-291). Such a recommendation however, should not be made in the light of a single aspect, in this case the control of an aggressive local weed. The impact of *P.juliflora* on natural ecosystems is much more complex and its own invasive character could be easily accelerated and very damaging if planting is promoted on the basis of biological control.

Furthermore, although *P.juliflora* has been widely observed to inhibit the growth of plants beneath and around its canopy and various laboratory analyses have proven the inhibitory impact of *P.juliflora* extracts on seed germination and seedling growth of other plant species, little has been done to measure the actual concentration of allelochemicals released into the open soil. Most experiments have focused on the inhibitory potential of *Prosopis*, but have failed to measure actual in situ levels and interactions. Therefore, it may be too early to suggest that the invasiveness of *P.juliflora* is attributed to its allelopathic potential.

But if seen within a more complex approach, allelopathy may - among other factors - be one contributing factor that increases *P.juliflora*'s invasiveness and the application of *P.juliflora* plant extracts (rather than planting) may prove useful within carefully planned and managed biological control of unwanted local weed species.

Rarely represented findings even suggest that *P.juliflora* is associated to autotoxicity, which defines growth inhibition of a plant species by toxins produced by the same species (RICE 1979 in WARRAG, 1995 p. 415). WARRAG (1995) found that seed germination and early seedling growth of *P.juliflora* was inhibited when treated with its own leaf extract. WARRAG concludes that similar processes must take place in the soil, after experiments in a leaves-sand media brought similar results as those with direct leaf extract application. He therefore recommends not to use *P.juliflora* leaves for soil amendments in mesquite nurseries, as it would inhibit the growth of *P.juliflora* seedlings where planting was an objective. On the contrary, in areas where *P.juliflora* has become a pest its allelochemicals (phytotoxins) could potentially be used as "precursors or intermediates in the synthesis of other chemicals" to control its own invasiveness (WARRAG 1995, p. 420).

Similar findings were previously made by WARRAG (1994) on the impact of *P.juliflora* pericarp. Pericarp aqueous extracts with concentrations of 20 gl^{-1} (with a pH of < 4.22 and osmotic potential of $< -0.14 \text{ MPa}$) inhibited 100% of *P.juliflora* seed germination as compared with the distilled water control and the least concentrated (5 gl^{-1}), which still delayed the germination process. However, he points out that the inhibitory effect of plant extract "could be attributed to its low pH, low osmotic potential and/or naturally occurring chemicals" (WARRAG 1994, p.80-83). The relatively low osmotic potential may not be a significant factor in this case, as the highest extract concentration in

the experiment had still an osmotic potential of -0.35 MPa in the highest concentrated extract solution (WARRAG 1994, p.80).

In comparison: a study from semi-arid Venezuela has shown that *P.juliflora* flourished widely in a dry-forest with a far lower osmotic potential ranging from - 0.83 and -4 MPa during the rainy season to -3 and -4 during the dry season (ALARCON & DIAZ 1993, p. 433). Much more of significance could be the impact of the very low pH of extract solution on seed germination.

Acidic soils are rather underrepresented in the semi-arid and arid drylands of Eritrea where rather high soil pH rates cause loss of soil fertility. However, it may well be the case that autotoxicity takes place. One research finding that would strengthen this hypothesis is the previously discussed fact that while grown *P.juliflora* trees are able to access deeper ground water levels due to its long tap roots, seed germination of *P.juliflora* highly relies on moisture availability. KAARAKKA (1996) had stated that *P.juliflora* establishes itself in depression zones with increased moisture levels and this could be widely observed throughout Eritrea (see chapter 3.3.2). It may be a contributing factor that moisture availability helps to dilute the level of autotoxins that have proven to delay or inhibit *Prosopis* seed germination. But - as already suggested for the assessment of *P.juliflora* allelochemicals potentially impacting on other tree species - experiments that are set within natural conditions taking soil and water related factors into account would be urgently required for any reliable assessments of potential toxicity processes.

SHIFERAW (2004a) presents a slightly different approach to *Prosopis*' invasiveness. Assessing the plant characteristics that foster the spread of the species in the Middle Awash Rift Valley of Ethiopia he focuses mainly on seed production and distribution patterns. According to SHIFERAW the rapid invasiveness of *Prosopis* is based on i) high production of small, hard seeds which form soil seed banks, ii) it being a prominent fodder tree resulting in wide seed dispersal, iii) seed accumulation in "long-lived but viable seed reserves" (seed banks), iv) production of seeds with different germination ability "spreading germination over time and space", and lastly v) its great ability to re-sprout (SHIFERAW 20004a)

Based on the wide range of findings by various experts on *Prosopis* invasiveness, the following is a list of key contributing actors that take place in different stages.

Stage 1: High seed germination

- ✚ Prominent fodder tree (especially during drought season) leads to increased seed distribution
- ✚ Higher germination ability (*P.juliflora* established itself where other plants did not)
- ✚ Higher potential of primary production in arid conditions (drought or in desert climates) due to availability of mature trees for seed production
- ✚ Soil seed banks viable for the long-term

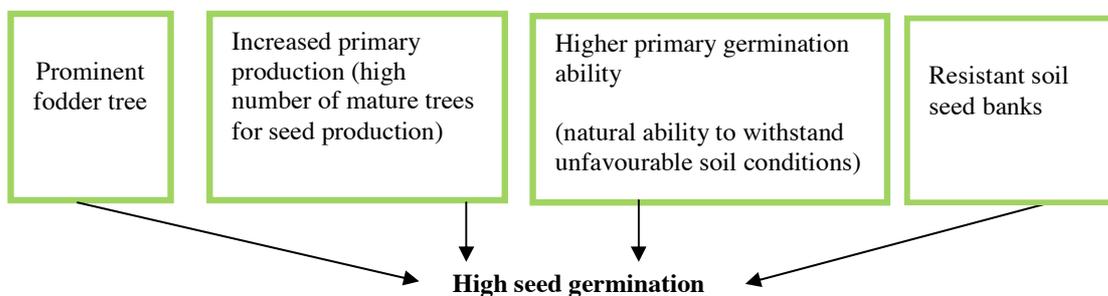
Stage 2: Superior botanic features for survival

- ✚ Long tap root system
- ✚ lack of soil-plant nutrient correlation (“independence” from soil condition)
- ✚ allelopathic effects
- ✚ high ability to re-sprout

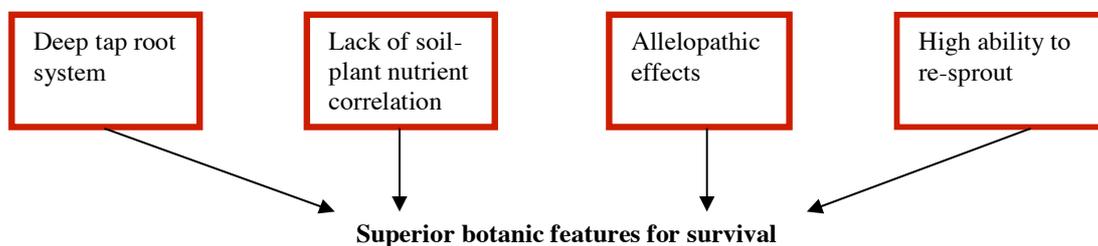
Graph 3.2: Invasiveness chart of *Prosopis*

(Design: author, based on various sources as stated above)

Stage 1



Stage 2



The invasiveness of *P.juliflora* at the expense of native tree species has also been reported from other countries in the region: A Sudan Vision Daily article states that “Mesquite [*P.juliflora*] out-competes a range of native species in arid areas. Where conditions are most suitable, it can become the dominant form of vegetation, forming monoculture thickets and forests.” (Sudan Vision Daily, 1st March 2008).

Several research papers actually make this direct link between the arid conditions *Prosopis* thrives in and its invasiveness. SERTSE (2005) for example similarly states on its invasiveness: “In areas of Ethiopia where *Prosopis* [*P.juliflora*] has invaded, the environment is very hot, with limited rainfall and saline soils. Few plants can thrive here, but these conditions are conducive for *Prosopis*. There are no natural enemies, pests or diseases. [...]” (SERTSE 2005).

One needs to keep in mind that it is of course not foremost the external environment or climate that is advantageous to *Prosopis* invasiveness as often implied, but primarily its superior botanic characteristics that very concretely allow higher seed germination, survival, and regeneration rates, especially during early growth stages, as compared to native tree species growing under the same conditions.

High primary seed production, reserve and germination are key aspects of *P.juliflora*'s invasiveness. In-between however comes the dispersion of those seeds through wind, river streams and random surface water runoffs, through irrigation canals, and lastly through the droppings of wildlife and particularly livestock.

3.3.3 Soil Processes under *P.juliflora* within Land Management Efforts

While major research efforts on ameliorating soil processes under trees have taken place for humid temperate or tropical soils there is much less reliable data available for of tree application processes in dry-land ecosystems (GARG 1999; BHOJVAID 1998, p. 181).

In Eritrea, the conservation and regeneration of soils is a key activity within land management efforts that are widely taking place within the context of Food and Environment Security. The impact of *Prosopis* on Eritrea's soils would therefore be a crucial assessment within these efforts.

However, while ample research has been conducted to assess the impact of *Prosopis* on wastelands there is less research available on its role within land management efforts under 'normal' conditions.

In an experiment in NE Brazil soils under *P.juliflora* were similar to those of the natural catingaa. Only LF-N (75%), LF-Po (60%), available P (120%) and K (105%) were greater than the catingaa. No differences between catingaa and *P.juliflora (algaroba)* were obtained for the soil microbiological parameters.

Similarly in another trial, paired comparison of the soil chemical values under *P.juliflora* canopies (after 13 years of planting) versus outside canopies values (buffel grass) showed no differences in total nutrient pool or organic matter levels. However under canopies, there was a substantial rise of microbial biomass C and N content, alkaline phosphatase, and β -glucosidase (WICK and THIESSEN *et al.* 2000, p. 67-68).

Research into nutrient availability under *P.juliflora* canopy soils vs open desert grassland soils conducted by KLEMMENDSON & TIEDEMANN (1986) showed a similar significant increase in soil nutrients under the canopies. There was a regular increase in all test sites in N and S availability, while slight varieties in test conditions lead to differences in the increased amount of soil K and P (p. 479).

It has also been mentioned that *Prosopis* has the potential to establish a symbiosis with N-fixing rhizobia (WICK and THIESSEN *et al.*, 2000, p. 67).

In sharp contrast to those mostly rather beneficial findings are accounts made by SHARMA & DAKSHINI (1998) stating that *Prosopis* "has become aggressive and has not only successfully invaded several habitats but has also caused substratum degradation in these by causing loss of finer soil particles...and increased [...] salt content of soils in dry conditions." It was stated that the increased Na affects physio-chemical structure of soil and increases dispersion and loss of finer particles. Increase in soil pH was said to reduce the availability of Zn due to absorption of Zn on the organic colloids in such conditions. This lead to negative correlations of soil pH and Na with leaf Zn in *P.juliflora*. The improved Zn status of *P.juliflora* soils therefore does not imply improved ability (SHARMA & DAKSHINI 1998 p.63).

Although the majority of research presents soil ameliorating processes under the influence of *Prosopis* this often happens within a one-track approach that is not incorporating other possible ecological impacts, e.g. its impact on native tree species over

long-term. Potential soil improvement under *Prosopis* can only be of value if other related negative impacts can be excluded: rural communities would be able to make little use of potential soil improvements under *Prosopis* while native species for example may continue to 'disappear' (as locally reported).

3.3.4 *P.juliflora* within Regeneration Efforts of Saline and Sodic Soils

Irrigation is highly promoted within national efforts to boost agricultural growth and related GDP. In Eritrea, the land area under irrigation still constitutes less than 1% of the total area. The government however aims to vastly increase agricultural production under irrigation to meet its policy objectives of national self-reliance and food security.

However, the long-term risks following the overuse of formerly productive farmland, particularly in regard to intensified production through the means of irrigation, remain widely unmentioned or poorly assessed within related national action plans.

Many experts have demonstrated that the severe degradation of sodic soils is often a direct result of excessive overuse and long-term irrigation practices in dry land areas. With exception of lands in Eastern Sudan and Eastern Eritrea situated in the extremely arid coastal plains, most wasteland or deserted areas are a direct encounter of overuse or inappropriate land use patterns. This lead to secondary salinisation and alkalisation processes in some soils.

Soil sodicity is characterised by high pH, low organic matter content, excessive exchangeable sodium, high clay dispersion, and deep hard pan formation (BHOJVAID *et al.* 1996, p. 139). This has lead to increased degradation of land resulting in the loss of its productivity, which becomes visible as loss of vegetation or declining agricultural outputs.

According to BHOJVAID (1998) the five mechanisms that contribute to the amelioration of degraded soils by trees are: (1) Soil organic matter increases as a result of C fixation in photosynthesis. This is transferred into the soil by leaf litter and root activity; (2) Soil nitrogen increases due to nitrogen fixation by some leguminous trees; (3) Nitrogen mineralisation and microbial biomass increases due to rhizosphere effect of trees on soils; (4) Soil and air temperatures and moisture regimes (soil micro-climate) are improved by tree canopies; (5) Soil nutrient amount increases through nutrient pumping from greater depths

by roots and uptake through litter. In the case of sodic soils additional specific mechanisms by trees have been identified as: (1) Soil alkalinity is reduced by acidification; (2) Improved infiltration and leaching activity leads to decline of sodium toxicity; (3) the decrease of clay dispersion results in improved soil stabilisation. However it has been concluded that fertility restoration and sodicity alleviation are the prominent factors, which increase with tree age (BHOJVAID 1998).

BHATIA *et al.* (1998) have referred to *P.juliflora* amongst leguminous trees as the “most suitable species for the afforestation of all common types of wasteland.” (BHATIA *et al.* 1998, p.208)

However, although GARG (1999) has described the high and valuable potential to use leguminous trees for rehabilitating sodic or degraded land, he still refers to this undertaking as a “challenging task” because of the inhospitable and unfavorable conditions that one encounters in sodic lands. During a trial, GARG has used 11 tree species for his experiment including native and exotic ones. *P.juliflora* followed by *Dalbergia sissoo* Roxb. Ex D.C. was the most successful in rehabilitating sodic wasteland in terms of high survival rate, biomass production, leave litter nutrients, litter mass and organic carbon in top soil, as well as N content. After 6 years under *P.juliflora* plantation soil pH was reduced from 9.8 to 8.6 and exchangeable sodium percentage (ESP) decreased by 65%. Soil bulk density was decreased and water-holding capacity improved as a result of planting, which is closely linked to the deep rooting system. After six years roots penetrated 100cm deep into the compacted soil, while horizontal roots spread up to 85 cm (GARG 1999, p.281-86).

A similar study trying to ameliorate sodic soils by trees for wheat and oat production with five tree species (*P.juliflora*, *A. nilotica*, *Eucalyptus tereticornis*, *Terminalia arjuna* and *Albizia lebbek*) showed that soil amelioration was highest under *Prosopis* canopies in topsoil and lowest under *Eucalyptus*. Phosphorus concentrations in wheat and oat plant tissue were highest in those samples grown in *Prosopis* soils (SINGH & SINGH 1998, p.453)

WARRAG (1994) found that *P.juliflora* pericarp aqueous extracts had a low pH (< 4.28). The recycling of these plant parts into the soils may be a contributing factor to soil pH melioration under *P.juliflora* on sodic soils (WARRAG 1994, p. 80).

3.3.5 *Prosopis* - An Ecological Indicator for Desertification?

According to MENSCHING (1990) indicators for desertification are visible or identified changes within a hot semi-arid or arid ecosystem, which are a result of inappropriate human impact or human activities of communities living in those drylands. This includes very much all physical factors that indicate an accelerating degradation of the natural resource base as a consequence of human mismanagement slowly developing into desertification. MENSCHING has identified the following potential indicators:

- 1) Vegetative indicators: e.g. degradation of vegetation, replacement of native plant species by drought-resistant species
- 2) Hydrologic indicators: e.g. loss of water content (“aridification”) of soils as a result of loss of vegetation, temporary or permanent decline of groundwater levels, change in water run off levels and patterns of rivers, soil salinisation in irrigation schemes (as a hydro-pedological indicator)
- 3) Morphodynamic/pedological indicators: e.g. soil erosion, gully and barranco development, development of sand accumulation/dunes, dust particle in the air, thinning of soil layers and increase of sand and stone content in upper soil layers, soil nutrient depletion
- 4) Secondary (or indirect) indicators: transformation among local communities affected by the changes occurring in the natural environment, e.g. changes in local management systems, visible changes in migration patterns (such changes always need to be looked into as they can be subject to other causes)

(MENSCHING 1990, 15-20; MIDDLETON 1991, p.14/15)

Similar definitions are being made by other authors: KAARAKKA (1996) describes that the main physical forms (or indicators) of land degradation and desertification in an area are the degradation of soils and the local vegetation. Soils degradation can occur in the following forms: (1) water erosion, (2) wind erosion, (3) compaction, and (4) waterlogging, salinisation and alkalisation. Vegetation degradation consists mainly of two forms: the reduction of vegetation cover and the change towards a less productive type of vegetation. Reduction of vegetation is the result of tree cutting and for land clearance, fuel wood and fodder, over-browsing as well as overgrazing of range lands. The change of type of vegetation involves the type of composition and possibly also the types of plants, e.g. bush

encroachment into an open grassland area were vegetation changes into bushland or sometimes thicket. The structure and functionality of semi-arid and arid savannas are determined by soil water content, available nutrients, fibre and herbivory (KAARAKKA 1996, p.7).

In regard to the above *Prosopis* in Eritrea would fit potentially well into the section of *vegetative indicators*, as it reportedly changes the type and composition and replaces the native vegetation simply through its fast spread (based on its invasive plant characteristics) and the increasing numbers of shrubs and trees that can be easily observed within Eritrea's natural ecosystems. This is particularly true for the riverine forests where some parts of the forest, for example around the river Gash banks near Tesseney, have formed into inaccessible mono-thicket, destroying the natural composition and ecological balance of that part of the forest making it worthless as a source of animal browsing, shelter or collection of forest products for consumption.

Even worse is the situation in some parts of neighbouring Ethiopia. According to the World Health Organisation (WHO) (2002) a quarter of grazing land of zone three of the Afar Region, which is situated in the west of the country, has been taken over by *Prosopis* leading to a significant loss of native grass species and grazing areas vital to the local pastoralist communities (WHO Ethiopia Humanitarian Update 28 February 2002 in www.who.int/disasters/repo/7651.doc).

But is the invasion of a species into a certain area - ultimately changing the original vegetation features of this area - a sufficient indicator and contributor for the process of desertification or land degradation? Or may the invasive species, in this case *P.juliflora*, simply have the upper hand over most of the native species due to its advantaged botanic makeup? This would potentially allow it to spread also in a healthily balanced ecosystem that does not show signs of desertification. The riverine forest inventory by SOS Sahel & MoA (1999) for example suggested "that in most areas the forests are relatively healthy and undegraded, [...]" (SOS Sahel & MoA 1999, p.10). This did not save them from *P.juliflora* continuously invading them and slowly causing an imbalance of the natural vegetation composition, which would suggest that *Prosopis* does spread in healthy ecosystems.

However on the contrary, having observed vast parts of the riverine forest it remains somewhat questionable as to why the forests have been identified as "relatively healthy and undegraded" during the inventory. The remaining forest spots may have maintained their

balance, but on the contrary government, academic and historic accounts agree on the matter that the riverine forests in Eritrea have been subject to vast deforestation throughout the 20th century. Deforestation and therefore the decline in total land area covered by the native forests clearly is a degradation of this forest making it potentially more vulnerable to alien intruders such as *Prosopis*. This was also confirmed by GHEBRESLASSIE (2005) who states that “forest health of Eritrea’s riverine forests is severely declining” and that “in some areas, due to the clearance of forests for agriculture, the opening encourages colonization of the undesirable and invasive *Prosopis* [...] tree species” (GHEBRESLASSIE 2005, p.10), which would suggest that *Prosopis* is invading degraded forest resources.

According to MENSCHING *Calotropis procera* with its plate-like leaves is fast spreading throughout the Sahelian zone and the Sahara desert as far as the Maghreb. The plant is not palatable and increasingly establishes itself in areas on which native browse plants and grasses have been degraded or completely disappeared becoming an indicator for degraded grazing areas (MENSCHING 1986, p.9). *Prosopis* in Eritrea is very often found alongside *Calotropis procera* suggesting that it too favours degraded areas.

Photo 8: *Prosopis* thicket and *Calotropis procera*



(Photo: author)

Although in a slightly different context this has also been confirmed by other experts stating that “there seems to be a tendency that the species [*Prosopis*] usually becomes

established on sites which to some extent already are degraded” (HABTE 2003 in LAXÉN 2005, p.26).

Reports by locals made during field visits have also claimed that *Prosopis* would decrease the water table and eventually dry up wells, as it grows densely around well areas. If this was the case *Prosopis* may also be a vegetative-hydrologic indicator by contributing to the decline of the water table in the micro area around wells.

Photo 9: Intrusion of *Prosopis juliflora* around a pump house in Germaika (western Eritrea)



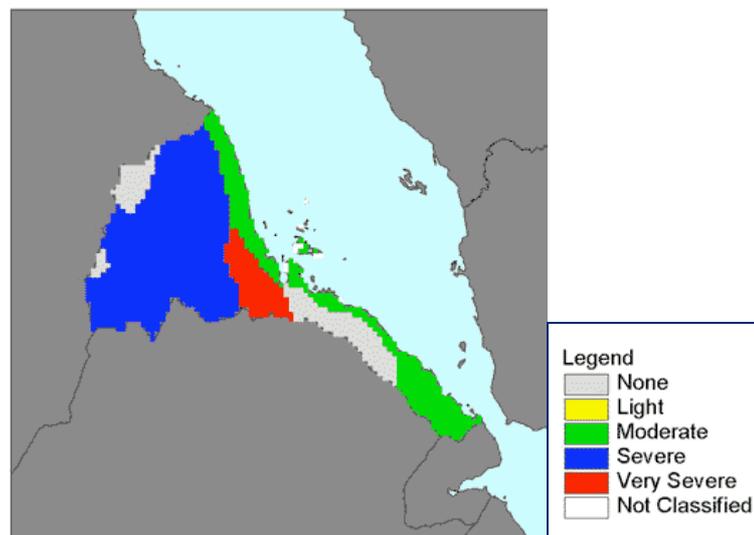
(Photo: Dr Alan Nicol, ODI, made available for this study)

At this point, one needs to make a distinction between *P.juliflora* being an indicator for desertification or being the cause of it. Although the two can be somewhat interlinked, if one wants to assess whether *P.juliflora* indicates that desertification is taking place one needs to establish a range of other indicators. *P.juliflora* - although it may cause local degradation of land where it has become abundant - is not a primary cause of desertification. Rather desertification is a complex process within arid lands based on a string of both anthropogenic and physical factors such as climatic variability and the overuse of land resources.

However, once desertification is taking place many of the indicators, e.g. soil erosion - even if not initially causing desertification but rather being an indicator of it - may then contribute to the acceleration of the desertification process; either directly, as for example through soil erosion, or indirectly, as soil erosion leads to losses in soil nutrient and water content, available land size and high levels of stone matter all causing a loss of land productivity, which then forces farmers to intensify their production in order to produce reasonable amounts. This land overuse, which is also one of the leading causes for desertification, can on the other hand also become a result (effect) of it creating a ‘vicious cycle’.

Map 3.5: Soil degradation in Eritrea

(Source: FAO 2005: www.fao.org/landandwater/agll/glasod/glasodmaps.jsp)



P.juliflora has been stated by some locals as an indicator for desertification in the Western Lowlands alongside other plants such as *Calotropis procera*, which only came into the area during the last couple of decades when desertification in the Western Lowlands became more apparent (mostly as a direct result of increased stress caused by resource depletion and population growth).

As discussed previously in this chapter, *P.juliflora* may also spread in relatively healthy ecosystems but can still indicate and accelerate desertification in other areas. SOS Sahel & MoA (1999) for example found that the greatest degradation of riverine forests is found in the returnee villages such as Talatasher, Tekreret and Ad Elit near the Sudanese

border mainly as a result of vast deforestation taking place during the 70s and 80s (SOS Sahel & MoA 1999, p.18). Talatasher is also one of the places in Eritrea in which the spread of *P.juliflora* has reached very high levels. It is possible that there is to some extent a correlation between desertification and the level of alien species spread such as *Prosopis*. In the case of Talatasher however there may be other contributing factors that caused the spread of *Prosopis* such as the local irrigation schemes, the village's proximity to Eastern Sudan (where *Prosopis* is abundant), and high numbers of livestock - contributing to the spread of seeds through droppings - within refugee settlement areas.

It has been established within chapter 3.3.2 (Assessment of *P.juliflora*'s Invasiveness and its Impact on Native Species) of this study that in the context of Eritrea *P.juliflora* favours habitats with increased water availability, as it is those areas that are mostly invaded. On the contrary desertification generally widely decreases water table levels and soil moisture content suggesting that the hypothesis of *P.juliflora* invading areas experiencing advanced levels of desertification is contradictory to that finding.

According to IQBAL and SHAFIQ (1997) for example *P.juliflora* is in fact a "common weed of waste lands" in India (IQBAL and SHAFIQ 1997, p.459). While there is a difference between the definition of waste lands (which can also be waterlogged) and areas with desertification, many arid waste lands show in fact similar signs of degradation as those areas with high degree of desertification: High salt content, soil erosion, nutrient loss and a compact soil structure being a few of them. The finding would suggest that *Prosopis* does establish itself widely under such unfavourable conditions.

Also, even if it has been shown that *Prosopis* normally chooses prime habitats with increased water or moisture content, such as the riverine forests, irrigation schemes or road side micro-depressions, moisture content levels and micro-ecological balance within a *Prosopis* habitat may not necessarily be higher, but rather relatively higher in regard to the surrounding land area meaning that an invaded road side may in fact lay in the middle of an area suffering from intensive desertification.

LAXÉN by contrast (2005) takes a very different approach: He states that "the growth of the native tree stands is also so slow that they easily become depleted around villages. On the other hand, *Prosopis* is growing at such a rate that the villagers are not able to deplete the stands without heavy machinery or concerted efforts. Rather, *Prosopis* stands [...] only grow

denser as they are used. In this way a fairly small area of *Prosopis* is able to provide a village with all the fuelwood and fodder it needs in one area and thereby spares the remaining adjacent native *Acacia* vegetation. *Prosopis* thus has a role in environmental conservation of the native woody vegetation in River Nile State if seen from a holistic and objective perspective” (LAXÉN 2005, p.103/04). This observation may apply to the River Nile State and is probably not only dependent on the local climate setting, but also on factors such as population density, local customs and policies on the cutting of live trees and similar. In the context of Eritrea it would be very hard indeed to make a similar statement: the cutting of live trees (except *Prosopis*) is strictly prohibited and can only take place with a special permit meaning that not the availability of *Prosopis* but local policies protect the natural vegetation.

During field visits in Eastern Eritrea, which has a very arid climate and scattered *Acacia* bushland vegetation, it also became clear that the disappearance and replacement of native species by *Prosopis* is a key concern to the rural communities again suggesting the *Prosopis* does contribute to the degradation of the natural vegetation and therefore indicates desertification.

The situation is not entirely conclusive and land degradation and desertification in Eritrea is so wide-spread that it will be hard to identify healthy systems, in which *Prosopis* may also be present. Therefore, it can be said that *Prosopis* widely spreads within degraded land areas and potentially contributes to (mainly vegetative) degradation processes, but it will be somewhat difficult to determine that *Prosopis* has spread on the basis of a degraded natural environment and that it is therefore an indicator of it.

3.4 The Socio-economic Impact of *P.juliflora* in Eritrea

3.4.1 *P.juliflora* Infestation in Crop Land Areas and Silvo-Pastoral Range Lands

The productivity of crop land and pastoral range lands is key to household and national food security. Any loss of land productivity poses a threat to food security. The impact of *Prosopis* on both crop and range lands is therefore crucial.

SINGH *et al.* (1998) and BHOVAID (1996) state that in a pot trial testing using soil from *P.juliflora* canopies ranging from 0 - 30 year old plantations wheat productivity significantly increased with the age chronosequence. The remediation process contributed to higher germination, survival, plant growth and grain yield. Crop yield using the soil from a 30-year old restored sodic soil plantation even surpassed that attained from a non-sodic farm soil by 4.5 –fold (SINGH & SINGH 1998, p. 461; BHOJVAID 1997, p.189)

However on the contrary, PANDIT *et al.* (1995) observed “dense thicket” of *P.juliflora* on the border of Bajra (*Pennisetum typhoides HB-3*) crop, which resulted in poor growth of the Bajra seedlings near the border of the field. After testing possible inhibitory effects of *P.juliflora* leave, stem and root extracts he found that shoot rate of cultivated Bajra was significantly inhibited by stem and root extracts of 3-5% concentration (PANDIT *et al.*, 1995, p. 145-148). A similar finding was made by NOOR & SALAM (1995) who found that extracts from fruit and seed of *P.juliflora* considerably delayed and reduced germination, root, shoot and seedling growth of cultivars such as maize and wheat. However, both trials suggested that such inhibitory substances in the soil may in deed be low due to rain and continuous irrigation (NOOR & SALAM 1995, p. 89).

“[...] farmers are facing lot of problems [with *P.juliflora*] because this tree invades lands aggressively.” (India Workshop Papers, 1986). This sums up the issue on the ground. While research trials may support or reject the idea of *Prosopis* inhibiting crop growth, the fact remains that the species is spreading into farm land causing loss in land size for cultivation and labour and high costs of intensive eradication as well as injuries.

Arid and semi-arid silvo-pastoral systems are believed to cover about a third of intertropical Africa’s total land and sustain about 60% of the total livestock of the continent (LE HOUEROU 1987 in KAARAKKA 1996, p. 12). In Eritrea, grazing land covers about 56.3% of total land area (not including the riverine forests, open woodland or barren land) (NAP 2001, p.1), while figures provided by the FAO (1997) state around 65% when grassland, shrubland and riverine forests are combined. Pastoral rangelands are to be found both in the mostly semi-arid Western Lowlands and the hot desert climate of the Eastern Lowlands both including the slightly higher elevated escarpment zones which lead into the highlands. However, it is the Western Lowlands where pastoralism has become a much more dynamic economy. Better rains and range land areas, major river systems, fertile alluvial soils, and

major trade and migration routes into Ethiopia¹² and the Sudan have led to a much greater population density and economic activity in the Western Lowlands (mostly covered by the administrative region Gash Barka). According to the NAP (2002) 49% of Eritrea's livestock base can be found in Gash Barka alone - this means that the prime habitat of *Prosopis* has also the highest number of animals in the country, which are mainly owned by agro-pastoralists and pastoralists although a considerable amount belongs to immigrant farmers, who have settled in the region during the last 40-50 years.

Browsers can consume various parts of woody plants such as leaves, twigs, bark, bulbs, flowers, seed pods and fruits. They are of particular importance during dry seasons when the herbaceous layer has dried out. Tree and shrub browsing is an important fodder source and supplement, and is practiced by camels, sheep, goats and camels while the latter two are particularly dependent on it.

Pastoralists living in semi-arid ecosystems recognise and value the existence of trees. Not only do they provide shade to herders and their animals, and offer a valuable source for browsing/fodder, but they enhance overall soil conditions and herbaceous productivity within pastoral grassland areas. Soils under tree canopies have been widely reported to have higher concentration of organic matter, nutrient availability and increased availability and activity of the microbial biomass (WICK & THIESSEN *et al.*, 2000, p.59). Trees provide forage for browsing animals, which in turn, introduce nutrients through manure.

The enriched zone beneath and around trees and shrubs in arid and semi-arid ecosystems are often called *island of fertility* or *resource islands* (BELSKY *et al.* 1993 in WICK & THIESSEN *et al.* 2000, p.60).

Within pastoral ecosystems the species selection is traditionally based on added value such as shade, fruit, wood quality or the tree being a valuable browsing source. The native *Ziziphus joazeiro* in NE-Brazil, for example, has no marketable fruits and its integration by local pastoralists may have been related to its beneficial effects on soil nutrients and sustainable productivity. Research had shown that nutrient content, organic matter and biological activity were highest under the canopy of *Z. joazeiro*, not only relative

¹² Migration and trade routes from and into Ethiopia have been closed since the start of the border war in 1998 and have remained closed until this date (2006).

to the introduced *P.juliflora* or the buffel grass, but even compared to the native thorn forest (catingaa) (WICK & THIESSEN *et al.* 2000, p. 59-60 and 68).

However, although *Prosopis* does have added value such as being a source for fire wood and a prominent browse, pastoralists and farmers in Eritrea have expressed great concern about the damaging impact *Prosopis* is having on native grassland and range land species. As previously outlined in detail within this study *Prosopis* is spreading particularly within the riverine forests, but also alongside river banks in the Eastern Lowlands compromising the growth of native species and the accessibility to grazing areas and water points. While *Prosopis* seems a valuable fodder source for pastoral communities during the dry season - and in particular within the context of continuously decreasing grazing areas - pastoralists primarily view it as a threat to their key range lands.

