Alien invasive *Prosopis*: A curse or a blessing?

by
Auala H, Cloete C, Gottlieb T[1], Haimbili E, Hembapu N, Kabajani M, Ndjamba J, Shekunyenge A, Shipani H and Shuuya T*
**Corresponding author*

Abstract

Prosopis is an alien invasive tree/shrub found throughout most of the town lands and many of the ephemeral rivers in Namibia. They are exceptionally noteworthy in the Stampriet Artesian Aquifer in the Auob and Nossob basins in south-eastern Namibia. In particular, commercial farmers and service providers usually find them a factor reducing land productivity and difficult to eradicate. On the other hand, some communal farmers and most residents in informal settlements find them a valuable source of income and resources. If people living in the Auob and Nossob basins had the interest, capacity, funding, equipment and markets,

* Authors listed in alphabetical order

there is potential to generate a sizable income from *Prosopis*. Most of the residents and other authors, however, suggest cooperative and appropriate management, including targeted eradication, as the best approach.

Zusammenfassung

Prosopis ist ein standortfremder invasiver Baum/Busch, der überall in den Ortschaften und an vielen der Trockenflüsse in Namibia auffindbar ist. Besonders nennenswert sind die am Stampriet artesischen Brunnen in den Auob und Nossob Flussbecken im Südosten Namibias. Vor allem für kommerzielle Farmer und Dienstanbieter sind sie schwer auszumerzen und sie reduzieren Landproduktivität. Anderseits sind sie für einige Kommunalfarmer und die meisten Einwohner der informellen Niederlassungen eine wertvolle Einkommensquelle und Produktionsmittel. Wenn die Einwohner an den Auob und Nossob Flussbecken das Interesse, Fähigkeit, Finanzierung, Ausrüstung und Märkte hätten, besteht großes Potenzial ein beträchtliches Einkommen aus der *Prosopis* zu ziehen. Die meisten Einwohner, als auch andere Autoren, schlagen zusammenarbeitende und zutreffende Verwaltung, einschließlich gezielte Ausmerzung, als Vorgehensweisen vor.

Introduction

Prosopis plants are alien species that were introduced in Namibia in the early 1900`s to provide fodder for livestock and shade. There are different versions of the introduction of *Prosopis* species in Namibia. Several authors, such as Muller (1985), Smit (2005) and Zimmerman (1991), have documented that it was initially brought by Professor K. Dinter into Okahandja, Namibia, from South America in 1912 to be planted as a fodder tree. First invasions only appeared later in the 1950s when farmers settled on individual farms over large parts of southern and central Namibia (Smit 2005). Smit further stated that six *Prosopis* species, which are all known to be from the *Algarobia* division of the genus, have been introduced and became fully self-propagating in southern Africa. A seventh species, *Prosopis cineraria*, was also introduced to Walvis Bay, Namibia, in 1971 but it was unsuccessful

Since the first introduction of *Prosopis* in Namibia, it has spread rapidly in some areas such as the Swakop River (Visser, 1998 as cited in Smit (2005)). Dense infestations also occur in the Nossob and Auob Rivers (Muller 1985). According to de Klerk (2004), *Prosopis* has invaded dry river courses in southern and central Namibia and contributes to a substantial decline in land productivity caused by bush encroachment. According to various stakeholders in the Nossob and Auob basins, *Prosopis* plants have taken over large areas of the basin at the expense of local vegetation which seems to have been totally outcompeted in certain areas. *Prosopis* densities have been increasing and it is believed that this is due to run off and the flow of the rivers during high rainfall months. Livestock and humans have also aided in spreading the seeds from one place to another. According to (Smit, 2005) *Prosopis* plants are regarded as having the most adverse ecological impacts compared to all other alien plants in Namibia. They affect water resources, displace native species and reduce the aesthetic value of the area. The majority of inhabitants of the Nossob and Auob basins which include commercial farmers, communal farmers, informal settlement residents and service providers stress that the invasion of *Prosopis* has caused an enormous decline in the carrying capacity and the value of their land. Total eradication of *Prosopis* has proven to be extremely difficult if not impossible to achieve. Therefore better management and appropriate land uses coupled with the concerted efforts of all stakeholders is required to reduce its invasiveness in areas densely infested (van den Berg, 2010).

However, there are conflicting views between stakeholders in the basin concerning *Prosopis*. Some people are advocating for its eradication, while others are encouraging its preservation as a major source of income, particularly for women in informal settlements. Relevant local authorities are faced with the daunting task of having to understand the impacts of *Prosopis,* both positive and negative, and having to find amicable solutions to address these issues and mitigate the impacts thereof. Bearing in mind all the conflicting views that exist about *Prosopis* there is an urgent need to understand its socio-economic and environmental impacts. It is against this background that a study was initiated to analyse these impacts and enhance understanding thereof.

Objectives of the study

The overall objective of this study was to analyse the environmental and socio-economic effects of *Prosopis* in the Auob and Nossob basins and to make recommendations that could improve sustainable land management. The study focused on: population dynamics of *Prosopis*, inter-relationship between *Prosopis* and water, impacts of *Prosopis* on local plants, impacts of *Prosopis* on animal nutrition, use and management of *Prosopis* by stakeholders and opinions of stakeholders towards *Prosopis.*

According to van den Berg (2010), it is imperative to have a thorough knowledge and understanding of the little understood impacts of *Prosopis* on the environment, both positive and negative. Currently, these negative impacts include competition with local plants, alteration of the flow of rivers, and the abstraction of ground water. Furthermore there is still limited knowledge with regard to the socio-economic effects including the financial gains that could be generated from *Prosopis* products such as firewood, charcoal, and timber if it is fully exploited (Smit, 2005).

Cover photo: *Prosopis pallida* *Photo: Wikipedia*

The study area

The Molopo-Nossob Basin is part of the catchment area for the Molopo River, a tributary of the Orange-Senqu River (Veelen & Baker, 2009). The Orange-Senqu is an international river basin shared between four countries, Botswana, Lesotho, Namibia and South Africa. The Nossob and Auob rivers originate in Namibia and extend across four regions which include, Hardap, Karas, Khomas and Omaheke Regions (Carlson, et al., 2009) before crossing the border into Botswana and joining the Molopo. They occupy an area of 367,201 km^2 with 33% of this area in Namibia; the human population along the Auob and Nossob basins is sparsely distributed. The main water uses along the basin include agriculture, and domestic (human consumption) (Carlson, et al., 2009).

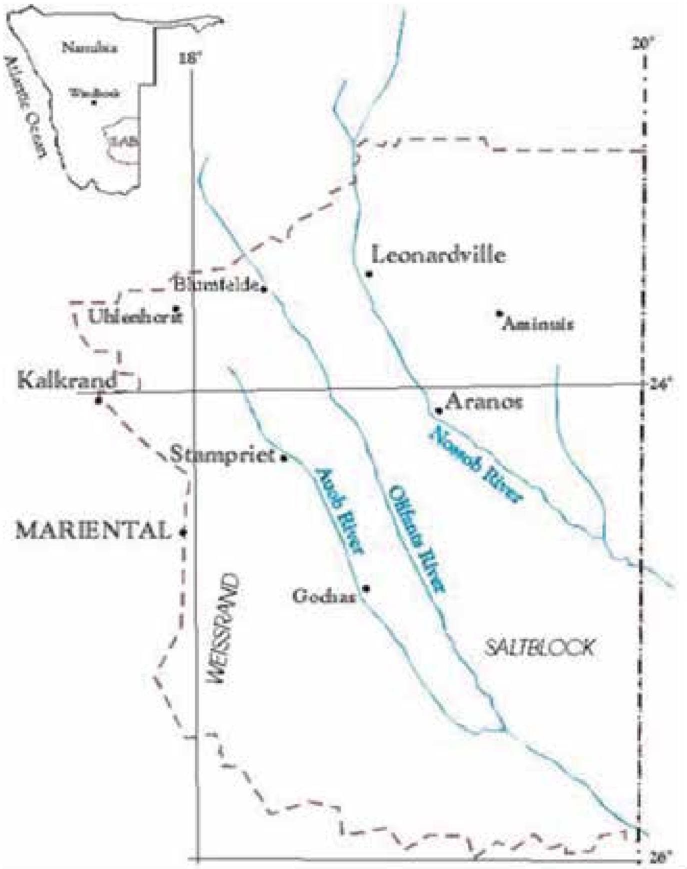


Figure 1: Location of the Stampriet Artesian Basin

Source: Directorate of Water Affairs and Forestry / Japanese International Cooperation Agency (DWAF/JICA 2000).

A major part of the Auob and Nossob rivers is underlain by the Stampriet artesian aquifer, one of the largest aquifers in Namibia. The aquifer is a major source of water to the inhabitants of the basin and particularly valuable because it lies under the Kalahari which is dry with low rainfall ranging between 250-350 mm per year (Mendelsohn et al., 2009). The Stampriet Aquifer Basin covers about 71 000 km² or about 8.6 % of Namibia's total surface area (Alker, n.d). The Auob and Nossob rivers are ephemeral endoreic water courses and may only flow after above average rainfall and terminate in the Kalahari. This study was conducted in Stampriet, Bernafay, Gochas, Leonardville and Aranos, all towns that are located along the Auob or Nossob rivers.

Vegetation

The Auob and Nossob basins fall entirely within the savannah biome (Mendelsohn et al., 2009), consisting of mixed tree and shrub savannah vegetation zones. Some of the common plants in the area include Acacia species and *Rhigozium trichotomum*, an indigenous invader bush in the area. Dunes of 10-15 m height are found in the Kalahari (National Planning Commission, 2007), covered with grass such as *Stipagrostis amabilis Eragrostis trichophora, E. lehmanniana, Centropodia glauca* and *Brachiaria glomerata*.

Invasive vegetation can be defined as species of vegetation that are not native to an ecosystem, able to spread and establish very quickly at the expense of the local plants. Such vegetation has the potential to cause immense economic and environmental impacts (USDA, 2009 & Groom *et al*., 2006 within van den Berg (2010)) as found with *Prosopis*.

Namibia does not have specific legislation regarding alien invasive species such as *Prosopis.* Several sets of legislation are considered applicable to the control and management of such species, however. Bethune et al. (2004) noted the following as part of the legal framework that can be used.

1. Article 95 (l) of the Namibian constitution is the core foundation of biodiversity conservation in Namibia and, although it does not refer directly to alien invasive species, maintenance of biodiversity includes alien invasive plant control.
2. The policy of the Ministry of Environment and Tourism looks at importation of exotic species into the country.
3. Namibia's Green Plan stipulates that the precautionary principle needs to be used when environmental policies are made (Development bank of Southern Africa & SAIEA, 2007).

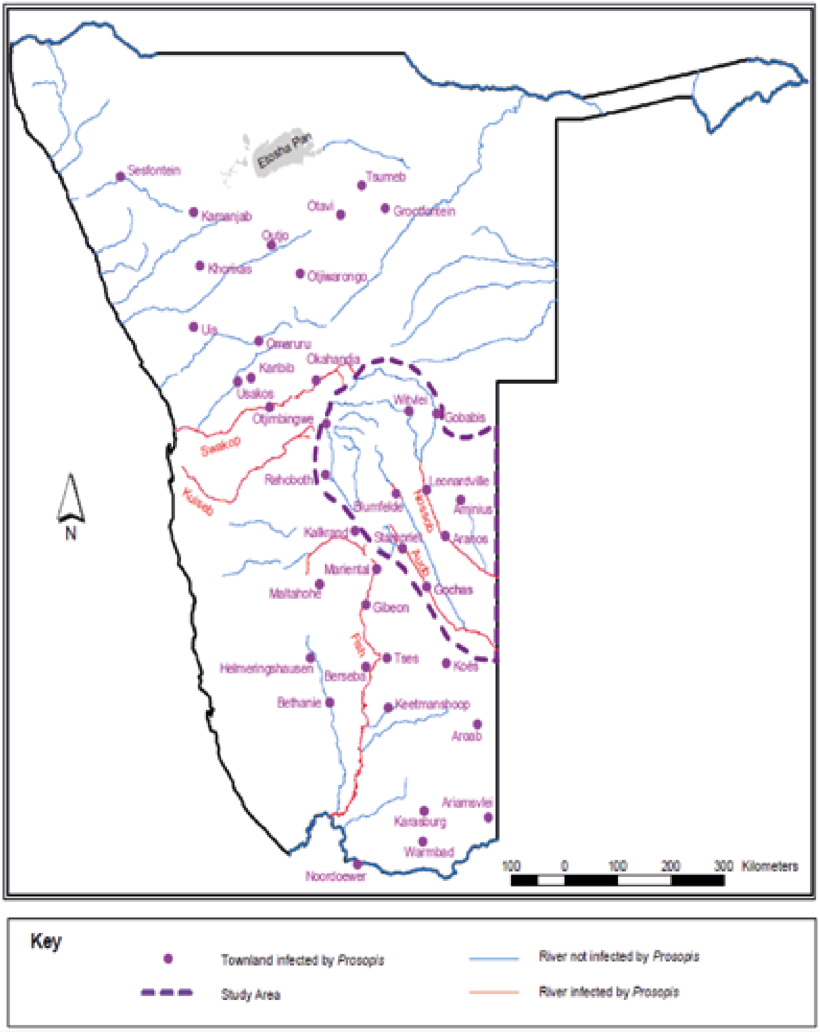


Figure 2: Rivers invaded by Prosopis in Namibia

Source: Mendelsohn et al. (2002) in Smit, (2005).