3.4.2 *P.juliflora*'s Role within Agroforestry- Systems

In sub-Saharan drylands the introduction of agro-forestry into croplands seeks the lift up of nutrients and water into the upper soil obtained by the tree roots in deeper soil layers which are inaccessible to the crop. However, while trees are beneficial to nutrient and water cycles, preservation of soil moisture and structure, they can potentially also compete with the crops for water and soil nutrients. Identification of species suitable for agro-forestry, and modification as well as careful management are key to retain the positive effects of tree roots and reduce those which are negative (JONES & SINCLAIR *et al.* 1998, p.197). Some of the management techniques that have proven to increase crop yield within agro-forestry practices are the trimming of roots or even shoots known as pruning. Pruning above ground slows down root growth in some plants as it tries to keep a balanced ratio between root and shoot, which has been termed as "functional equilibrium" by Brouwer (BROUWER 1962 & 1983 in JONES & SINCLAIR *et al.* 1998, p. 197).

JONES & SINCLAIR *et al.* (1998) in an agro-forestry experiment in the semi-arid region of north-east Nigeria (mean annual rainfall 644 mm) found that *P.juliflora* seems to have a particular sensitivity to shoot pruning. Beside *P.juliflora*, *Acacia nilotica*, *A.seyal*, *A.senegal* and *Balanites aegyptiaca* - all of which are common tree species in Eritrea - were transplanted with Sorghum, which is a key cereal in Eritrea. After two months of planting

P.juliflora had the highest mean root length density, it being nearly four times higher than that of *A.nilotica*. When *P.juliflora* shoots were pruned, there was a significant decrease in root length, particularly in the upper soil layers, which are shared with the sorghum crop, while by contrast no change of root length appeared in *A.nilotica* after its shoots were pruned. This suggests a sensibility in *P.juliflora* to shoot pruning. This characteristic had a direct impact on the soil water content of the sorghum crop. While the largest reduction in soil moisture was measured in pruned *A.nilotica* (as pruning had no effect on roots) and unpruned *P.juliflora*, soil moisture content was greatest in pruned *P.juliflora*.

Sorghum root density was reduced in the presence of all trees suggesting high competition between tree and crop for soil water and nutrients. However, there was one exception: In pruned *P.juliflora* plots where a reduction of tree root growth was observed following pruning (although interestingly still overall higher than in the rest of the trees) sorghum root length densities were consistently higher. It was suggested that although *P.juliflora* overall had higher root length density and water intake, a smaller proportion was derived from the crop zone under *P.juliflora* than *A.nilotica* as it has a deep rooting system and root length density increases with depth. An alternative explanation given was that a lower proportion of *P.juliflora* roots was active in water intake, but no measurements have been made in this regard.

The final outcome was the sorghum grain yields (positively correlating with sorghum root length density) were significantly higher in control (without any trees) and in pruned *P.juliflora* plots than all other plots. In general however, yields overall increased with distance from the trees. This may also suggest that not only under ground competitions for water or nutrients are taking place, but the lack of light due to tree shading may play another important role. In fact, in pruned *P.juliflora* a reduction of root growth (and therefore water intake) as well as in shading had taken place (JONES & SINCLAIR *et al.* 1998, p.203-205).

The above finding would suggest that pruning of shoots is a vital method within successful agro-forestry management where *P.juliflora* has been planted. However, as crucial is the fact that these results also give a fundamental insight into the potential overall management of *P.juliflora* in areas where it had not been carefully planted, but where it has invaded and infested fertile agricultural land and rangelands or depleted the natural vegetation.

Introduction of species with high biomass production for afforestation or restoration purposes however, should always ensure that this production does not come at the expense of future nutrient availability (SHARMA & DAKSHINI 1998, who argue that *P.juliflora* depletes soils) or at the expense of local ecosystem balance. According to SINGH *et al.* (1996) an important aspect in assessing the competition for moisture and nutrients is the depth and structure of the rooting system of the tree or shrub and the crop. As most woody perennials tend to have a deeper root system than non-woody perennials, deep tap rooting trees such as *P.juliflora* should be desirable in most agro-forestry systems. Knowledge about the root distribution of trees and shrubs used in agro-forestry systems is essential in making an effective choice of species, in designing the system and managing it. Moreover, within rural development approaches the knowledge should be shared with farmers who often believe that trees and shrubs in agro-forestry system may compete with their crops (SINGH *et al.* 1996, p. 323).

In Eritrea, “strong differences in opinion were expressed on the use of mesquite [*Prosopis*] in community forestry programmes” (HABTE 2000, p.4). It is vital that any assessment in this regard takes a holistic approach considering a range of environmental and socio-economic factors. However, given the great level of interference into the local natural resource base (see for example chapter 3.3.2) and the difficulties to control the species’ spread (even if planted within desert areas, as it can spread further through migrating livestock) new planting initiatives of *Prosopis* in Eritrea within agroforestry systems seems to increase further complicate the issue of its management.

3.4.4 *P.juliflora*, Animal Husbandry and the Livestock Sector

Animal fodder or precisely the lack of it as a result of dwindling grazing areas is *the* key problem facing pastoralists and other animal owners in Eritrea today. This concern is followed by little access to and availability of veterinary services and poor quality of livestock markets (PENHA/NUEYS 2002). The lack of grazing areas and therefore livestock feed was also mentioned by pastoralists respondents (50%) as the primary cause of food insecurity in their communities followed by the lack of rainfall (30%) and the need for cash (20%) forcing them to sell more livestock (AWALOM 1996, p.6). Availability of and

accessibility to range lands and pastures have dramatically decreased as a result of war, which led to the closure of the border to Ethiopia where many dry season pastures were located. Furthermore, inaccessibility of many grazing areas in the Gash and Setit area in the southern parts of the Western Lowlands has occurred, as former grazing areas are now marked as security zones, mine fields or military camps. The continuous expansion of agriculture and cash crops for export at the expense of former rangelands (e.g. the vast establishment of banana plantations alongside the river Barka) is another key cause for the loss of grazing lands.

The situation - further intensified by processes of desertification and drought - has led to a desperate situation among pastoralists whose livelihoods are directly dependent on the productivity of their livestock and many have become destitute in recent years and dependant on food aid as a result of this (PENHA/NUEYS, 2002; BOKREZION *et al.*, 2006).

The lack of fodder is also the leading cause for a rather under-developed livestock sector in Eritrea. Although the related line ministries attribute this foremost to the dry climatic conditions in Eritrea (“we are not Sudan or Ethiopia who have vast fertile and humid areas ideal for the fattening of livestock for export”) and less to the huge loss of grazing areas, there seems to exist an overall desire to improve the situation and develop the livestock sector. But related stakeholders, local policy makers in particular, face an overall lack of answers and direction as to how this could be managed without the necessary feed base¹³. Livestock has a potential to provide meat, milk, butter and hides to households as well as local and national markets increasing food security and income. Leather and livestock exports could increase national income and foreign exchange budgets. According to the MoA (NAP 2002) 26% of the country’s GDP is derived from agriculture with 15% of that being contributed by the livestock sector.¹⁴ The latter is a significant amount considering that crop-based agriculture has seen great development in recent years through targeted promotion, reformed structures, newly introduced technologies and general financial investment while the livestock sector has in comparison barely had any input in this respect. This demonstrates that the livestock sector could potentially play a central role

¹³ Personal notes made during discussions with staff from the Ministry of Agriculture and during a seminar on the livestock sector in Eritrea held by the Association of Eritrean in Agricultural Sciences (AEAS) in Asmara in 2003 and 2004.

¹⁴ Similar, but slightly different figures are provided by the IMF stating that the agricultural sector in Eritrea is providing 15-30% to the country’s GDP of which 10% is contributed by the livestock sector (source IMF, in FAO 1999)

in Eritrea's food security and national development. The central question remains how the fodder shortages can be met.

The issue requires certainly a holistic approach including issues such as cross-border migration, the protection and mapping of key migration routes, water points and key dry season range lands; furthermore, the regeneration and protection of existing grazing and rangelands, the classification and clear demarcation of communal grazing areas, as well as the research, introduction and marketing of new feed bases (e.g. irrigated fodder grass) and alternative fodder resources and supplements such as feed blocks. But what is the actual and potential role of *Prosopis* in Eritrea's livestock fodder dilemma?

According to LAXÉN (2005) more households owned livestock as compared to about 10 years before, but in contrast animal numbers per household seemed to have decreased by about half. He noted however that there had been a significant increase in livestock numbers in a few households that had "specific commercial interests in livestock rearing", so much so the livestock populations statistics for 2000 - 2002 compiled by the Federal Ministry for Range Management in Khartoum, were on the increase in the River Nile State by about 2 - 4% per year. LAXÉN is convinced that this increase in commercial livestock activity is directly linked with the locally growing *Prosopis* stands stating that "without *Prosopis* forage this would have been almost impossible" (LAXÉN 2005, p.102)

Internationally, many researchers and practitioners praise *Prosopis juliflora* pods as a very nutritious forage and fodder resource, which is high in soluble sugars, has "low concentrations of tannins and other unpalatable chemicals, and has moderate to high digestibility." *Prosopis* leaves however - although rich in protein and minerals and highly digestible are relatively unpalatable to livestock due to the unfavourable content of condensed tannin (PASIECZNIK *et al.* 2001, p.97, 105).

The Riverine Forest Inventory and Management Plan for Eritrea (1999) also states that *Prosopis* seed pods are highly palatable while the foliage is relatively unpalatable to livestock; however the authors stated that goats and camels would eat it if nothing else was available (SOS Sahel & MoA 1999, p.64), a finding which was also made by other experts. PASIECZNIK *et al.* (2001) suggest that all animals will browse *Prosopis* foliage during the dry season when not much else is available to livestock. He pointed out that palatability was better for goats followed by sheep, less compatible with camels and unpalatable to horses,

but that leaf debris after being cut off a tree was potentially a good fodder, as the toxic substances such as tannin would diminish a few days after (PASIECZNIK *et al.*, p.95)

While *Prosopis* is widely praised as a valuable feed base to animals some several records on the utilisation of *Prosopis* as animal feed suggest that the amount of pods consumed by animals is crucial in determining the effects it is having on animal health. Injury, illness and even death of livestock that were browsing *Prosopis* have been a major concern to rural communities in the lowlands of Eritrea (see chapter 4.6. for detailed survey outcomes). Similar reports of *Prosopis* harming and killing animals who eat the plant (it is not always entirely clear which parts of the plant cause the damage) have also been made from local communities in other parts of the world: Ravindra Bhatt a participant at the *P.juliflora* workshop in Karnataka, India, back in 1986 commented during workshop discussions: "I have visited Kutch four weeks back and travelled extensively in *Bunni*¹⁵ areas. Shepards complain about *Prosopis*. They say the thorns harm the cattle, pods chokes the throat and they report that many have died because of eating *Prosopis* pods [...]"(India Workshop Papers, 1986).

Death among animals caused by eating *Prosopis* pods was also reported in another trial using 24 yearling desert sheep in which three groups were fed intact *Prosopis* pods while the fourth group was fed with 44% sorghum grain, 29% *Aristida funiculata* (*humra* in Arabic), 25% cotton seed-cake and 2% mineral and vitamin mixture. The three groups consuming solely *Prosopis* were reported to have been dying after about three months. When the animals were later slaughtered the reason for the death was found to be ruminal impaction caused by pods that have been improperly digested. This had lead to the production of excessive amounts of bacterial lactic acid in the animals resulting in severe acidosis and dehydration. Before the death a weight loss of 14% in body weight was measured while animals who had received *Prosopis* pods as a supplement showed a gain in body weight of 54% (ABDELGAABAR (1986 a, b) in LAXÉN 2005, p.53)

When *P. pallida* pods (the composition of which is similar to *Prosopis juliflora* pods) were used as a sole feed ration to cattle, a 1% illness rate was observed. It was assumed that this was caused by "the regression of rumen bacterial cellulase activity, due to the high sugar content of the pods" (ALDER (1949) in PASIECZNIK *et al.* 2001, p.89).

¹⁵ *Bunni* areas are large grassland areas

However, in Eritrea the use of *Prosopis* as a feed base consists to a great extent on free browsing, which makes it very hard to monitor the level of pod feed intake of animals making them vulnerable to illness and death if healthy amounts are exceeded. Animals are particularly prone during the dry season when *Prosopis* is still relatively abundant while other palatable grazing and browsing resources have become scarce. During this time animals are particularly at risk, as they usually experience increased dehydration and loss in body weight due to insufficient fodder and water resources. This is specifically the case in the central, western and northern parts of the Western Lowlands which are usually more arid than the southern and eastern parts (although the phenomenon exists over the entire region) as well as the Eastern Lowlands.

“*Prosopis* pods are used in Sudan mainly for livestock fodder, which is normally browsed directly from the trees. In the Tokar delta of Red Sea Province *Prosopis* pods have been collected on a large scale and ground in a mill for livestock feed. Individual households everywhere in Sudan where *Prosopis* is growing also collect the pods, which are directly given to fenced-in livestock as fodder” (ELSIDDIG *et al.* 1998 in LAXÉN 2005, p.21). While communities in other countries seem to widely collect *Prosopis* pods so they can be processed (e.g. grinded) and used as a nutritious supplement with other feed this praxis is not used in Eritrea.

Other sources have stated that it is mainly “the foliage that is inedible by all herd animals, so that it provides negligible fodder compared to the native species it replaces” (Sudan Vision Daily, 1st March 2008).

Photo 10: Community project on *Prosopis* based fodder production in Kassala State, Sudan



(Photos: by Pastoral and Environmental Network in the Horn of Africa; unpublished, made available for this study)

3.5 Does *P.juliflora* Endanger National and Household Food Security?

“Food security is access by all people at all times to adequate nutritious food to lead a healthy and productive life [...]” (FSS 2003, p.5). Food is also recognized - among other - by the Declaration of Human Rights as a standard for healthy living and for all governments and countries it is a fundamental development policy objective. Eritrea’s Food Security policy is outlined in detail in the Food Security Strategy (FSS) Draft Paper 2003 and the Food and Environment Security in Eritrea report¹⁶. The main objective of the FSS drafted by the Government of Eritrea is “to ensure over the long-term that all Eritreans have adequate and nutritious food to lead healthy and productive lives. Food security is one of the pillars and fundamental objectives of our development strategy.” (FSS 2003, p.3). Eritrea is rated as a food insecure country, both at the national and at the household level, and there is a long list of underlying causes of food insecurity that need to be taken into account. Generally, factors such as drought and erratic rainfalls, war, population growth, and poverty strongly contribute to food insecurity in Eritrea. Population growth and poverty are understood to play an important part in the context of a fragile natural environment that does not have the necessary capacity to mitigate their impact on the natural resource base resulting in its decline. While the specific underlying causes of national food insecurity - among other issues - also include unsupportive policies, lack of foreign exchange to import food, and the lack of capacity to forecast droughts and impending food shortages, specific causes for food insecurity at the household level are aspects of lacking (access to) food in markets or the lack of capacity to either produce food or generate an income to purchase it (FSS 2003, p. 7; MoA 1997, p.4).

Yet, if one wants to understand the impact *Prosopis* has - actually as well as potentially - on Eritrea’s food production and security one has to first examine the role of the natural resource base and the impact of natural degradation within the concept of food security.

According to the national FSS and the Food and Environment Security report factors such as falling crop yields as the “result of the loss of massive quantities of topsoil throughout the country, declining soil fertility, reduction in soil organic matter as manure is burnt for fuel, and shrinking holding sizes” (FSS 2003, p.8) combined with drought, poor

¹⁶ No year stated, 1997 estimate

pest control, low levels of agricultural investment and loss of community assets such as pastures and forests (FSS 2003, p.8; MoA 1997, p.4) have lead to a situation that makes especially households - around 80% of which are directly dependant on agriculture and animal production - prone to food insecurity.

Soil erosion and degradation as well as shrinking land plots per capita and natural resource assets seem to be those factors contributing to food insecurity that are also, in one way or the other, directly interlinked with the issue of *Prosopis*.

Soil erosion is believed to account for around 62 tons per ha (gross) annually with most of it coming from barren land and crop land (MoA 1997, p.36). However a great deal of soil erosion, particularly by water is taking place in Eritrea's highlands, where *Prosopis* infestation is not an issue at this point (with exception e.g. around Keren), as its regional habitat are the Western and Eastern Lowlands. Soil erosion in the plains of the lowlands is not as severe and takes place in form of water erosion during the rainy season alongside the river beds of the Western Lowlands and through random surface runoffs as well as wind erosion especially through sand whirls and storms.

The loss of natural resource assets leading to food insecurity are based on a range of factors, such as previous vast deforestation, overuse of natural resources as a result of poverty, population growth and war. The increasing shortage of productive land availability is becoming a particular problem in Eritrea that is directly linked to the issue of food security. On the one hand, land productivity is decreasing as a result of wide-spread land overuse resulting in desertification and accelerated drought and on the other hand the loss of land or access to land is a result of closed borders¹⁷, inaccessible mine fields and at the household level also a consequence of the continuing expansion of commercial agriculture (BOKREZION *et al.* 2006, p.29/30; PENHA/NUEYS 2001). Population growth has a further impact on both the quality and availability of land for food production. While population density in Eritrea is generally still relative low¹⁸ with the highest population concentration to be found in the central and southern Highlands, it is the Western Lowlands that have seen the greatest population increase (with possible exception of the capital city) during the last

¹⁷ Closed borders to neighbouring Ethiopia as a result of the Ethio-Eritrean border war 1998-2000 have lead to the inaccessibility of key cross-border pastures. This has badly affected migrating agro-pastoralists and pastoralists in both Western and Eastern Eritrea. The closure of borders has not only meant a loss of access to grazing and water resources for livestock, but has also increased the pressure on available resources within Eritrea (PENHA/NUEYS 2001; BOKREZION & FRE *et al.* 2006, p. 30)

¹⁸ At an average of around 32 inhabitants per km²

decade. Returnees from the Sudan, forced resettlement from Ethiopia between 1998 and 2000, internally displacement and in-country migration from the crowded highlands into the Western Lowlands have resulted in a staggering increase of population numbers into the area.

Eritrea's environmental policies however are less an effort to protect and manage the natural environment for the sake of biodiversity but rather more to ensure sustainable land productivity and natural resource management as a key basis to national development and food security for its population. Nevertheless, the protection of land and land productivity is key to this effort.

While several accounts have been made towards the soil ameliorating aspects of *Prosopis* - which are challenged by other experts and need to be assessed for Eritrea - and while *Prosopis* may be a possible candidate in the prevention of soil erosion or sand shifting, other factors are still of concern: *Prosopis* is known for invading all sorts of ecosystems and the loss of productive land, native species and biodiversity, grazing areas and crop harvest can significantly damage food stability once it reaches a certain level.

Indications that *Prosopis* is a threat to food security has also been made by others: NOOR & SALAM (1995) report from Pakistan: "*P.juliflora* during the last 45 years, has invaded all kinds of communities in the flat plains of Karachi and has now become dominant by completely eliminating the natural vegetation." (NOOR & SALAM, 1995, p.83).

According to the WHO (2002) *P.juliflora* "has reportedly covered a quarter of the grazing and farmland of zone three in Afar Regional State" and a local zonal wild life and forestry protection expert at the Animal and Agricultural Development Department claims that "pastoralist grazing lands have decreased significantly since the dangerous weed found its way into the area 10 years ago." (WHO Ethiopia Humanitarian update, 28 February 2002 in www.who.int/disasters/repo/7651.doc).

The director of Community Museums of Kenya (CMK), representing the Ilchamus community in submitting a case against the UN's Food and Agricultural Organisation (FAO), gave a clear statement in the East-African regarding the seriousness of *P.juliflora*: "As a UN body charged with the mandate of dealing with food security, it [CMK] is curious that FAO introduced and participated in the propagation of this invasive weed on the pastures of this highly marginalised community, the Ilchamus," He explained that by taking

over the Ilchamus' land, the weed "is causing serious food insecurity and is threatening their existence." (UNEP 2004).

Similarly, GEESING *et al.* (2004) report that the invasion of *Prosopis* into adjacent fields, wadis and fallow land in Yemen became so much of a concern that "the situation was perceived to be threatening food security; hence it became of primary importance to explore alternative ways to improve food and fodder availability" (GEESING *et al.* 2004). And in a 2000 special report of the Food and Agricultural Organisation (FAO) and the World Food Programme (WFP) FAO/WFP Crop and Food Supply Assessment Mission to Sudan within their Global Information and Early Warning System the invasion of *Prosopis* in "the spate irrigation schemes in Gash and Tokar, on the New Halfa scheme and in the rainfed areas of Kassala State, the invasion of farmland by "mesquite" (*Prosopis juliflora* and *P. chilensis*) is of so much concern" that it was considered a mission highlight. This demonstrates that *Prosopis* is increasingly regarded as a threat to national food security within respective countries and that it is ever more becoming an issue in the global development community (FAO/WFP Crop and Food Supply Assessment Mission to Sudan, 12 January 2000).

While *Prosopis* is currently no (visible) threat to food security in Eritrea due to a level of infestation that still remains relatively low, it can potentially become a very serious risk over the long-term. Reports from other countries where *Prosopis* has covered vast land areas and has made them completely inaccessible, demonstrate that the same can potentially happen in Eritrea. The impact of this could be dramatic in this small country.

While some experts suggest income generation by the utilisation of *Prosopis* by-products to mitigate or even eliminate poverty, such activities will most probably not be able to divert the immense economic, social and ecological effects that would occur when ecosystems turn increasingly into an inaccessible monoculture.

Chapter 4: An Assessment of the General View on *P.juliflora* among Rural Communities

4.1 Survey Objectives and Methodology

A small socio-economic survey (36 households) was carried out within this study to assess the views on *P.juliflora* within rural communities who are facing the spread of *P.juliflora* in their area. This is crucial for the collection of data, local experiences and attitudes towards *P.juliflora* and enables one to draw a broader picture on the ecological and socio-economic impact the species has in Eritrea, particularly in the view of the lack of available information and research on the subject there. The rural population, mainly consisting of agro-pastoralists, pastoralists, small-scale farmers, and agriculturalists possess detailed knowledge about their environment and are in the best position to provide an account of past and present trends and developments with regard to *Prosopis*, of the challenges and threats faced or the benefits and opportunities won, of the changes that took place in their immediate environment and the efforts that have been made to either control or promote *Prosopis*.

The survey presented in this study provides an overview of the extent of the spread of *Prosopis* and the impact it has on rural livelihoods and the native environment.

The experiences and attitudes among the rural communities towards *Prosopis* collected through surveys and interviews are also essential for the design of an appropriate *Prosopis* management plan. Not only do they point out which aspects are of immediate concern (high risk areas), but they will most probably also provide information with regard to management practices and approaches that would be appropriate and sustainable within a given setting. In order to achieve sustainable and effective results, natural resource and environmental management practices require close cooperation with the communities who are on the one hand using those resources but who are also getting increasingly affected by changing environmental conditions

The survey was based on face-to-face interviews using questionnaires, which were designed by the author to assess the impact *Prosopis* is having on rural livelihoods in Eritrea. The questionnaire was based on the presumption that in the semi-arid Western

Lowlands the majority of habitants had a negative attitude towards *Prosopis*. This presumption was based on information and feedback retrieved by the author during several earlier field visits. The questionnaire therefore uses mainly questions referring to negative effects, but also possible benefits *Prosopis* has on rural livelihoods to find the rationale behind broad negative attitudes and at the same time to identify those aspects of *Prosopis* that respondents would find beneficial.

During the development of a management plan, aspects perceived to be of major concern to the rural communities - for example the loss of land to *Prosopis* - would need to be accommodated by finding the most appropriate solutions and to make them a priority in the action plan. On the other hand areas that may be viewed as beneficial - for example fodder production - would provide room for further development, training in and promotion of those areas. This would offer rural communities not only a chance of balancing out the economic losses they may face due to the spread of *Prosopis*, but would also shift the rural poor who experience levels of desperation and victimisation in face of *Prosopis*' invasion towards a more hopeful and pro-active position where currently eradication of *Prosopis* seem too much of an investment.

Furthermore, the questionnaire includes some questions on the year of occurrence of *Prosopis* and areas of distribution for mapping purposes to assess the history and level of spread, which so far has been insufficiently recorded for Eritrea.

The questionnaire (see appendix) is using both closed-ended and open-ended questions. Closed questions include mainly dichotomous questions¹⁹ and numeric ones to narrow down a particular area of interest and provide clear and easy coding during the analysis. Open-ended questions mainly of multiple-answer nature offer the respondents the opportunity to make several choices, e.g by counting all the benefits of *Prosopis* they can think of. In those cases the most predictable answers have been pre-stated on the questionnaire for time-saving purposes, but were not read out to the respondents in order not to influence the respondent's choice or opinion. Furthermore open-ended questions included unstructured questions, where respondents were given the freedom to add what was really of importance to them, as it may not have been covered by the rest of the questions.

¹⁹ A dichotomous question is one that offers two choices - usually 'yes' or 'no'.

Each questionnaire included 30 questions (and eight additional questions regarding background information such as name of home village, age, occupation, ethnic group etc). Each interview lasted around 45 mins to 1 hour. Within the survey a total of 36 interviews were conducted, 11 of which took place in Tesseney, 9 each in Akurdet and Engerne and 7 in Gahtelay.

4.2 The Study Area and Background of Respondents

Interviews were carried out in four sites in both the Eastern and the Western Lowlands with more emphasis on the latter covering three of the four sites. This is because the Western Lowlands are socially, economically and ecologically very diverse and dynamic making them a region of major national importance regarding water reserves and biodiversity as well as economic income, trade, and food security - any major environmental impact or hazard taking place there has a significant effect not only on the region itself, but on the nation as a whole.

There is no precise population figure available for the Western Lowlands as an agro-climatic entity. However the administrative regional district (*zoba*) Gash Barka²⁰ with an area of 37,000 km² covers the vast majority of the Western Lowlands on which a population estimate can be made. Figures stated for Gash Barka are around 560,000 including the returnee population (1989-1999) of over 103,205 (SOS Sahel & MoA 1999, p.16; http://en.wikipedia.org/wiki/Gash-Barka_Region,_Eritrea). The main ethnic groups in the Western Lowlands are the Tigre followed by the Kunama, Tigrinya, Nara, Hidareb, and in to a smaller extent Saho and Bilen. Some of them, such as the Tigrinya or Saho, have only settled there in larger numbers during recent decades by immigrating there from the Central and Southern highlands in the search of land and trading opportunities or as returnees from neighbouring Sudan.

The small socio-economic survey involved three sites in the Western Lowlands namely Tesseney, Akurdet and Engerne and one site in the Eastern Lowlands, which was Gahtelay. The majority of the respondents were of Tigre origin followed by Hidareb,

²⁰ The Gash and the Barka are the biggest river systems in Eritrea. A large proportion of the Western Lowlands belongs to the Gash-Barka catchment area. Gash Barka is also the name of the administrative district that covers the majority of the Western Lowlands area.

Tigrinya, Nara and Saho. However, the study did not assume nor did it identify any differences in attitudes towards *Prosopis* based on ethnic groups.

Respondents were mostly male (except for 2 female), but as this was an introductory study dealing with the environmental impact of an invasive plant species and possible gender variations were not taken into account at this point. Respondents were agro-pastoralists, farmers and pastoralists from different income groups. In general, the survey aimed to identify a range of existing attitudes and perceptions towards *Prosopis* in Eritrea (as this has not been assessed before for Eritrea) using random interviewee selection; variables such as gender, age, and occupation were not taken into specific consideration at this point.

Site 1 - Tesseneay

Tesseneay town - located at 584 m in the subzoba of Tesseneay - is situated near the river Gash and just 45 km east of the Sudanese border. It is a vibrant and dynamic frontier town with about 18,000 inhabitants of various ethnic and social backgrounds. Agro-pastoralism, pastoralism, rain-fed agriculture and irrigated commercial farming are the key production systems. There are several agricultural schemes in the area including Alighider and Talatasher producing cash crops such as *teff* or cotton. The town and people have close cultural and trading links with Eastern Sudan.

It has hot semi-arid climate with an annual precipitation of 300 - 400 mm. Sand storms and flash floods during the rainy season are common. *Prosopis* around Tesseneay is particularly found in the irrigation schemes, the riverine forests and along road sides.

Site 2 - Akurdet

Akurdet town at an elevation of 637 m is situated in the subzoba of Akurdet in the east of the Gash-Barka region. It is located at the river Barka and is climatically and topographically somewhat under the influence of the escarpment and highland zone.

Key production systems are agro-pastoralism, rain-fed farming, horticulture and irrigated farming and cash crop production with emphasis on banana plantations for the national market and export. The climate is semi-arid with an annual rainfall reaching 300-400 mm and average monthly temperatures ranging from 25 - 34°C (KIBREAB *et al.* 2002, p.11), flush flooding after intense rainfall is common.

In Akurdet *Prosopis* is found mainly in the riverine forests alongside the Barka river and its tributaries and in crops situated alongside the river banks.

Site 3 - Engerne

Engerne is situated about 40 km east of Akurdet and has a similar climatic, ecologic and socio-economic make up. It is situated at the Barka river and the main production systems are small-scale irrigated farming and agro-pastoralism .

Prosopis is in particular invading the irrigated crops, the riverine forests and the settlement areas.

Site 4 - Gahtelay

Gahtelay with an elevation of 323 m is situated within the Eastern Escarpment/Lowland zone about 72 km east of the capital Asmara and 42 km west of the Red Sea port of Massawa. The area is situated along the main transport route that connects Asmara with Massawa, which has turned it somewhat into a small trading town selling goods such as water melons, vegetables and salt and providing small gastronomic services to by passing visitors - such as lorry transporters, tourists and government officials - on their way to the port or the capital.

Traditionally, Gahtelay has been an agro-pastoral settlement, however within an Eritrean-Israeli project during 1996, irrigation pipes and motor pumps were established enabling some of the residents to manage small-scale irrigated farmland and gardens.

In the Gahtelay area *Prosopis* is particularly found at the main road and within the settlement and alongside river banks.

4.3 Perceptions about Occurrence and Level of Spread

In the Western Lowlands 100% of the respondents believed that *Prosopis* was brought into their area by livestock with some specifying that it had been introduced specifically by camels coming from the Sudan. Some respondents in Engerne claimed the species was

brought by donkeys coming from the Sudan, which had been held by the Ethiopians in closed compounds near Engerne.

However, when asked at the end of the interview if they had something to add a couple of respondents made comments in regard to deliberate introduction or planting of *P.juliflora* by humans in certain areas. Particular references were made to a horticulturist by the name of Gebru who still lives in Akurdet. It was claimed that he had planted *Prosopis* as a live fence around his garden to protect it from the intrusion of livestock. Today, he faces the invasion of *Prosopis* into his own gardens and struggles with its eradication. Similar cases of farmers and large landowners planting the species in own initiative to protect their crops from intruders or shifting sand dunes, who later were unable to get rid of the species have also been reported from other countries, for example Yemen (GEESING *et al.* 2004, p.9)

In Eritrea, another similar account was made in regard to a well-known Italian investor by the name of Roberto Baratollo who invested into farming ventures in Aligider in 1928 and Tekreret in Western Eritrea during the Italian colonisation. It was claimed by a couple of respondents that he later planted *Prosopis* in the area with the aim “to hurt livestock”.

During field visits, staff of the local Ministry of Agriculture also mentioned that *Prosopis* had been planted by freedom fighters during the liberation struggle, as they were highly dependent on natural resources and the species seemed to provide them continuously with wood for fuel and construction purposes. A senior forester from the agricultural research centre in Halhale not too far from the capital Asmara in the central highlands confirmed that this may have been the case, but he also affirmed that no concrete evidence for such planting had been found (personal communication with Mr Berhane Habte, Halhale).

While there was general consensus that it was livestock coming from Sudan which introduced *Prosopis* into Eritrea, the time of introduction suggested by the respondents in the Western Lowlands covered a period of 31 years with one respondent from Tesseney claiming it was as early as 1970 and another one - ironically from the same area - stating it was in 2001.

Quite different are the accounts from Gahtelay in the Eastern Lowlands: The majority of respondents (71%) claimed that *Prosopis* there had been introduced by the

Ethiopian authorities and the Derg army during Ethiopian occupation during the 1980s while some claimed that livestock and seed dispersion by wind had led to the introduction of *Prosopis*. The introduction of *P.juliflora* in the Gahtelay area by Ethiopian authorities and/or the army can be viewed as very reliable, as all of the 71% of respondents also stated the same years of introduction (contrary to the Western Lowlands - as shown above - where accounts regarding the year of introduction varied quite substantially). According to respondents in the Eastern Lowlands introduction took place quite clearly between 1986-88 with the majority suggesting it was during 1986.

From exactly where the Ethiopians introduced *P.juliflora* into Eastern Eritrea could not be established, however this paragraph seeks to assess its introduction there further. *Prosopis* could have been brought from Western Eritrea where it had most probably been introduced prior to 1986 (see above) or it could have been brought from North Eastern Ethiopia (Afar Region), a *Prosopis* habitat, which has a geographical proximity to the Eritrean Eastern Lowlands.

The introduction via neighbouring Ethiopia is a valuable possibility. According to SERTSE (2005) *Prosopis juliflora* is reported to have been introduced to Ethiopia in the late 1970s at a nursery (Goro nursery) in the Dire Dawa area in Eastern Ethiopia [not too far from the border to Somaliland²¹] where it had possibly been introduced from India. The introduction into the Afar region (Eastern and Northeastern Ethiopia) might probably have taken place from Dire Dawa or has perhaps even been introduced independently from Kenya or the Sudan by foreigners working in the Middle Awash Irrigation Project during the late 1970s and early 80s. SERTSE further states that the planting of *Prosopis* in fact has taken place intensively in large areas until 1982 and was continued by the Food for Work Programme from 1986 to 1988, the same period during which it was also introduced to Eastern Eritrea. Respondents stated during the interviews that it was planted as a natural resource base and that at the time of planting the species was protected by the Ethiopian administration from animals and humans alike.

The Afar region of Ethiopia shares a border with the Southern Red Sea Region²² of Eritrea in the South East of the country, so *P.juliflora* may have in addition potentially also

²¹ Somaliland has declared its independence from Somalia in 1991 after the collapse of Mohamed Siad Burre's dictatorship. It has a sovereign government and institution but still needs to be internationally recognised.

²² The Southern Red Sea Region is an administrative entity covering the southern part of the Eastern Lowlands.

come into Eritrea by migrating livestock crossing the border²³. Although this possibility exists, the introduction of *P.juliflora* into Eastern Eritrea from Ethiopia through livestock is rather unlikely for the following two reasons:

Firstly, SHIFERAW (2004) states that *P.juliflora* is found widely in Zone 1 and Zone 3 of the Afar region of Ethiopia (apparently reaching from Metehara of East Shewa and Melkaworer to Ayssayita and Dubti covering a total of 400 km alongside highways). It is however the hot Zone 2 of Afar region and not Zone 1 and 3 that shares a border with Eritrea; although livestock may also have come from more fertile areas further inside Ethiopia the Zone 2 would still have been crossed by livestock before entering into Eritrea, but *Prosopis* is reportedly not majorly spreading there.

Secondly, the southeastern region of Eritrea bordering Ethiopia's Afar region (Zone 2) is the hot desert of the Danakil Depression. Except for a small account in Ti'o town at the coast *P.juliflora* is actually not visibly spreading in this part of Eritrea either. The hot desert climate could have been a factor that prohibited *Prosopis* to establish itself there naturally. But by the time the animals would have reached the distant areas around Massawa or Gahtelay, where *P.juliflora* is widely spreading under more favourable climatic conditions, many days or even weeks would have passed since the departure from *Prosopis* infested Afar, by which time the animals may not have been carrying viable seeds in their intestines anymore.

During the interviews one respondent claimed that livestock have contributed to the "import" of *Prosopis* into Eastern Eritrea from Western Eritrea, not by migrating across the highlands from west to east, but by being transported by road and gathered there for livestock fattening purposes - during the years following the country's independence - before they were shipped from the port of Massawa to Saudi Arabia to be sold there for meat production.

Now that *P.juliflora* is widely found in both the Western and the Eastern Lowlands it is being further spread through animal droppings within the country. Respondents all stated that they believe livestock is the main factor for the spread of *Prosopis* in Eritrea and this perception has been mirrored by the bulk of related research in other countries. Livestock feed on *Prosopis* in big numbers, particularly during the dry season, and when

²³ Before Eritrea's independence from Ethiopia in 1991, this border would have been an administrative border, as Eritrea was officially seen as a province of Ethiopia at the time.

seeds pass through the gut of the animals the digestive acid leads to the scaring of the hard seed coat, so that seed germination quickly follows the onset of the rain or during irrigation (LAXÉN 2005, p.21; PASIECZNIK *et al.* 2001, p.3; SOS Sahel & MoA 1999, p.64)

While respondents in Gahtelay in the Eastern Lowlands gave similar accounts for the introduction of *Prosopis* with a majority claiming it was precisely in 1986, the case is very different in the Western Lowlands where the range is covering a total of 31 years. On the basis of a clear consensus among respondents and research experts that *P.juliflora* was brought into Eritrea by livestock from the Sudan, one should assume that the earliest *Prosopis*-encounters and reports should be found in areas in proximity to the Sudanese border and probably somewhat later in areas further away from the border. From the three sites that are within the Western Lowlands the *subzoba* (sub-region) of Tesseney is clearly the closest. Neighbouring the Sudanese border directly, Tesseney town is just 45 km away. This area has very close cultural and socio-economic links with Kassala State in Eastern Sudan and the migration with and trading of livestock plays a central role in the local economies and interactions. The furthest away from the Sudan border is Engerne at about 270 km followed closely by Akurdet at about 230 km. Both towns are situated around 40 km away from each other. However, the data collected during the survey shows a different tendency in regard to the species' introduction than expected. The majority of respondents in Akurdet stated that *P.juliflora* came into their area before 1985 with half of them believing it was in the early 80s, still almost a third claimed it was during 1970-1979. Respondents in Engerne mostly suggested that *P.juliflora* was introduced into their area during the 80ies with a third claiming it was before 1985 and two third reporting it was between 1985 and 1989. The figures could be logically related to each other: Engerne is situated about 40 km west of Akurdet and although seed dispersion through livestock will not reflect that of a symmetrical radius respondents in Akurdet and Engerne provide similar periods for the introduction of *Prosopis*, with the majority in Engerne giving slightly later accounts than those in Akurdet.

In contrast and rather unexpectedly are the outcomes obtained from Tesseney. The area is closest to the Sudan and some of its local *Prosopis* resources provided the latest years of *Prosopis* occurrence with a majority claiming it occurred in the beginning of the 90s, the time that marks the end of the war and the independence of Eritrea in 1991 and well after the official references (e.g compare BEIN *et al.* 1996) that it had come from Sudan in

the 1970s. It could not be established in this study why later dates for *Prosopis*' occurrence were provided in Tesseney.

It may also be useful at this stage to look into the claim by one respondent who reported that *Prosopis* had been introduced by the Italian investor Roberto Baratollo who invested into farming ventures in Aligider in 1928 and Tekreret in the Western Lowlands during the Italian colonisation. It was said that he planted *Prosopis* purposely to damage livestock herders with whom he had clashed earlier. He reportedly threatened them by saying he would plant *Prosopis*, so it would take away the water and grazing land for their livestock. Roberto Baratollo went on to open the Asmara Textile Factory in the capital in 1954, which was nationalised alongside the plantations under the Ethiopians in 1975. If Baratollo had planted *Prosopis* at his Aligider farm - near Tesseney and the Sudanese border - it must have been before 1975 by which year Baratollo would have lost his ventures to the socialist Ethiopian authorities (*derg* regime) and left Eritrea.

Table 4.1: Year of *P.juliflora* occurrence

	<i>When did Prosopis occur in your area? (Western Lowlands only)</i>	
	count	%
1970-1974	1	4.5%
1975-1979	1	4.5%
1980-1984	6	27.3%
1985-1989	8	36.4%
1990-1994	4	18.2%
=/> 1995	2	9.1%

	<i>When did Prosopis occur in your area?</i>			
	Akurdet 230 km from Sudan	Engerne 270 km from Sudan	Tesseney 45 km from Sudan	Gahtelay (Eastern Lowlands)
1970-1974	16.7%			
1975-1979	16.7%			
1980-1984	50.0%	33.3%		
1985-1989		66.7%	28.6%	100%
1990-1994			57.1%	
=/> 1995	16.7%		14.3%	

The data obtained for the year of *Prosopis* occurrence as perceived by respondents in relation to their age was unanticipated. One may have assumed that older respondents particularly those of over 40 years of age would be those providing early accounts of *Prosopis* occurrence in their area, as they would be old enough to have witnessed and

remember any introduction of the species prior to 1980. However, the opposite was very much the case: Respondents who claimed that *Prosopis* occurred between 1970 and 1979 were between 26 and 40 years old and could not even have personally witnessed the introduction, while statements about the most recent occurrence after 1990 and 1995 have been made by those above 55 of age.

One reason for this could be that a couple of the older respondents in the Western Lowlands stated during interviews that they were not able to recall the year of introduction and that they were therefore providing the year in which *Prosopis* became a significant and visible problem while it had in fact been introduced earlier.

The accounts ranging from 1970-1979 within this study must be based on the transfer of information from older generations or simply on individual perceptions, as those who gave these accounts were too young to have witnessed or remembered any introduction during that time, however the counts within this study are very small. Although this study is not necessarily representative, it clearly shows that the majority of respondents in the Western Lowland believe that *Prosopis* had been introduced during the 80s.

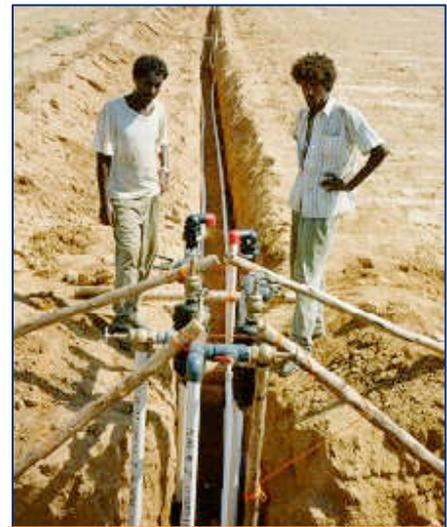


Photo 11:
Irrigation system in Gahtelay
Source & Photo: Israel Ministry of
Foreign Affairs , 1996

4.4 Perceptions Regarding the Impact of *P.juliflora* on Crop Land

As previously described in detail in chapter 3.4.1 and 4.2 crop production is a major economy in the Western Lowlands (which covers the administrative Gash Barka Region). Main crops of small-scale rainfed farming within a subsistence economy include millet, sorghum, maize, wheat, groundnut, and pulses etc. Although there is a considerable amount of irrigated commercial farming, mainly cash crop production and horticulture taking place in the south west and alongside the Gash and upper Barka rivers, the vast volume of agricultural crop production is for subsistence consumption and is happening widely within semi-sedenterised agro-pastoralist production systems and other forms of livestock herding.

Agro-pastoralism and pastoralism are also a leading subsistence economy in the Eastern Lowlands. However due to the hot desert climates with average annual rainfall ranging from 50 mm in the southern and northern coastal areas of the Eastern Lowlands to around 180 mm in the central parts and slightly higher elevated areas towards the west there is a higher emphasis on animal production and fishery with some areas showing no crop production at all (e.g. some coastal areas in the Afar region in the south) while others depend highly on spate irrigation and rain harvesting methods (e.g. Afabet area in the north).

The site of Gahtelay can be described as a semi-desert consisting mainly of barren land plots and gentle rocky hills. However in 1995, a project jointly carried out by MASHAV, ERRRA and USAID initiated and supported irrigated horticulture and farming activities on a small-scale enabling habitants to grow water melons and vegetables. These farming activities now take place alongside traditional subsistence economies mainly based on livestock herding and rearing.

Although the survey is not fully representative due to the relatively small number of people interviewed it perfectly mirrors the distribution pattern of the various household economies regarding crop and animal production. In the Western Lowlands the majority of respondents own both crop and animals. While settled mixed farming economies are widespread in Eritrea they are commonly found in the highland areas. In the hot semi-arid central parts of the Western Lowlands the combination of crop and animal production takes usually place within agro-pastoralist systems. While agro-pastoralists stay mostly in their settlement during the rainy season from July to September and until the harvest period around October to December they engage in migrating with their animals during the dry season, however there can be big variances in the migration pattern as well as the duration they stay in dry season camps.

The two sites with the highest involvement in crop production are Akurdet and Engerne. Both are situated at the Barka River and Akurdet especially has a long history of irrigated crop production and horticulture, which started under the Italians in the beginning of the 20th century. Although many of its plantations and gardens were destroyed during the 30-year war for independence Akurdet has always remained a kind of stronghold for irrigated farming in central Gash Barka. It is therefore not surprising that it had a relatively

high number of respondents who were solely depending on crop production and who did not own any animals, which is otherwise rather unusual for this region.

Table 4.2: Subsistence Economies among Respondents

	<i>Do you have both animals and crops?</i>							
	Akurdet		Engerne		Tesseney		Gahtelay	
	Count	%	Count	%	Count	%	Count	%
- animals and crop	4	50.0%	6	66.7%	6	54.5%	2	28.6%
-animals only					2	18.2%	3	42.9%
-crop only	4	50.0%	3	33.3%	3	27.3%	2	28.6%
Total	8	100.0%	9	100.0%	11	100.0%	7	100.0%

The highest numbers of respondents relying exclusively on animals could be found in Tesseney and in Gahtelay in the Eastern Lowlands; again this pattern reflects very well the situation on the ground. Tesseney subzoba and town is a vibrant area regarding the rearing and marketing of livestock. Although Tesseney near the river Gash also holds agricultural schemes in the west of the sub region and around the town they are widely comprised of strongly mechanized farming and cash crops. While rain-fed agriculture at small-scale is also well represented, Tesseney remains a key centre for pastoralists and other livestock owners who frequently use range land resources and livestock markets in neighbouring Sudan.

Photo 12: Juvenile *Prosopis* trees on a crop in Tesseney subzoba



(Photo: author)

In the Western Lowlands, the vast majority of respondents 89.9 % (count 25) who own crops face the invasion of *Prosopis*. In Gahtelay the figure is much smaller with less than two third (meaning that over one third claimed they had no *Prosopis* invasion on their crops)²⁴. The main reason for the comparatively low level of *Prosopis* infestation on crop land in Gahtelay is surely the fact that crop production in the area has only recently taken off. This is certainly the case for irrigated land plots - which are a prime habitat for *Prosopis* - as these were widely established in Gahtelay only in 1995. Furthermore, a relatively small land area of Gahtelay is covered by crop land making it also much easier for farmers and agro-pastoralists to manage or weed any *Prosopis* seedlings.

When asked what respondents thought were the effects of *Prosopis* on their crop land, the majority in all sites agreed that *Prosopis* was taking water away from the crop. This was followed by the concern that nothing else would grow where *Prosopis* is established. That this is the second greatest concern regarding the effects of *Prosopis* on crop land is somewhat surprising, as in Eritrea infestation of *Prosopis* witnessed on (non-irrigated) crop land is not so abundant that crops were not able to grow. Therefore, rather than being a result of crop land being covered by *Prosopis* (and therefore land size decreased for the growth of crop seedlings) the perception that nothing else grows on the fields needs to be either based on a severe competition for water and nutrients (between *Prosopis* and the crop), the interference of *Prosopis* roots with crop rooting or some kind of allelopathic impact as suggested by some research (see chapter 3.3.2), one or a combination of which is resulting in the lack of crop seed germination or seedling survival. Possible inhibitory allelopathic effects have been reported by a number of experts. PANDIT *et al.* (1995) for example observed poor growth of *Bajra* seedlings towards the edges of a field in India that was surrounded by *Prosopis* thicket. In an experiment he found that *Bajra* shoot rate was significantly inhibited when adding *Prosopis* stem and root extracts. However, such experiments have so far only taken place within laboratories and have not taken into consideration the natural conditions such as the dilution of potential harming extracts in the soil by rain.

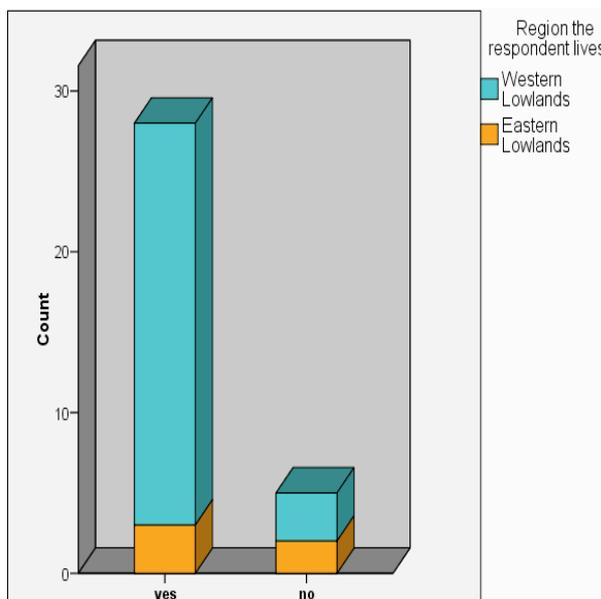
²⁴ The percentage for Gahtelay is not fully representative due to the relative low number of interviews carried out there (count 7)

About one third of the respondents stated that the invasion of *Prosopis* into crop land decreased their harvest and that the species would take valuable nutrients away from the crop. It was also reported that horticultural fruit trees cultivated for human consumption were affected by the presence of *Prosopis* resulting in tree fruits lacking resistance against the influence of pests and bugs, which affected mainly healthy fruit production.

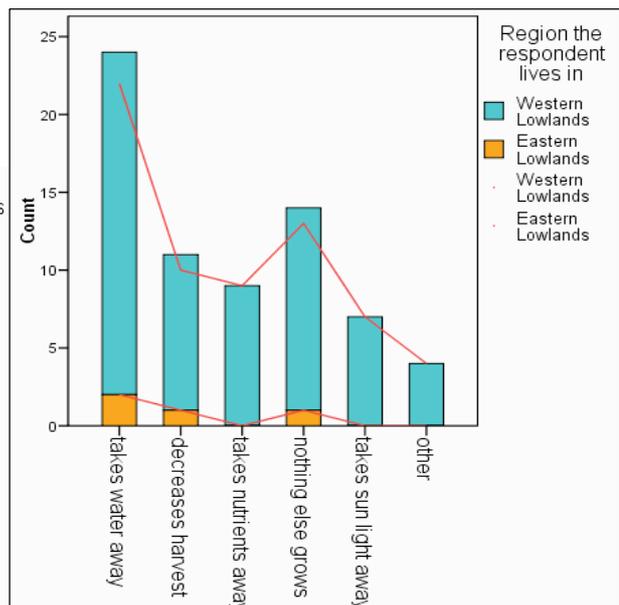
In Gahtelay the perceptions were similar. The intake of water by *Prosopis*, the inhibitory effect it has on other plants and the decrease in harvest were mentioned as the main negative effects with a slighter relative emphasis given on the latter.

Other negative effects on crop land as mentioned by a couple of respondents in the Western Lowlands included that *Prosopis* made crop management more labour intensive and that it was poisonous. One person stated that *Prosopis* has no impact on his crop.

Respondents in Gahtelay stated that *Prosopis* was only of use to their crops when it had been burnt and that particularly maize would grow excessively on fields cleared of *Prosopis* by fire. Generally however, control by using fire is not an option, as large-scale land clearance by fire is not traditionally or legally practiced in Eritrea.



Graph 4.1:
Does *Prosopis* invade your crops?



Graph 4.2:
Effects of *Prosopis* on crop production

4.5 The Impact of *P.juliflora* on Range Lands, Riverine Forests and Native Plant Species

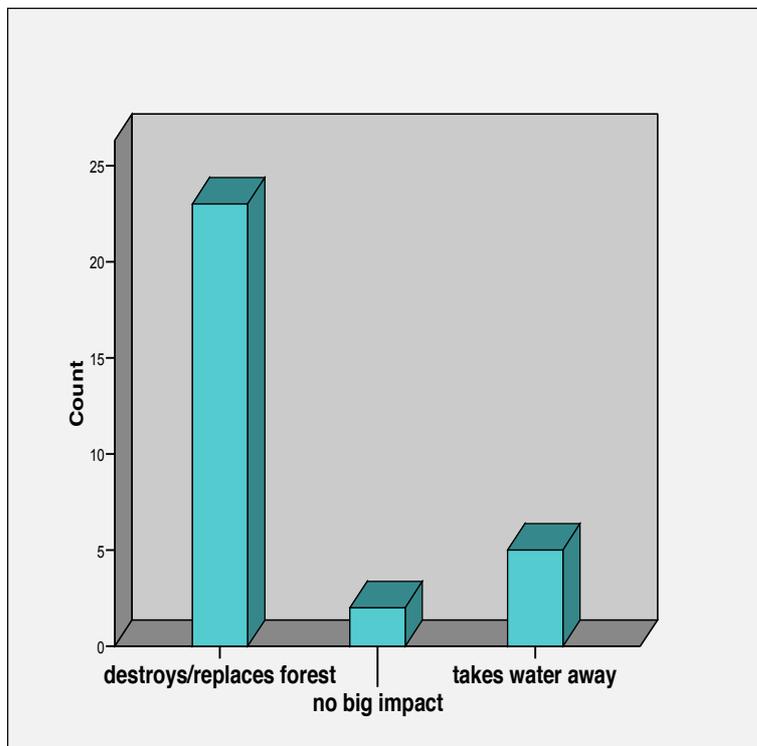
The riverine forests in the Western Lowlands with its characteristic *Doum palm* vegetation play a very unique importance in the ecology and livelihoods in this region (see chapter 3.3.1).

A large proportion of the population in Gash Barka live in proximity to the forests, which are providing essentials such as water, food, animal fodder, fire wood, and other forest products that can be sold at local markets. According to SOS Sahel & MoA (1999) most, if not all, families within the 80% rural population of Gash Barka will use *Doum palm* (called ‘*arkobkaway* locally) products with the collection of *Doum palm* leaves and the production of leaf products being the most common activity. The survey carried out within their Assessment and Management of the Riverine Forests Project revealed that “on the basis of economic analysis alone [...] the riverine forests in their present condition generate more value per capita for the local population than any other form of land use (Dom forest generates 17.8 Ncfa²⁵ /person/day compared with wage labour on irrigated farms of 15 Ncfa/person/day)” (SOS Sahel & MoA 1999, p.16/17). The riverine forests also entail benefits that cannot be costed such as the provision of water, shade and shelter as well as being a place of extraordinary ecology and biodiversity. Given the immense importance of the riverine forests to the rural communities in Gash Barka throughout the year, but in particular during the dry season when resources are scarce, the invasion of *P.juliflora* into this valuable ecosystem is understandably very alarming to the people who depend on those forests.

When questioned about the impact that *Prosopis* has on the riverine forests the respondents made their concern evident: The majority gave a very clear statement claiming that *Prosopis* was destroying the riverine forests and replacing them. Old *Doum palm* trees (the most characteristic species of the riverine forest) remained relatively undamaged - although its hard fruits (called ‘*akat* locally) reportedly get a bitter flavour - but it was the young *Doum palm* stock that was damaged and destroyed (“burnt”) by *Prosopis*.

²⁵ Ncfa (also Nfa or Nkf) is the abbreviation for the local currency Nakfa. In 1999, the year the assessment was concluded - Nfa 17.8 were about US\$2.2. Today (2008) this would equal about US\$1.2

A couple of other respondents referred this problem to all native forest plants stating that



only mature plants remained in the forest as young seedlings were not growing as a result of the impact of *Prosopis*. While some felt there was no significant impact of *Prosopis* on the forests.

Graph 4.3: Negative impact of *Prosopis* on the riverine forests

This is confirmed by SOS Sahel & MoA (1999) who

reported (see chapter 3.3.1) that *P.juliflora* was the only species that “shows excellent regeneration from seed” in the riverine forests which causes “great concern” (SOS Sahel & MoA 1999, p.14). The moist ecologic conditions in the riverine forests are ideal for *Prosopis* seed germination, which is with up to 50,000 seedlings/ha significantly greater than those of the native forest species suggesting that *P.juliflora* has the upper hand. This substantial scientific evidence supports the views and experiences of the respondents during the survey who believe that their highly valuable forest resources will disappear in the long-run, as they are already witnessing the affect of non-native species mixing and changing vegetation type.

The decline of the riverine forest will have alarming consequences for the communities living in this area, particularly those with a high dependency on forest resources. According to SOS Sahel & MoA (1999) communities highly dependent on forest resources for their livelihoods (in the range 45-60%) are significantly higher in the (river) Barka area (with 30% of households) than in the river Gash area (with only 2% of households) for the same range of dependency. Communities with a lower livelihood dependency rate with the range of 15-30% make up the largest proportion and show similar

numbers for both river areas: 45% of households in the Barka area and 59% in the Gash area belong to this category of riverine resource dependency.

The lowest dependency however was found in refugee villages such as Talatasher, Tekreret or Ad Elit where only 10-15% of resources were derived from the forests, which were quite significantly degraded in those areas during the 70ies and 80ies (SOS Sahel & MoA 1999; p.18).

Traditionally, the management of the riverine forests was regulated by village by-laws, which were enforced by and institution of village elders called the *lijna*. Usually, one particular member of the *lijna* called *abo gereb* (forest father) was responsible for the issues regarding protection of forest resources. One of the biggest offences was to cut a live tree. When such an offence was committed the offender was punished by the village council and usually had to give his best sheep or goat to be slaughtered for the village, alternatively cash fines were imposed. During the liberation war most of the traditional forest management systems collapsed and in most places until today the forest management rules are now set by the Ministry of Agriculture (MoA). Although the role of the *abo gereb* still exists there are several limitations to his authority and motivation such as the lack of a regular salary and of clear legislation. The local MoA imposes fines for offenses like the cutting of live trees without permission, which is forbidden, but the determination and calculation of trees is often not clear with the exception of the *Doum palm* which has been valued at 505 Nakfa²⁶ (SOS Sahel & MoA 1999, p.28/29).

The cutting of live *Prosopis* trees is a different case: It is the only tree species in Eritrea for which the MoA has given permanent permission to cut (Personal Communication with Mr Berhe in 2002, Head of Forestry Department of the Ministry of Agriculture branch, Akurdet). Although many experts and MoA staff met during the undertaking of this study expressed the view that they see the potential benefits of *Prosopis* and do not share the opinion of the majority of villagers that eradication is the only option, the fact that they have allowed the cutting of *Prosopis* (whereas the cutting of any other live trees is strongly prohibited) mirrors that there is some sense of urgency at the policy level which is seeking to deal with the spread of this species.

²⁶ Value refers to 1999 when the SOS Sahel & MoA report was published. At the time, 505 Nakfa were about US\$62.

For the villagers, *Prosopis* invasion undoubtedly increases the pressure on the riverine forests which are a crucial livelihood and rangeland resource for the local communities in Western Eritrea, particularly during the dry season. According to SOS Sahel & MoA (1999) increased pressure on forest resources has brought some “beneficial developments” in recent years, as it prompted some villages²⁷ in partnership with the MoA and local administration to revive the traditional systems and put stronger control measures in place (SOA Sahel & MoA 1999, p.30). In view of those developments riverine forest resources could be strengthened and the negative impact of *Prosopis* invasion reduced by creating more efficient and motivating control regulations and regeneration activities through mutual partnerships among local communities and authorities.

The level of infestation of *Prosopis* in open grassland areas is up until now relatively low. Dense *Prosopis* stands or thickets away from the rivers, irrigation schemes, roads and settlement areas, which have all been identified as *Prosopis* prime habitats in Eritrea (compare chapter 3.3.1) have not been witnessed in open savannahs where distribution patterns of *Prosopis* consist commonly of sparsely scattered shrubs. This however does not imply that it does not pose a problem to these dryland ecosystems - that make up the leading vegetation type in both the Western and the Eastern Lowlands - and those who rely on their productivity. In regions where the livelihoods of agro-pastoralists and pastoralists directly depend on the productivity of those grasslands for essential livestock production and where land productivity is already constrained by drought, desertification, re-occurring pests and the loss of land size to agricultural expansion, the infestation of *Prosopis* will - although it may provide added value to some extent - generally cause a further loss in the eco-balance and available land size of those areas. Furthermore, the scattered *Prosopis* vegetation in open grassland savannah may also intensify in the future, as more mature *Prosopis* trees will provide a steadily increasing number of seeds, which may germinate during heavy rainfalls and flooding events.

When asked how respondents thought *Prosopis* was impacting on open grass land areas they stated numerous negative effects, which are overall very similar to those stated

²⁷ A particular reference has been made to the village of Hashenkit around 7 km north of Haikota and 10 km from the river Gash where “dammering” and “household forestland” is practiced. A strong sense of collective or household ownership of the forests and social cohesion/social pressure have been named as important management factors for successful preservation of the natural forests.

regarding the impact on crop land areas. Their key concern was again that *Prosopis* dries up grazing areas as it consumes a lot of water. They also claimed that the infestation of *Prosopis* on their grazing land degraded the natural vegetation and both grasses and trees were not growing or not growing sufficiently. Respondents furthermore stated that *Prosopis* depletes the soil of nutrients and that its canopies prevent the sun light reaching the grazing land. These concerns seemed to be of higher relevance than they were in the context of crop production as around 50% more people made those statements in regard to their grazing areas. This is on the one hand surprising, as one would have assumed that factors such as soil nutrient availability and sun light are of greater importance to crop production than to the productivity of dryland grazing. However, this shows that even the relative small number of *Prosopis* in open grassland areas already impacts on the productivity of those already highly fragile ecosystems, which are further strained by the effects of desertification. It also demonstrates that animal production and the availability of grazing areas for herds are of particular importance to those communities.

Similarly, communities in the lake Baringo area in Kenya claimed that “ground cover of herbaceous species underneath *Prosopis juliflora* stands have decreased on both communal and individually controlled land” (MWANGI 2005, p.37)

Other effects that were mentioned included that *Prosopis* was hindering the access to grassland areas, which would be the case at some road sites or river edges (e.g. near the river Gash before entering the town of Tesseneay), as *Prosopis* has formed such a dense thicket that no animal or human is able to pass through it.

Furthermore that *Prosopis* concentrates around wells and that these would soon have less water and ultimately dry out in the presence of *Prosopis*. A similar view was reported by the Community Museums of Kenya (CMK) on behalf of the Ilchamus community who claimed that “besides draining the water table in these districts, the weed [*P.juliflora*], which flowers throughout the year, leaves much of the soil bare and prone to erosion” (UNEP 2004)

Graph 4.4: Negative impact of *Prosopis* on open grazing land

A couple of respondents also pointed out that it was not only the quantity of the grass that was affected by *Prosopis* but also the quality of it.

Closely related to this could be the views of respondents when asked if they valued *Prosopis* (at least) during the dry season when grazing areas had widely dried out (with some potential exception in the very south of Gash Barka)

and when fodder resources were scarce resulting in a visible decline of animal productivity, market prices and scarce provision of animal-products and nutrition particularly among pastoralists households.

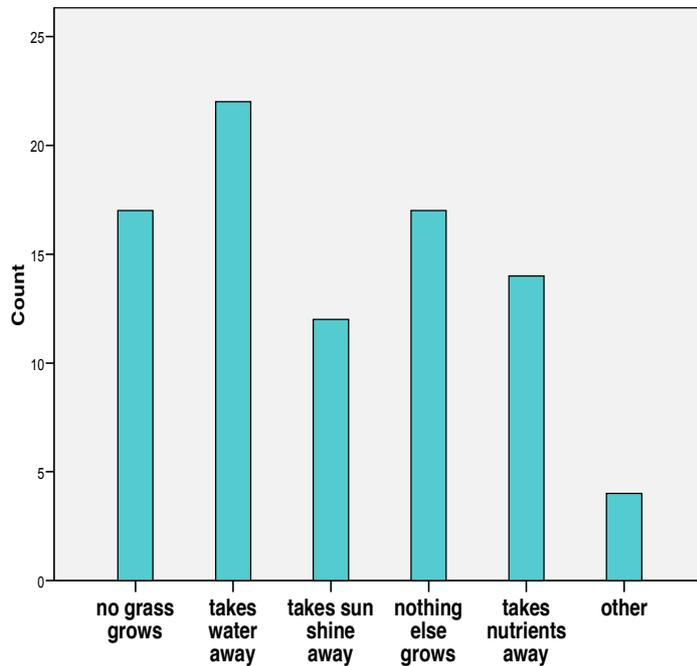


Table 4.3: Role of *Prosopis* during the dry season (by project site and by production system)

Owning...	Are you glad to have <i>Prosopis</i> during the dry season?	
	Yes	no
	Count	Count
animals and crop	3	14
animals only	2	3
crop only	1	11

	Are you glad to have <i>Prosopis</i> during the dry season?			
	Akurdet	Engern e	Tessen ey	Gahtelay
	%	%	%	%
no	100.0%	100.0%	54.5%	100.0%

Tesseney was the only site where a small majority found *Prosopis* a valuable fodder resource during the dry season when everything had dried out. The other three sites had an absolute majority declaring that even the fodder situation during the dry season was no reason for them to value *Prosopis* during that period. This was even the case in Gahtelay where the dry season lasts generally longer than in the Western Lowlands (counted in months, as the dry season in Gahtelay occurs during summer and not the winter months) and where annual rainfall on average reaches about half of the amounts in the other three sites. In contrast, Tesseney - where respondents valued *Prosopis* during the dry season - was the only site where habitants were probably the least dependant on it, as they had generally better opportunities to mitigate the effects of the dry season due to their proximity to the Sudan: they were provided with more alternatives such as better access to cross-border rangelands or increased engagement in cross-border market activity and trading. It shows that people in Tesseney seem to have a much more positive attitude towards *Prosopis* than other sites, which proceeding chapters will attempt to explain.