Climate

The mean annual rainfall across the study area varies between 179 mm in Stampriet, 178 mm in Gochas and 244 mm in Leonardville (Mendelsohn et al. 2009). The rainfall decreases from north to south (Smit, 2005). The mean annual potential evaporation varies from between 3 000 mm in the north and 3 500 mm in the south (Alker, n.d).

Water resources

Water has been identified as one of the crucial aspects that impact sustainable development in Namibia (Krugmann, 2001). It is estimated that more than 35,000 people live in and extract water from the Auob and Nossob basins mostly for livestock, households and irrigation purposes (Alker, n.d). Table 1 gives a brief overview of the water resources in the study area.

Basin/River	**Catchment area (km^2)**	**Average depth of aquifer (m)**	**Stored volume (Mm^3)**	**Extraction (Mm^3/annum)**
Nossob	50050	0-150	57000	0.20
Auob	52702	0-60	180000	4.97

Table 1: Water resources and extraction in the Auob and Nossob basins.
Source:Alker,(n.d)

The Auob and Nossob basins are part of the larger Stampriet aquifer. Despite being in the Kalahari with its deep sands, it is one of the most productive and largest aquifers in Namibia. Water from the catchment area in the Khomas highlands flows underground to reach the Stampriet aquifer (Mendelsohn et al., 2009). The aquifer is artesian, meaning the groundwater is stored under pressure and upon excavation it flows from underground to the surface. This characteristic is a crucial motivator for the number of boreholes in the area.

The area has more than 6 000 boreholes that on average yield about $30m^3$/hour (Alker, n.d; Mendelsohn et al. 2009). The water is of good quality and requires little purification before supply for human use. A hydro census was undertaken on 1,269 farms within the Stampriet aquifer and the results are presented in *Table 2*.

Borehole description	**Number**
Total number of boreholes in the Stampriet Aquifer	6 280
Boreholes in use	4 915

Table 2: Results of the hydro census carried out on 1,269 commercial farms in the Stampriet Aquifer *Source:Alker,(n.d)*

Socio-economic activities

The water resources of the Auob and Nossob basins can be viewed as one of the most important factors that influence the economic activities in the area. Irrigation farming is hence the main income generator in the area combined with livestock farming. According to a study done by Barnes et al. (2005), the Hardap and Omaheke regions have forest resource values of N$460 million and N$768 million respectively. This shows that despite the area being semi-arid, it still has forest resource values and if explored, could generate an income to benefit stakeholders in the area. This basis can relate to how *Prosopis* can be used for income generation in the areas.

Methodology

The study sites that were selected are: Stampriet, Bernafay and Gochas in the Auob Basin and Aranos and Leonardville in the Nossob Basin (*Figure 1*). The study sites were selected in collaboration with the CPP-ISLM under the Ministry of Environment and Tourism (MET), that focuses on promoting Integrated Sustainable Land Management (ISLM) practices. This study was intended to provide baseline information guiding implementation of planned projects.

Data were collected by using belt transects with quadrats of 6 m in width and 10 m in length laid across different habitats (dunes, gravel plains and dunes). The parameters under consideration were recorded at an interval of 10 m and alternative 10 m intervals were skipped. Transect walks were carried out on the 1) resettlement farm Bernafay in Stampriet, 2) Farm Osterode Suid in Stampriet, 2) Farm Glave in Stampriet, and 3) Farm Noasanabis in Leonardville, and 4) Mr Martin's farm in Leonardville. During transect walks, *Prosopis* species were observed and counted including under *Acacia erioloba* and *Boscia* species to elucidate the relationship *Prosopis* have with local plants.

Observations on *Prosopis* included the number of stems, presence of moth cocoons, presence or absence of pods, the colour and length of pods. Height and canopy cover were measured for each *Prosopis* and its nearest neighbour. Grass cover was recorded in each plot by estimating the density along a measuring tape through the walking transects.

To assess the root characteristics of *Prosopis*, one tree was dug in each of three different habitats (dunes, gravel plains and river). The circumference of the taproot for each tree was measured for 1 m below the soil surface at 10 cm intervals. This was done to determine how the roots of *Prosopis* are growing in the three habitats (dunes, gravel plains and river) and how this is related to the availability and use of water by these plants. In addition, the distribution of roots with depth was assessed.

The socio-economic data was collected through interviews in the study sites with various stakeholders. Commercial farmers, projects and service providers were identified and contacted to set up appointments. Interviews with communal farmers and informal residents were administered randomly on the resettlement farm of Bernafay and the informal settlements of Gochas, Stampriet and Leonardville. The total number of interviews conducted was 86 and of this total, 10 were commercial farmers, 29 communal farmers, 36 informal residents, 10 service providers and 2 projects that worked with *Prosopis* and are located in the study area.

The quantitative data that was collected on socio-economic aspects was organised and analysed by using Microsoft Excel and Statistica 7 software. The Shannon Wiener index, with the formula: ($H' = -\sum (Pi) (\ln Pi)$ was also used to compare the plant species diversity of different areas including the farms where *Prosopis* had or had not been cleared in Leonardville. GPS data were analysed using the Quantum GIS (QGIS) software version1.7.1.

The qualitative data collected were computed by developing scales ranging from scores of 1-5 and analysed using Microsoft Excel. The opinions of stakeholders about *Prosopis,* success of the type of management measure employed to control *Prosopis* and the density of *Prosopis* were computed on these scales. The opinions of stakeholders on the various problems caused by *Prosopis* were ranked on a scale from 1-3. The calculation on the uses and benefits of *Prosopis* were based on the responses of the interviewees.

Case studies were written with contributions from various stakeholders who had interesting information on *Prosopis.* They were incorporated to illustrate various bio-physical and socio-economic aspects of *Prosopis.*

Results

Prosopis populations and their dynamics in the Auob and Nossob basins were found to be similar. In the two basins a total of 343 *Prosopis* trees were measured individually, 256 in the Auob River and 87 in the Nossob River. These individuals were measured in transects covering three habitat types: river course and river floodplain, gravel plains and dunes. *Figure 3* below compares the average density of *Prosopis* (trees/ha) in the Auob (n = 256 quadrats) and Nossob (n = 87 quadrats) Basins. The Nossob Basin has a higher density (trees/ha) in the gravel plain and river compared to the Auob Basin. The river habitat has a high density followed by the gravel plain and then the dunes respectively in both basins.

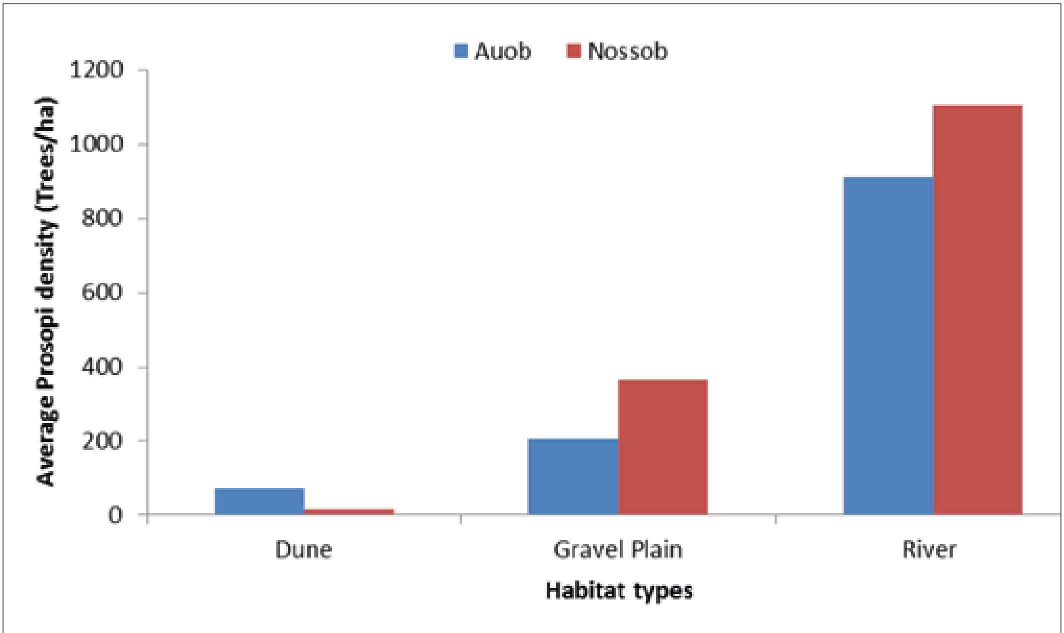


Figure 3: Average Prosopis density in the Auob (n = 256 quadrats) and Nossob (n = 87 quadrats) Basins

Stakeholders' opinions on *Prosopis* population in the Auob and Nossob basins - Figure 4 shows that the majority of the stakeholders interviewed stated that the population of *Prosopis* in both the Auob and Nossob basins has rapidly increased. Only a small percentage of stakeholders (2%) in the Auob Basin said that the population of *Prosopis* has decreased.

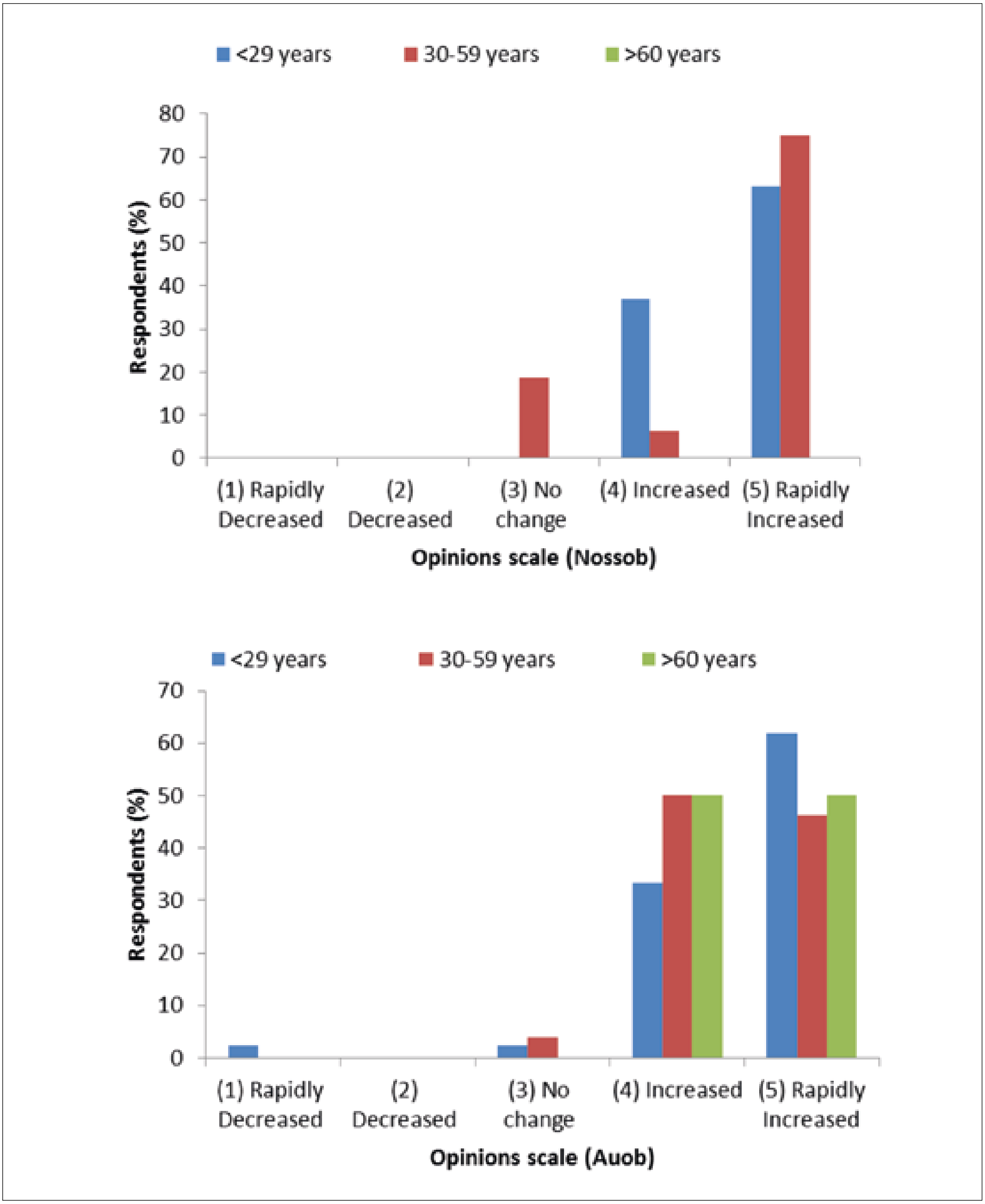


Figure 4: Stakeholders' opinions concerning the increase or decrease of Prosopis population in the Auob (n =73 persons) and Nossob (n =35 persons) Basin based on length of time that the respondents have lived in the area.

A one-way Analysis of Variance (ANOVA) was conducted to test if there are significant differences between the height (m) and canopy cover (m^2) of *Prosopis* in the three habitat types (*Figure 5*). Field observations indicated that the height and canopy cover of *Prosopis* trees that were found on the dunes are significantly taller with a larger canopy cover than those in the gravel plain and river. However, there is no significant difference between height and canopy covers of the *Prosopis* that were found in the gravel plain and river.

A step further was taken to test if there are significant differences between the height and canopy cover of *Prosopis* trees that were found in the Auob and Nossob basins. A one-way ANOVA was conducted and according to the P-values (height: P-value=0.17706; canopy cover: P-value=0.34474) at 95% confidence interval, there are no significant differences between the height and canopy cover.

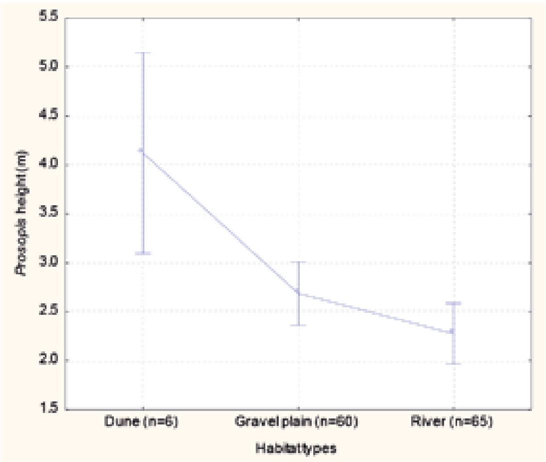
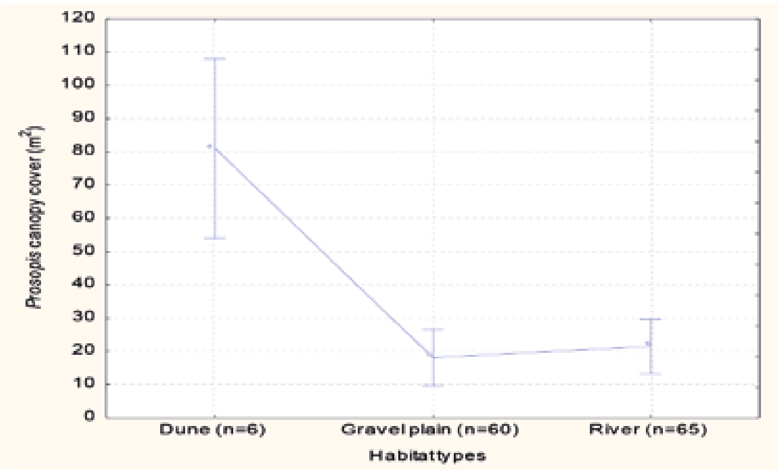


Figure 5: Average Prosopis height and canopy cover in different habitats. (Error bars represent 95% confidence interval here)



A one way ANOVA was also done to find out how tree spacing affects the average number of pod clusters per *Prosopis* tree in the gravel plain and river in the Auob and Nossob basins (*Figure 6*). Individual *Prosopis* trees produce more pod clusters (approx. 40) compared to the clustered ones (approx.10) on average. This test showed that there was a significant difference in the average number of pod clusters per tree in two habitats in the Auob (P-value<0.001). This concurs with general observations in the field where individual trees had more pod clusters than the clustered trees. The statistical results for the Nossob basin showed no significant differences in the number of pod clusters per tree.

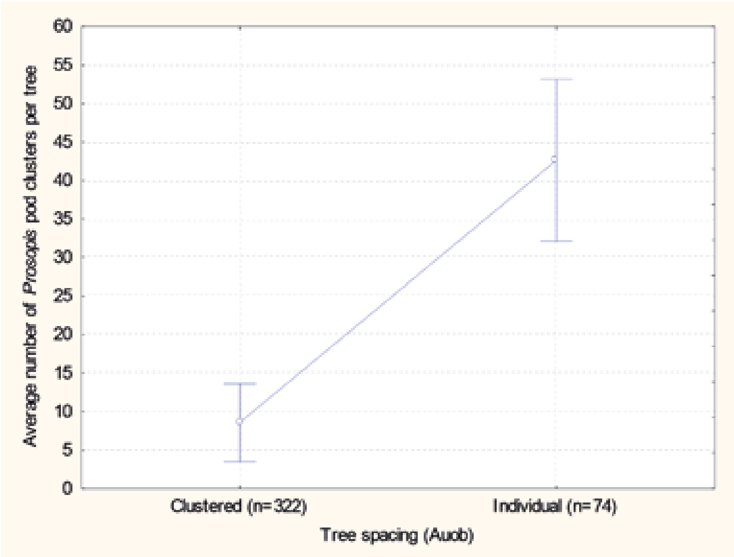


Figure 6: Average number of Prosopis pod clusters in relation to tree spacing in the gravel plain and river in Auob Basin

In order to assess the root characteristics of *Prosopis*, one tree was dug in three different habitats (dunes, gravel plains and river). The circumference of the taproot for each tree was measured for 1 m below the soil surface at 10 cm intervals. *Figure 7* shows that the taproots for all the trees had linear relationships with depth. As the depth increases the taproot circumference becomes smaller (R^2=0.889 for the dune, 0.835 for the gravel plains and 0.708 for the river). However, the one tree that was dug out in the river side had a taproot that only extended to 0.5 m below the soil surface. The tree however had many lateral roots.

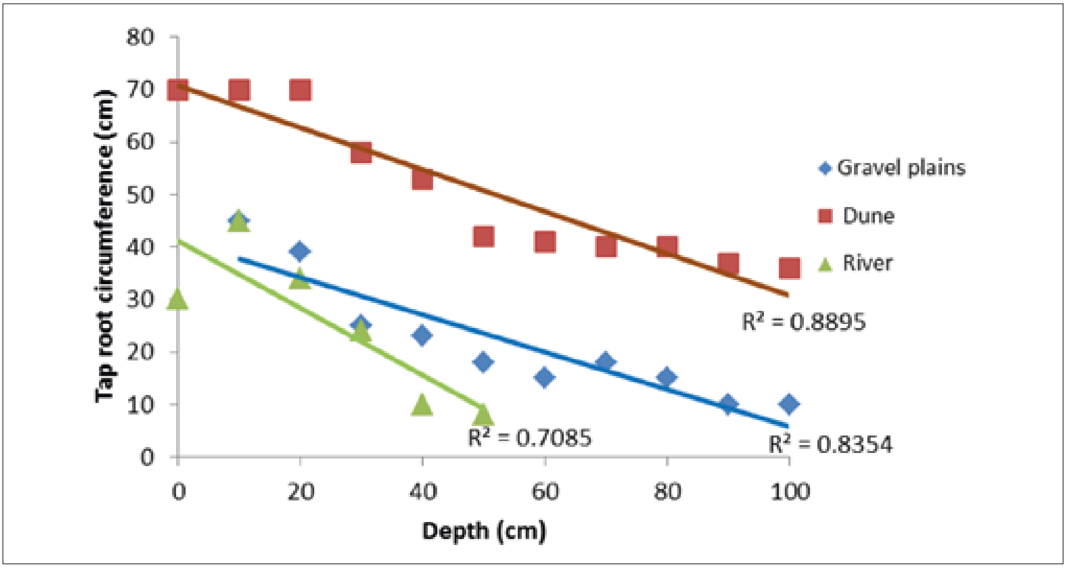


Figure 7: The circumference of taproots from trees that were dug out in the Auob Basin (n=1 for each habitat)

Figure 8 is also based on the same trees whose taproots are shown in *Figure 7*. This shows the distribution of lateral roots and the depth at which they stem out from the taproot. The trees by the river side and gravel plains had most of their lateral roots at 0 to 0.3 m. The tree on the dune had the majority of its lateral roots at 0.3 to 0.6 m.

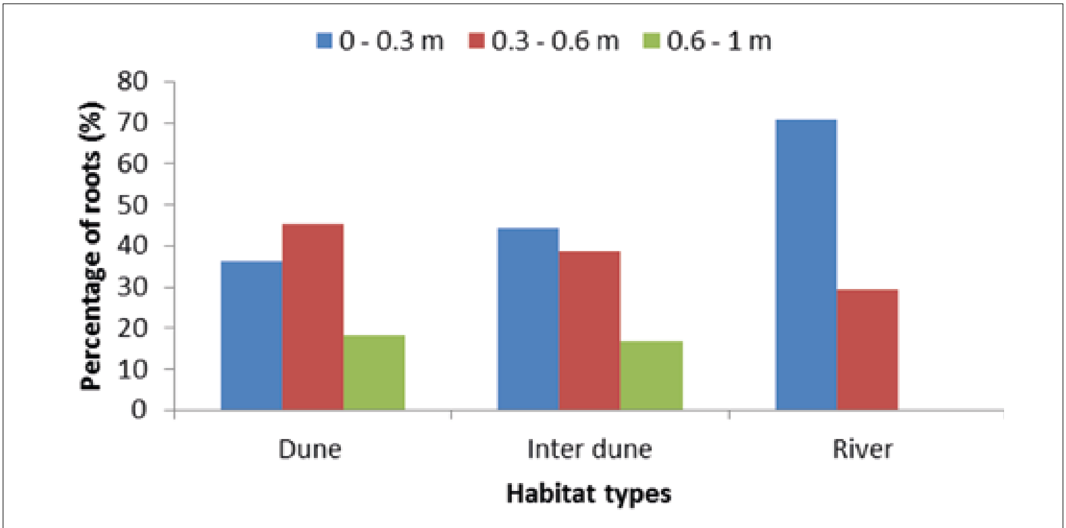


Figure 8: Percentage of Prosopis lateral roots found at different depths in various habitats in the Auob Basin (n = 1 tree per habitat type)

The inter-relationship between Prosopis and water

Various stakeholders were asked to give their views with regard to the inter-relationship between Prosopis and water. The majority of stakeholders (81%) were of the opinion that Prosopis was reducing underground water. Furthermore 19 % of the stakeholders interviewed were of the opinion that Prosopis was responsible for damage to water infrastructure.