The respondents who decided they valued *Prosopis* during the dry season came from different production systems. An increased tendency becomes apparent for pastoralists ('animals only') if one compares the proportion of respondents who responded positively with the absolute number of respondents in each production system: while only a fraction of those owning 'crop only' and 'animals and crop' were valuing *Prosopis* during the dry season, about two third of those owning animals only (even if the total number was small) stated they were glad they had *Prosopis* during the dry season.

When questioned about the impact of *Prosopis* on soils (within any kind of land use) an overall majority claimed it was degrading rather than improving the soil with the exception of respondents in Tesseney where the majority thought it was improving soils. As described in chapter 3.3.4 there is a wide range of research evidence available that suggest *Prosopis* clearly improves chemical soil composition and structure of compact saline soils and sodic wasteland areas (GARG 1998; BHATIA *et al.* 1998; BHOJVAID 1997). Experts are however divided regarding the impact of *Prosopis* on non-sodic soils. KLEMMENDSON and TIEDEMANN (1986) for example stated that nutrient availability under *P.juliflora* canopy soils vs. open desert grassland soils showed a significant increase in soil nutrients under

Prosopis canopies. However others (SHARMA & DAKSHINI 1998) argue that *Prosopis* contributes to soil degradation.

Soils in Gash Barka although generally highly degraded are not sodic wasteland soils and sampling that has been carried out by the author in Akurdet and Mograib suggested that soil pH was low to moderate alkaline ranging from around 7.7 in Akurdet and between 7.56 to 8.12 in samples from Mograib, where some of the soil profiles alongside dry riverbed showed high levels in soil compression. Moderate levels of alkalinity are typical for tropical drylands and a wide naturally occurring phenomenon. However, soil salinity and compression are still common either as a result of inappropriate irrigation methods or naturally occurring salt crystallisation as a result of ascendant soil water movement along the capillary system travelling from the shallow groundwater in the Barka river towards the upper soil layers.

In the riverine forests soils are generally relatively fertile and an alien species like *Prosopis juliflora* which is known for its high water consumption and whose nutrient intake was found not to correlate with local soil nutrient availability (SHARMA & DAKSHINI 1998, p.63-67, see chapter 3.3.2) will quickly contribute to ecological imbalances, which can cause degradation. Nevertheless, it is far more difficult to assess the impact that *Prosopis* is having on soils in open grazing areas in Eritrea, especially as their composition, fertility and level of degradation vary widely depending on their location, natural vegetation and intensity of use.

Table 4.4: The impact of *Prosopis* on soils

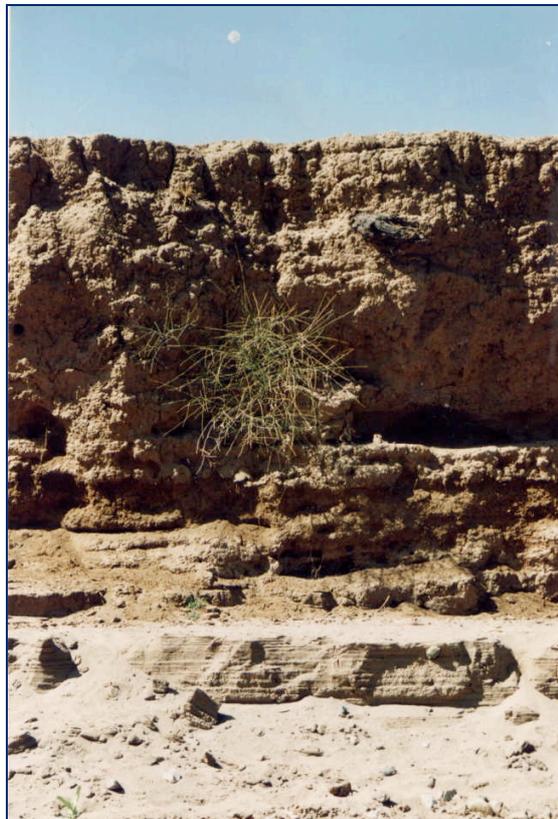
	Do you think <i>Prosopis</i> degrades or improves the soil?							
	Akurdet		Engerne		Tesseney		Gahtelay	
	Count	%	Count	%	Count	%	Count	%
Degrades	7	87.5%	9	100.0%	2	33.3%	5	83.3%
Improves	1	12.5%			4	66.7%	1	16.7%

Respondents in both Akurdet and Engerne agreed that *Prosopis* was degrading their soils. This view may be due to the fact that they have a higher dependency on crop based agriculture (including small-scale irrigation) and - according to SOS Sahel/MoA (1999) - also on the riverine forests (alongside the river Barka) as compared with respondents in

Tesseney (river Gash) the only site where the majority of respondents claimed *Prosopis* was improving their soils. This means that respondents in Akurdet and Engerne are firstly heavily depending on land use areas (crops and riverine forests) which already comprise of a relatively good soil composition and structure (be it even through means of ploughing, watering and the use of mulching/fertilising regarding the soil of crops), so that signs of degradation may be more apparent. Secondly the two key land use areas in Akurdet and Engerne are both prime habitats of *Prosopis*. This could lead to a more general negative perception of *Prosopis* and its impact.

However soil degradation under the impact of *P.juliflora* has been reported elsewhere. SHARMA & DAKSHINI (1998) for example measured the loss of fine soil particles and increased salt content under the influence of *Prosopis* (SHARMA & DAKSHINI 1998, p.63). In contrast many other studies have confirmed *Prosopis*' ameliorating impact on soil, particular on soils that have already experienced a high level of degradation.

Photo 13: Soil profile of fertile river bank in Mograyb (near Akurdet)



(Photo: author)

Why respondents in Tesseney felt *Prosopis* was improving their soils seemed at first somewhat harder to interpret and also unexpected in the light of responses that have been given in regard to the negative effects *Prosopis* was reportedly having on their crop land and grazing areas including the depletion of nutrients and the decline in harvest and grass species. However, after some more detailed analysis it became apparent that those who stated that *Prosopis* was improving soils had stated in a different set of questions regarding the positive effects of *Prosopis* that the species was useful in slowing down or halting soil erosion and desertification processes. Therefore, the perceived ability of *Prosopis* to improve soil does not generally relate to improved chemical parameters of the soils, but to such land areas that are foremost physically degraded therefore suffering visibly (for the respondents) from the effect of soil erosion, and where the leading impact of *Prosopis* is to avoid the loss of soil.

“Plants we know in Gahtelay are disappearing because of *Prosopis*.”

Somewhat of a surprise may be the outcomes from Gahtelay, where a majority of respondents felt that *Prosopis* was degrading their soil. The area is a semi-desert with very scattered vegetation. The land is hot, dry, hilly and rocky, widely barren and soils are naturally shallow and quite compact with high sand and stone composition and due to the scarce grass savannah vegetation the organic matter, soil nutrient and micro-organism content is presumably very low. Here, one would have assumed that *Prosopis* was not a major competitor to other tree and plant species and that its rather abundant litter composition and soil-plant interaction would have positively contributed to soil quality including improved microbial biomass C and N content and soil permeability. But in Gahtelay, the majority of respondents claimed *Prosopis* was degrading their soils. One issue that surely plays into this perception is that people there have seen their native plant and grass species being affected by *Prosopis* and have reported that they were disappearing. Deep-rooted grasses were reported to be particularly affected. It was reported that even here in a hot dryland environment with scattered vegetation native species were disappearing under the presence of *Prosopis* and would not produce new seedlings. Some added that the hard soil structure did get “soft” under the influence of *Prosopis*, but in a way that wasn’t beneficial and that the problem remained that soil was being depleted of its nutrients and that it therefore lacked fertility.

Similar accounts have been made in Kenya from where it was reported that “the plant is also blamed for making the soil loose and unable to sustain water” (BBC News Report, 07 August 2006, Kenya).

In Gahtelay, it was further reported that *Prosopis* was growing on saline soils at the coast inside and around the port of Massawa even if the level of infestation was not as high as in the Gahtelay area which is located under the relative influence of occasional run-offs from the highlands. However, one respondent in Gahtelay reported that *Prosopis* was also viewed as an invader in Massawa due to its competition with the native mangrove species. Similarly communities in Kenya’s Baringo area claimed that *Prosopis* had “killed off other important and useful native trees such as *Iltepesi*, *Ilkiloriti*, *Ilwai*, *Kalalia* (*Euphorbia* spp.) (MWANGI 2005, p.44).

Detailed soil sampling and soil analysis from a variety of *Prosopis* habitats with different age sequences would have to be taken in order to make a distinct analysis regarding the impact of *Prosopis* in various ecological settings and different soil classes. Although it may well be that such sampling would bring along scientific evidence one way or the other, the results may still not be of much significance when it comes to assessing and addressing the ecologic and socio-economic impact of *Prosopis*: the species may prove to have soil ameliorating abilities, but the fact remains that respondents in all sites were highly concerned about its water intake, the loss of harvest, and the decline of the native vegetation. It became clear during most of the interviews that respondents in all sites are particularly worried about the loss of quantity and quality of native plant and grass species as a result of *Prosopis* invasion which is potentially leading into a vegetation transformation with irreversible extent.

4.6 Perceptions Regarding the Impact of *P.juliflora* on Livestock

As outlined in detail under chapter 3.4.4 of this study the majority of research looking into the feed potential of *Prosopis* praises the species as a very nutritious and valuable fodder resource. Emphasis is given to *Prosopis* pods, which have been described as being high in soluble sugars, low in unpalatable chemicals and with a moderate to high digestibility.

Prosopis leaves on the contrary are widely said to be relatively unpalatable to livestock due to the unfavourable content of condensed tannin. It is however reportedly used by livestock owners during the drought season when fodder is scarce (PASIECZNIK *et al.* 2001, p.97, 105). Although it is acknowledged by several sources that leaves are generally unpalatable, little is reported about any potential negative impacts that either *Prosopis* pods or leaves can have on livestock. Instead, it is widely being praised as a valuable feed source suggesting that *Prosopis* is a key resource for livestock in rural India, the Sudan and countries of the South American subcontinent, either as a browse or as processed supplement to be mixed with other feed.

Views and experiences derived during the survey in the Western and Eastern Lowlands of Eritrea regarding the use of *Prosopis* as a livestock feed however do not mirror the positive accounts stated above. When asked how respondents themselves utilised *Prosopis* only those in Tesseney (81.8%, count 9) and Gahtelay (14.3%, count 1) mentioned its utilisation as a fodder source with no respondents in Akordet or Engerne using it as such. This does not necessarily mean that their animals do not use *Prosopis* as a browse. Free ranging animals can hardly be controlled in that respect, yet it becomes apparent that *Prosopis* is not viewed as a valuable feed source when it comes to its household utilisation.

To give some more insight into the status of *Prosopis* as a fodder tree one can also compare responses provided when the respondents were asked what they thought were the benefits of *Prosopis* (see graph 4.9. below in chapter 4.7): Only two respondents out of 37 mentioned *Prosopis* as a beneficial fodder resource. Although the big majority in Tesseney stated that they were using *Prosopis* as a feed base for livestock, when asked about *Prosopis*' benefits in another question it was not mentioned (and therefore perhaps not regarded) by them as a major benefit although multiple responses were encouraged.

Some more insight into the reasons that contribute to this phenomenon can be obtained by understanding the views that people have regarding the impact of *Prosopis* on their livestock. When asked about the effects the species has on their livestock the accounts given (multiple responses) were very negative. 100% of the respondents in the Western Lowlands (excluding 3 missing values of "don't know") stated that *Prosopis* caused symptoms of paralysation among animals, followed by 88.9% who claimed it caused injury by thorns, and 55.6% that it was poisonous to animals; the same number also stated it eventually caused the death of livestock. Yet, it is hard to control the feed intake of freely

roaming animals and therefore the ever-green *Prosopis* shrubs have remained as an animal browse, which was acknowledged by respondents in Tesseney.

A few respondents noted that *Prosopis* causes reduction in milk production in animals and that it leads to life-long illness, internal organ damage and diarrhoea. There were also references made to newborn livestock which were reported to be born paralysed if the mother animal had eaten a lot of *Prosopis*, which occurred particularly in donkeys. It was also reported that camels were in general quite resilient towards thorns from other plants, but were suffering under the effects of *Prosopis* thorns, which cause infection.

Interestingly, the effect of paralysation was not a concern to respondents in the Eastern Lowlands and no one made a reference to such symptom. There, the effects of plant toxins and death were the main concerns, while injury by thorns was generally less of a problem.

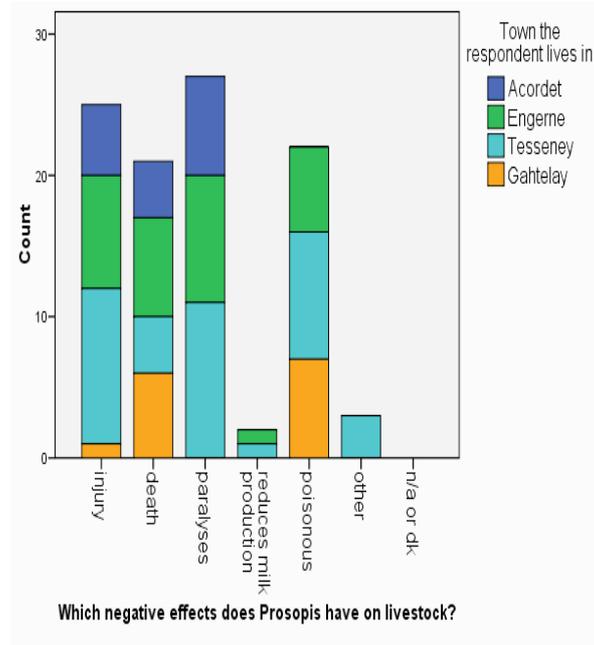
In literature, references reporting paralysation among animals feeding on *Prosopis* have not been found. It was however stated that Topical 1% juliflorine - an antimicrobial alkaloid found in *P.juliflora* - had no lethal impact on rabbits during testing, but that it led to irritation and inflammation, lethargy, prostration and weakness in the animals (AQEEL *et al.* 1991 in PASIECZNIK *et al.* 2001, p.100). These effects could maybe be viewed as a sort of “paralysation” in the animals, as they are unable to move.

Similar references were also made to wild animals eating *Prosopis*. It was stated that especially monkeys like eating the pods causing change in their behaviour. According to respondents, monkeys “used to run fast” and “on occasions they were attacking livestock”. However, mesquite made them sluggish (slow), unable to run fast or to hunt livestock. Monkeys were even reported to be too lethargic to make their usual sounds.

Research in the Western Lowlands of Eritrea demonstrates that local perceptions stand in direct contrast to international research (compare chapter 3.4.4) which suggests that pods are highly nutritious, well digestible and generally palatable to livestock, while the leaves are relatively unpalatable, but nevertheless used widely as an alternative browse during the dry season. Respondents in Eritrea believe that ‘fruit’ (i.e. pods) are the primary cause of harm to livestock, including illness and death, followed by thorns which cause external injury, with negative effects from leaf consumption only the third most frequently mentioned problem.

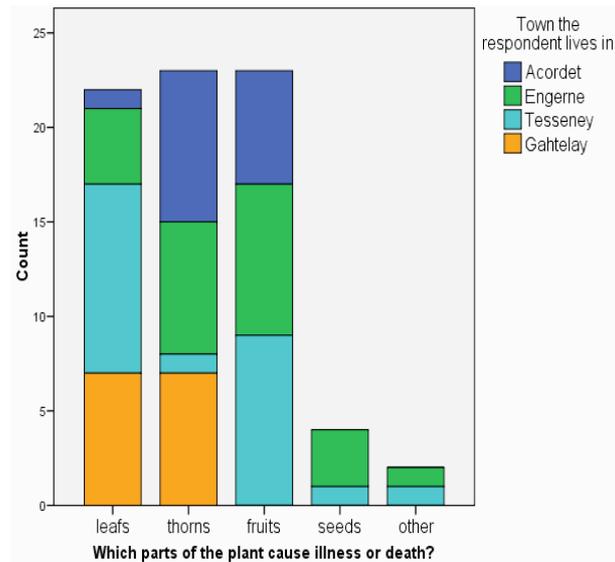
Graph 4.5: Perceptions of negative effects of *Prosopis* on livestock (by project site)

Furthermore, while concern with regard to leaves and thorns varied slightly (respondents in Akordet expressed hardly any concern regarding leaf consumption, while those in Tesseney were little concerned about the impact of thorns) there was much less variation in the perception that consumption of pods is harmful across all three sites in the Western Lowlands.



Graph 4.6: Plant parts perceived to cause injuries and death (by project site)

Research on the utilisation of *Prosopis* as animal feed elsewhere suggests that the quantity of pods consumed by animals is a crucial factor regarding the effect on animal health. Illnesses and death have been reported when pods were fed as a sole substitute to little other feed. However, most of these reports are the result of



research trials where animals have been fenced in and are given feed portions. Although it does give an insight into possible effects and symptoms in a highly controlled environment, such trials do not exemplify the general conditions on the ground. Livestock management in rural Africa - including Eritrea - is very much based on free roaming with little supervision as to the quantities of a particular feed that is consumed; therefore this kind of research - unless integrated into concrete livestock management alternatives - may bear little relation

to the daily concerns of livestock owners over illness and death caused by *Prosopis* among free browsers.

It was also claimed by the respondents that livestock that was eating too much of either *Prosopis* pods or leaves went through different health stages: at first they seem healthier and gain in body weight then they lose weight, while over a longer period the health of the animals slowly deteriorates “just as it does with AIDS” and finally the animal would either become paralysed or die. A similar account - although also less extreme - was made by LAXÉN (2005) in New Halfa in Eastern Sudan where villagers reported that livestock was not gaining weight which was seen as an indication that animals there had consumed a slightly higher degree of *Prosopis* in the diet than those in the Gandato Scheme area, which showed weight gain (LAXÉN 2005, p.55).

One statement that has been made by several respondents in both the Western and the Eastern Lowlands is the fact that livestock was unsellable or could only be sold at a cheap price at local livestock markets when the buyer found out that the animals had either eaten *Prosopis* or had recently been in a *Prosopis* infested area. The main concern for the buyer was that the animal would soon suffer ill-health as a result of it.

A similar result was recorded in Kenya where the Ilchamus community reported that the meat of livestock could not be sold due to the bad taste of the meat as a result of *Prosopis* consumption (BBC News report 2006; UNEP 2004).

Respondents in Eritrea also expressed that *Prosopis* thorns caused a major problem to both livestock and humans. Not only was the chance greater to inflict injury by *Prosopis* thorns than by those of other thorny plants because *Prosopis* branches hang very low to the ground, but the structure of the thorns was reportedly such that it was “not an additional part of the branch” by “sitting on it”, but that it was “rooted inside the branch” making it much stronger and also much harder to get rid of. Respondents also claimed that the thorns were toxic and that the injuries it inflicted cannot be healed with the same remedies that are usually used for injury through thorns. Instead, the locals have found new ways of treating injury by *Prosopis* thorns with *Prosopis* leaves which they grind and then apply to the wound.

In the Sudan, LAXÉN (2005) came across similar reports on thorn injuries and increased infection, but hospital staff explained that infection was primarily the

consequence of poor hygiene (LAXÉN 2005, p.90). Yet, respondents in Western Eritrea insisted that *Prosopis* thorns were poisonous leading to infection in both humans and animals, which does not occur with thorns of other species.

A rare account similar to that by the Eritrean respondents included in an IUCN report (2001) on Rajasthan (India) testifying that “its [*P.juliflora*] thorns cause dangerous infections”.

DUKE (1983) has also stated that “the thorn from mesquite [*P.juliflora*], on penetrating the eye, causes more inflammation than expected from the physical injury. The irritation may be due to waxes. Injection of cerotic acid is destructive to the eye [...]” and he adds that the “Amerindians” applied the *Prosopis* leaves for conjunctivitis (DUKE 1983).

This shows that such reports do exist elsewhere and that communities in Western Eritrea who apply *Prosopis* leaves to treat the infected area had adapted (through introduction of indigenous knowledge or the independent development of local knowledge) methods that the “Amerindians” who live broadly in native *P.juliflora* habitats use.

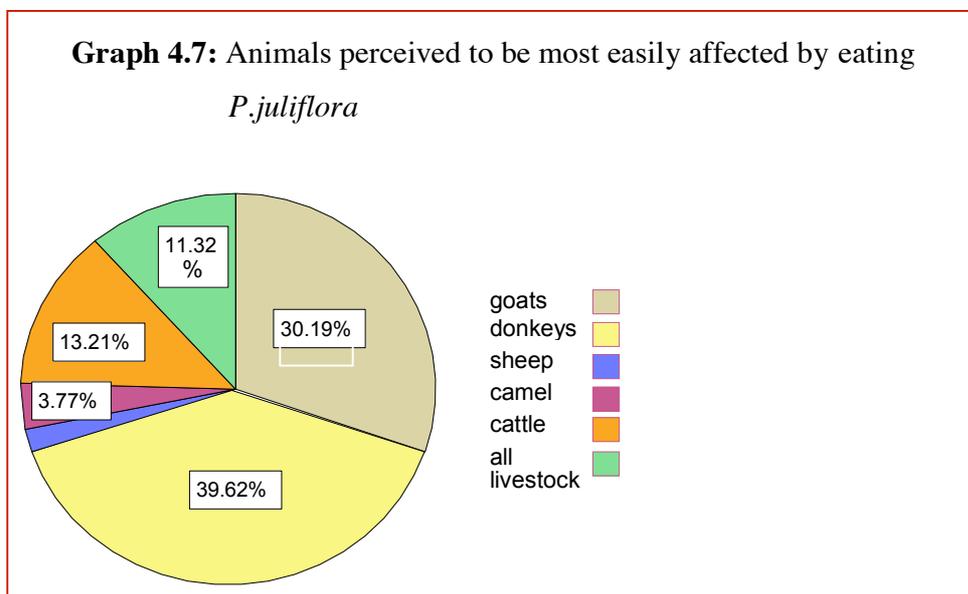
The method to apply *Prosopis* leaves however seems not to be a familiar one in the Eastern Lowlands where respondents similarly claimed that thorns were toxic and hard to heal. They reported that the only effective method of healing was by applying ice (which is not always available, but which can sometimes be found at local beverage huts where water and other drinks are cooled with ice).

Respondents further stated that owners who notice that animals have been affected by *Prosopis* will try to lead them away from the *Prosopis* area for recovery. It was stated that animals that were weakened or had fallen ill as a result of *Prosopis* consumption were usually able to recover if the owner was keeping them in a *Prosopis*-free area over a period of about three months.

Negative reports on the effect of *Prosopis* on livestock also included thorn injury to the udders of lactating animals which caused significant proportions of milk to escape from the animal through the puncture. A decrease in milk production was also reported as a result of animals browsing on *Prosopis*, as well as a change in the taste of the milk to a bitter flavour. In contrast, research suggests that *Prosopis* pods actually improve milk production while “no effects on milk flavour were noted at less than 50% pods in the ration, though as a sole feed some taste change has been suggested” (SILVA 1990b in PASIEZCNIK 2001,

p.89). In relation to milk flavour, the challenge would lie in the fact that monitoring the rations consumed by free-roaming animals is almost impossible.

According to the respondents (nearly 70%) in both the Western and the Eastern Lowlands, donkeys closely followed by goats were clearly the most easily affected as a result of feeding on *Prosopis*. Cattle was relatively resilient while camels and sheep were less easily affected, some even claimed they were resistant. Nevertheless, over one-tenth of respondents believed that all livestock was equally affected.



However, these findings also contrast to outcomes from other sources. While PASIECZNIK *et al.* (2001) for example also suggest that *Prosopis* is unpalatable to horses (which belong into the same family as donkeys and mules) he states that palatability was better for goats (which were considered very sensitive by the Eritrean respondents) followed by sheep and less compatible with camels (which again were considered relatively resilient) (PASIECZNIK *et al.* 2001, p.95).

Interestingly: although the sequence in resistance levels in animals provided by the respondents in Eritrea does not entirely mirror the references made in other research documentation, it does however seem to correlate with levels of the animals' ability to break seed dormancy probably by the action of stomach acids. According to PASIECZNIK *et*

al. (2001) cattle and goats have the most beneficial effects on seed germination (making them also the most effective distributors of *Prosopis*) while ingestion by sheep, camels and pigs was reported to lead to reduction in seed germination (HARDING 1991 and DANTHU *et al.* 1996 in PASIECZNIK *et al.* 2001, p.78). Similarly, earlier records also suggested that seed germination was 82% with horses, 69% with cattle but only 25% with sheep (MOONEY *et al.* 1997 in PASIECZNIK *et al.* 2001, p.126). Both references have the same sequence for animals' ability to break down seed dormancy as the sequence provided by respondents in Eritrea regarding the resilience of animals towards *Prosopis* feed. Horses, cattle and goats showed the highest levels of breakdown in seed coats (triggering high seed germination), but were the ones least resilient to *Prosopis* feed, whereas camels and sheep demonstrate a very low ability to break down seed coating (with reduced seed germination following ingestion) and are reported to be least affected by eating the plant. This suggests that there may be a scientific correlation between the two and that the breakdown of seed coating affects animal health. This however would need to be looked into by veterinaries and so far it seems that no innutritious or toxic elements have been found in *Prosopis* that could cause such harm during seed coat breakdown, as PASIECZNIK *et al.* stated that "no significant quantities of antinutritional factors have been isolated from *Prosopis* pod fractions (e.g. Rajaram and Janardhanan 1991, Vijayakumari *et al.* 1997)" (PASIECZNIK *et al.* 2001, p.87).

As previously discussed the cause for illness and death among livestock that were on a solely *Prosopis*-based diet was recorded to be due to ruminal impaction caused by pods, which have been improperly digested (ABDELGAABAR (1986) in LAXÉN 2005, p.53). Both findings suggest that there is no correlation between the ability of an animal to breakdown seed coat and its resilience towards *Prosopis* or at least the parallel sequence observed above cannot be sufficiently explained at this stage.

Villagers in Kenya were also reporting death among their animals as a result of *Prosopis*, but under different circumstances: they claimed that many goats were losing their teeth as a result of eating the pods of *Prosopis*, which the locals call the "mathenge" tree. The loss of teeth is caused by the continuous chewing of the hard, sweet pods, which get stuck between the teeth causing tooth decay, and eventually the death of the animals, as they become unable to graze (BBC News Report, 07 August 2006, Kenya).

4.7 The Socio-economic Benefits of *Prosopis* in Rural Communities

While there has been some research on the health effects of *Prosopis* consumption for livestock, most international attention has focused on possible economic benefits. The utilisation of *Prosopis* and its related (mostly) economic benefits for rural households and communities is one of the key issues in the international discussion over *Prosopis* and its management. According to many researchers and practitioners the potential of *Prosopis* has not been fully realised by rural communities who could benefit economically. Therefore, the exploitation (utilisation) of the species is widely propagated among local communities by experts. Areas of utilisation include fire wood, charcoal, construction material, animal feed, planting within agro-forestry and soil regeneration projects or as a source of gum, wax, honey, human nutrition or medical remedy. Moreover, *Prosopis* wood has been widely praised as being of high density and durability, producing charcoal of good quality. Overall, the exploitation of *Prosopis* to the benefit and development of communities and as a measure of controlling its spread is the main approach that is currently being internationally pursued.

Respondents in the Gash Barka region and in the Gahtelay area of Eastern Eritrea gave an insight into the utilisation of the resource *Prosopis* - what is after all a free and widely available resource in a generally overstretched and fragile dryland system.

The key questions here were how respondents and their families themselves used *Prosopis* and which benefits they thought *Prosopis* was providing to their communities in general. The aim was to identify any discrepancies between the actual and the potential utilisation within households and areas where appreciation for *Prosopis* existed, which could be built upon in the future. For both questions multiple responses were encouraged.

There were huge differences in both the extent to which *Prosopis* was used in the four sites as well as what it was used for (which are somewhat related). While Akordet and Engerne - with a distance of only about 40 km from each other and a similar environmental make up - showed great similarities in this respect, it was the site of Tesseney (near the Sudanese border) which illustrated the biggest discrepancy to the other three sites by revealing a particularly high level of use. In Tesseney, respondents were using *Prosopis* on an average of 6.1 values, meaning that each respondent was on average using *Prosopis* for six different items or activities, as compared to Engerne and Akordet with an average of

only 1.3 and 1.4 values per respondent respectively, slightly exceeded by Gahtelay in the hot arid Eastern Lowlands with 2.1 values or items per respondent. This means in abstract terms that respondents in Tesseney make up to three times more use of *Prosopis* than respondents living across the highlands in the east of the country in Gahtelay and up to a staggering six times more than their counterparts living in the same region.

With this relative high level of utilisation occurs naturally also a high level of diversity as to how *Prosopis* is used in Tesseney. Respondents stated that they used it as fence or shelterbelt material, as fuel wood, charcoal, livestock fodder (as noted above), windbreaks, shade and construction (primarily for housing). Interestingly also there was a broadly equal distribution among all values meaning that there was no particular preference for using *Prosopis* for one thing above another.

The situation in the other three sites is very different. In Akordet and Engerne *Prosopis* was only used as a fuel wood resource, for charcoal, construction and fencing²⁸, with a clear majority using it solely as a source of energy.

In Gahtelay, there was clearly more variety, yet the majority only used it for fencing/shelterbelts and fuel wood, making Gahtelay the site where *Prosopis* the greatest variation regarding its qualitative and quantitative use within a single site.

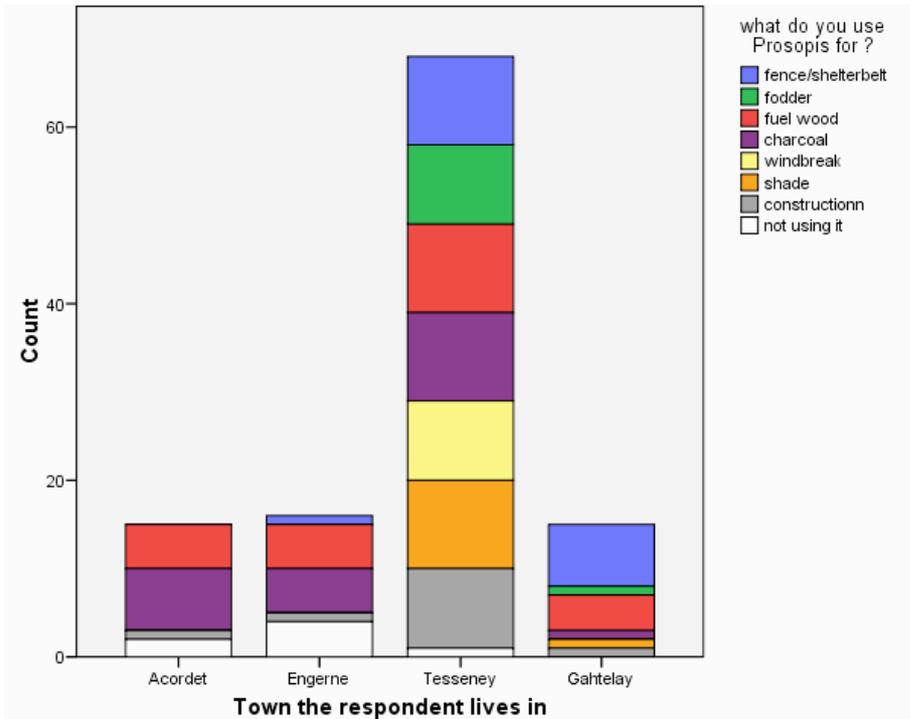
The highest relative number of people not using *Prosopis* at all was found in Engerne where almost half were not using it²⁹ followed by Acordet where about a quarter were not utilising *Prosopis*. In Tesseney only a tenth were not using it while in Gahtelay all of the people interviewed were using it, however with a high local variance in the manner of usage.

When asked which benefits are most valued, one might expect the results to reflect the distribution of values that were provided when asked what the respondents themselves used it for. Particular given that *Prosopis* is a freely available resource would support the assumption that people could use it for all those areas that they regard as beneficial.