The water consumption by *Prosopis* was estimated by using the tree density calculated in the Auob and Nossob Rivers per hectare (45515/hectare and 55250/hectare) respectively and the water usage of *Prosopis* per litre per day as adopted from Maitre (1999) which is 50 litres/tree/day. Thereafter, the water consumption per year and per hectare was extrapolated from the density and from the water usage per day, per tree. The water usage for the Auob and Nossob basins was then determined by using the total area of the individual catchments. Water consumption from the Auob was calculated to be 4.0 Mm^3/ annum while that from the Nossob was calculated to be 7.5 Mm^3/ annum. In ten years, the consumption is estimated to be 10.0 Mm^3 in the Auob and 20.0 Mm^3 in the Nossob at the predicted rate of density increase.

The impact of Prosopis on local plants

An average Shannon Wiener index was calculated to determine the plant species diversity in the Auob and Nossob basins. The index was calculated by averaging the total number of different plant species that were found in two transects conducted in both basins. The Auob was found to have a higher plant species diversity (H' = 0.78) compared to the Nossob (H'= 0.65).

The Shannon Wiener index was calculated to determine the plant species diversity in two different farms, cleared and uncleared, along the Nossob River. The index was calculated by averaging the total number of plant species found in the sampled farms separately. There was high plant species diversity in the farm where *Prosopis* was cleared out (H'=0.9) as compared to the farm where *Prosopis* was not cleared (H'=0.6).

The number and sizes of *Acacia erioloba* growing in areas of the same size where *Prosopis* had and had not been cleared out on the farm were measured in comparable transects. This was done to verify the assumption that in areas where *Prosopis* is cleared and treated, other plant species and grass tend to grow. There was a high number of *Acacia erioloba* (both seedlings and large trees) in the farm where *Prosopis* was cleared out (22 seedlings and 8 large trees) compared to the farm where it was not cleared out (2 seedlings and 3 large trees).

Figure 9 shows that there is a higher number of *Prosopis* (ranging from seedlings to big trees) growing under *Acacia erioloba* compared to *Boscia* species (*albitrunca* and *foetida*). Most of the *Prosopis* growing under *Acacia erioloba* were seedlings, followed by small trees.

Notwithstanding the differences in the number of *Prosopis* growing under *Acacia erioloba* and *Boscia* species, a One-way ANOVA test was run to see if there is a significant difference between the canopy cover and height of both *Acacia erioloba* and *Boscia* species. The results indicated that there is no difference.

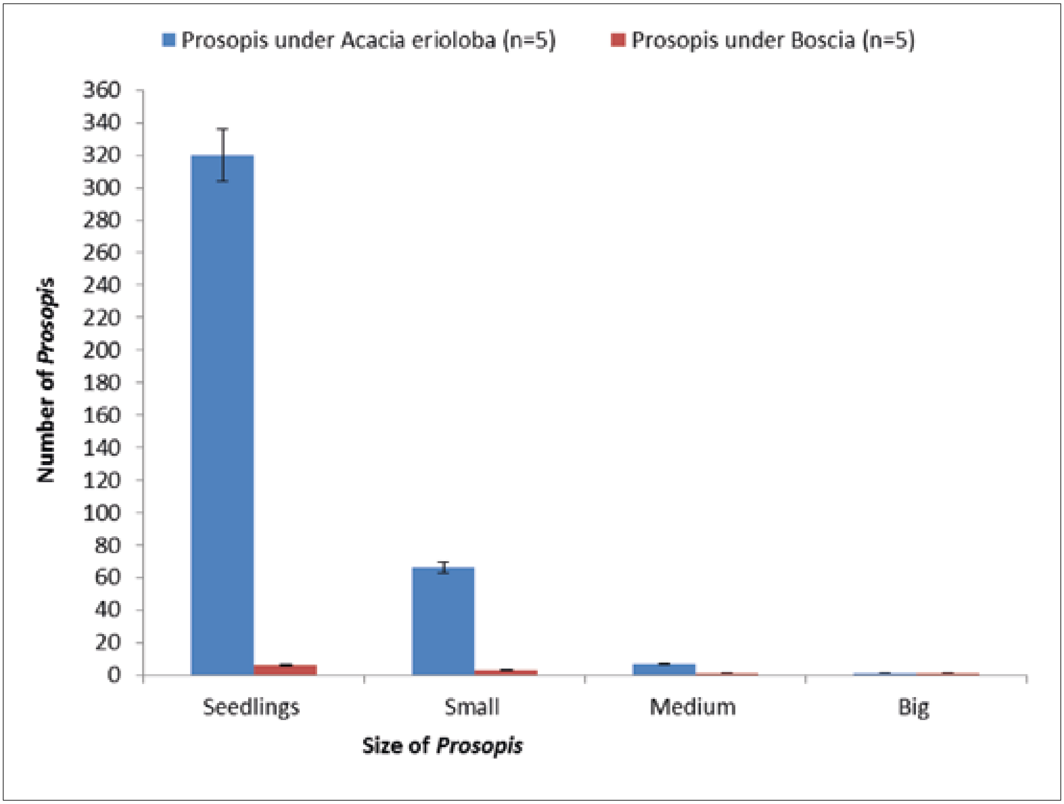


Figure 9: The numbers and sizes of Prosopis growing under Acacia erioloba (5 trees) and Boscia species (5 trees) in the Auob and Nossob basins

Stakeholders in the research area were asked whether *Prosopis* do or do not out-compete local plant species. Most of the communal farmers are of the opinion that *Prosopis* have out-competed local plant species. Whereas, most of the informal residents, commercial farmers and service providers do not believe that *Prosopis* has out-competed local plant species.

The impacts of *Prosopis* on animal nutrition

Of the stakeholders that were interviewed, a total of 37 owned livestock. Livestock owners belonged to two groups (10 commercial and 27 communal farmers). It was found that 10.8% of the respondents were commercial farmers who said they feed their livestock Prosopis pods. Based on the same sample, 65 % of the communal farmers indicated that they feed their livestock Prosopis pods.

The farmers who indicated that they feed *Prosopis* pods to their livestock were asked to give an indication on how they exactly fed the pods to their livestock. *Figure 10* shows that most of the farmers fed only the pods to their livestock (86%). A small number (3-4%) indicated that they mix *Prosopis* pods with other supplements such as Lucerne, Maize, Beans, Prickly Pear, Licks, Molasses, salt, phosphate and *Acacia erioloba* pods among others.

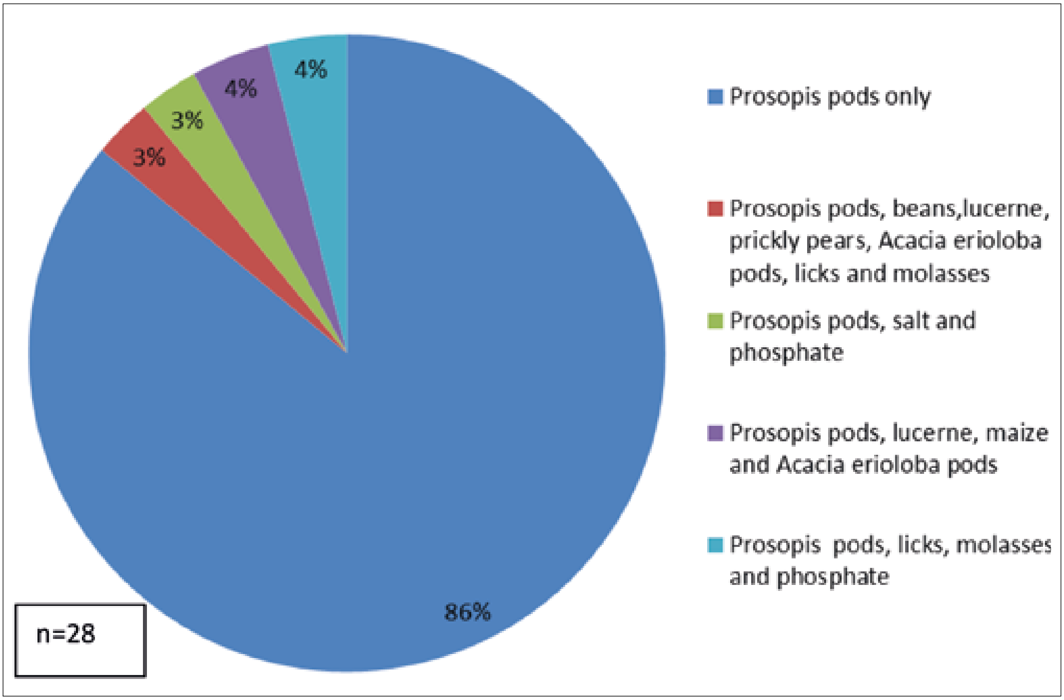


Figure 10: The way farmers feed Prosopis pods to their livestock

Prosopis pods have a high percentage of digestible crude protein while other products have higher values of other important nutrients *(Table 3*). The farmers mixed the various feed types to acquire optimum nutrition for their livestock.

	Digestible crude protein %	**Digestible nutrients %**	**Fibre %**	**Carbohydrates %**	**Ca %**	**P %**
Lucerne	12.5	56.3	35.1	37.1	1.1	0.22
Maize	7.5	83.4	1.7	72.3	0.01	0.25
Prosopis pods	17	71.6	26.3	47.4	0.5	0.08
Acacia erioloba	8.1	60.6	30.4	49.8	0.69	0.14

Table 3: The comparison of the nutritional value of lucerne, maize and Acacia erioloba and Prosopis pods. Source: Smit (2005)

Uses and management of *Prosopis*

Various stakeholders were asked to identify the products they derive from *Prosopis.* In general, communal farmers have a diversity of uses for *Prosopis* compared to other stakeholder groups. Some of these uses includes *Prosopis* pods and leaves as fodder and firewood. Informal residents are the only stakeholder group that consume *Prosopis* pods as a food substance to a significant degree. *Prosopis* wood is also used as firewood, turned into furniture and charcoal for commercial purposes.

Figure 11 compares the products derived from *Prosopis* in the Auob and Nossob basins. In the Auob Basin, 36% of the respondents indicated that they use *Prosopis* pods as fodder compared to 24% in the Nossob. Firewood is the highest use of *Prosopis* in the Nossob Basin with 36% and 33% in the Auob Basin. The manufacture of furniture and the use of cocoons for silk production were only identified in the Nossob Basin, whereas medicinal value from *Prosopis* was only identified in the Auob. Furthermore, the number of respondents that indicated that they produce charcoal is 2% in the Auob and 4% in the Nossob.

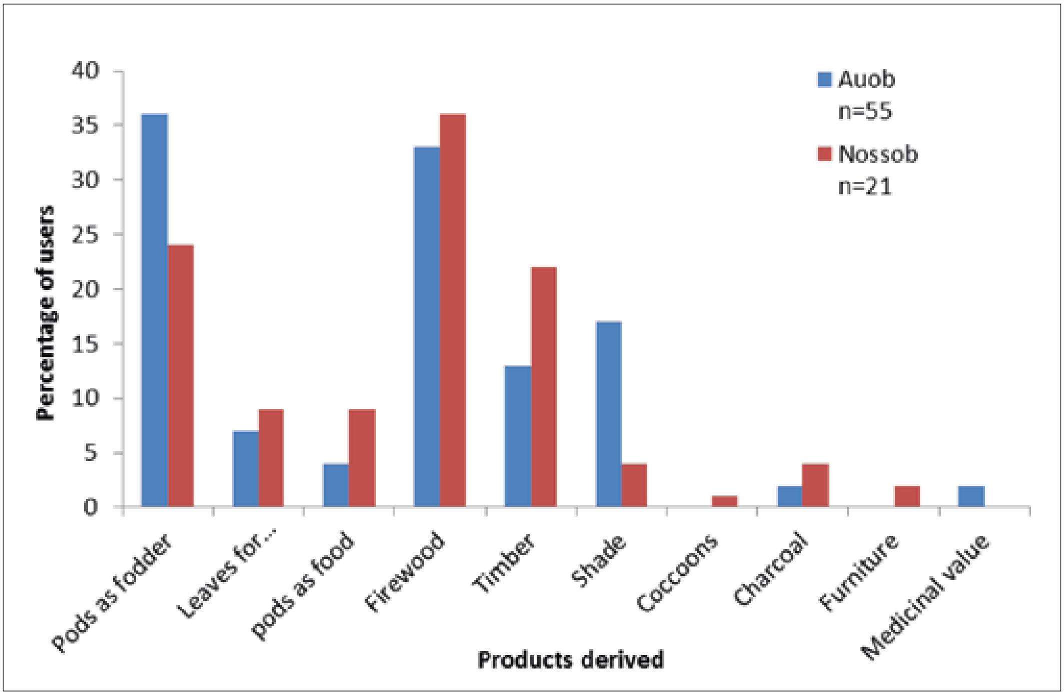


Figure 11: Comparison of products derived from Prosopis by stakeholders in the Auob and Nossob basins

Figure 12 displays the type of uses that stakeholders have for *Prosopis.* Three categories were identified, namely: 1) commercial, 2) subsistence and 3) both commercial and subsistence. Communal farmers and informal residents use *Prosopis* across all three categories. About 80 % of the commercial farmers, 34% of the communal farmers and 28% of the informal residents derive a subsistence use from *Prosopis*. Only communal farmers and informal residents derive both a commercial and subsistence use from *Prosopis,* of which 62% were communal farmers and 47% were informal residents. The projects surveyed purely uses the products they derive from *Prosopis* for commercial use.

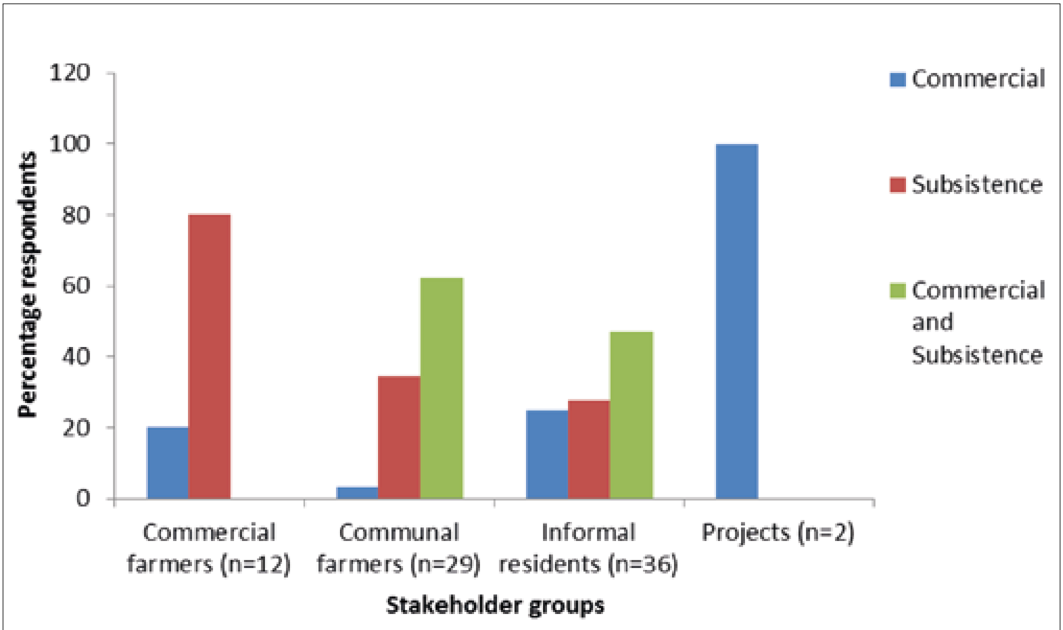


Figure 12: Types of uses for Prosopis by stakeholders in the Auob and Nossob basins

The economic potential from *Prosopis* has not been fully exploited by the stakeholder groups. We calculated the potential income from *Prosopis* pods, wood and charcoal based on the current density of *Prosopis* in the Auob and Nossob basins. The average price of N$320 per ton of *Prosopis* pods is based on the average price for a 50kg bag of *Prosopis* pods in Bernafay, Gochas, Stampriet and Leonardville. The assumed price of wood and charcoal is based on the response of the projects surveyed. These calculations show that of the three economic resources *Prosopis* wood yields the highest potential income compared to that of pods and charcoal.

Table 4, *Table 5* and *Table 6* display the potential income that can be generated from harvesting 5% of the current density of *Prosopis* in the Auob and the Nossob Basin. These calculations are based on the following assumptions: *Prosopis* yield 5ton/ha of pods, 10ton/ha of wood and 2ton/ha of charcoal which are all dependent on the size and height of the tree; these figures were adopted from (Smit, 2005). The potential income is based on 5% of the current density in the study area.

Basin	***Prosopis* density per ha**	**Harvest 5% of current *Prosopis* density per annum**	***Prosopis* Pod yield ton/ha**	**Average Price of *Prosopis* pods N$/ton**	**Potential income (N$)/ annum**
Auob	4612	231	5	320.00	368 960
Nossob	1191	60	5	320.00	95 280

Table 4: Predictions of economic potential from Prosopis pod (harvest 5% of density)

Basin	***Prosopis* density per ha**	**Harvest 5% of current *Prosopis* density per annum**	***Prosopis* wood yield ton/ha**	**Average Price of *Prosopis* wood N$/ton**	**Potential income (N$)/ annum**
Auob	4612	231	10	6250.00	14 412 500
Nossob	1191	60	10	6250.00	3 721 875

Table 5: Predictions of economic potential from Prosopis wood (harvest 5% of density)

Basin	***Prosopis* density per ha**	**Harvest 5% of current *Prosopis* density per annum**	***Prosopis* charcoal yield ton/ha**	**Average Price of *Prosopis* charcoal N$/ton**	**Potential income (N$)/ annum**
Auob	4612	231	2	1000.00	461 200
Nossob	1191	60	2	1000.00	119 100

Table 6: Predictions of economic potential from Prosopis charcoal (harvest 5% of density)

Table 7 displays the actual income generated from *Prosopis* pods within the various study sites. The current income generated from the sale of *Prosopis* pods in the three months of harvest is the highest in Stampriet with N$30 030 at an average price of N$33.00 per 50kg bag. Income generated within Bernafay is N$14 560 and in Gochas is N$12 550 at an average price of N$16.00 and N$13.79 per 50kg respectively. The lowest income of N$10 725 is earned within Leonardville at an average price of N$11.79. These calculations are based on the following assumptions: The actual income displayed in *Table 7* is the amount that individuals reported earn per study site at the average price of the specific study site. It was assumed that an individual can collect and sell up to ten 50kg bags within a day during the three months when *Prosopis* pods are harvested. The average price per bag in each area was based on the response of individuals in the respective study sites.

Study site	**Average price (N$) per 50 kg bag**	**collection 50kg bag per day**	**Actual income (N$) generated per annum**	**Percentage of potential income (N$)**
Bernafay (n=6)	16.00	10	14 400	0.41
Gochas (n=12)	13.79	10	12 411	0.35
Stampriet (n=9)	33.00	10	29 700	0.84
Leonardville (n=14)	11.79	10	10 611	1.16

Prosopis pods are only collect 3 months (90 days) of the year

Table 7: Income generated from Prosopis pods within communities in the study sites during three months of the year (90 days of pod collection per year).

Justus Muller is a game farmer in Leonardville. He has been involved in farming activities for the past 20 years on the farm Noasanabis. He originally started farming with livestock but transitioned to game farming. According to Mr Muller, his transition was prompted by the fact that his farm would fall victim to livestock theft because of the close proximity of it to the town. He also stated that game farming was an attractive alternative because of the economic incentive of trophy hunting. Additionally, Mr Muller has a golf course on his farm. In order to start the golf course he had to clear a dense thicket of Prosopis in the Nossob riverbed. The method of choice he used to clear the area of Prosopis was by cutting it above ground and burning the stumps. According to him the method is 90% effective and that regular monitoring of the cleared area needs to be done to prevent the seedlings left behind from growing into trees. He said that he and his neighbour are among the few commercial farmers in the area who attempted to manage the spread of Prosopis on their farms.

Mr Muller is of the opinion that Prosopis has both advantages and disadvantages. The advantages he identified are that Prosopis has economic potential and nutritional value for livestock. Mr Muller had his golf course cleared of Prosopis by a local Prosopis furniture factory. He went on to state that if a farmer used Prosopis pods as fodder one can see the difference between the livestock that feeds on Prosopis pods and the livestock that does not feed on Prosopis pods, with the former being fatter than the latter. Mr Muller stated that he fenced off the river on his farm to prevent the cattle from spreading the Prosopis seeds to other parts of his farm. According to Mr Muller, Prosopis has the potential to be a great economic resource and a means to employ the unemployed of the town through the production and sale of Prosopis products such as furniture, charcoal and pods as fodder.

Respondents were asked to identify the negative impacts of *Prosopis. In* response, 27% of the respondents identified the growth of *Prosopis in* dense thickets as negative. The reduction of underground water was identified as negative by 15% of the respondents. Both damage to water infrastructure and damage to property by *Prosopis* roots were identified as a negative by 13% of the respondents. About 14% of the respondents viewed the fact that *Prosopis* blocks the flow of the Auob and the Nossob Rivers as negative. Only 6% of the respondents stated that reduction of grazing was a negative impact of *Prosopis.*

Mr !Aibeb is a sanitation foreman, responsible for maintenance at Directorate of Water Supply and Sanitation Coordination Unit (DWSSC) in Mariental. He has been working there for 7 years. According to him, the main roles of DWSSC are to provide the rural people and communal farmers with a clean source of water. They also fix and service boreholes. Prosopis has been creating problems for their section because it has devastating effects on the pipes and their maintenance. Cases of Prosopis causing damages on the pipes are reported three to four times a year. Its roots coil around the pipes making it difficult to almost impossible to remove the pipes or extend the pipes. Prosopis also bends the pipes, making them change their path and hence making it hard to get water from underground. These damages are always costly as drilling a new borehole, to the depth of 200 metres, would cost close to N$700 000 because once the borehole is damaged a new one is required. Moreover, a lot of Prosopis in an area can have a negative effect on the water table as they take up a lot of water.

The stakeholders that were interviewed in both basins were asked whether they are implementing any control methods with regards to *Prosopis*. Commercial farmers are implementing a greater variety of methods in controlling *Prosopis* compared to other stakeholder groups. Most of the commercial farmers use cutting above the ground and applying chemicals (41%) as a control method. The chemicals that they use in controlling *Prosopis* include: Browser, Tordon, Virro exe and Access. The second common control method used by commercial farmers is cutting above the ground and burning (16%). Most communal farmers (41%) and informal residents (75%) are not implementing any control methods. The few that are implementing any control methods say they cut above the ground.

The stakeholders, including those who are currently not controlling/managing *Prosopis* were asked on the type of management that they think would be the best to apply in managing *Prosopis* in the Auob and Nossob basins. Most commercial farmers interviewed feel that *Prosopis* should be eradicated, whereas, most communal farmers feel that *Prosopis* should be managed (*Figure 13*). With management, they meant that some of the *Prosopis* trees should be cut out, while some should be left. Some stakeholders specifically mentioned that the big *Prosopis* trees should be cut down, while the small ones should be left to grow. On the other hand, informal residents would like to have the *Prosopis* left as it is. The project also interviewed service providers and they feel that *Prosopis* should be managed.

Mr Junius Francois is a commercial farmer running the well-known Wildmoor farm in Gochas, Stampriet area. He was born and raised in Gochas, Stampriet area. He farms with cattle and sheep and has been farming for 16 years now.

He believes that Prosopis is a problem in the area, but currently he has no Prosopis on his farm. He cut down all Prosopis and burned the stumps and the trees never grew again. He uses dead wood with old engine oil mixed with diesel to improve the burning process. He believes that Prosopis density increased rapidly over the years and the livestock contributes to the dispersal of Prosopis seeds. Mr Junius paid about N$1000 transport fees for labourers from Kavango region to help remove the Prosopis. It cost him a total of approximately N$20 000/ha to clear out Prosopis on his farm. He thinks that Prosopis has taken the productive land in some areas and that irrigation in the area reduces underground water but not Prosopis as some people think.