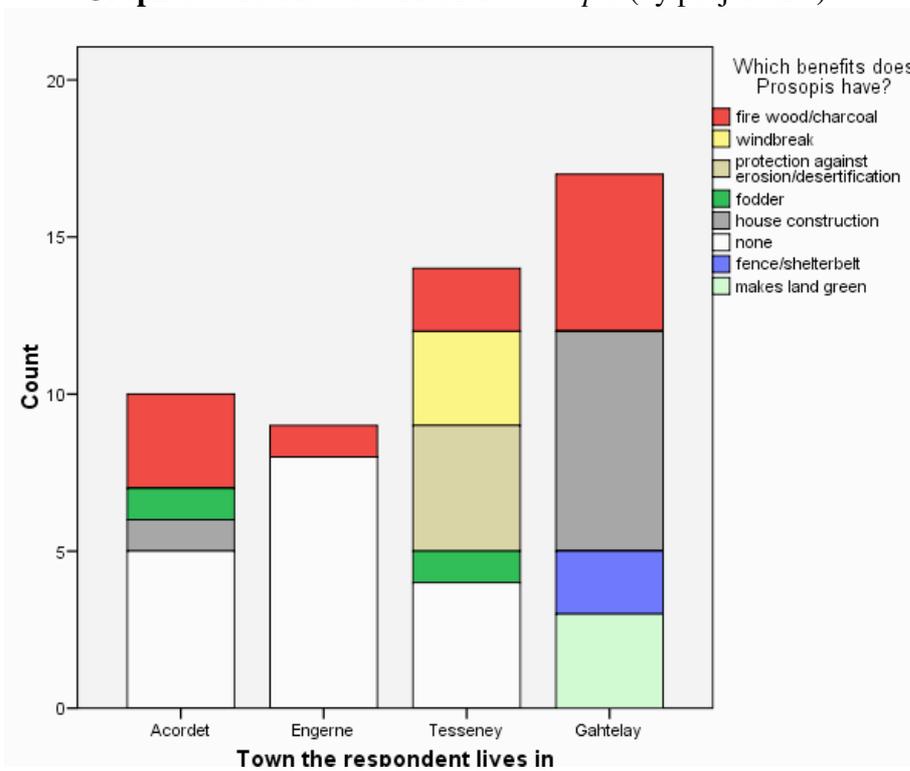
²⁸ This outcome is based on 18 interviews in the two sites only (see chapter 4.1. Survey objectives and methodology) and therefore it is not entirely representative and may be used in other areas also. Nevertheless the outcome mirrors the fact that high level of utilisation variety does not exist.

²⁹ based on actual number of respondents and not on multiple number of responses as presented in the Graph 4.9

Graph 4.8: Utilisation of *Prosopis* (by project site)



Graph 4.9: Perceived benefits of *Prosopis* (by project site)



Yet, the outcome is surprising, except for Engerne where the low level of utilisation is also reflected by the fact that most respondents feel that *Prosopis* has no benefits (in their view it is “completely useless”) and where the few respondents that do use it do so primarily for fire wood. The outcomes in the other sites however differ significantly from the outcomes that were retrieved when questioned about household utilisation of the species. Four findings are quickly evident:

- 5) Fire wood is the only area of utilisation that is viewed as (relatively) beneficial in all four sites (although some respondents claim the quality of fire wood was poor)
- 6) In the site of Tesseney only four (windbreak, fire wood, charcoal, and fodder) out of seven areas of actual utilisation are viewed as beneficial, although the benefits perceived are much lower than usage levels would suggest.
- 7) Gahtelay is the only site with an increase in positive responses regarding it as beneficial as fire wood and construction material in comparison to their relative usage levels in those categories, meaning that a relatively large number of people view it as useful in this regard, but do not actually use it for that purpose themselves.
- 8) A significant increase in respondents who consider *Prosopis* to be of no benefit at all has taken place, particularly in Tesseney where it is being extensively used. On the other hand, there was no such perception in the Gahtelay area where it is barely used.

These findings give a further insight into the generally negative perceptions of *Prosopis* in the Western Lowlands. Given their high usage, the finding in relation to Tesseney must be based on actual utilisation (experience) rather than hearsay. In Tesseney people seem willing or compelled to ‘stick with it’ although they do not consider it to provide much benefit. On average only *one* benefit was indicated per respondent although it is being used on average for *six* different items or activities per respondent. Akordet and Engerne are clearly the two sites where, in spite of abundant availability, local populations have decided that *Prosopis* has little value, and consequently they are not using it.

Although Gash Barka’s respondents all tend to view *Prosopis* to be of no or very little benefit, the considerable difference in the actual level to which *Prosopis* is used in

Tesseney in comparison to Akordet and Engerne could be due to a different ‘culture’ between the sites. By ‘culture’ one does not mean the traditional or inherited culture, but adapted ethos and views. Tesseney due to its proximity to the Sudan is a ‘melting pot’ of different groups, backgrounds, and skills. It is a focal point for traders, business people, refugees and returnees and as a result people are understandably often more open, acceptant, tolerant, diverse and adaptive in their habits and views than those who live in more ‘conventional’ areas and who are less exposed to exogenous groups, customs or information. Although one must be cautious in drawing conclusions too hastily across the board, anecdotal evidence from people who have worked, carried out research or implemented projects in all three sites confirms that it is much easier to bring new ideas into Tesseney and surrounding areas because residents tend to be more receptive to novelty, than is the case for inhabitants in areas far from the border or in more remote areas, who are generally a bit more reserved. More specifically, it seems that close cultural and trading links between Tesseney and the eastern Sudan, where *Prosopis* is abundant, have led to the adaptation of habits and techniques regarding the management of the species from across the border. The rather extensive use of *Prosopis* in Eastern Sudan as a freely available resource for local households has been recorded in detail by LAXÉN (2007), ELFADL (1997), ELSIDDIG *et al.* (1998) and others.

According to LAXÉN (2007) there was a higher dependency of poorer households on *P.juliflora* in Eastern Sudan, and the *Prosopis* shrub thicket provided them with an economic safety net, as they generated income by selling charcoal, fuel wood or poles, an outcome which was obtained on the basis of a very detailed household income analysis (LAXÉN 2005, p.92). The findings seem to differ from those obtained during the survey presented within this thesis for Eritrea: although this survey does not include variables on household income and respondents have been chosen randomly (therefore representing different income categories) the outcomes do not suggest that a positive correlation may exist between the level of use of (or dependency on) *Prosopis* and low household income. The reasons for this conclusion are:

- Tesseney shows notably equal distribution patterns with regard to how inhabitants are using *Prosopis* (see graph 4.8) (If there was a much higher dependency/utilisation of *Prosopis* among poorer households the outcome in Tesseney would be somewhat less homogenous).

- SOS Sahel & MoA (1999) claim that there is a slightly (but not significantly) higher dependency on riverine forests among poorer households. According to SOS Sahel & MoA the highest dependency (45-60%) on forest resources was found in the Akordet area where 30% belonged into this category, as opposed to only 2% of households in Gash for the same range of dependency. This would suggest that there are more poor households in the Akordet area than in the Tesseney area (which is situated near the river Gash). Yet, it was Akordet where *Prosopis* was hardly utilised as compared to Tesseney, which had relative high levels of *Prosopis* utilisation.
- When recording the average dependency on forest resources as a source of income for households in different social categories a slightly higher dependency on forest resources was noted among poorer households. However those differences were not significantly different with an average of 32% of poorer households depending on forest resources (although in some sites it was above 50%), 25% of middle-income households, and 23% of well-off households (SOS Sahel & MoA 1999, p.20), which indicates that there generally exists a relatively equal utilisation pattern of natural resources among all households.

The above is an indication for insignificant or no difference in the utilisation of *Prosopis* by different income categories in the Gash Barka region of Eritrea. While *Prosopis* is potentially a source of income generation, particularly for poorer and landless households (compare e.g. the case of Eastern Sudan as presented by LAXÉN 2007), communities living alongside the river Barka in Eritrea's western lowlands do not share this view and have made it clear that they consider *Prosopis* generally as 'useless'. The reason is probably directly interlinked with the high riverine forest dependency of those communities for their livelihoods. Especially poorer households show a high level of dependency on forest resources. *Prosopis* - which is invading riverine forests at a fast rate - is viewed as a serious threat to those resources and to their livelihoods. This may be a further explanation as to why the sites of Akurdet and Engerne - where dependency on forest resources is, according to SOS Sahel & MoA 1999, particularly high - show the most negative perceptions towards *Prosopis*, resulting in a low level of use.

Therefore in the case of communities living in proximity to riverine forest resources in Western Eritrea one can broadly summarise that the poorer the household, the higher its

dependency on riverine forest resources, and as a result the higher the aversion to *Prosopis*, which in turn results in a low level of utilisation.

Another case to affirm that there is no positive correlation or broader link between low income categories and *Prosopis* utilisation are experiences reported by inhabitants of the IDP-camp in Adi Keshi situated near the main route between Barentu and Haikota. These people are usually landless as they are refugees who have been living in camp settlements since their displacement during the 1998-2000 border war with Ethiopia. They therefore clearly belong to a poorer social category or a low income category. But even in the refugee camp people reportedly felt that *Prosopis* was “relatively useless for wood fuel and construction...” and allegedly “poisonous to livestock”. (KIBREAB & NICOL 2001, p.26).

This example shows that any promotion of *Prosopis* by international experts as a potentially valuable source for rural communities needs to be addressed with greater concentration on local realities, including perceptions that may be inconsistent with research evidence of potential health or economic effect.

4.8 Experiences Regarding the Invasion of *Prosopis* inside Settlement Areas

Settlement areas were identified as a prime habitat for *Prosopis* in Eritrea in chapter 3.3.1. While one may assume that the negative impact of *Prosopis* within settlements is minor as it does not directly interfere or compete with any form of productive system such as agriculture or rangelands, survey respondents also expressed major concern about the consequences of *Prosopis* invasion in their settlements.

100% of respondents claimed that *Prosopis* was growing in their settlement area. Respondents in Engerne said it had become a major concern. Shrubs were growing around the houses and huts and on roofs where they have become hiding places for snakes including particularly dangerous species (called *aselet* locally). The reptiles hide in the shrubs and are reported to have been increasingly found in houses. Respondents made verified reports of women and families who had been victims of snake bites in their homes.

It was also said that *P.juliflora* was growing so densely in some places that people and livestock had difficulties accessing their settlement area.

In the case of Gahtelay *Prosopis* has invaded the settlement and the areas around it so densely that respondents claimed the species was the reason for a limited settlement expansion in their village. The tree was expanding faster than the village and where it had established itself it was difficult to clear the area to build new houses. Even when it had been cleared for house construction it quickly re-grew around the new houses.

One father described the story of his son who was injured by a *Prosopis* thorn a few years ago, which then got infected so badly that he stayed out of school for a year. The area between the village and the school is infested by *Prosopis*, so his son was scared to go to school again. This was just one example, the respondent said, that showed how *Prosopis* in the settlement area of Gahtelay was impacting on its inhabitants.

The greatest concerns about the infestation of *Prosopis* within settlement areas were expressed in Engerne and Gahtelay. These are relatively small settlements where physical improvements such as asphalt roads, paved areas and bigger buildings are non-existent, making it easier for *Prosopis* to establish itself in the un-compacted earth.

Furthermore, community reports from Eastern Sudan and Kenya (Baringo area) have suggested that there was a significant increase in malaria cases as result of *Prosopis* thickets (MWANGI 2005, p.42; LAXÉN 2005, p.89). This causes a public health risk that would need to be assessed in the case of Eritrea where respondents did not mention an increase of malaria in the context of *Prosopis*.

4.9 General Attitudes, Perceptions and Experiences Regarding *P.juliflora*

An obvious majority in the sites of Akurdet and Engerne undoubtedly consider *Prosopis* to be a pest. This view reflects also the statements presented earlier, in which an overwhelming majority of respondents in the two sites claimed they were hardly utilising *Prosopis* and considered it as being of little or no benefit at all.

The opinion in both Tesseney and Gahtelay is markedly different, where a sense of indecisiveness and ambiguity could be observed when asked if they considered *Prosopis* a pest or a useful tree. The majority in both sites considered it neither as a pest nor as a useful tree, with an equal number in Tesseney unable to give a response to the question at all. This indecisiveness is also mirrored in survey outcomes presented earlier, where the distribution

pattern regarding the actual utilisation of *Prosopis* in both sites did not repeat itself when respondents were asked about the benefits of the plant. Their response showed that they use *Prosopis* for certain activities, particularly as construction material or livestock fodder, but that these were actually not viewed as genuinely beneficial.

Table 4.5: Do you consider *Prosopis* to be a pest or a useful tree?

	Do you consider <i>Prosopis</i> to be a pest or a useful tree?			
	Acordet	Engerne	Tesseney	Gahtelay
	Count	Count	Count	Count
pest	8	9	2	1
useful tree			1	
neither	1		4	6
n/a or dk			4	

During interviews respondents felt very strongly about the negative impacts of *Prosopis*, (particularly in Engerne) and they used the opportunity during the interviews to freely express their views. Some added information and contextual comments while others seemed very emotional and some even extreme in expressing their views. A collection and presentation of these views seem essential to demonstrate a) the immense gap between the ‘*Prosopis*-portrait’ presented by many experts on the one hand and views and experiences represented by (some) local communities on the other, b) the challenge that lies ahead in incorporating such negative views into effective *Prosopis* management, planning and implementation efforts including the active participation of the communities affected, and c) the need for researchers and practitioners to review or at least differentiate between some of their management and control approaches (which may not have validation for all semi-arid rural communities). The personal views on *Prosopis* provided by respondents included the following:

- ✚ “*Prosopis (temer musa*³⁰*) is a colonisation without weapons.*”
- ✚ “*Prosopis should be our second enemy; the government should shift to Prosopis once they have dealt with the Ethiopians*”³¹

³⁰ *Prosopis* is known to the respondents as *temer musa* (Tigre) or *temri musa* (Tigrinya). Compare chapter 3.2 for more details on the local nomenclature.

- ✚ “*Prosopis* can even grow on stone.”
- ✚ “*Prosopis* grows everywhere, we are sometimes not even sure if it also grows in our brains.”
- ✚ “Anyone who wants [promotes] the utilisation of *Prosopis* should be our enemy. We only need its destruction.”
- ✚ “If we had the power to do so we would destroy *Prosopis* overnight.”
- ✚ “*Prosopis* should be planted at the border between Eritrea and Ethiopia to protect us from each other. For us, this could be the only thing that’s useful.”
- ✚ “We [respondents in Gahtelay] used to love green colours before *Prosopis* but now we hate it due to the impact *Prosopis* has”.
- ✚ “For me the dry trees are better than a green killer.” [Gahtelay]
A similar community attitude also exists in other parts of the world. Locals in Rajasthan (India) for example “believe that trees have souls but people need to cut trees to survive; however it is not a sin to cut *P.juliflora*.” (IUCN 2001, p.149)
- ✚ “This *Prosopis* is like the HIV/AIDS epidemic.”

Considering research documents that report a wide range of realised or potential benefits of *Prosopis* for local communities, the views expressed above by rural inhabitants in Western Eritrea seem very extreme. Similar comparisons have nonetheless also been reported from Ethiopia, where rural habitants, too compared it to the war (SOS Sahel film on pastoralism in Ethiopia 1996) and others to a punishment by Allah (“yeAllah kuta new”) (SHIFERAW 2004, p.2)

Where does this leave practitioners and policy makers in the case of Eritrea and the necessary management of the issue? It seems yet another challenge lies ahead: although people are using *Prosopis*, only a few have actually accepted during interviews that they regard it as a useful source of fuel, fodder or similar. The high level of negativity pertaining

³¹ The comment refers to the recent Eritro-Ethiopian border war 1998-2000 and Eritrea’s current relations with Ethiopia. Although a peace agreement was signed in May 2000 by both parties and a cease fire has since been agreed, relations between the two countries are still very hostile with Ethiopia refusing to accept a key decision of the UN’s International Border Commission to grant some of the disputed territory to Eritrea. The matter is still ongoing and the re-eruption of armed conflict remains a risk.

to *Prosopis* amongst respondents also suggests that management will be made more difficult by the high general level of antagonism expressed towards the plant.

Yet it seems that many respondents are basing their views not on ignorance or a lack of experience, but on the species' failure to deliver demonstrable benefit. The following comments further demonstrate this view in the lack of beneficial qualities, thus defying the 'exploit-*Prosopis*-and-you-shall-benefit'- argument:

- ✚ “**Fuel wood and charcoal** made from *Prosopis* is of poor quality.”
- ✚ “*Prosopis* **charcoal** is not good; it has no power and it spreads sparks”
- ✚ “If we use *Prosopis* for house **construction** its wood soon turns into powder. The powder pours down on people who get skull sickness from it. That is also another problem.” Although references in this regard seem very rare DUKE (1983) similarly states: “Using the wood in a fireplace has caused dermatitis, as has working with seasoned wood.”
- ✚ “*Prosopis* cannot be used for **fencing** because its thorns hurt people and livestock as it soon dries up and left are only the thorns on your fence. So we stopped using it soon.”
- ✚ *Prosopis* is useless for **shading**. As it grows down to the ground people have no way to enter inside. Its thorns are poisonous so people go away from it. It is also dangerous as it hosts animals like snakes.

It is somehow unanticipated that so many comments were made by the respondents about the poor quality of *Prosopis* when used for socio-economic activities, particularly in the view of international research trials that have praised wood derived from *Prosopis* to be so hard that it is “comparable to the finest hardwoods” (SERTSE, 2005, p.2); other trials using a range of species found that *P.juliflora* and *P.alba* were the most promising due to high biomass production and good energy value. *P.juliflora* had the highest fuel wood value index (FVI) (GOEL & BEHL 1996, p. 58/59)³². Detailed and above all objective research trials (that take the local environmental conditions into account) would need to be

³² More details on those trials and *Prosopis* wood quality can be found in chapter 5.3: Maximising the Potential of *P.juliflora* within Rural and Urban Economies

conducted on the wood and charcoal quality of *Prosopis* in Eritrea to confirm or dismiss some of the experiences shared by respondents, observations and further social survey could also shed more light into the validity of such accounts. Nevertheless, it still remains the case that any proven scientific outcomes may still not change the perceptions or experiences on the ground of rural communities towards the poor quality of *Prosopis* and its inability to deliver at least partially. Again, this view seems also represented in other rural communities, as an IUCN report (2001) reports from Rajasthan (India): “Village people often contrast *A.nilotica* with its multiple uses to *P.juliflora* which is only good ‘for burning’” (IUCN 2001, p.149).

These views may be based on facts - in the given local environmental context that may not have been taken into consideration by laboratory based research - or more of a subjective view founded on the many extremely negative encounters people are facing with *Prosopis*. This means that even if, for example, the wood quality was excellent, general experiences towards *Prosopis* are so negative that people are oblivious towards anything that may actually be useful. Considering the large number of research trails that have demonstrated that *Prosopis* has many beneficial attributes, it seems that the latter is at least partially the case, unfortunately, in a management context such strong subjective perceptions are often not to be changed by the presentation of scientific facts alone.

4.10 Views on Management and Action Plan Efforts

In view of the broadly negative experiences, standpoints, and perceptions towards *Prosopis* in the rural context of Eritrea any management plan that seeks to tackle the issue by means of control rather than the very costly zero tolerance (eradication) approach will need to meet the ‘challenge of reason’ when working with the communities affected.

What are the views among some of the rural communities regarding the management of *Prosopis*? An overwhelming majority in all sites would simply like to see it completely eradicated by the government, with the main reason being that *Prosopis* was destroying the native vegetation. Mobilisation of the rural communities by the government to assist the eradication process was suggested by some.

Table 4.6: Would you like the government to eradicate it?

	Would you like the government to eradicate it?							
	Acordet		Engerne		Tesseney		Gahtelay	
	Count	%	Count	%	Count	%	Count	%
yes	8	88.9%	9	100.0%	10	100.0%	7	100.0%
no	1	11.1%						

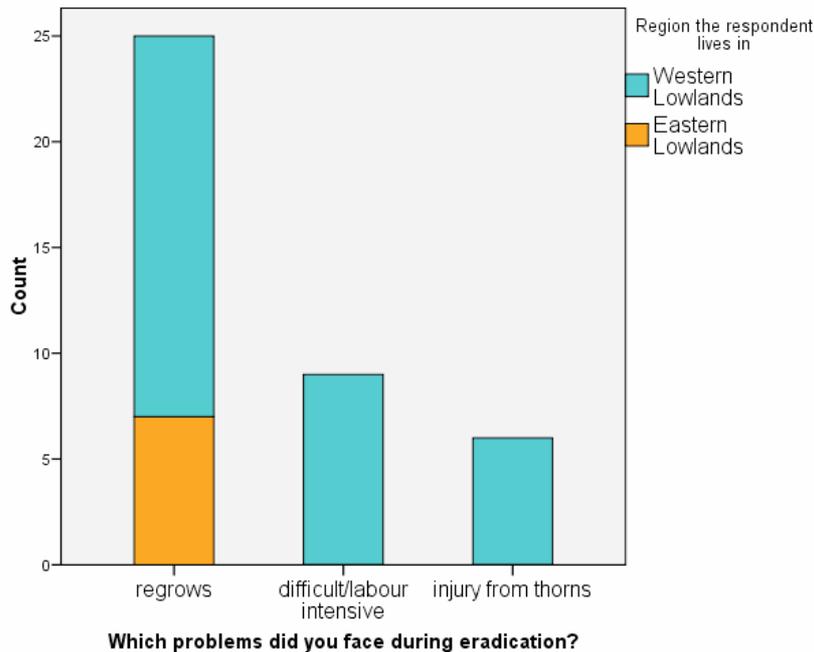
Table 4.7: Did you ever try to eradicate *Prosopis*?

	Did you ever try to eradicate <i>Prosopis</i> ?							
	Acordet		Engerne		Tesseney		Gahtelay	
	Count	%	Count	%	Count	%	Count	%
yes	6	66.7%	7	77.8%	8	72.7%	7	100.0%
no	3	33.3%	2	22.2%	3	27.3%		

Given the immediate urgency of the issue for many, a majority has also taken matter in their own hands and have attempted to eradicate *Prosopis* from their area including crop, grazing land and settlements. A couple of well-off respondents have personally invested considerably large sums of money into eradication. A farmer in Tesseney said he had invested 150,000 Nfa and another one in Gahtelay 100,000 Nfa³³, which was more than he had ever invested into his farm activities. But all attempts came to no avail. The eradication of *Prosopis* was labour and cost intensive, but it simply re-grew after a while (respondents made animals responsible for re-growth in areas where it had been eradicated). Some of those who have never attempted its eradication explained that the difficulties during the process (such as labour and injuries) and the failing success rate were the main reasons for never having tried to eradicate it themselves. Among those who had attempted just cutting it, it was claimed that *Prosopis* was already re-growing after a week. Others have implemented a more intensive eradication method: Farmers said that they were digging around the *Prosopis* roots trying to cut them and dig them out as much as they could. In a second step they would extend the digging area and put fire or charcoal on it for the roots further down to burn out. This method however is very labour intensive and needs to be repeated several times on the same plant to be potentially effective.

³³ This is the equivalent of US\$10,000 and US\$6,670 respectively.

Graph 4.10: Problems faced during eradication?



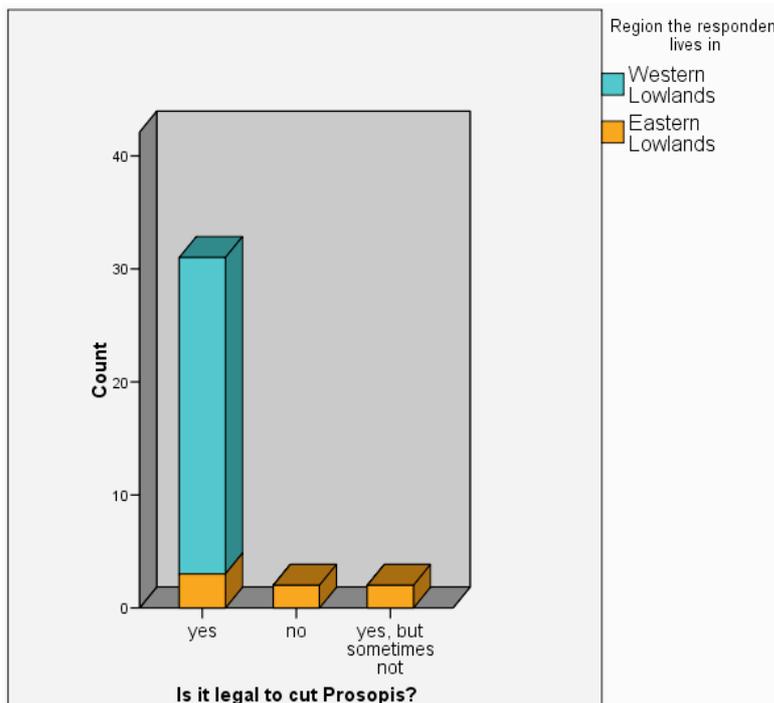
So far however, the government and related ministries (namely the Ministry of Agriculture and the Ministry of Land Water and Environment) have shown little initiative. There was an attempt by the local administration in Engerne who introduced a food for work programme for *Prosopis* eradication around 2001-2003. Respondents state that many people participated, but that the activity inflicted many injuries by thorns and that it was not successful. *Prosopis* simply re-grew while the project was still ongoing.

Some management and research plans have been made by the related ministries, but little has materialised and the only measure in place up to this date - and this may not even contribute to the control of *Prosopis*' spread - is the approval for the cutting of *Prosopis* wood from live trees, an absolute exception in Eritrea where cutting of live trees for energy purposes is strictly prohibited for conservation purposes. Permission to cut *Prosopis* live trees is clearly given in the Western Lowlands. All respondents there confirmed it and so did the director of the local Forestry department in Akordet during field visits.

Plans for research, assessment and eradication of *Prosopis* around irrigation schemes had also been mentioned by staff of the MoA and the MoLWE, but no concrete management or project activities seem to have commenced to date.

The situation is different in Gahtelay where there seemed to be some confusion among the respondents over the policy, with most claiming cutting was permitted; a few claiming it was generally allowed, but there were periods when it was actually prohibited; and others maintaining that it was not allowed at all. This suggests that there may be a need for a clearer local policy in the Gahtelay area in this regard.

Graph 4.11: Is it legal to cut *Prosopis*?



Finally, given the apparent urgency of management action that considers the range of challenges that need to be addressed in such a process, respondents were asked if they were willing to learn about (and be trained in) certain areas regarding the utilisation of *Prosopis* that may be beneficial to their households and communities. Usually, rural communities embrace education and training when they feel it empowers or benefits them, but only a small minority was happy to learn about any potential benefits of *Prosopis*. Some respondents explained that *Prosopis* had more disadvantages than advantages and therefore eradication would be the appropriate step. Others said that it would take too long to educate people about the benefits of *Prosopis* and that the plant would have spread everywhere by then.

Table 4.8: Willingness to learn about the benefits of *Prosopis*

	Would you like to learn about the benefits of <i>Prosopis</i> ?			
	Acordet	Engerne	Tesseney	Gahtelay
	Count	Count	Count	Count
yes	1	1	3	1
no	7	8	6	2
n/a or dk	1		2	4

A similar observation has also been made by BLOESCH (2001) who engaged in discussions on *Prosopis* with inhabitants in Engerne to assess the local energy situation. He states that “the men were not open to discuss any possible use of this plant and gave only the following negative characteristics...” before he presents a list including statements very similar to those that have been presented in this study. The only additional statement presented was that *Prosopis* wood was easily attacked by termites (BLOESCH 2001, p.16).

These attitudes will be a major challenge in the management of *Prosopis* and emphasise the degree to which a planning and implementation process must prompt local cooperation, which is crucial for success. The strength of the call for eradication contrasts sharply with ‘control’ as a potential leading management approach. But given the immense amount of investment that would be needed to eradicate *Prosopis* through the use of heavy machinery (which still does not guarantee a long-term success rate), mechanic eradication will have to remain as a limited measure reserved for small areas, with the possibility that other less conventional methods (e.g. bio control) might be found and integrated.

Until then, implementers of the *Prosopis* Management Plan will need to open a dialogue with rural communities, develop local skills and raise awareness about what can and what cannot be done on the issue. Starting with a small group of people who are willing to learn and to use demonstration techniques might be appropriate in trying to tackle the defiance of the communities to learn.

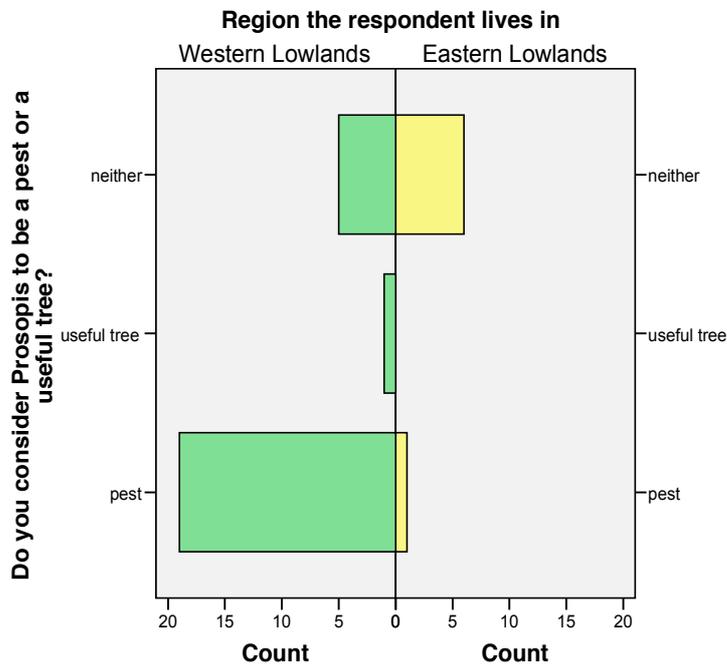
4.11 Perceptions of *Prosopis* in the Semi-arid Western Lowlands vs those in Arid Eastern Lowlands

Many experts argue that *Prosopis* causes a great deal of damage in semi-arid areas where it invades agricultural crops, grazing areas, rangelands and local forests, that it is however of immense importance to people in very hot arid areas, where land production is low and vegetation cover scarce. Forestry and land experts in Eritrea support this view and many have expressed that *Prosopis* can potentially be of benefit to rural communities, somewhat less in the Western Lowlands but surely in the Eastern Lowlands where it does not compete with local production systems and where natural resources such as fuel wood and animal browse are scarce. This view was widely upheld among local experts and overall verified by international research. This led to the presumption (hypothesis) by the author that views on *Prosopis* were cautious and utilisation constrained in the Western Lowlands (as observed during earlier field visits) while attitudes in the semi-desert of the Eastern Lowlands were more positive and its presence appreciated as a beneficial resource.

The previous chapters presenting the views, experiences and consumption of the local community in Gahtelay however have clearly demonstrated that the plant was not at all welcome. The arid area of Gahtelay showed hardly any differences in the level of people's appreciation or utilisation of *Prosopis* as compared to communities in the semi-arid Gash Barka region. In fact, at times Gahtelay came behind the site of Tesseney, for example regarding the actual level of use of *Prosopis* or the preparedness to learn more about *Prosopis* benefits if education or training were on offer.

The only area where Gahtelay met expectations was that they considered more *Prosopis*-related activities (such as house construction) to be beneficial than communities in the west. In the view of such benefits respondents in Gahtelay did not dismiss *Prosopis* as a pest, but felt to some extent ambiguous towards it, suggesting it was neither a useful tree nor a pest. But even on those grounds all respondents stated that they wanted to see *Prosopis* eradicated by the government clarifying that it actually was seen more of a pest than a useful tree.

Graph 4.12: Do you consider *Prosopis* to be a pest or useful tree?



The key concern for respondents in Gahtelay was the same as for those in the other three sites: the degradation and dwindling of the native vegetation including grass species under the presence of *Prosopis*. Gahtelay has very scattered bushland savannah vegetation of xerophytes set in a broadly barren, rocky and partly sandy land area, yet respondents made it obvious that the disappearance of the few native plant species within those dryland grazing areas was their greatest concern. Respondents mentioned that *Prosopis* was also growing further east around the port of Massawa where aridity further increases and *Prosopis* stands form the only green spots during the dry season. Massawa is set within an extremely hot and arid environment with a high occurrence of sandy lands. Yet according to respondents in Gahtelay even there *Prosopis* was generally not welcome and was competing with native mangroves at the coast under the direct influence of sea salt water.

Research trials and community projects have shown that *P.juliflora*, which is being used in arid lands to stabilise shifting sand dunes showed very high survival rates. GUPTA & SHINGH (1997) for example, reported that *P.juliflora* used for the same purpose in the Thar desert (India) had a survival rate of 91%. It out-performed all other tree species in height and crown diameter. *Acacia tortilis* was second best performer, but compared to *Prosopis* had a height of 42% less than that of *Prosopis*. Interestingly, while survival on sand dunes improved for most tree species when mulching treatments were applied, it had

no significant influence on the survival rate of *P.juliflora* and *A. tortilis* (GUPTA & SHINGH 1997, p. 207-209).