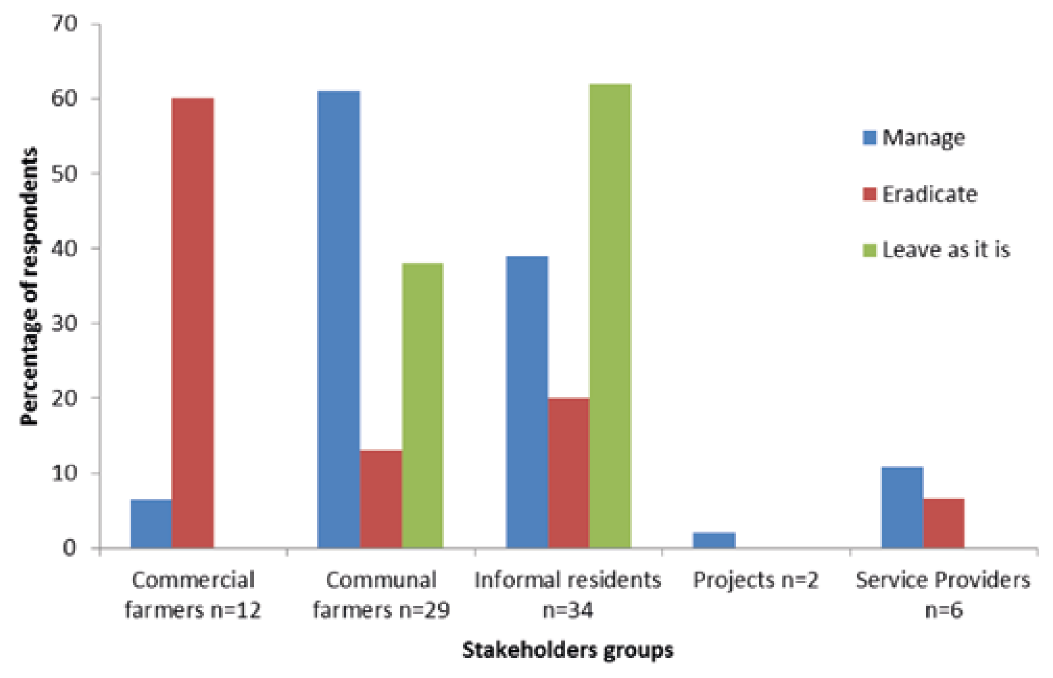


Figure 13: The opinions of stakeholders on the type of management measures for Prosopis in the Auob and Nossob basins

A step further was taken to inquire from stakeholders with respect to the support that they would require from government or non-governmental organisations (NGOs) in order to eradicate or manage *Prosopis* in their area. From the perceptions on the type of management given in *Figure 13*, the stakeholders were asked on the kind of assistance they would like to receive from the government and/or Non-governmental organisations. *Figure 14 and Figure 15* show the type of support that communal farmers and informal residents requested from government and NGOs. Most of the communal farmers and informal residents requested equipment. In addition, other requests included: government to control the *Prosopis*; government to control *Prosopis* as well as providing training and supply chemicals; initiate income generation.

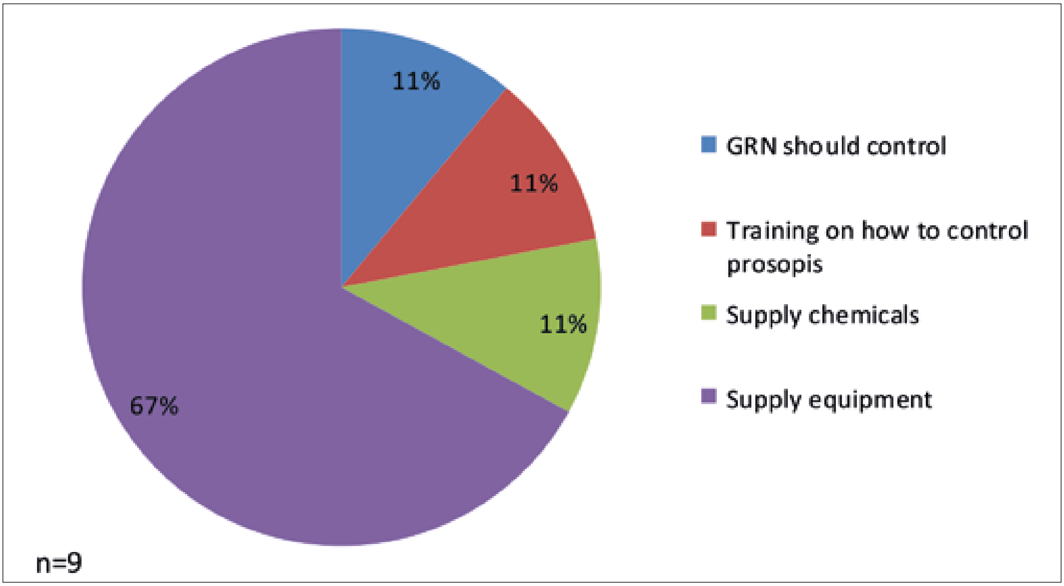


Figure 14: The support requested from government and non-governmental organisations by communal farmers with regards to the management of Prosopis in the Auob and Nossob basins

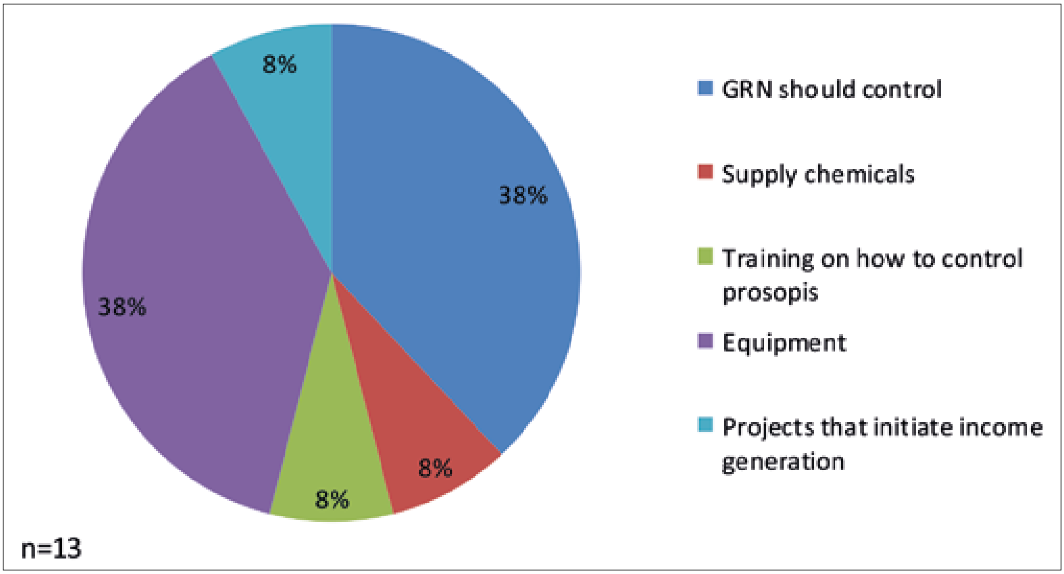


Figure 15: The support requested from government and non-governmental organisations by informal residents with regards to the management of Prosopis in the Auob and Nossob basins

Figure 16 is a result of a one-way ANOVA test, which tested whether the economic situation of stakeholders has an effect on their opinions towards *Prosopis*. The one-way ANOVA (P-value = 0.00001) shows that there is a significant difference in the opinions of different stakeholders towards *Prosopis.* Informal residents are more positive towards *Prosopis,* followed by communal farmers. Commercial farmers and service providers have a negative opinion towards *Prosopis.*

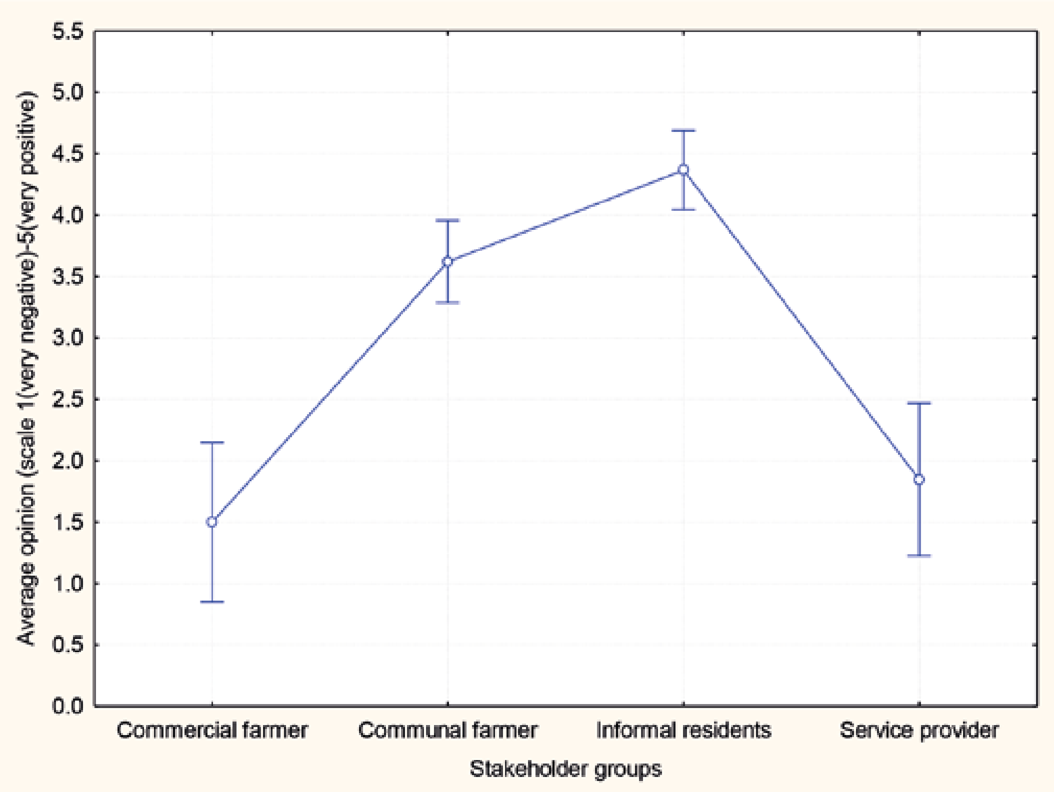


Figure 16: Comparison of the opinions of stakeholders towards Prosopis (scale 1=very negative, 2=negative, 3=indifferent, 4=positive and 5=very positive) in the Auob and Nossob basins

Discussion

As described in the literature, *Prosopis* is a woody, multi-stemmed, Acacia-like tree or shrub from the family Fabaceae (van den Berg, 2010). According to Pasiecznik et al (2001), tree size and form vary between species, populations and individuals, due to both environmental and genetic influences. The genus *Prosopis* has 44 tree and shrub species with straight spines that grow between 1-18 m high. Growth form of *Prosopis* is predominantly bushy, low-spreading multi-stemmed trees or shrubs but tree forms vary, including erect trees, flat-topped trees, and trees with decumbent branches touching the ground. *Prosopis* are commonly referred to as mesquite in America (Muller, 1985).

Muller (1985) has shown that *Prosopis* species are extremely drought-resistant plants and have the ability to compete with local or indigenous vegetation. *Prosopis* invasive species have traits such as allelopathic effects, extensive lateral roots and resistance to drought and defoliation that allow them to out-compete native vegetation species. Invasive species tend to have the ability to grow and reproduce more rapidly compared to native plants (van den Berg, 2010). *Prosopis* species are able to withstand a high level of water stress and have extensive fast growth of roots as well as a dual root system (Schachtschneider & February, 2010). The dual root system allows for the development of a very deep taproot (up to 53 m), as well as extensive lateral root development. The dual root system allows *Prosopis* species to rapidly switch between groundwater in the dry season and shallow soil water in the wet season, optimizing the use of available water and nutrient uptake (Schachtschneider & February, 2010).

In alignment with the literature, the results of this study indicate that in the Auob and Nossob river basins *Prosopis* is very common in the two basins and most dense in the riverine environment, less dense in the surrounding plains and least dense on the nearby Kalahari dunes. This supports the results of Smit (2005) and other authors.