However, although high survival rate of *Prosopis* is widely acknowledged some sources reveal the tendency of forestry experts to disregard valuable native species that could deliver similarly well. An article in the Sudan Vision Daily states in this respect: “Though there are potentially viable native alternatives to mesquite [*P.juliflora*], their use in new dune stabilisation projects has been limited to date. It is therefore recommended that greater investment be made in researching the potential of native plants and trees, and capitalizing on indigenous knowledge in environmental rehabilitation and desertification control. Some of the promising native plant species include *Tamarix aphylla* (Tarfa), *Leptadenia pyrotechnica* (Markh), *Salvadora persica* (Arak), *Imperata cylindrica* (Halfa) and *Capparis decidua* (Tundub).” (Sudan Vision Daily article, 1st March 2008).

The case of Gahtelay confirms that even communities living in dry desert ecosystems may still not value *Prosopis* simply on the basis of a scarce locally available natural resources base. For them the loss of their indigenous dry plants to a *Prosopis* monoculture is of great concern - even under the aspect of slower regeneration and biomass productivity of native species. Future research into well-performing native species and their use in related forestry and sand stabilisation projects could be a possible answer. Even if performance is relatively low compared to *Prosopis*, native species have several other benefits. They would also improve accessibility to land and settlement (as native species do not form inaccessible thickets) and protect the native vegetation, biodiversity, and local ecosystem balance.

Chapter 5: The Question of Management of *P.juliflora* in Eritrea

5.1 The Case of Misidentification of *Prosopis*

The precise identification of the existing *Prosopis* species in all regions of Eritrea and the wider Horn of Africa and Eastern Africa region is vital for maximum effectiveness of related management and control measures.

Misidentification of *Prosopis* species, e.g. *P.juliflora* and *P. pallida* as described under chapter 1.2 has taken place in Eritrea and the Sudan. PASIECZNIK *et al.* (2001) describes the process of taxonomical misidentification of *P.juliflora* (Sw.) DC as *P.chilensis* (Molina) Stuntz during the early century in Sudan. Plant samples were further either misidentified as *P.juliflora* in 1966 in the herbarium at Kew in the United Kingdom or maybe plant samples of small *P.chilensis* populations had been sent instead. Although today it is widely acknowledged in the Sudan that it is in fact *P.juliflora* and not *P.chilensis* that is widespread, the problem of misidentification has to some extent persisted and has spread throughout neighbouring countries or those that had *Prosopis* seeds from Sudan introduced by foresters as *P.chilensis* (PASIECZNIK *et al.* 2001; p.22).

In the case of Eritrea the confusion still persists: the majority of existing local research papers and government documents refer to the locally fast-spreading invasive plant as *P.chilensis* (Mol.) and not *P.juliflora*. Some state that both species are present with *P.chilensis* spreading in most parts of the country, especially in the Western Lowlands, while *P.juliflora* is only found in some parts of the Eastern Lowlands (personal communication during 2003 with Mr Berhane Habte, Head of Forestry Research Unit, Halhale, Eritrea in 2003; HABTE 2000, p.3).

It can however be confirmed with great probability that most *Prosopis* ranges in Western and Eastern Eritrea are in fact *P.juliflora* (with a possibility of some minor *P.chilensis* stands). This conclusion is underlined by several references, which are based on laboratory analysis of local plant samples. The following facts underline the presence of *P.juliflora* (and not *P.chilensis*) in Eritrea:

- *Prosopis* plant samples taken in 1996 in the Western Lowlands (Gash Barka Region) during a plant inventory assessment carried out by SOS Sahel UK and MoA (supported by experts from Bangor University) confirmed the species as *Prosopis juliflora* (personal communication with Mr Duncan Fulton, Bangor University, UK during 2002). Therefore the “Management Plan for the Riverine Forests of the Western Lowlands of Eritrea” by SOS Sahel and MoA 1999 is one of the very few documents on Eritrea that refers to the species as *P.juliflora* throughout.
- PASIECZNIK *et al.* (2001) refer to tetraploid samples from Kenya and the Sudan that had previously wrongly been identified as *P.chilensis*, but which are now confirmed as *P.juliflora*. This underlines that *P.juliflora* is available in the Sudan, as well as in Eritrea where it is reported to have been introduced from eastern Sudan (author’s survey, chapter 4; BEIN *et al.* 1996).
- *P.juliflora* has furthermore also been widely identified in Ethiopia - Eritrea’s second major neighbour state - following previous misidentification as *P.chilensis* (e-mail communication with DEMISSEW SERTSE, Ethiopian Agricultural Research Organization in Addis Ababa, Ethiopia / University of Göttingen, Germany during 2007). This is potentially another underlining factor for the presence of *P.juliflora* in Eastern Eritrea, where it has reportedly been introduced from Ethiopia (author’s survey, chapter 4; HABTE 2000, p.12).

A small possibility remains that *P. chilensis* does exist alongside *P.juliflora* in the Eastern Lowlands as no references to plant samples that have been taken from there for genetic identification could be tracked down. In any case, correct identification needs to take place in all parts of Eritrea. A couple of experts in Eritrea have reported to have found a thornless *Prosopis* species in eastern parts of the country (personal communication during 2003 with Mr Berhane Habte, Head of Forestry Research Unit, Halhale, Eritrea in 2003; HABTE 2000), which after HARRIS *et al.* (2003) is “rarely observed in *P.juliflora*”.

Misidentification can lead to a range of management implications, as different *Prosopis* species - even if they are very similar to each other - do differ in their response to certain management techniques. This could lead for example to a lower success rate using biological control or silvicultural planting (HARRIS *et al.* 2003, p. 163).

Misidentification of *P.juliflora* however is not specific to the Horn of Africa Region. Some scientists for example state that *P.chilensis* is in fact a synonym for *P.juliflora* (BHASKAR & KUSHALAPA 1986; p.1)

5.2 Management Strategies in the Past and Today

In Eritrea, the state of knowledge, design and appropriate practices regarding *P.juliflora* management strategies is very limited. This is mainly due to an overall lack of reliable field data, systematic research and local assessments that could work as a basis for the design of appropriate management measures. While some rural communities have tried to manage and eradicate *Prosopis* within their immediate surroundings (chapter 4.10) there has been little or no action taken by government or the private sector to date that may have covered a wider area or taken a more coordinated management approach. BLOESCH (2001) states that the local administration in Engerne had allocated some funds for the eradication of *Prosopis* along access roads and irrigation fields. According to respondents an eradication project had taken place around 2001-2004, but had not been successful as the species simply re-grew. BLOESCH furthermore states that foresters from the MoA in Gash-Barka were planning “to feed *P.chilensis* to goats in a controlled test in order to disprove the toxicity of this plant” (BLOESCH 2001, p16). It could not be established if such project has been carried out, and although they are a start, given the urgency of the spread of *Prosopis* action would need to take place at regional level on the basis of a well-planned holistic management plan.

Quite different is the management situation in neighbouring Sudan. There, a presidential decree for the eradication of *Prosopis* was issued on 26 February 1995, followed by campaigns to start the eradication process. According to LAXÉN this decision came “as a total surprise” to the communities, experts and NGOs in the arid north of the country where *Prosopis* has been successfully used and even promoted for sand dune stabilisation (Sudan

Vision Daily³⁴ 2008, LAXÉN 2007, p.13). KHALIL³⁵ pointed out that it is especially in those areas that *P.juliflora* is of use for the local people. It has been used in the Kosti area at the White Nile and in the Shandi area as firewood and building material. But even in Halfa - the location of the government's eradication programme - in Eastern Sudan where a vast agricultural irrigation scheme is situated locals have used *Prosopis* as fire wood and animals browse the pods for fodder. KHALIL however emphasised that eradication has been the main management approach in the whole of the Sudan - but particularly around the main agricultural schemes, which the government seeks to protect - costing the government several hundred million US Dollar. This has been particularly the case in the Halfa Agricultural Irrigation Scheme, a major irrigation scheme where up to 40% of the land area is today infested by *P.juliflora*.

According to KHALIL, the eradication of *P.juliflora* in major government-owned agricultural schemes, such as the ones in Halfa in the East or Gazeera in the South of Khartoum, is decided by the Project Administration of the schemes. The proposal for eradication needs to get the go ahead from the Ministry of Agriculture and Forestry, which itself needs the approval from the Council of Ministers within the so-called Ministry of Ministers. Once the approval for eradication of *P.juliflora* is official contacts are made to companies that have the necessary heavy machinery and know-how. So far this has been mainly a local company called Rawiyan Co. and a company from Sweden. The FNC acts as a consultant to the eradication company and the Project Administration of the agricultural scheme prior and during eradication. The Ministry of Finance provides the finances for eradication. MAGID (2007) also made references to the institutionalised *Prosopis* management of Halfa Scheme stating that: "According to Elsiddig (2005) and Anon (2003) mesquite [*Prosopis*] eradication in New Halfa Agricultural Scheme provides a special case as it involves institutions, judicial and public organizations. (MAGID 2007, p. 28)

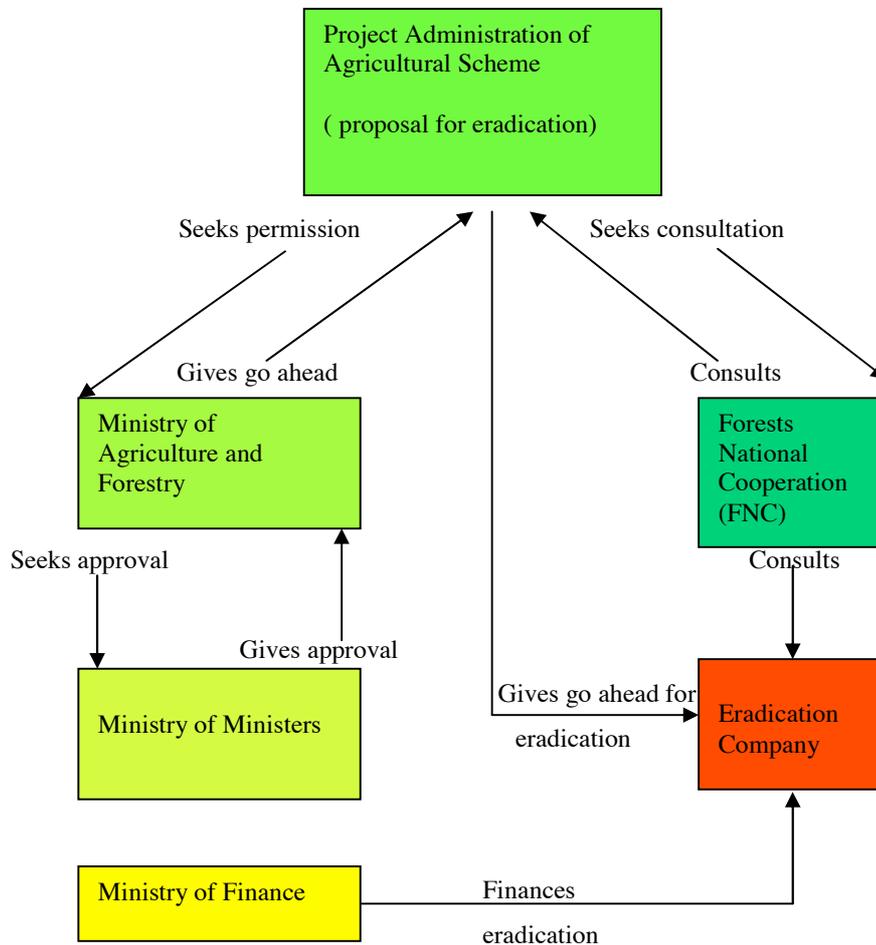
³⁴ The article can be found under the URL

<http://www.sudanvisiondaily.com/modules.php?name=News&file=article&sid=32202>

³⁵ Personal interview with SAYEDA KHALIL, Information and Statistic Department of the Forest National Cooperation (FNC) in March 2007, Khartoum, Sudan).

Graph 5.1: *P.juliflora* Eradication Management System in the Sudan

(Source: Personal interview with S. KHALIL, FNC, Sudan; Design: Author)



The above management system includes a range of stakeholder action and consultation as well as a monitoring committee. Although the set up of an institutionalised system to tackle the issue of *Prosopis* is potentially a very effective measure, the system does seem to lack sustainability and the integration of alternative approaches. It mainly concentrates on the eradication within industrial production schemes and fails to integrate measures such as exploitation of *Prosopis* resources or the management and control of *Prosopis* on vast areas of small-scale rural land plots or along river banks, although the infestation of *Prosopis* in the riverine forests alongside the river Gash and Baraka (the Barka river in Eritrea) is intensifying.

Eradication has cost the government of the Sudan several million US Dollars³⁶ and the success rate is modest even when the root system is removed, as *Prosopis* is spread repeatedly via animal droppings, water or by wind storms. As a result, Sudanese expert opinion about the management practices of the past is slowly shifting towards a more viable approach. In the 1st of March 2008 edition of the Sudan Vision Daily an article stated: “Mesquite [*Prosopis*] is currently still spreading, and complete eradication of the tree in Sudan is considered by UNEP and others in the forestry and environmental management field to be physically impossible, economically unviable and more importantly, not warranted. The recommended alternative is control, with elimination in high-value irrigated land only”.

While Eritrea has so far generally only witnessed minor management practices such as small-scale eradication mostly based on the efforts of individual farmers or pastoralists other countries such as the Sudan have invested more into *Prosopis* management by creating a broader and centrally coordinated scheme. Nevertheless, in both cases the issue of *Prosopis* management has not been that of a great success story as it has proven both unsustainable and lacking in sufficient resources.

The potential of *P.juliflora* for the regeneration of degraded soils as well as fuel wood production has been outlined by the majority of related documentation. However, according to KAARAKKA (1996) several experts have pointed out that too often the way has simply been cleared for industrial plantations consisting of fast growing alien species at the cost of native plants. Although Sudan, for example, up to 1980 was the only country that reportedly practiced successful management of natural *Acacia senegal* forests, it was also pointed out that this was due to the economic gains made from the production of gum arabic from this species rather than the natural forest conservation (WORMA 1984 in KAARAKKA 1996, p.13), which does not necessarily make it less successful.

The long-term benefits and disadvantages of planting alien tree species within both natural conservation efforts and economic plantation need to be properly assessed for each case. Many experts and researchers have also outlined that there is in fact a great potential

³⁶ According to MAGID (2007) 4.3 million US\$ have been authorised by financial authorities for the eradication of *Prosopis* in Halfa. (MAGID 2007, p. 28)

in the variety and management of indigenous trees. Ethiopia for example reportedly has 49 indigenous species of *Acacia* alone. These local multipurpose leguminous species can be used in well-managed plantations as economic resources for fuel-wood and charcoal, fodder, construction material and so on, alleviating the pressure from declining natural forests (TEKETAY 1996, p.209). Successful afforestation however requires the knowledge of appropriate plantation techniques, such as the so called “intensive root zone management”, which ensures a maximum survival of the planted seedlings (BHOJVAID & TIMMER *et al.* 1996, p. 39)

Photo 14: *Acacia* Afforestation near Engerne, Western Eritrea



(Photo: author)

5.3 Promotion, Control or Eradication - an Assessment

The National Environment Management Plan for Eritrea (NEMP-E 1995) acknowledges the fact that the introduction of exotic species can have “devastating effects on species and ecosystems” causing a direct threat to the native flora (NEMP-E 1995, p.83). Furthermore, the National Biodiversity Strategy and Action Plan for Eritrea (NBSAP-E 2000) has included “alien invasive species” as one of its top ten strategic elements for action (MoLWE

2000, p.37). The socio-economic effects and potential benefits have also been acknowledged by policy makers and national experts, recognising its invasive character and the potential benefits which - even if not accepted by rural communities in Eritrea - have been an area of focus for researchers and practitioners.

The particular question of *Prosopis* and its appropriate management however may after all not be straight forward. In a similar case back in 1993, the Ministry of Agriculture wanted clarification on the issue of *Eucalyptus* plantations, which had sparked debate in the country due to their excessive water and nutrient intake and reportedly allelopathic effects on adjacent crops. In an attempt to clarify the matter the ministry invited two scientists from the Australian Tree Seed Centre and from the International Centre for Research in Agroforestry who carried out an advisory visit to Eritrea to assess the situation. The report says that “There was no general answer as to whether planting eucalyptus is good or bad for the environment. The decision on whether to plant eucalyptus must be made on a case by case basis, taking into account local circumstances such as views of local communities, land availability, competing land uses, performance of alternative tree species, forest product requirements and so on”. It was also suggested that due to the comparatively small size of land cover by *Eucalyptus* its impact on the environment was rather insignificant. It was however recommended to plant eucalyptus away from riverbanks and arable land and to carry out further in-depth studies in relation to environmental restoration (NEMP-E 1995, p.72).

In the case of *Prosopis* there may be a similar range of issues that need to be considered locally to assess its environmental and socio-economic impact. However, the above statement in regard to *Eucalyptus* having an ‘insignificant’ impact on the environment due to plantations being “very small compared to the total area of the country” should be disputed. In fact it is somewhat contradictory to the recommendation to assess the environmental impact on a local and case-by-case basis, as in a given local setting the impact may become very significant. Carefully structured management should therefore also include aspects of (future) risk assessment and necessary prevention measures for such risk. One of the primary risks of alien species is their uncontrolled spread at the expense of native species.

The reproduction and spread of an alien plant species occurs naturally, but it can be exaggerated through negligence towards unwanted spread or in other cases even through

random promotion of planting. Spread control measures are therefore vital to decrease unwanted invasion of alien species into more fragile ecosystems, as this could lead to undesirable environmental impact *locally*, regardless of the total land size covered by the alien species at the time. An example could be the high ecological and socio-economic value of the riverine forests, which according to the NAP 2002 cover less than 1% of the total land area of the country (NAP 2002, p.59), however it would be a scientific disaster to suggest that these resources are therefore not of much significance to the country as a whole. Riverine forests consist of an enormous level of biodiversity and are of great value to the local communities. In the case of *P.juliflora*, which is widely invading those patchy forests, the total land area covered by *P.juliflora* may not be extensive, but nonetheless the damage and potential threat that it causes to these resources and those who depend on them is significant.

It was suggested by the two scientists assessing the environmental impact of *Eucalyptus* that decisions should be made “on a case by case basis taking into account local circumstances”. **Promotion** of *Prosopis* for example within supplementary livestock fodder production would require local case-by-case assessment of the locally available ‘ingredients’ that could be mixed into a *Prosopis*-based fodder supplement, such as straw, wheat bran, urea or molasses. Again the potential impact of the introduction of new feed also need to be assessed in each case, as large-scale introduction in a village or an area could lead to changes in socio-ecological habits, such as abandoned herd migration due to a locally available feed source, which could lead to local overgrazing.

However, promotion of *Prosopis*-based energy plantations are probably not a real option in the case of Eritrea: The spread of *Prosopis* is already causing problems and brings along severe disadvantages for local communities and the wider environment, and planting would create an unacceptable increase in the risk of spread, even if such plantations were carefully assessed and managed.

A case-by-case approach is probably also needed if **eradication** of *Prosopis* were to become the preferred policy. The environmental impact of eradication would probably be minor at least in the case of Eritrea, where invasion is comparably recent and moderate. However, eradication has an immense socio-economic impact, as it is very labour intensive and expensive, but on the other hand the impact could also be positive, as local communities have made it clear that eradication is what they want. The sites would also

need to be managed post-eradication to avoid regrowth, which is proving a major challenge in sites where eradication has taken place in recent past. Therefore, the advantages and disadvantages of such an investment would need to be assessed in each case.

While promotion and eradication require attention on a case-by-case basis due to possible high negative impact they could cause during implementation, **control** measures are there to mitigate negative effects where they exist and to re-establish balance. Due to the alien character of *P.juliflora* and the harm it can cause to native species and biodiverse ecosystems the control of *Prosopis* could be an overall concept and approach. This study on the ecological and socio-economic impact of *Prosopis* in Eritrea has provided evidence of a range of harmful or undesirable factors that come with the spread of this species. Threats have outnumbered (potential) benefits. This is the basis for an urgent need to control its spread and to mitigate the negative impact it has.

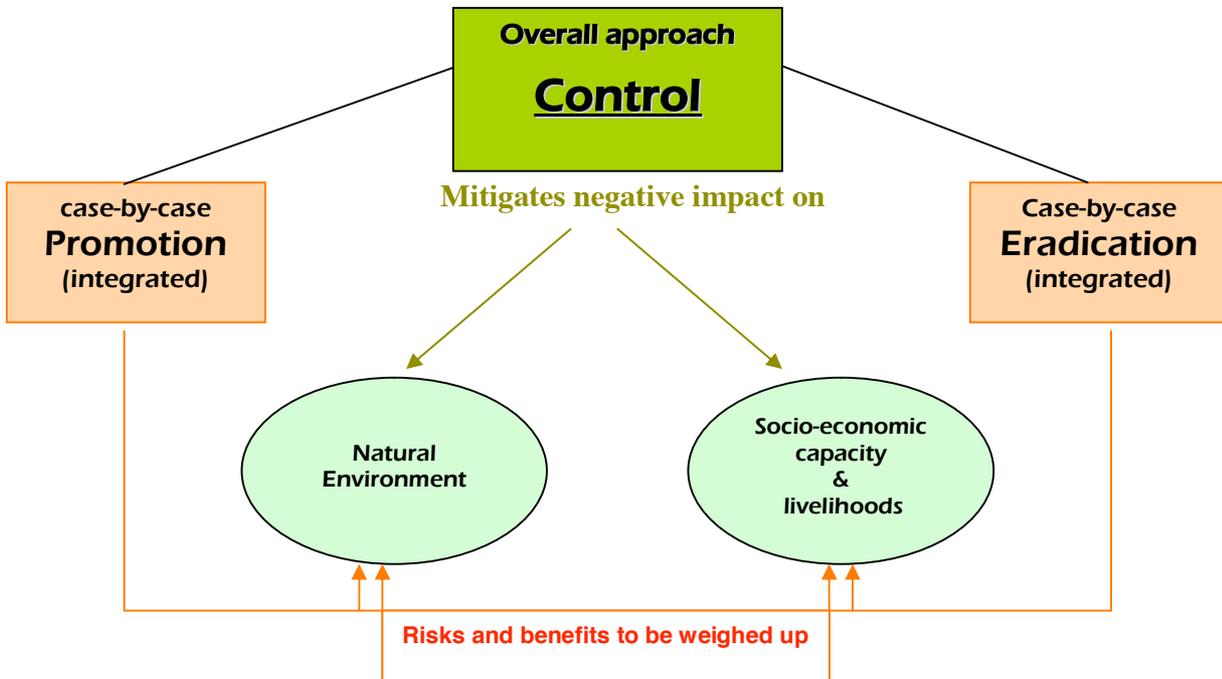
This doesn't mean that benefits of *Prosopis* should be disregarded, nor does control need to halt strategic promotion of such benefits. Promotion of effective *Prosopis* utilisation is a vital factor in an environment that continuously faces the species' spread. On the other hand control does not mean eradication either. Control is much more an intermediate overall approach consisting of concrete steps for action, most of which can be implemented immediately on either a regional or national basis in Eritrea (e.g. the weeding of *Prosopis* seedlings on crop land through mobilised communities on large-scale) because the impact of such control measures is broadly speaking not harmful.

While control takes place both targeted promotion and eradication could be integrated as management options as part of a detailed and limited case-by-case assessment where appropriate. This means that both promotion and eradication would be confined to a small area or project and only implemented after careful consideration.

Control also integrates promotion of benefits, as to how to exploit *Prosopis* where it already exists. This should be an integrated part, as exploitation (utilisation) of *Prosopis* should not be regarded as a sufficient control measure when applied on its own.

Graph 5.2: Integrated Control Management of *Prosopis*

(Source & Design: Author)



In chapter 3.3.2 (Assessment of *P.juliflora*'s Invasiveness and its Impact on Native Plant Species) of this study, botanic factors³⁷ that contribute to the invasiveness of *Prosopis* were identified for different growth development stages. To draw a list of these and similar factors is helpful finding the identification of appropriate control measures. A key aspect of control management is the control of further spread. And this process depends on 'internal' (botanic or plant characteristic) and 'external' (environmental) factors.

The internal factors appear in different development stages of the plant (from seed to mature fodder tree) and the next step would be to assess which stage (factor) can be controlled and managed.

³⁷ The botanic factors identified for *Prosopis*' invasiveness were retrieved from a wide range of scientific bibliography (see chapter 3.3.2 for details), however some research experts may differ regarding those outcomes

		managed until exhausted)
Stage 2	Higher (natural) germination ability	x ³⁸
Stage 3	Long tap root system	<ul style="list-style-type: none"> ✓ Cutting of the shoots (pruning) will reduce roots ✓ Labour-intensive destruction of roots by burning techniques ✓ Trenching around trees decreases lateral roots
	<p>Lack of soil-plant nutrient correlation</p> <p>Allelopathic effects</p> <p>Ability to re-sprout easily</p>	<p>x</p> <p>x³⁹</p> <ul style="list-style-type: none"> ✓ No cutting of the stem (only the branches) above ground ✓ Cutting of stem 10 cm below grounds + possible treatment for example application of fire or diesel oil.

³⁸ Control of seed germination is potentially possible, for example though extensive heat (boiling) or the addition of acid. However these methods are broadly carried out within laboratory conditions. To inhibit the natural seed germination process within the complex context of the surrounding natural environment and for a larger geographic area is at this stage not really feasible. There may be inhibiting bio control measures existing, however research in this regard is so far very scarce and any bio control measures cannot simply be replicated, but need to be very carefully assessed for different climates and local ecosystem habitats.

³⁹ According to research on potential allelopathy of *P.juliflora* it was recorded that the growth of some plant and grass species seemed to get inhibited by *Prosopis* while others are more tolerant (see chapter 3.3.2). Potentially sensitive species could be replaced with more tolerant ones however, again this is more feasible within a laboratory than it is in a natural environment.

Stage 4	Prominent fodder tree	<ul style="list-style-type: none"> ✓ Avoid browsing of animals in areas (e.g. through enclosure the area) with intense <i>Prosopis</i> infestation Clearance of trees ✓ Harvest of pods in order to process (grind) them into a fodder supplement binstead, which also prevents seed germination.
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The above table shows a range of control measures that can be carried out to inhibit or slow down the impact of particular plant characteristics in *Prosopis* that contribute to its invasiveness and spread. They need to be addressed and integrated into any management plan.

On the contrary there are hardly any contributing ‘external’ factors that can be controlled within *Prosopis* management. External factors that have a positive influence on the spread of *Prosopis* in Eritrea can be summarised as following:

- ✚ Climate (mostly semi-arid, no frost)
- ✚ Altitude (mostly in lowlands or below 1,500m)
- ✚ Water/moisture availability in prime habitats (such as the riverine forests or irrigated crop land)
- ✚ Wind and run off water distributing seeds
- ✚ Free-browsing animals distributing seeds (can be controlled to some extent)

The management or *P.juliflora* in general and its control as a particular measure however require a broad data and knowledge base including specific site data and recommendation for small block areas. This should include:

- **Design of *Prosopis* Management Maps (PMM)** ranging from smaller scale maps (around 1:50,000) for general planning purposes, over medium scale maps (around 1:25,000) for more specific planning purposes (e.g. based on specific habitats) to large scale maps (around 1:10,000) for areas that require more detail or acute cases, such as the rapid invasion of *P.juliflora* into riverine forests (SOS Sahel and MoA, p.15). The large-scale PMMs should have areas marked as high, medium and low risk and include special recommendations for intervention.
- **Socio-economic survey** similar to the one outlined within this study. This should be a broad survey to identify the impact *P.juliflora* is having on rural livelihoods, the knowledge and knowledge gaps regarding *P.juliflora* in rural communities, the attitudes, challenges and needs that arise in those communities facing a continuous spread of *P.juliflora* within their lands. There should also be small-scale surveys within each area that has been allocated for management action.

5.4 A Draft Framework of Appropriate Measures within a National Action Plan on *Prosopis* for Eritrea

**National Action Plan on *Prosopis* (NAPP)
A Framework for Eritrea⁴⁰**

1. Justification of the NAPP

- 1.1 *Prosopis* is continuously infesting new land areas at the expense of palatable, multi-purpose native species, essential dry season and wet season rangelands such as the riverine forests, and crop land.
- 1.2 This infestation may lead directly or indirectly to the shortage of such resources potentially ultimately leading to hardship or increased food insecurity among affected communities.
- 1.3 *Prosopis* potentially is a public health hazard to people - especially where it grows within settlement areas - as increased reports of snake bites have been made (due to the animals hiding in the shrubs) and international research has suggested increased allergic reaction and asthma as a result of *Prosopis* pollen distribution.
- 1.4 *Prosopis* as a multi-purpose tree has the potential of providing a wide range of by-

⁴⁰ This NAPP Framework has been designed by the author. It is the first framework of its kind and is solely based on research outcomes within this presented study and personal perceptions for appropriate action regarding the management of *Prosopis* in Eritrea.

	products beneficial to increase food security and reduce poverty through income generation.
1. Goal and objectives of a NAPP	<p>Proposed objectives:</p> <p>1.1 To secure natural resources such as land, water, riverine forests, and other native vegetation that may be dwindle as a result of <i>Prosopis</i> invasion.</p> <p>1.2 To secure crop land area and productivity (both irrigated and rain-fed) as well as pastoralist rangelands, which may be reduced as a result of <i>Prosopis</i> invasion.</p> <p>1.3 Improve settlement conditions for villagers that have seen their settlement area infested and reducing related health risks (such as snake bites or asthma).</p> <p>1.4 Identifying <i>Prosopis</i> by-products that can be used to increase household food security and income generation creating a balance regarding those livelihood areas that have been negatively affected by <i>Prosopis</i> infestation.</p> <p>1.5 Raise community awareness about <i>Prosopis</i> including its plant characteristics (e.g. soil seed banks, re-sprouting when cut) and improved (commercialised) utilisation.</p>
2. Priority areas for action (both	Proposed Priority areas:

⁴¹ *Prosopis* Management Map

<p>thematically and geographically)</p>	<p>2.1 Thematic priority areas</p> <ul style="list-style-type: none"> • Riverine forests and river banks • Crop land (rain-fed and irrigated) • Settlement/road areas • Open grassland <p>2.2 Geographic priority areas</p> <ul style="list-style-type: none"> • Immediate areas along the Barka and Gash rivers (including riverine forests and other production systems). • Other priority areas (e.g irrigation schemes around Tesseneay and Talatasher) need to be identified after an in-depth survey and inventory has been carried out. <p>2.3 Areas on PMM⁴¹ that have been identified as high and medium risk levels</p>
<p>3. Research Action</p>	<p>Proposed Research Action:</p> <p>3.1 Carrying out an in-depth socio-economic survey based on questionnaires or alternatively focus-group discussions in wide parts of the Western and Eastern Lowlands where <i>Prosopis</i> is found.</p> <p>3.2 Carrying out small-scale research projects on the use of insitu <i>Prosopis</i> stands as local and commercial energy resources to meet the energy needs of the rural and periurban population.</p> <p>3.3 Analysing the plant-soil correlation, nutrient and water intake of <i>Prosopis</i> in different</p>

	<p>habitat areas and in comparison with useful/common native species using small research plots to identify where <i>Prosopis</i> is mostly competing with native plants</p> <p>3.4 Setting up research project on innovative usage and processing of <i>Prosopis</i> such as fodder supplements, baking flower, honey or gum.</p> <p>3.5 Setting up research projects looking into unconventional control measures such as bio-control.</p>
<p>4. Control and Management Action</p>	<p>Proposed action:</p> <p>4.1 <u>Control:</u></p> <p>Control the further spread of <i>Prosopis</i> through means of (where appropriate) :</p> <p>4.1.1 The trimming of shoots (pruning) to inhibit growth of root system and branches, e.g. at the edges of crop land⁴²</p> <p>4.1.2 The manual removal of young <i>Prosopis</i> seedlings (below 12 months), e.g. at least twice a year from crop land and communal removal from key community rangelands</p> <p>4.1.3 Awareness-raising programme discouraging cutting of the stem as a control measure (e.g. on farm land), as it re-enforces growth.</p>

⁴² See chapter 3.4.2 (on Agro-forestry) or Jones & Sinclair 1998, p. 197 and p.205

⁴³ SOS Sahel & MoA (1999), p.64

⁴⁴ Indian Workshop Paper (1986), p.2

⁴⁵ E.g. SERTSE (2005). These methods have proved effective by some reports, but there not by a significant number. Such methods therefore should be tested for their effectiveness, before they are being promoted.