Prosopis on the dunes are sparsely distributed compared to those that are found in the gravel plain and river habitats and grow taller with a wider canopy. The increased height and canopy of trees in the dunes concurs with Singh (1996) as cited in Smit (2005), who described *Prosopis* plants as heliotrophic and spacing apart of six to ten meters apparently allows optimum plant size. Smit (2005) also noted that *Prosopis* trees become suppressed in denser stands when they are deprived of access to light. Therefore in denser areas such as the gravel plain and river trees are less tall and have a smaller canopy because there is a high inter-plant competition for resources especially for light compared to sparsely populated habitats such as the dunes. Also, in the river and gravel plains where the *Prosopis* is densely populated, the numbers of pods on the plants are fewer than those of the *Prosopis* in the dunes. Even though there was a notable difference, the difference was not significant.

Most of the interviewees in this study said that there is a rapid increase of *Prosopis* in the Auob and Nossob basins. Some of the respondents observed that viable areas such as soccer fields and farm camps are currently infested with *Prosopis*. According to Smit (2005) towns such as Leonardville, Aranos, Stampriet and Gochas are within the area where *Prosopis* were planted intentionally at the settlements. The original *Prosopis* trees around farmsteads and government institutions can still be observed in many cases. Furthermore, farmers in the central and southern Namibia had previously planted *Prosopis* along the rivers to avoid soil erosion (Smit, 2005). This could have contributed to high densities of *Prosopis* along the river habitat in both the Auob and Nossob.

Meanwhile, no significant differences were found in this study between the height and canopy cover of individual trees in the three habitats. What was significantly different was the production of pod clusters per individual trees which were more numerous (mean of 40 pod clusters) on solitary trees and sparse on trees crowded together (10 pod clusters per tree. This factor could be, *inter alia*, an unstated reason behind the preference for management over eradication by some stakeholders as indicated elsewhere. It may relate to the suggestion that big trees be cut down, which would mean fewer seeds for further dispersal. Understanding of this issue will require further investigation.

Results from excavation of *Prosopis* roots in the three basin habitats indicated that a high proportion of lateral roots grow in the top 0.3 m of soil in the river and plains habitats while more lateral roots grew at 0.3 m and 0.6 m depth on the dunes. The dune individuals tap roots were also larger in the first metre of growth. While these preliminary results do not confirm the dual root system indicated by Schachtschneider and February (2010) they do indicate the variability of growth in differing habitat types and soil and moisture conditions and this could be a reason as to why they do so well in comparison to local plants. Opinions obtained from stakeholders support the idea of extensive water extraction which has been reported in various publications pertaining to *Prosopis* (Maitre, 1999).

Respondents state that "*Prosopis* use a high amount of groundwater," which is confirmed by Harding and Bate (1991) who elaborated that *Prosopis* species in the Karoo and Kalahari regions are thought to be dependent on groundwater. Since the Auob and Nossob basins form part of Kalahari, it can be speculated that *Prosopis* there use groundwater. Furthermore 19% of the stakeholders highlighted that *Prosopis* was responsible for damages to water infrastructure such as water pipes and borehole casings. The roots of *Prosopis* plants clog the boreholes and pipes thus causing extensive damage that is costly to repair.

According to Maitre (1999) there are three main kinds of evidence that would verify that *Prosopis* species are able to interact with groundwater:

- deep root systems to reach aquifers which are normally at depths of several metres below the surface;

- studies of plant water relations which indicate access to water supplies when surface soils are dry; and
- Close associations between the distribution of *Prosopis* and groundwater at least in arid to semiarid areas.

In general, positive impacts on other plants by *Prosopis* are limited. According to Mares et al., (1977), *Prosopis* trees have important effects on other vascular plants throughout the Americas by providing shelter and ameliorating the microclimate. Moreover, according to East and Felker (1993) some grass species are known to favour conditions below the canopy of *Prosopis* species to the open spaces in between. No evidence of positive impacts was noted in this study nor were they mentioned by stakeholders.

Richardson and Wigen (2004) and Smit (2005) have elaborated how *Prosopis* negatively impacts other vascular plants and how they disadvantage other species. The general negative impacts of *Prosopis* include the invasion into crop fields, reducing grazing areas, wetlands and lakeshores. It also makes the area invaded by *Prosopis* species less accessible to humans and animals (Pasiecznik et al., 2001; Mwangi and Swallow, 2005; Smit, 2005). The results of this study agree with these observations.

In parallel it is believed that in areas where *Prosopis* is cleared other species are able to grow. This was also supported by Maritz (pers. comm, 2012). However, according to Shannon Index when applied to the current study, the natural Auob basin had the higher species diversity compared to the Nossob where *Prosopis* was cleared out in one of the sampled farms. This could possibly be attributed to the fact that after clearing land of *Prosopis*, it will take time for other plant species to start growing because of the allelopathic chemicals from *Prosopis* that are still retained in the soil. Another reason for the differences in species diversity between the two basins could be the adaptation of the different plant species to the basin.

Within the Nossob basin, however, the area that was cleared had a greater diversity than the area that was not cleared. Moreover, this study found a greater number of *Acacia erioloba* seedlings and tall trees where *Prosopis* had been cleared than where it had not been cleared. The observation that in areas where *Prosopis* is cleared out different plant species grow could simply be due to reduced competition since *Prosopis* invasions are known to suppress small growing indigenous trees, shrubs and grasses due to its competitive advantage for moisture and light (Esler *et al* 2006; Jarrel *et al* 1982, as cited in Smit (2005)). Zimmerman (1999), as cited in Maitre (1999) shares the same view when their study confirmed that mortalities of *Acacia erioloba* were experienced in the Kuruman River due the drop in water levels worsened by out-competition by *Prosopis.* Moreover, seedlings of *Prosopis* usually grow under the shelter of other plants and they can restrain less healthy plants when they compete for water and nutrients (Smit, 2005). *Prosopis* is also reported to out-compete indigenous plants in bare, overgrazed lands of low fertility.

The canopy of *Prosopis* can also influence the intensity as well as the duration of light received by the plants under it. Apart from this, there is also competition for water and nutrients between *Prosopis* and other species. In general, *Prosopis* has a competitive advantage and will quickly spread (Pasiecznik et al., 2004). However, under *Acacia erioloba* a greater number of *Prosopis* seedlings were found than under *Boscia* sp. trees in the Nossob basin. This could be the result of the greater provision of shade from the *A. erioloba* attracting livestock who then deposit the *Prosopis* seeds in this locality. Whether availability of seeds or competition for water and nutrients is the deciding factor for increased *Prosopis* seedlings is not known.

Despite the fact that *Prosopis* is an alien invasive species and poses a threat to the environment it has a number of economic benefits. Many studies on *Prosopis* have elaborated the different uses of *Prosopis* products but none of the studies include Namibia. In general, different products can be derived from *Prosopis* such as wood for use either as fuel or for structural purposes and pods which are a source of food for humans and for livestock. In Peru, pods are used as commercialised syrup and coffee substitutes (Pasiecznik, et al., 2001). Pods are also used for bread flour. Some authors, e.g. Oduol et al. (1986), Harding (1987) and Smit (2005), have studied the nutritional properties of pods of different *Prosopis* species. According to Smit (2005) the food value of pods from species of section *Algarobia* is almost as good as that of lucerne, maize, barley or soya. Harding (1987), Harding and Bate (1991) and Smit (2005) clearly explained that a mixture of the *Prosopis* pod flour with maize forms an excellent feed for livestock and it is estimated that only 850g milled pods will supply enough nutrients and protein for a 60 kg sheep daily. According to Felker and Moss (1996), in Mexico, Argentina and Brazil *Prosopis* pods are an essential source of animal feed. Sweet varieties of pods are used for human food in Peru (Jama & Zeila, 2005). Some stakeholders in the Auob and Nossob basins indicated that they mix ground *Prosopis* pods with other fodder sources although extensive information on the efficacy of this approach was not obtained.

Leaves of *Prosopis* species, although not eaten by man directly, are often consumed indirectly when used as food for animals. *Prosopis* bark is used as a tanning agent. Some people make honey from *Prosopis* flowers. The fruit of several native species is made into various foods and drinks, some 'rustic' foods and delicacies, and these are important in local nutrition and trade (Simpson (1977), Pasiecznik et al. (2001), Mwangi and Swallow (2005)).

According to Mwangi and Swallow (2005), *Prosopis* wood is a useful construction timber and for making furniture. (Smit, 2005) pointed out that there is one small-scale operation located in Brakwater near Windhoek where *Prosopis* wood is processed for furniture in Namibia. During this study a factory making furniture was also located in Leonardville although not fully operational at the time.

During the interviews several people touched on the nutritional value of *Prosopis* pods. However, *Prosopis* pods have low phosphorus content (0.08) reflecting the low phosphorus content of the soils in the Auob and Nossob basins (Mendelsohn et al., 2009). Mixing the pods with other feeds such as lucerne therefore augments the phosphorus supply to livestock.

The fact that *Prosopis* pods are plentiful in the field and free could be the reason many communal farmers' livestock are fed on the pods. For the commercial farmers feeding livestock with *Prosopis* pods seems to be a cheaper option (approximately N$10 for a 50 kg bag) compared to other feeds bought from commercial outlets. It is believed by some stakeholders that livestock contributes to the spread of *Prosopis.* Therefore, some of the commercial farmers are reluctant to use *Prosopis* pods directly for fodder. They believe that milling the pods destroys the seeds, as recorded by Smit (2005).

However, *Prosopis* have both positive and negative effects on livestock. On the negative side, the green *Prosopis* pods contain tannin and are usually bitter; this can lead to poisoning in livestock (Matthews & Brandt, 2004).

Mr. Flip is a commercial farmer who was born and raised in Gochas. He went to school in Mariental and completed his tertiary education in South Africa with a degree in rangeland. He has been farming in the salt block Kalahari for 35 years with sheep and cattle. His opinion of Prosopis is based on the notion that Prosopis can be a major issue in one area and in another be minor or not an issue at all. He confidently claims that Prosopis is not any issue at all in the salt block Kalahari; for 35 years there has only been 10 Prosopis on his farm, not decreasing or increasing in numbers. He contends that there are no dense thickets of Prosopis growing in the salt Kalahari. He believes that Prosopis does not really grow there because the water is aggressively saline and also the water table is so deep that it is impossible for Prosopis seedlings to survive.

Mr. Flip does not feed Prosopis pods to his livestock because he believes that Prosopis pods reduce the metabolic activities of the livestock. He claims that once they are fed with Prosopis pods the livestock just laze around at the water point waiting till their next feed and refusing to go out and graze. He feels that in order to tackle the issue of Prosopis in infested areas, individuals must take responsibility and initiative, instead of waiting for the government to give them a solution.

The variation of uses between commercial and communal farmers (*Figure 10*) may be due to the scale of economic activities. Commercial farmers within the Auob and Nossob basins practice livestock and crop farming on a large scale and communal farmers practice livestock and crop farming on a much smaller scale. Communal farmers therefore make use of a wider range of *Prosopis* products to meet their daily needs because they do not have the income to buy other products. However, more commercial farmers use *Prosopis* pods as fodder compared to communal farmers. This may be because commercial farmers buy bags of *Prosopis* pods from informal residents whereas most communal farmers cannot afford to buy *Prosopis* pods or they have to sell the pods that they harvest in order to get some form of income.

A communal farmer interviewed had the following to say about the use of *Prosopis:*
"I know about gums, pods and cocoons. My wife eats the gum from Prosopis. We use the gum and mix it with sugar to make syrup as spread on bread. Sometimes there is nothing to eat in the house so we just eat the pods and go to sleep."
The above phrase reflects the dependence of lower income communities (communal farmers and informal residents) on *Prosopis* as a resource.

The types of products that can be derived from *Prosopis* have not been fully exploited by either communal farmers or informal residents, due to lack of equipment and knowledge. The consumption of pods as a food substance can be further developed into flour, syrup or beverages. In the native countries of *Prosopis* (Central and South America) *Prosopis* flour has been converted into soluble powders and could be used as cocoa powder or a coffee substitute. According to Pasiecznik *et al* (2001) the reason why *Prosopis* became an invasive species in some countries is because the full range of its uses are not known. The development of *Prosopis* as a food substance could improve the livelihood of the informal residents who have limited employment opportunities and are extremely poor (National Planning Commission, 2007).