- 4.1.4 Regular cutting of coppice re-growth (not the stem) to prevent the formation of flowering wood and to reduce seed supply⁴³
- 4.1.5 Digging of small trenches around certain *Prosopis* trees (e.g. at the border to crop land) prevents the roots from infiltrating neighbouring lands spots⁴⁴
- 4.1.6 The eradication of *Prosopis* in certain infested land areas e.g. with high level of animal movement to control spreading through animal droppings or simply primary seed production by mature trees.
- 4.1.7 Effects of free communal animal grazing in *Prosopis* areas need to be mitigated by the communities and the local administration e.g. through enclosure of highly infested areas where eradication is not possible to prevent browsing animals from accessing them.
- 4.1.8 Raise awareness of collecting and processing (grinding) *Prosopis* pods as supplementary animal fodder to prevent seed germination following the digestive process.
- 4.1.9 Apply other methods that have been reported as useful, e.g. the application of used motor oil to tree stumps or the cutting and burning of stems below ground⁴⁵.

	<p>4.2 <u>Eradication</u> (Small-scale; based on case-by-case assessment)</p> <ul style="list-style-type: none"> - <i>Eradication always to be followed by control measures (as above) to maintain effective <i>Prosopis</i> management -</i> <p>4.2.1 Eradicate <i>Prosopis</i> from areas where it inhibits certain livelihood and production practices, e.g. in irrigation channels or where <i>Prosopis</i> thicket prevents access to rivers.</p> <p>4.2.2 Eradicate in areas with high infestation levels and prime seed germination conditions (e.g. thicket near the rivers) to prevent high degree of primary seed production of mature trees</p> <p>4.2.3 Eradicate in areas with high infestation levels and intense animal mobility to prevent seed spread through animal droppings (in cases where enclosure of area is not possible as a control measure)</p> <p>4.2.4 Eradicate <i>Prosopis</i> shrubs and trees where they have been reported to cause a health hazard (e.g. within settlements areas where snake bites have increased)</p>
	<p>4.3 <u>Promotion</u> (Small-scale; based on case-by-case research & assessment)</p> <p>4.3.1 Promotion of <i>Prosopis</i> (if applicable) within small insitu energy stand to meet fuel wood needs.</p>

	<p>4.3.2 Promotion within animal fodder production (processed as supplementary fodder).</p> <p>4.3.3 Promotion of research, investment and action of innovative usage of <i>Prosopis</i> for products such as baking flour and honey.</p>
<p>5. Natural Regeneration</p>	<p>Set up project and community-activities to support and strengthen natural regeneration in areas that had/have been invaded by <i>Prosopis</i></p>

The above system and action plan are just a potential concept designed on the existing knowledge base and experiences. Any plan will need to be carefully checked against and adopted to existing national policies and legal regulations. Furthermore, as for every successful environmental management or action plan a good theory or well-designed scheme will not be sufficient if the plan does not consider a whole range of interacting factors.

In the case of *Prosopis* this would mean that its management is not solely a question of control, exploitation, eradication or promotion nor will any simple combination of those measures be successful. A sustainable and effective *Prosopis* management or action plan requires a holistic and community-based mobilised approach. A wide range of related departments, experts and actors at national and regional policy level will therefore need to be involved, including the Ministry of Agriculture under which also the Department of Forestry comes, the Ministry of Land Water and Environment, the Ministry of Mines and Energy (e.g. regarding issues such as charcoal production), and the Ministry of Industry and Department of Trade (regarding aspects of investment or the commercial trade with *Prosopis*-based products). Actors from the private sector and civil society, such as investors, traders, NGOs and CBOs would also need to be consulted and actively included in the management on the ground. While investors and traders would be able to assist with

aspects of investing, costing, exploiting, marketing, and selling of *Prosopis*-based products such as processed fodder supplements, fire wood and charcoal and possibly honey, gum, or flour etc. NGOs and CBOs would be in a position to assist the line ministries with issues of community-awareness and mobilisation, training, research, project design and implementation, dissemination and education.

However, the most important actors in the management of *Prosopis* will be the rural communities themselves. The livelihoods of the communities are hugely affected by *Prosopis* be it in the form of unwanted invasion into rangelands and crops or in the form of *Prosopis* utilisation as a source of energy, fodder, and construction material. It would surely not be sufficient to simply acknowledge the rural communities as stakeholders of the *Prosopis* management or action plan and to call for community-participation on action steps that have been decided at policy level. What is really needed is a continuity of active consultation and collaboration with and involvement of those communities affected by *Prosopis*.

In the case of Eritrea this could prove to be a major challenge. Particularly in the Western Lowlands, where *Prosopis* has caused the degradation of range lands and crops, attitudes of local communities are very negative. Views that are so extreme that some respondents compared *Prosopis* to the HIV/Aids epidemic and as “the second biggest problem after the war” will not be easy to address. Unusually amongst community empowerment efforts, the majority of respondents are not even interested in learning about any benefits *Prosopis* could bring to them, so greatly are they convinced about the damage the species is causing to their livelihoods and their environment. The state of attitudes towards *Prosopis* will most probably prove to be a main challenge in any management plan that may consider not eradication but control as a key approach or that may even include case-by-case promotion such as *Prosopis*-based feed or charcoal production.

But this makes it even more important to involve local communities in the design and implementation of such a management plan right from the start. If no common ground can be found between local communities and those in charge of the design and coordination of a national action plan on *Prosopis* its implementation and any cooperation with the rural population would be based on a top-down approach that is likely to fail to gain the necessary local commitment and motivation. Indeed, there is a genuine risk that the negative attitudes towards *Prosopis* may undermine any management efforts at all, even if

they may be beneficial to those communities. This risk has to be assessed and managed appropriately. Local communities are truly concerned about the impact of *Prosopis* on their livelihoods and see eradication as the only way of dealing with this efficiently. Nevertheless eradication has proven to be cost and labour expensive and often without much result creating a sense of dilemma among the rural population (and other stakeholders alike), as to how to deal with the problem. The majority of respondents therefore wants the government to eradicate *Prosopis* in their area. But eradication with specialist machinery - even if implemented on a case-by-case basis - is likely to be also too costly for the government to be applied as a key management practice for the long-term. The case of intensive eradication in the East of Sudan - a country with much more resources than Eritrea - has already demonstrated this.

Therefore, if control and exploitation measures were to be applied effectively, a change of attitudes among local people would need to take place. In order to achieve this, mutual communication and collaboration, awareness-rising activities and demonstration, exchange visits with other communities within and outside of Eritrea, training in the processing of attractive *Prosopis*-based products and marketing skills for income generation, as well as mechanisms that ensure community access to any benefits won from the exploitation of *Prosopis* would all potentially lead to a shift in attitudes and the start of result-oriented community action. However, it is crucial that during this process negative community perceptions are not being dismissed. Any researchers or policy makers coming from 'outside' need to keep in mind that those perceptions are derived from direct experiences with *Prosopis*. Therefore, the perceptions and concerns of local communities should be taken seriously, need to be acknowledged during community consultations and accommodated while trying to find appropriate solutions which are acceptable and realistic for all stakeholders. According to SOS Sahel & MoA (1999) in regard to Community Forest Management elsewhere, past experiences have shown that "a formal written agreement is necessary to ensure that both the community-based management and the regional authority take the new relationship seriously". It was also stated that "it is likely that provisional recommendations should be made in the first instance, with the option to change things as and when required" (SOS Sahel & MoA 1999, p. 32). As a result, a sense of ownership would be developed among the rural population affected by *Prosopis* resulting in effective and sustainable implementation of the *Prosopis* Action Plan.

In the process of making effective management decisions the following action steps should be taken⁴⁶:

- 1) Identify the site (*Prosopis* habitat) for management intervention (following the identification of high and medium risk areas on the PMM⁴⁷, general assessments and community consultations);
- 2) Take into account general management recommendations as outlined in the NAPP⁴⁸;
- 3) Take into account specific management recommendations derived from the socio-economic surveys and as outlined in the large-scale PMM for the particular habitat block;
- 4) Draw up a detailed *Prosopis* management plan draft for the particular site taking local environment as well as local and national policies into account;
- 5) Make field visits to discuss and verify proposed action steps of the *Prosopis* management plan draft in full consultation with the local communities and related departments;
- 6) Make amendments to the plan where needed;
- 7) Draw up an agreement with local communities (who need to continue management initiative) regarding key action steps and guidelines prior to action;
- 8) Commence community action including a local monitoring and reporting system; regularly evaluate actions and outcomes and amend where necessary.

It should also be mentioned at this stage, and particularly in view of the action steps proposed within this chapter, that the control of *Prosopis* is a very challenging and complex management task that needs to take place over the long-term. Many experts on *P.juliflora* claim, or at least imply, that *Prosopis* can be controlled through its exploitation or

⁴⁶ The management action steps are based on a similar concept outlined by SOS Sahel & MoA (1999) for the management of riverine forest resources (SOS Sahel & MoA 1999, p.45)

⁴⁷ *Prosopis* Management Map (see above)

⁴⁸ National Action Plan on *Prosopis* (see above)

utilisation alone. But this is not the case if other essential and direct control measures are overlooked. Control by the means of exploitation is a common trend in various research and development reports that many seem to follow as a convenient response to the paradox of *Prosopis*. But this perception needs to be addressed very urgently, as it may promote a very incomplete and therefore ineffective management approach when put into practice.

The grinding of *Prosopis* pods as a local or commercial feed supplement would indeed reduce the spread of seeds for germination. However, the harvest of gum or honey from *P.juliflora* does not control its further spread, and neither does the cutting of *Prosopis* for charcoal, fuel wood, furniture or construction poles; it may in fact enhance its spread, as the cutting of *Prosopis* branches near the stem or the cutting of the stem above ground reinforces the tree's growth. Therefore it is time for experts to view the exploitation or utilisation of *P.juliflora* in semi-arid lands neither as a control measure in its own right nor as a too-good-to-be-missed opportunity. It would be better recognised for what it has widely become: a way to make the best use of a species that has undoubtedly turned into a burdensome reality in many semi-arid dryland areas and a means to outbalance the losses that rural people face as a result of *Prosopis* invasion.

If one wants to control the spread of *P.juliflora* then the utilisation of its by-products can be an integrated and attractive management aspect that is of benefit to the people, however the emphasis in any control management plan really needs to be directed at very concrete action steps that prevent the spread and germination of seeds and the growth of seedlings and mature trees to contribute to *Prosopis*' eradication or mitigation in the long-term. Such steps, as discussed above within this chapter, could for example be the enclosure of some *Prosopis* areas to avoid access for browsing animals, the manual removal of new seedlings from crops and rangelands at least twice a year, the regular chopping of re-grown coppice to prevent flowering, or in some areas the application of seed feeding bio control agents.

Similarly, in a 2006 FAO paper AL-SHURAI suggests an integrated management approach for Yemen. He states: "Therefore, the solution of the problem is at present only possible by implementing an integrated approach, which should include mechanical and manual control, rational and limited chemical control, use of biological control agents for preventing spread of the plant and utilization of pods and wood." (FAO 2006, p.29)

5.5 Short Assessment of some Non-mechanical Control Measures in the Context of Eritrea

Bio control

DE LOACH & CUDA (1994) carried out a research trial in Texas using Mesquite Cutworm, *Melipotis indomita* (Lepidoptera: Noctuidae) as a bio-control agent for several *Prosopis* species. Although the mesquite cutworm developed well on most *Prosopis* species (development took slightly longer on *Prosopis juliflora* than on other *Prosopis* species) DE LOACH & CUDA pointed out that “a substantial amount of testing” would need to be done to define the host range of the mesquite worm, as it may also feed and reproduce on tropical woody legumes other than *Prosopis*, which of course could affect other vegetation. If careful testing has taken place and a foliage feeder is of interest as a bio-control agent DE LOACH & CUDA consider the mesquite worm as a possible candidate in countries where *Prosopis* has become a pest (DE LOACH & CUDA 1994, p.43/44).

However, the trial has not taken place on live trees; larvae were provided with cut leaves of several *Prosopis* species in the laboratory raising concern about the prohibiting impact the cutworm would have on the actual development, growth, and spread of the species in a natural environment. Furthermore, Eritrea lack the capacity and expertise to carry out substantial trials in this regard and really needs to be provided with a more advanced and environmentally established solution where it could simply carry out testing on some trees native to Eritrea to ensure that they would not be damaged following the introduction of a bio-control agent.

Of much more value in the context of Eritrea would seem to be the findings collected by ZIMMERMANN (1994). He points out that selection of insects should be confined to those destroying seed only, as the seed is considered a key attribute of *Prosopis* invasiveness. Furthermore, the focus on seed-feeding insects would also resolve arguments based on the useful attributes of non-seed plant components that would be lost with other agents. ZIMMERMANN also points out that bio-control needs to be supported by other control measures, particularly in areas where *Prosopis* seed banks exist, as the positive impact of seed-feeding may not be noticeable until the seed bank is exhausted.

ZIMMERMANN suggests that “chemical and mechanical control of *Prosopis* species have been met with limited success because they are labour-intensive and expensive, with cost of application usually far exceeding the value of the land ... Long-term, economic management of the weed will probably only be achieved through biological control” (ZIMMERMANN 1991, p. 179).

It has been suggested by several experts that bio-control using seed feeding insects is best used in the early stages of spread to avoid the development of vast quantities of seed banks (ZIMMERMANN 1991, p.184). The level of spread of *Prosopis* in Eritrea when compared to Sudan or Ethiopia is relatively low. The 30-year war of independence between 1961-1991 could be the reason for that⁴⁹, as it had a considerable impact on livestock numbers and movement hindering the spread of *Prosopis*. If biological control was considered a serious option by the experts and line ministries in Eritrea, it would be ideal to assess and potentially start this process without delay.

Ecological control (or “auto-control”)

Another control method one comes infrequently across is that of “ecological control”. It has been suggested that *Prosopis* stand density (e.g. in *Prosopis* thicket) eventually declines when left to its natural course, as other native species become increasingly established and that current encounters of dense *Prosopis* mono cultures may be an indication that these thickets are in their early stages (El SIDDIG 2005 in MAGID 2997, p.31). Although, in the context of Eritrea and other countries, this ‘measure’ would without doubt be the most affordable and environmentally friendly, such observations seem to have been made in insufficient numbers and without a robust scientific grounding, especially considering that *Prosopis* has shown an invasive character for decades in countries of West Africa and in the Sudan, and for a full one or two centuries in the case of India.

Even if native species were to re-establish themselves within the *Prosopis* thicket, there is no guarantee that the cycle might not resume at a later stage, with *Prosopis* yet

⁴⁹ During a seminar on the spread of HIV/AIDS in Eritrea that took place in Asmara in 2003 the South African guest speakers suggested that the spread of HIV/AIDS in Africa was the lowest in Eritrea. They said that - ironically - the war for independence and the related restrictions on movement (particularly from outside into Eritrea) had saved it from the epidemic spread of the disease. They claimed that on this basis Eritrea had a chance to act fast to prevent such a spread in the future. Although extensive awareness-raising campaigns have since taken place and people are widely aware of the risks and the necessary preventative measures, HIV/AIDS has nevertheless spread significantly in Eritrea and has become a serious public health problem.

again dominating native species, with the total area of thicket likely to expand further as the key issue of seed production and distribution would not have been addressed.

Chemical control

Attempts have also been made in other countries to use chemical applications such as dicamba, picloram and triclopyr, ammonium sulphamate, or herbicides, and these have proven successful for short to medium-term eradication. However, the implications for the environment can be very damaging and treatments did not resolve the re-sprouting and re-occurrence of *Prosopis* (MAGID 2007, p.30) over the medium to long-term.

5.6 Maximising the Potential of *P.juliflora* within Rural and Urban Economies

Prosopis has become a reality in Eritrea and in neighbouring countries such as the Sudan and Ethiopia, and is becoming an increasing challenge to the livelihoods of the rural population including local production systems. The concerns and unfavourable impacts of *Prosopis* on Eritrea's rural communities have been outlined in detail and many have made it clear that they want to see it eradicated as it has more disadvantages than advantages for them. In fact, the disadvantages are such that communities feel *Prosopis* poses a direct threat to their livelihoods. However, in the view of the immense cost and labour that eradication by machinery over a very wide land area would produce alongside a questionable success rate for such an approach, it seems unlikely that such a mechanical eradication could take place.

In the context of a management plan that therefore stresses control rather than complete eradication as a leading approach one should consider the accounts of some communities elsewhere that seem to highly or fairly depend on *Prosopis*-related production. The maximisation of *P.juliflora* potential to the benefit of the communities affected by its presence needs to be an important part of any *Prosopis* Management Plan, strategically as well as practically.

The following seeks to give a short insight about the possible areas that could be economically exploited:

According to IQBAL and SHAFIQ (1997) less than one percent of plants worldwide have been sufficiently studied with regard to their ecology and potential contribution to local communities. This was especially the case for plant species of the arid and semi-arid environments, however an increased awareness and research input has been seen over the last years (IQBAL and SHAFIQ 1997, p.459) and multipurpose trees such as *Prosopis* have received particular attention.

Energy resources and timber production

GOEL & BEHL (1996) in their experiment showed the high fuel wood quality of *P.juliflora* in comparison with other multipurpose species (*A.auriculiformis*, *A.nilotica*, and *Terminalia arjuna*). *P.juliflora* (followed by *A.nilotica*) was found to be the most suitable species for short harvest rotation cycles on energy plantations (which could be insitu stands where plantation is not regarded beneficial) due to its high wood density, biomass yield, low ash and moisture content, as well as good combustion heat at the juvenile stage.

Importantly, the wood density, which is an essential parameter for fuel wood quality as well as the determination of harvest rotation cycles, varied only very slightly in *P.juliflora* and *A.nilotica* in regard to tree age (GOEL & BEHL 1996, p. 58/59). It was suggested that *P.juliflora* should be harvested in 5-year rotations (and *A.tortilis* in 6-year rotations). In a previous study GOEL & BEHL had also examined the potential of 6 different species of *Prosopis* for short rotation fuel wood forestry programs on alkaline soil sites. They found that *P.juliflora* and *P.alba* were the most promising species due to high biomass production and good energy value. *P.juliflora* had the highest fuel wood value index (FVI)⁵⁰.

This outcome suggests that *P.juliflora* is potentially a major candidate for renewable energy resources in Eritrea and the wider region. This may be particularly the case in rural areas where competition for natural resources is growing and where access to alternative energy resources is rare.

⁵⁰ Fuel wood Value Index: High calorific value and density, and low water and ash content account for high FVI.

Table 5.2: Fuel wood quality of different *Prosopis* species under trial

Source: GOEL & BEHL (1995), p. 19

Species	Calorific value (kJ g hoch -1)	Density (g cm hoch -3)	Ash (%)	Moisture (%)	FVI
<i>P. juliflora</i>	23.53+/- 0.15*	0.736 +/- 0.05	2.30+/- 0.15	36.13+/-1.20	2084
<i>P.alba</i> I	22.65 +/- 0.19	0.682 +/- 0.03	2.65 +/- 0.15	33.17+/- 2.40	1752
<i>P.glandulosa</i>	21.72+/- 0.63	0.555+/- 0.08	2.60+/- 0.02	36.94+/- 1.06	1249

*Mean +/- S.E.

Energy ‘plantations’ based on in situ *P.juliflora* ranges could potentially be established on enclosed plots heavily affected by *Prosopis*, as the new planting of seedlings would probably not be an option in Eritrea and many other semi-arid regions considering the risk of further spread.

BLOESCH (2001) suggests that “*Prosopis chilensis*”-infested⁵¹ areas in Eritrea far away from urban centres (e.g. Karora) could be converted for charcoal or briquettes production, lowering thereby the transport costs to the peripheral local market” (BLOESCH 2001, p.17).

Within an experiment of sodic wasteland rehabilitation in Northern India (see chapter 2.3.2) GARG (1999) determined an optimal fuel wood harvesting rotation. He argued that deforestation needs to cease in an effort to keep land productive and to prevent further spread of degraded environments such as sodic wastelands. However, in his opinion, parallel to this, tree plantations should be intensified on already existing wastelands to respond to the fuel wood needs of rural India, which he estimates to be around 86% of all wood harvested (GARG 1999, 281).

In his experiment *P.juliflora* produced the highest mean annual increment (MAI) in the sixth year, which was entire two years earlier than the second successor *D.sissoo*. Also,

⁵¹ Based on the misidentification of *Prosopis juliflora*, which was commonly thought to be *P.chilensis*, see chapter 5.1 (The Case of Misidentification) for details

on a 20x20 m plot and six year interval basis, *P.juliflora* (57 t ha⁻¹) produced more than three times as much biomass as *D.sissoo* (15 t ha⁻¹). However, it must be remembered that biomass production can vary considerably from place to place according to external conditions such as climate and edaphic factors.

In a similar experiment *P.juliflora* produced the highest biomass, closely followed by *Casuarina glauca* 13987 and by a larger margin by *Acacia nilotica* and *A.tortilis* which produced only about half of the amount in biomass (TOMAR *et al.* 1998, p.313).

Of economic importance is also the use of timber for construction purposes. SHUKLA & KHANDURI *et al.* (1994) have run tests with six different tree species used for construction in India (area of Dehra Dun). It was found that *P.juliflora* timber was very suitable for construction purposes, as it exceeded the other plant species in terms of strength and resistance parameters.

HABTE (2000) outlined that *Prosopis* wood in Eritrea was used for fencing stakes or construction timber, but also for “local bed making” (HABTE 2000, p. 7). However, utilisation of *Prosopis* for bed making and carpentry was not mentioned as a benefit during the survey suggesting that - although it takes place to some extent - respondents did not mention it as a benefit.

Table 5.3: Nail and screw withdrawal resistance

(Source: SHUKKA & KHANDURI *et al.* 1990, p. 142 ; amended)

Condition	Nail/screw driven in <i>green</i> condition and pulled out immediately				Nail/screw driven in <i>dry</i> condition and pulled out immediately			
	Nail withdrawal resistance		Screw withdrawal resistance		Nail withdrawal resistance		Screw withdrawal resistance	
Species	Side (kg)	End (kg)	Side (kg)	End (kg)	Side (kg)	End (kg)	Side (kg)	End (kg)

<i>P.juliflora</i>	242	192	345	260	256	163	350	269
Average of the two other local species most resistant ⁵²	154.5	117.5	277.5	193	117	105	291	206

It was also stated that *P.juliflora* is suitable for construction as a "group C" timber, which can be used for special railway sleepers, for bridges, and crossings and as a "class I" timber for tool handles and dunnage pallets. Other reports state that *P.juliflora* timber is so hard that it is "comparable to the finest hardwoods" (SERTSE, 2005, p.2)

Table 5.4: *Prosopis* timber properties

(Source: SHUKKA & KHANDURI *et al.* 1990, p. 145 ; amended)

	Properties ⁵³			
	Weight a 12% m.c.	Bending strength	Toughness	Hardness
<i>P.juliflora</i>	Very heavy	Strong	Extremely tough	Extremely hard

Fodder

According to PASIECZNIK *et al.* (2001) people collect *Prosopis* pods in high quantities to feed their livestock or sell them to merchants. In Peru they "earn an equivalent of less than US\$5/day, as during the production season pods fetch a very low price because of their abundance (e.g. US\$27/t in February 1995)". Rural communities have also built storage facilities allowing them "to supply ranchers in other regions of the country throughout the year [...] they profit from the fact that the price for *Prosopis* pods can quadruple by the end of the dry season in September, when other forages are lacking." Although it was stated that

⁵² The two local species tested alongside *P.juliflora* for nail and screw resistance were *Tectona grandis* and *Millingtonia hortensis*.

⁵³ Properties given by SHUKKLA *et al.* for
 Weight range: "heavy - moderately heavy - very heavy - extremely heavy"
 Bending strength: "weak" or "strong"
 Toughness: "Not tough" to "extremely tough"
 Hardness: "Soft – moderately hard – hard – extremely hard"

the commercial production of *Prosopis* pods is not well documented in government statistics it has been suggested by a couple of sources that 12,635t have been collected in 1996 in northern Peru 60% of which was transported to and sold in the capital Lima. Estimates of a total availability of 400,000t of *Prosopis* pods/annum in northern Peru alone suggest that there may be more financial benefits still to be won (PASIECZNIK *et al.* 2001, p. 89).

Processed *Prosopis*-based feed supplements have also been researched and successfully used by communities in other countries such as the Sudan and India (MAGID 2007, p.72; CONROY & SUTHERLAND 2004)

Gum and honey production

Gum is exuded from the sap-wood and used in the paper and cosmetic industry (source: DE OLIVEIRA ANTONIO 1992 in WICK and THIESSEN *et al.* 2000, p. 601) and in regard to its quality gum derived from *P.juliflora* is believed to be similar to that of gum Arabic, which is produced in Eritrea and other countries in sub-Saharan Africa.

The production of honey from *P.juliflora* is also said to be possible and the honey of good quality and taste.

Commercial values

MAGID (2007) in his thesis demonstrates some of the yields and economic values of *Prosopis* by-products worldwide (after NAS 1980). Although the figures provided are a couple of decades old the following is a short insight into some of the suggested commercial values and potentials of *Prosopis*:

- “In the Chaco Province of northwestern Argentina, 140,000 tons/year of *Prosopis* logs are harvested for furniture and flooring. It has also been suggested that on a 15-year rotation, expected yields are 75–100 MT/ha, on 10-year rotation, 50–60 MT.
- In the state of Texas, 15,000 tons of *Prosopis* chips and chunks are processed yearly for sale in retail stores across the United States. Also in the United States, a small but fast-growing *Prosopis* lumber, flooring and furniture market has developed.
- In Peru, 180,000 tons of *Prosopis* pods are used annually for livestock feed.

- In Mexico in 1970, 40,000 tons of *Prosopis* pods were used annually for livestock feed.
- In Gujarat state of India, 300,000 30-kg bags of *Prosopis* charcoal are produced each year for sale in large cities.
- In Haiti in 1991, the total value of the charcoal industry (principally resulting from *Prosopis*) was \$50 million, and the charcoal industry supported 150,000 people.
- In the Sahel, about 16 million cubic meters of firewood are required per year. Senegal imports 50,000 cubic meters of wood each year from neighboring countries. *Prosopis* is a major provider of firewood for Senegal.”

(MAGID 2007, p.25)

The above accounts demonstrate that *Prosopis* in Eritrea may currently be economically underexploited. The very negative standpoints of communities towards *Prosopis* may directly impact on their views and actions in regard to its utilisation creating a highly ‘*subjective impact-and-utilisation-balance*’ instead of a practical, objective or scientifically valid one. Research and experiences from communities elsewhere clearly show that *Prosopis* can be very beneficial, particularly in socio-economic terms. However, in the context of Eritrea and potentially other countries it is crucial that - in the view of communities who see their livelihoods as threatened by *Prosopis* - such benefits are promoted in an integrated manner, accompanied with explicit acknowledgement that they are only a means to mitigate the problem of *Prosopis* and neither a means of eradication or of addressing wider issues of poverty.

Similarly MAGID (2007) reported on a joint initiative in Matama village, in the Nile state of Sudan. There, a “popular committee for the development of Matama” was set up in collaboration with the Forests National Corporation of Sudan, the Forest Research Centre, the University of Khartoum, and the Ministry of Agriculture of Nile State along with “a group of artists” to develop a model for the economic exploitation of *Prosopis*. Although it appears implementation on the ground had not commenced at the time of writing (2007) the committee came up with creative ideas as to how the rural communities could use *Prosopis* particularly through means of its wood. The following was suggested:

- Woody shades for the highways and desert ways of some institutions [meant are probably popular routes and access roads to institutional branches in remote areas]
- Benches and desks for schools
- Different shapes as toys for children
- Boxes for keeping fruits and vegetables
- Household utensils
- Decorative products
- Production of cart wheels for carrying wastes
- Manufacturing of tables and chairs and walking sticks
- Kitchen tools

(MAGID 2007, p. 27)

A similar initiative could potentially also be started in the rural context of Eritrea using it for popular traditional household utensils and local woody products, but also by introducing innovative craft skills.

5.7 Environmental Policies and related Legal System

Eritrea's environmental policies are established within a holistic development context founded on the leading principle that the country's development is based on a three-track development approach including food security, environmental protection (to ensure land productivity) and economic development. One of the overall objectives is to achieve a status of self-reliance for the country and major policies are set up within the context of this ambition. It is important to be aware of this. Eritrea's overall environmental policies are less a direct effort to protect and manage the natural environment for the sake of nature and biodiversity but more to ensure sustainable land productivity and natural resource management as a basis for food security and national development. Nevertheless there is a great level of awareness, action and mobilisation at policy and community level regarding the protection and regeneration of the natural environment. In fact - although there are still many gaps existing - the Government of Eritrea has put great effort into environmental protection and has a considerable track record in the management of natural resources and in this regard, Eritrea is ahead of many other Sub-Saharan countries. The broad

establishment of hillside terracing, national afforestation initiatives, the enclosure of areas for regeneration and the prohibition of tree-cutting for fuel wood consumption (with the exception of *P.juliflora*) are just a few policies and activities that are taking place in order to protect the natural environment.

There are several key environmental policies. The agricultural policy is outlined in Agriculture Policies and Strategies and in the Ministry of Agriculture Profile (e.g. 1992-1996) (SOS Sahel & MoA 1999, p.40). However, much of it is integrated in the Food Security Strategy (FSS, 2003) and in the Interim Poverty Reduction Strategy Paper (I-PRSP 2003)⁵⁴, which are further national key policy papers.

Food security is one of the "... pillars and fundamental objectives of our development strategy" it is "to ensure over the long-term that all Eritreans have adequate nutritious food to lead healthy and productive lives" (FSS 2003). Most policies on agriculture and the natural environment seek to achieve this overall objective by creating sustainable conditions for effective land productivity over the long-term.

Since 1994 with the introduction of a new land policy, land ownership lies with the state. One objective of the new land proclamation (No 58/1994) was to combat environmental degradation by reforming the traditional land tenure system through the introduction of clear land use planning and the lifelong usufruct right to its prior owner. The new land policy sought to do so by "determining land use, determining the manner of expropriating land utilised for development and national reconstruction and determining the power and responsibility of institutions which will implement the proclamation (NAP 2004, p.14)". Some benefits have emerged out of the new land proclamation such as social equity in 'land ownership' and lifelong land usufruct, which in turn would encourage personal investment in the protection of land resources that have been allocated to a particular household over a long period as to compared to traditional systems (NAP 2002, p.16) which, in some parts of the country included user rotation. Similarly however, disadvantages on the other hand seem to undermine these apparent benefits, as the new system, under which the government is able to expropriate or re-allocate land for national development, and the inability of family members to inherit land can itself create a lacking sense of ownership and responsibility, which may in reverse be disadvantageous to

⁵⁴ The Food Security Strategy Paper (2003 Draft) and Interim Poverty Reduction Strategy Paper (2003 First Draft) are two of the Government of Eritrea key policy documents for national development.

environmental protection of the land the proclamation seeks to achieve. Further, some objectives such as land-use planning that may also help to remove a source of conflict by clarifying borders has not eventuated. Eritrea still has no national land use classification map nor a land use planning map; a shortfall which is increasingly impacting rural livelihoods, particularly pastoralists and agro-pastoralists in the Western Lowlands who see grassland areas dwindling⁵⁵ and migration routes are being cut off by agricultural expansion. Furthermore in the view of this study, a detailed land use classification and planning map would be advantageous in the planning and implementation process of *Prosopis* management and the identification of priority areas to be tackled, regenerated or protected.

The riverine forests - a *Prosopis* prime habitat - are not only key pastoralist rangelands and generally an important livelihood resource, but also a primary source of biodiversity including a wide range of fauna and flora, which the government seeks to improve and conserve. This is also required under its obligations by the Convention on Biological Biodiversity. The Government is also a signatory to several international environmental conventions such as the UN Convention to Combat Desertification (UNCCD) and the Convention on International Trade in Endangered Species, to which it became a signatory in 1994, as well as the Framework Convention on Climate Change and the Convention on Biological Biodiversity which were signed in 1995 (SOS Sahel and MoA 1999, p.10 and p.41).

The management of the invasive species *Prosopis* would need to take place within the context of national and international policies and conventions.

⁵⁵ Reasons for the increasing shortage of grassland areas have been described in details in: Bokrezion H. & Fre, Z. et. al (2002): Eritrean Pastoralism in 2002: New challenges and the need to raise awareness on pastoralist livelihoods. PENHA/NUEYS study. Asmara/London. They range from border closure and mine fields to expanding agriculture and environmental degradation.

Chapter 6: Discussion, Conclusion and Recommendations

6.1 Global Perceptions towards *Prosopis* among Rural Communities vs the Trend of *Prosopis* Promotion among Experts: a Discussion

The study has shown that there are discrepancies between international research findings and the views of rural communities regarding the issue of *Prosopis*. This chapter therefore addresses an international gap in the discussion about *P.juliflora*: the collection and comparison of perceptions of rural communities around the world who see their livelihoods threatened by *Prosopis*, followed by full acknowledgement and integration of their concerns within rural development action.

Cases may well exist where *Prosopis* is of use to landless people or those who live in sandy desert climates (but even this is not necessarily the case - as the case of Gahtelay has shown - and one needs to assess if this is locally applicable). This chapter is not an attempt to dismiss the positive attributes of *Prosopis*, but an attempt to put these into a broader grass roots context, as experts seem to fail to some extent to compare the benefits to the losses that rural communities are encountering with *Prosopis*. The species unarguably has great benefits to some. And those who benefit from it will continue to do so, as *Prosopis* will most probably stay where it has established itself.

Of concern to researchers, practitioners and policy makers however should be foremost those who clearly suffer under the effects of *Prosopis* - and continue to do so. This study was carried out within the assumption that is widely portrayed by experts at all levels: *Prosopis* is a harmful weed where agriculture and pastoralist rangeland management exist, but that it is a useful source during the dry season, within desert ecosystems, for poorer households and to those who learn how to exploit it.

This illustration however has not just been challenged by Eritrean respondents during the survey. Leaving aside 'scientifically correct' research trials and studies 'measuring' the benefits of *Prosopis* and as a result 'scientifically validating' them, and instead turning more towards subjective experiences, views and 'peoples' stories' (mostly collected during interviews, within rural development reports, the press, or during local workshop discussions) the alarming situation becomes quickly very apparent: Rural

communities are literally fighting *Prosopis* because they feel it is not just “a harmful weed” but a threat to their existence.

Researchers, academics and policy makers tend to dismiss certain rural community perceptions, which are seen as ‘scientifically non-viable’ or to some extent ‘unreasonable’. During the interviews in the lowlands of Eritrea a couple of people for example mentioned that *Prosopis* ‘attracts heat’. Although it seems rather unlikely from a scientific view point that a lush and largely ever-green plant would decrease air moisture or increase local temperatures, a similar account has in fact also been reported thousand of kilometres away in Rajasthan (India) stating that “much of the area used to be covered with native trees, which local people believe used to increase rain, whereas now *P.juliflora* is dominant.” (IUCN 2001, p.149). While this does not prove that this is in fact the case, it is ‘a reality’ for those concerned.

A similar example is the particularly inflammatory effects of *Prosopis* thorns, an issue that is barely looked into in related research documents. Respondents in Eritrea for example have claimed that *Prosopis* thorns cause infected wounds in both animals and humans, which are not caused by other kinds of thorns.

LAXÉN - who came across similar reports from farmers in Eastern Sudan - visited a local hospital to enquire as to whether such claims could be confirmed. However, local hospital staff maintained that it was not the thorn that causes the infection, but poor hygienic conditions, resulting in a few cases of amputation per year. This is just one example of many demonstrating that the consultation of experts (although highly essential) can lead to the dismissal of accounts made by rural communities among professionals - because (we) ‘experts’ - tend to value the opinion of each other as we are sharing a better level of communication and understanding (sense) among each other. Barely any research paper confirms the inflammatory effects of *Prosopis* thorns, yet such claims were not just made by Eritrean communities. Rural inhabitants in Kenya also reported that the thorns of the plant [*P.juliflora*] are [...] poisonous, so once an animal is pricked, the solution is to cut off the affected area (BBC News Report, 07 August 2006, Kenya). In fact, the specific inflammatory effects of mesquite thorns - unlike other thorns - were mentioned by communities in other parts of Kenya (UNEP 2004; MWANGI 2005, p.43), Rajasthan (IUCN 2001) and the Sudan (LAXÉN 2005).

A very serious step against the invasion of *P.juliflora* has been taken by the Kenyan Ilchamus (Njemps) community, which is native to Baringo district in Rift Valley Province. They have submitted an official complaint to the Public Complaints Committee of the Environmental Management Committee (NEMA), which is the environmental watchdog of the Ministry of Environment and Natural Resources. The complaint was directed against the Food and Agricultural Organisation (FAO) of the UN who were accused of “introducing and financing the propagation of *Prosopis* under the Fuel Wood/Afforestation and Extension Programme in 1982.” The case was believed to have “serious political implications [for the FAO], as the FAO enjoys diplomatic immunity in host countries.” The committee outlined that “it will first establish whether FAO's country director is exempt from such quasi-legal proceedings. If he is, the Committee said it would seek the intervention of the Ministry of Foreign Affairs”. The hearing is expected to determine who will pay for the removal of *P.juliflora*. The legal ground for the hearing is the propagation of noxious weeds which is claimed to be contrary to the provisions of the Noxious Weed Act, cap 325 of the Laws of Kenya.

Similarly, in Namibia the fast propagation of *Prosopis* reportedly led to a country-wide epidemic of an allergy among the population in the 1990s. It is reported that "The Namibian government dragged its feet in clearing the weed until the country's president, Sam Nujoma, contracted the allergy himself" (UNEP 2004)

The representative of the Ilchamus community explained that by taking over the Ilchamus' land, the weed "is causing serious food insecurity and is threatening their existence." (UNEP 2004).

Furthermore, pastoralists and farmers in Eritrea, Kenya, India and other countries have claimed that they were losing livestock due to severe indigestion, tooth decay leading to teeth falling out, and inability to sell livestock that has been fed with *Prosopis* in local markets. In Eritrea it was claimed that the buyer would fear upcoming weakness and illness of the animal, while the Ilchamus community in Kenya reported that the meat of livestock could not be sold due to the bad taste resulting from *Prosopis* consumption (BBC News report 2006; UNEP 2004).

These issues further contribute to the food insecurity of the livestock-owning communities as they are losing animals and essential animal by-products for household consumption as well as the necessary income generated from livestock sales.

While there are some positive accounts regarding the household use of *Prosopis* in Eastern Sudan (LAXÉN 2005) others have stated that “over 90% of livestock owners in eastern Sudan regard mesquite [*P.juliflora*] as a liability. Mesquite pods are not used as animal feed, mesquite thorns are injurious to animals and dense mesquite thickets reduce productivity of grazing enterprises and interfere with mustering of stock” (BABIKER 2006, p.3; EL SIDDIG 1998).The negative accounts made by rural communities against *P.juliflora* are extensive and should be of great concern, not only to the communities themselves, but to all stakeholders concerned.

It would be too simple - and in a rural development context to some extent patronising - to merely dismiss such negative perceptions and experiences among local communities. By providing optimistic research outcomes or by announcing that such perceptions are commonly based on the lack of knowledge as to how the species could be beneficial to rural communities will not accommodate their concerns sufficiently. Moreover, it will in practice most probably not achieve the desired outcomes (e.g. poverty mitigation through the utilisation of commercialised *Prosopis* by-products), as some important facts have been excluded: While many documents calculate and present the benefits of *Prosopis* - for example, by providing figures as to how many million people in India or elsewhere are dependent on *Prosopis* fuel wood, and how many million dollars are generated annually in local markets - no document has been found that calculated the losses, which are reported by rural communities. For example, the economic cost of losing at times vast amounts of

- grazing lands,
- forests & native plant species
- crop land & harvest
- irrigation pipes and wells
- land for the construction of settlements
- access to land, water and settlement
- livestock

health

including the costs for weeding, labour, health treatments, etc. and - as some community account suggest - even the cost of social losses, such as customs, traditions, hope, and trust in organisations, experts and governments that have either propagated the planting of *Prosopis* in the first place or that are now reluctant to sufficiently address the concerns of the communities affected like the case of the Ilchamus community in Kenya has shown. While the former (losses and costs of livelihood related resources) is a fact, the latter (social costs such as the loss of hope and trust) may seem somewhat too subjective. However, if communities compare *Prosopis* to the war or the HIV/AIDS epidemic and others take the UN (FAO) to court over their *Prosopis* planting programmes then these are concrete and socially significant developments, which should not be dismissed as a subjective list of individual perceptions.

These communities have a very intensive knowledge base regarding their surrounding natural environment, which has by no means remained static, and they have managed to successfully adapt themselves to all sorts of changes and dynamics - natural as well as anthropogenic - that have been thrown at them. Therefore the concerns expressed are based on 'reality on the ground'

Furthermore, it can be assumed that most rural communities who are highly depending on their locally available natural resource base would have tried to use 'the tree' (*Prosopis*) for the most obvious: as a source of fire wood and charcoal; for building construction; and as a browsing source for livestock. Indeed, these are some of the benefits that are so highly promoted by experts. However at grass roots level, the opposite is the case: communities - including those who participated in planting initiatives a few decades ago - have described *Prosopis* as a "punishment by Allah" and "like the war" in Ethiopia; they have branded it as "only good for burning" in Rajasthan district of India, they have called it a "green killer", and "like the HIV/AIDS epidemic" in Eritrea and a cause of "serious food insecurity [...] threatening their existence" in the Baringo district in Kenya.

Researchers, experts, development workers and policy makers in the meanwhile remain somewhat oblivious to this situation. A pest management expert from the World Agroforestry Centre (Icraf) stated in regard to the situation in Baringo district: "While I would encourage enough research before such a species is introduced in a new place, I think the biggest problem is that the local population in Baringo has not come to appreciate

Prosopis as a resource...” (UNEP 2004). In Ethiopia experts and NGOs call foremost for ‘control through the means of exploitation’, in Eritrea the issue is not addressed in either way, and in Rajasthan communities faced a Japanese-funded aid programme back in 1993 that further propagated and planted over 20,000 *P.juliflora* seedlings on the hilly wastelands (IUCN 2001). It is now widely claimed that India’s rural communities heavily depend on *Prosopis* as a valuable fuel source, which is used as a ‘*Prosopis* success story’ in the introductory part of many Indian and international research documents (MWANGI *et al.* 2005, p.8; CONROY *et al.* 2004, p.10; PASIECZNIK *et al.* 2001, p.2)

According to the UNEP, the complaint and concerns of the Ilchamus community were addressed within a document of workshop proceedings sent to The EastAfrican where the Ministry of Environment stated that it was unable to tackle the *Prosopis* situation, because of "shortage of vital information and tools to deal with the problem." It was further pointed out that "There is today a political urgency to accurately define and quantify the extent of the *Prosopis* problem and its management options by involving broad public participation." the official representative of the Ilchamus community had also been present during the workshop where he had reportedly complained bitterly about the propagation of the weed by FAO. According to the UNEP, much of his speech had been “curiously enough edited out of the document” (UNEP 2004).

6.2 Discussion of Study and Concluding Summary

Socio-economic and political developments in Eritrea during the last ten years have resulted in various patterns of migration within Eritrea in general and the Gash-Barka region (Western Lowlands) in particular. Hence, the Western Lowlands of Eritrea may today be the most dynamic and diverse region in the country, as different communities with a range of socio-economic structures and cultural heritages are now sharing it as a common habitat. Although this can be a source of great potential and diversity for future development, it may also increase natural resource scarcity and competition particularly for land and natural resources, on which particularly the rural communities closely depend. This again underlines the urgency for appropriate and sustainable conservation and land management systems including pro-active management and control of invasive species, such as *P.juliflora* before it spreads further and reaches a high risk level.

The study has shown that there are a lot of expert findings and perceptions regarding *P.juliflora*, worldwide as well as in the context of the Horn of Africa region, which sometimes seem to take the situation on the ground insufficiently into consideration.

Firstly, *P.juliflora* is widely presented as a plant species that thrives in dry climates and that is more drought resistant than the native species giving it the upper hand while spreading. This could wrongly imply that *Prosopis* preferably invades dryland 'hot spots' such as desert areas, degraded open savannah or rocky hill sites. But research within this study has demonstrated once more that *P.juliflora* in fact has a much bigger reliance on (or preference for) water consumption than often stated. Prime habitats for *Prosopis* in Eritrea, which have been identified as riverine forests, irrigation schemes and cropping areas, immediate settlement areas and road sides, all tend to have a high relative water or soil moisture availability as compared to the surrounding open areas. Also, in Ethiopia reports have stated that one of the prime invasion habitats for *P.juliflora* are areas in zones 1 and 3 of the Afar region and it was exactly those areas which the UNEP-EUE had classified as being frequently (mostly seasonally) flooded. This preference of *Prosopis* needs to be widely recognised in any national management efforts of *Prosopis*, which will make it much easier to identify actual as well as potential high risk areas.

Secondly, of particular importance are the accounts of local communities facing *Prosopis* invasion that have been presented in this study and some of the discrepancies that have occurred following rural accounts and general research reports leading to the widely used term of 'the paradox *Prosopis*'. It has been shown that rural communities in Eritrea, the wider region and other parts of the world alike have expressed great concern regarding the spread of *P.juliflora*. They see the species as a serious risk to the natural resource base upon which their livelihoods so strongly depend and they therefore believe that *Prosopis* is a direct threat to their existence. As previously discussed in this study (in chapter 4.8) it is somewhat patronising in the context of development and possibly counter-productive to simply dismiss such extremely negative perceptions and experiences among local communities by providing optimistic research outcomes as a response to their concerns or by explaining that their concerns could be addressed and their perceptions changed if communities would learn about the benefits *Prosopis* has in store for them. The study has shown that it has been suggested by some experts that *Prosopis* was introduced to countries

concerned without a parallel introduction of appropriate local knowledge about the species. It is questionable if this is really the case and whether it holds the key to a rather complex problem. These communities have a very intensive knowledge base regarding their surrounding natural environment and have widely managed to adapt themselves to all sorts of changes that have occurred in their environment - natural and man-made - in the recent past. Indeed, there have been numerous reports of damaging impacts of *Prosopis* from concerned communities in India, a country where *Prosopis* was introduced well over a century ago, a period that can be considered long enough to establish a local if not indigenous knowledge base about the utilisation of the tree. However, rural communities depending on the natural environment should be considered knowledgeable enough to figure out how to utilise a tree even if it is an introduced species. Trees - although their botanic composition may vary greatly - are generally still used in a similar way: as a source for fire wood, wood manufacturing, charcoal, construction, shade and if palatable potentially for livestock browsing or for provision of edible fruits or honey. These benefits, which are highly promoted as benefits of *Prosopis* and which are widely regarded as 'the answer' to the problems the species causes in rural areas do probably not need decades to emerge within rural communities and it may not require a major training or awareness raising programme to initiate such activities. One could however acknowledge that certain other areas such as the mechanisation of fodder production, the preservation of wood, or the utilisation of various plant parts as a potential remedy against diseases is knowledge that may take longer to develop.

To strengthen the argument yet further that a sufficient local knowledge base regarding the use of *Prosopis* should broadly exist, one should note the case of *Prosopis* leaves being crushed by people in Western Eritrea and applied specifically to treat infected injuries caused by *P.juliflora* thorns, as it was claimed common remedies do not work. DUKE (1983) reported that "the Amerindians applied the leaves [of *P.juliflora*] for conjunctivitis". This means that treatment methods indigenous to the native *P.juliflora* ranges has also been adopted by a community in North-east Africa (and maybe elsewhere) that has been isolated by war for several decades during the early introduction of *Prosopis* (in the 70s or 80s) and had only been confronted with the species for a few decades. This proves - regardless of the fact if the remedy itself is effective or not - that the indigenous or local knowledge base towards *Prosopis* has been developing in countries where it has been

introduced and that the lack of rural knowledge of how to use *Prosopis* efficiently should certainly not be regarded as the key reason for the lacking utilisation and enthusiasm among rural communities towards *P.juliflora* as widely implied.

One key issue that seems to accompany this research study (and some other studies for that matter) is the discrepancy between research findings and scientific evidence on the one side and the accounts and views of rural communities on *Prosopis* on the other. Without validating one over the other it is a challenge to assess where the contradiction of such outcomes is rooted. Research for example says *Prosopis* is an excellent fire wood and timber for construction. Yet some communities stated it was brittle and of poor quality, causing sparks, skin diseases or attracting termites (see chapter 4). Scientists were praising *Prosopis* soil ameliorating characteristics while rural communities claim it was degrading soils and threatening the native vegetation. Researcher and practitioner are applauding its multi-purpose use while rural communities were widely dismissing it as “useless” or “only good for burning”.

One should assume that a comparison of *Prosopis* invasion with the war, the HIV/Aids virus or the devil - however extreme it may seem - is a comparison directly derived from negative personal encounters with the species and the huge impact it has made on the rural livelihoods of some communities. These effects are felt even more in a livelihood situation that is already prone to environmental changes and where a high degree of time and labour has to be invested into every day survival.

On the other hand a range of positive and confirmed scientific findings cannot be dismissed either. One reason for the discrepancies could be the context of scientific trials. They often take place within the laboratory or a confined demonstration plot, which lacks the impact of external realities on the ground. A research trial that measures the characteristics of woods will mostly be carried out in a laboratory, where the wood may have been dried or stored, one won't have termites, and the researcher is not living or sleeping under the *Prosopis* wood, which was reported by locals to cause skin irritation. Similarly endless trials have taken place about the positive development of *Prosopis* energy plantations to meet rural fuel wood needs, but have failed to recognise that the spread of the species is causing the depletion of the natural vegetation and many other problems that need to be taken into consideration. Such specific experiments, which are taken out of the wider context of the local setting, may bring results, which may - although valid and valuable - not

be complimentary to the challenges on the ground. Research outcomes that identify the kind of animals that get easily affected by eating *Prosopis* and to determine the proportion of pods (in percentage) that is harmful is in deed crucial knowledge to some, but for pastoralists who traditionally owe all kinds of livestock, sometimes in their hundreds, which are free roaming that information is of little use.

Besides, it seems inappropriate in a rural development context to use a ‘*Prosopis*-control-measure’ by simply suggesting to a community that is practicing farming or nomadism - a way of life adopted from their forefathers - to earn a living using *Prosopis* by starting a small carpentry or bee-keeping business or to join the local charcoal trade. This is unfortunately, how many research reports and approaches come across - in fact the ‘good news of exploiting *Prosopis* for income generation’ seems to be *the* approach adapted by most. Although it is necessary to face the issue of *Prosopis* and its ever-growing presence by finding ways of managing and utilising the species in ways that are potentially beneficial to rural communities, it is the lack of sincere appreciation of the grounded concerns of rural communities who feel visibly threatened by its spread, the lack of effort to accommodate those concerns, as well as profound control measures that are actually stopping further spread rather than simply utilising the plant, which need to be addressed.

The decision of Kenya’s Ilchamus community in the Rift Valley Province to take the Food and Agriculture Organisation (FAO) of the United Nations to court over the introduction of *Prosopis* into their area is another illustration as to how damaging residents feel the impact of *Prosopis* invasion is on local livelihoods and the lengths to which communities are prepared to go in the fight against the species. Therefore, researchers, experts and policy makers alike should take the concerns of the rural communities seriously.

They need to be incorporated in any assessment and management planning even if certain research trials or surveys have demonstrated the potential benefit of *Prosopis*. On the other hand, this study and others have indeed demonstrated that *Prosopis* can be of benefit to communities. For example by providing fuel wood or a substitute to animal fodder particular during the dry season, resources which are both very high in demand in Eritrea and the wider region and which can be used for income generation. Therefore, these two stands - the threats and the benefits - need to be combined and more importantly acted upon in an integrated strategy that seeks to find the appropriate way forward. In terms of approaching this complex situation it seems appropriate to work closely with the

communities concerned by *Prosopis* invasion, to acknowledge the threats and disadvantages they experience as result of the invasion, and to work out management practices that foremost teach feasible and affordable control measures (physically halting the spread) alongside attractive exploitation techniques of a species that has become very much an unpleasant reality. It seems that rural communities as well as researchers, experts and policy makers alike need to refine their positions and show more flexibility and adaptation in approaching the issue of *Prosopis* in theory and in practice. Rural communities by acknowledging that *Prosopis* has become part of their environment and that even huge amounts of investment will not achieve its eradication. These communities need to recognise this new reality and be open to learn about how they can control as well as exploit the species. They also need to start taking responsibility at community level for the action required (even if this is only possible after some training and awareness rising) to manage this species by using new practices and not wait for government to arrive with big machinery to eradicate it. Researchers, experts, NGOs, the academia and policy makers on the other hand will need to take a step back in their quest to promote *Prosopis*-based benefits and income generation as *the* answer to the problem or in some cases even a way to rural poverty reduction. While *Prosopis* can be of substantial use and usually causes little damage in hot, sand desert areas, this study has shown that in the semi-arid areas of Eritrea and other parts in the region and even in hot arid climates where no agriculture and extensive livestock herding is taking place, *Prosopis* clearly is felt as a threat to rural livelihoods. There, it has reached extreme levels of invasion ultimately even proposing a risk to household and regional (in-country) food insecurity by destroying vital natural resources and obstructing the access to it.

It seems that in the same way rural communities share their common experiences and perceptions so do international researchers and practitioners. The study has demonstrated that, however valid robust laboratory research might be in strict technical terms, people's experiences of the same issues in a local context can be (and in the case of *Prosopis* in Eritrea and elsewhere emphatically are) hugely different. But even researchers present results and recommendations based on 'scientific perceptions' which can be influenced by the positive research outcomes that have been presented and published over decades or by regular communication among scientists and policy makers (rather than a farmer or pastoralist in a remote area). Or sometimes (we) experts and policy makers need

longer to grasp changes taking place on the ground: *When good trees turn bad: the unintended spread of introduced plantation tree species in India* is the title of a 2005 publication by the FAO dealing with the issue of *Prosopis juliflora* (among other tree species) in India. Maybe a shift has in deed widely taken place, but needs time to be recognised.

As discussed in chapter 4, exploiting *Prosopis* e.g. chopping its branches near the stem or the stem itself for fire wood and charcoal production or harvesting gum or honey will not control its spread - as many experts suggest or at least imply. The approach of 'controlling *Prosopis* by exploiting it' will not be sufficient on its own and therefore most probably lead to ineffective management. Therefore, locally appropriate control measures (as outlined in the management plan of this study and suggested by others - see chapter 5.3) that can actually halt further spreading need to be urgently identified and implemented. This would clear the path for an effective and appropriate management approach, which promotes both the control (halting) of *Prosopis* spread and the potential exploitation of the species. To keep the balance between the promotion of control and the promotion of exploitation (utilisation) right it is also crucial that researchers as well as practitioners start to recognise any additional benefits derived by *Prosopis* in any given area for no more than they have often become: a means of balancing out the losses that farmers, pastoralists and the local natural environment alike have widely faced as a result of *Prosopis* invasion on their land.

Thus, the 'paradox *Prosopis*' that so many researchers refer to may not be so much of a mystery after all. If some refer to *P.juliflora* as the devil and others call it a savior, some think it is an aggressive weed and others believe it is a multipurpose wonder tree one needs to see the external factors that may lead to this divergence in views. An invasive evergreen tree seems most likely to have a different impact in a dry, hot, and sandy desert environment or a degraded, unused sodic wasteland with little accessibility to natural resources than in a productive semi-arid area where it invades crop lands, irrigation systems, local forests, marsh lands and open grassland. Therefore one aspect that can lead to different perceptions regarding *P.juliflora*'s role is understandably the climatic condition and environmental context in which it grows. Most experts in fact agree on this. But even here caution needs to be applied to not automatically imply that all communities living in

desert environments will embrace *P.juliflora*, as the survey carried out within this study in the semi-desert of Gahtelay has shown; even there perceptions can be very negative.

The real question however remains if *P.juliflora* is indeed a paradox *within* different semi-arid areas. It has become evident within this study that the majority of rural habitants that practice farming, horticulture, commercial agriculture, livestock production, agro-pastoralism and pastoralism in Eritrea, the Sudan, Ethiopia, Kenya, Yemen, India, and Pakistan have clearly expressed their struggle with *Prosopis*. Where does this leave those reports that have proven that *Prosopis* has made considerable contributions towards the livestock feed situation, the rural economy of the household income and food security situation of often poorer households? These accounts are of great value to the question of *Prosopis* and the issue of rural development. Yet, they are often unbalanced, as they fail to present integrated reports and costing of the actual losses that have occurred as a result of *Prosopis*. Or they praise the benefits to some (e.g. *Prosopis* based income generation to the landless or poor) without outlining the losses to those who are negatively affected (e.g farmers or herders).

Thirdly, SOS Sahel & MoA (1999, p.64) stated in their Riverine Forests Inventory and Management Plan that “In the Eritrean context it [*P.juliflora*] is an entirely inappropriate species, which will cause a great deal of disruption to agriculture, forestry and other forms of land use if it is allowed to spread”. Almost ten years later, not much has happened at policy level to address this alarming situation.

The planning and implementation of a *Prosopis* Management Plan in Eritrea will be a major challenge for many reasons: Lack of knowledge and information, missing data and expertise on the matter, lacking resources, and rural communities who do not really want to engage in discussions that suggest anything other than eradication. However, Eritrea’s policy makers and the communities have a long track record when it comes to environmental protection and related community mobilisation, which will be crucial and a real benefit to any planned management activity regarding *Prosopis*.

In a time where population growth, post-conflict and climate change put an increased stress on Eritrea’s natural resource base its protection is of particular importance. The issue of *Prosopis* in Eritrea is still a new subject and debates and research action will need to continue. There may be different opinions, standpoints, ideas, and measures arising in the coming years as to how to best manage the species or in deed even, whether further

planting shall take place within community agro-forestry programmes. Some approaches may be effective and others may fail, this is part of the process, but the biggest risk of all would be to ignore the issue, as in the meanwhile *Prosopis* is spreading into new riverine forest areas, irrigation schemes, settlements and crops and each year new seedlings will have established themselves to a point where they will be hard to remove. Generally, *Prosopis* in Eritrea is currently a low risk problem factor, but nevertheless one that is very alarming, as it is continuously spreading at a fast pace. The situation is still at a relatively early point where much can be achieved if coordinated action is started. However, it has started to visibly impact rural livelihoods and interfere with key national development objectives such as the protection of environmental and agricultural productivity, public health, and food security. Therefore, Eritrea's policy makers in collaboration with international multilateral organisations and NGOs will need to take the lead and finally actively integrate the issue of *Prosopis* in related environmental and development programmes before the issue reaches a level of high risk.

6.3 Recommendations for Research and Sustainable Intervention

Recommendations for research:

- Conducting and collecting research data on the issue of *Prosopis* including socio-economic surveys as well as ecological research and inventories.
- Research into control measures such as enclosure, communal weeding and seed consuming bio control agents.
- Collecting experiences from other countries.

Recommendations at policy level for sustainable intervention on the ground:

- Consultations with communities affected.
- Changing extreme levels of negative attitudes towards *Prosopis* into more accepting outlooks through the means of information, education, demonstration trials, exchange visits and awareness raising activities as well as skill training on *Prosopis*-based products and crafts.

- Identify priority areas for intervention regarding *Prosopis* management and control. In view of the thousands of people whose livelihoods are directly depending on the productivity of the riverine forests on a daily basis it is recommended that the riverine forests are a *Prosopis* habitat which should receive highest priority in any planning and implementation efforts. This may be followed by irrigated and rain-fed cropland, immediate settlement, and open grazing land areas.
- Producing a mutual written agreement among communities and the authorities as to how *Prosopis* should be managed: more than anything this would send a signal that the management and control measures that have been agreed upon are taken seriously at both levels and will be followed up.
- In any management plan, drawing up clear-cut responsibilities for the various stakeholders including a regular monitoring system.
- To build and increase capacities of both the local communities as well as related ministry departments including provision of necessary technologies as well as information, education and training in regard to surveying, plant inventories, use and marketing of *Prosopis* by-products, biodiversity conservation and similar. This could also include a training for trainers for both extension workers and community trainers in the processing of *Prosopis* by-products such as animal fodder supplements, baking flour, charcoal, gum or honey.
- To enclose small areas and spaces highly infested with *Prosopis* to prevent animal browsing, but to make them accessible for humans to enable them to exploit the resources for processed fodder or firewood instead.
- To set up a national *Prosopis* Task Force (with trained extension workers) with a mandate to continuously enforce and review the issue including participation in international and regional training programmes, workshops and conferences to allow them to keep up-to-date on the issue and to learn about new management approaches or usage of *Prosopis* in other countries that could be adapted if they are appropriate and beneficial in the context of Eritrea.
- Focus *Prosopis* management and action on the halting (control) of further spread by applying concrete measures (see table 5.1: A List of Botanic ('Internal) Factors contributing to *Prosopis*' Invasiveness and Appropriate Control Measures). Any

aspects of *Prosopis* exploitation should only be integrated into management action rather than being the key focus of it.

- Draw a Risk Assessment and Management Plan including actual and potential risks occurring as a result of the infestation by *Prosopis* (for example, loss of dry season rangeland areas essential to animal productivity) and those risks that may occur during the planning stage and implementation process of the National *Prosopis* Action Plan (for example, lack of financial resources).
- Strengthen and regenerate natural vegetation resources, particularly the riverine forests in order to mitigate the impact of *Prosopis*. For example, extend afforestation efforts in *Prosopis* risk areas and re-introduce traditional control systems of the forests (e.g. the *abo gereb*, where applicable) to protect the native forest resources.

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11. Which disadvantage/negative effects does it have for the grassland? (Multiple answers possible) (Only for pastoralists/agro-pastoralists)

- a) it takes water away c) it take sun light away
b) it takes nutrients away d) nothing else grows next to it
e) grass does not grow f) don't know
g) Other (please specify): _____

12. Which disadvantage/negative effects does it have for livestock? (Multiple answers possible)

- a) animals get injured (e.g. by thorns) e) it's poisoning/toxic for animals
b) animals die from eating d) Others (please specify): _____
c) animals get diarrhea _____
d) animals get paralysed e) don't know

13. If you have seen/heard animals dying by eating it, which part of the plant do you think caused the death? (Multiple answers possible)

- a) leaves d) seeds g) don't know
b) thorns e) plant juice
c) fruits f) other (please specify) _____

14. Have you lost animals yourself because they ate Prosopis/died of injuries by thorns etc?
YES _____ NO _____ Don't know _____

(NEXT 2 QUESTIONS ONLY IF LAST ANSWER WAS "YES")

[15.a) How many have you lost?

Number _____ Don't know _____

15.b) Which kind of your animals died? (Multiple answers possible)

Specify: _____]

16. Do you think/experienced that some animals get effected more easily by eating it while other do not/are immune? (Quote which animals)

_____ get effected easily _____ do not get effected
don't know _____

(QUESTION 17 is for farmers/agriculturists and agro-pastoralists only)

17. Do you think Prosopis influences the outcome of crop harvest negatively?

YES _____ NO _____ Don't know _____

18. What are in your opinion the advantages (positive effects) of Prosopis (for the nature, you and/or the animals)?

Specify _____

No advantages _____ don't know _____

19. What do you use it for? (Multiple answers possible)

- a) fence/shelterbelts e) windbreak i) Others _____
b) livestock fodder f) bricks j) I do not use it
c) fuel wood g) building construction
d) charcoal production h) shade

20. Have you ever used Prosopis for fuel wood/charcoal production?
 YES_____ NO_____ Don't know_____

21. Do you think it has a good quality for the use of charcoal?
 YES_____ NO_____ Don't know_____

22. Does the local government to your knowledge allow cutting of Prosopis or do they say it needs to be protected?
Can be cut_____ **It is forbidden to cut**_____ **Don't know**_____

23. Do you think Prosopis improves the soil in your area or does it degrade it?
Improves soil_____ **Degrades soil**_____ **Don't know**_____

24. Did you ever try to eradicate (Killing) Prosopis from your crops/grassland?
 YES_____ NO_____ Don't know_____

25. If yes, what problems did you face?
Specify_____

26. If not, why not?
Specify_____

27. Would you wish the local government would try to eradicate it?
 YES_____ NO_____ They do/did try_____ Don't know_____

28. Keeping everything in mind what you know/experienced with Prosopis: Would you consider it to be a pest/weed, a very useful tree or neither?
Pest/weed_____ **Useful tree**_____ **Neither**_____ **Don't know**_____

29. If you were taught how you can make use of Prosopis so it would benefit you and your family, would you like to learn/know about it?
 YES_____ NO_____ Don't know_____

30. Do you have anything to add that is important to you?
No_____ **Yes, (specify)**_____

Thank you for your time.

List of Abbreviations

BBC	British Broadcasting Channel
EC	European Commission
ERRA	Eritrean Relief and Rehabilitation Agency
FAO	Food and Agriculture Organization of the UN
FNC	Forest National Cooperation (Khartoum, Sudan)
FSS	Food Security Strategy
GoE	Government of Eritrea
IDP	Internally Displaced (refugees)
I-PRP	Interim Poverty Reduction Paper
IUCN	The World Conservation Unit
MAHSAV	Israel's International Cooperation Program
MoA	Ministry of Agriculture
MoLWE	Ministry of Land Water and Environment
NEMP-E	National Environmental Management Plan for Eritrea
NAPP	National Action Plan for Prosopis (Draft) ⁵⁶
NWLZ	North-western Lowland Zone
PMM	Prosopis Management Map ⁵⁷
UNDP	United Nations Development Programme
UNDP-EUE	United Nations Development Programme: Emergencies Unit for Ethiopia

⁵⁶ First draft framework designed by the author within this study (see chapter 5.4.)

⁵⁷ New concept recommended by the author (see chapter 5.4.)



The four survey sites