Elizabeth Afrikaner is a 64 year old communal farmer. She is originally from Grootfontein and has been living in Leonardville for 45 years. She farms mainly with goats, sheep, and horses. She perceives Prosopis to be a good tree because of the benefits they derive, which include shade, pods, and firewood. Elizabeth and her grandchildren collect Prosopis pods that she feeds to her livestock; the surplus is sold to commercial farmers for income to sustain the family. The pods are sold for N$10 for a 50 kg bag; they can collect between 5 to 10 bags a week and normally sell up to 4 bags weekly. She does not experience any constraints with the sale of Prosopis pods and urges local authorities to help them find a market to sell various products that can be produced from Prosopis.

Regardless of all the positive attributes of Prosopis, she also acknowledges the negative impacts including its rapid growth in the area and abstraction of groundwater.

Mr. Henni Harmse is a commercial farmer from Stampriet in the Hardap region. He has been farming with sheep and vegetables for 36 years. He believes that Prosopis is increasing and becoming a big problem which no one is doing anything about. This is especially in the Stampriet, Gochas, and Bernafey area. He believes that Prosopis is a negative tree and uses lots of water and that is the reason why he decided to eradicate Prosopis from his farm.

He cuts the trees and applies chemicals; he first used a chemical named Tordon. He said that this chemical was very effective, but unfortunately it was an unregistered chemical that he had to stop using. He now uses Virro exe which, according to him, is the best chemical after Tordon. He said that it is very effective because the Prosopis do not grow back. This farmer pointed out that management/control of Prosopis should be a joint venture between all commercial farmers. He said the only way they can control Prosopis is if everyone clears out Prosopis on their farms and applies a monitoring plan. "It does not help that I clear out my farm and my neighbour does not. When the river flows, it brings down the seed from my neighbours and the seeds start to grow in my farm again."

He said that even though Prosopis is a bad tree, it has its benefits, too. People can collect the pods and sell them as fodder for income generation. Not only can they do that but furniture, charcoal, and firewood can also be produced from Prosopis. He mentioned that Prosopis pods are a good supplement and livestock that feed on Prosopis pods are always in a good condition; he, however, does not feed the pods to his animals because he believes that they spread Prosopis.

He said that he wishes that the chemicals that are used in controlling Prosopis would be subsidised by the government. "It is very expensive to clear out Prosopis. It costs about N$12000 / hectare (labour included)."

Prosopis is a renewable resource and the production of products from it can be sustained for years to come. The potential income that can be generated from *Prosopis* in both the Auob and Nossob basins is estimated in the results section. Currently, the potential of *Prosopis* as a resource is under-exploited in both the Auob and Nossob basins. The current value-added products derived from *Prosopis* by communal farmers and informal residents is limited to the sale of pods for fodder, but as Table 3 indicates, *Prosopis* pods have a great potential to be developed into livestock supplements due to its nutritional value.

Prosopis wood provides a valuable wood resource for informal and communal farmers in the form of fuel and timber. The high biomass production, high wood density and low ash and moisture content make *Prosopis* a good energy source. The wood density is in the range

700-1200 kg/m^3 (Pasiecznik., Felker et al. 2001). The project manager of the *Prosopis* furniture factory reported that the wood of *Prosopis* has a high structural density of 98%, which makes it more stable and less likely to shrike. He continued in stating that the furniture made from *Prosopis* is of good quality and durable and has excellent marketing potential. *Table 5* displays the potential economic benefit *Prosopis* wood presents to the region. If only 5% of *Prosopis* is harvested in the Auob and Nossob basins a possible income of N$14 411 250.00 and N$3 722 750.00 can be earned from the production of wood. Similarly, the charcoal from *Prosopis* wood is regarded as good quality and has great economic potential. A total of N$9 223 200.00 can be generated from the current density in the Auob and N$2 382 560.00 in the Nossob Basin.

Although the communal farmers and informal residents in Bernafay, Gochas, Leonardville and Stampriet viewed *Prosopis* as an essential economic resource to sustain their livelihood, the use of *Prosopis* as an economic resource is limited to the sale of pods, firewood and fencing poles within these communities. The main source of income for communal farmers in Bernafay, Gochas and Leonardville is from livestock farming and/or a communal vegetable gardening scheme. The salaries earned from the gardening scheme are dependent on production. While conducting interviews it was observed that unemployment within the informal settlement of Gochas, Stampriet and Leonardville was widespread. Respondents also indicated that *Prosopis* was the only source of income for some. A respondent was recorded stating the following: “We get our income from the products of *Prosopis*. Our livelihoods rely on the products from *Prosopis.* There is no work around here.”

Results indicate that the income generated from the sale of *Prosopis* pods varies among study sites. Bernafay consists of 14 households, based on the results it is possible for an individual to earn N$14 400 at an average price of N$16.00 in the three months (90 days) harvesting from selling *Prosopis* pods (50kg bags) in each household. This is only 0.41% of the potential income that can be earned in the Auob basin. In Gochas, it is possible for an individual to earn N$12 411 in three months harvesting from the sale of *Prosopis* pods at an average price of N$13.79. This is only 0.33% of the potential income that can be generated from the sale of pods in the Auob basin. In Stampriet the current income that is generated from the sale of *Prosopis* pods is N$27 700 at an average price of N$33.00 per 50kg bag. This presents 0.84% of the potential income that can be generated in the Auob basin. In Leonardville a total of N$10 611 is generated from the sale of *Prosopis* pods, this is 1.16% of the potential income in the Nossob basin. These results indicate that only a small fraction of the potential income is currently earned from the sale of *Prosopis* pods by the local communities.

Charcoal and wood are used as a commercial resource within the Auob and Nossob basins, but due to lack of information the income earned at community level could not be calculated. However, based on the interviews conducted we know that a bundle of firewood is sold at N$5.00, droppers at N$10.00 and fencing poles for N$15.00. *Prosopis* pods, droppers and fencing poles are sold to commercial and communal farmers and firewood is sold among the informal residents.

Money from a menace

Nicholaas Mostert is a commercial farmer in the Leonardville area of the Omaheke Region. Born in Windhoek, he grew up in Leonardville and started farming at Farm Texas 26 years ago. Like most farmers in the area he farms with small livestock (sheep and goats). He however is a farmer with a difference.

In addition to owning butchery, Nicholass has an interesting business deriving resources from Prosopis. Nicholaas uses the Prosopis growing on his farm to make wood, planks and charcoal. His business is well established and he exports to South Africa. On the local market a 20 kg bag of wood sells for N$20 and an 8 kg bag for N$10. The charcoal is sold at N$10 for a 5 kg bag.

He feels that Prosopis is not a problem for him as he is able to utilise it and make money. What he does not like is the fact that he cannot use the small Prosopis shrubs for anything as they are too small for droppers or wood. He hopes to one day go into energy production where he can use the Prosopis on his farm to generate electricity through burning of charcoal.

For Nicholaas the Prosopis density on his farm is increasing but he is calmed by the fact that he can use the pods for his livestock and he runs an extensive Prosopis wood market. He is one of many who have learned to embrace the Prosopis challenge by making money from a menace.

According to Laxén (2007) there is a higher dependency of poor and low income communities on *Prosopis* as an economic safety net in Sudan, as they generate income by selling charcoal, fuel wood or poles. The findings of this study seem to have similar results, with the addition of sale of pods as contributing to the safety net, with communal farmers and informal residents deriving a wide range of *Prosopis* products. The sustainable development of *Prosopis* as an economic resource has the potential to improve the economic standing of the communal farmers and informal residents, if they are involved in the development of products.

Kempen Henk is a 40 year old man who lives in Leonardville since 2003. He owns a factory in Leonardville that uses Prosopis timber to produce furniture, charcoal, firewood, poles and posts. The factory was established in 2006 and employed 22 permanent employees. But due to a decrease in orders of Prosopis products and marketing challenges in Namibia the factory currently employees 5 permanent employees. Occasionally depending on orders, he employs casual workers. He said, many of his employees gain skills and knowledge on how to generate income from Prosopis products and once they leave his factory, they engage in collection and selling of Prosopis products on their own.

The factory harvests Prosopis timber from surrounding commercial farms and has to transport the wood into town. Henk said at present transport cost is N$24.00/km. In future; he aims to reduce transport cost by building a mobile factory.

With regards to the markets, Henk said that he operates on a tender basis. In the past, one of his big projects was to supply timber to the Swakopmund Jetty. Currently, he is supplying wood to a school in Okavango Region (Divundu). The costs that he incurs in producing these products involve harvesting and marketing permits (N$20.00 each valid for 3 months), transport permit for each product (N$15.00 valid for 6 days).

Henk went on to say that other input cost such as machinery are expensive; a wood cutting machine can costs N$225,000, the charcoal kiln can cost N$2,600.

Henk stated that, the Nossob River in Leonardville is heavily infested with Prosopis but Prosopis is now moving out of the river into the farm land. Henk believes that animals are playing a major role in spreading Prosopis. He felt that Prosopis are out-competing other species such as Acacia erioloba because of its extensive root system. However, he views Prosopis as a tree that can benefit the community because it has economic potential. He believes through enterprises such as his project Prosopis can be removed from the area in a sustainable manner.

According to Pasiecznik *et al*., (2001) many control methods have been attempted after decades of attempted eradication, principally in the USA, Argentina, Australia and South Africa. The development of sustainable agro-forestry systems has been suggested as the only method for increasing productivity in invaded areas (Oduol et al., 1986; Smit, 2005). Several methods may be used to control alien invasive species namely: mechanical, chemical, biological and indirect methods which do not aim at killing the alien invasive species.

Stakeholders' decisions on whether to manage or eradicate *Prosopis* or not is highly influenced by their opinions towards it and by whether the *Prosopis* meets their economic needs or not. Commercial farmers own private lands for commercial purposes. Therefore, they are concerned with the negative effects that *Prosopis* will have on their land. One of the effects of *Prosopis* on farmlands includes the reduction of grazing land (Mwangi and Swallow, 2005). Commercial farmers try by all means to eradicate or control *Prosopis* on their farms but most of the methods that are used are not successful and the *Prosopis* just re-grows. Similar results were obtained by Pasiecznik *et al* (2001) and he proposed that people's opinions of invasive species depend upon whether or not their economic needs are met by the species.

Unlike commercial farmers, communal and informal areas are shared properties. Therefore, this means that there are not so many attempts made in controlling the spread of *Prosopis* and this fact leads to increase in invasions in these areas (Mwangi and Swallow 2005). The type of management measures used by different stakeholders will also be influenced by their income status. Commercial farmers have a stable form of income compared to communal farmers and informal residents. Therefore, commercial farmers can afford to buy equipment, chemicals and herbicides that they can use to manage or eradicate *Prosopis*. On the other hand, communal farmers and informal residents do not have a stable means of generating income. For example, in Bernafay, a salary of N$10 is paid to each worker per day of work (National Planning Commission, 2007). Therefore, these people cannot afford to buy equipment, chemicals and herbicides, but rather they opt for other alternatives, cheaper control methods or opt not to control *Prosopis* at all. These methods are however not always successful, in a sense that *Prosopis* continues to re-grow.

It is also stated that managing *Prosopis* is not an easy thing and requires a lot of work and follow up. Eradication of *Prosopis* has high costs and according to Harmse, H (. Pers. comm., 2012), he incurred costs (including labour) of approximately N$ 12 000 per ha to eradicate *Prosopis* in his farm. With all the difficulties in the management of *Prosopis* by the different stakeholder, it can now be seen why they are requesting for assistance/support in the controlling of *Prosopis (Figure 14* and Figure 15). It can clearly be seen that the kind of assistance that the different stakeholders requested for from the government and non-governmental organisations is influenced by their economic situation and the kinds of benefits they derive from *Prosopis*. Several explanations exist as to why the respondents that stated that they do not use *Prosopis*

Father Walter Desa is over 70 years old, originally from the United States of America. He has been living in the Cambridge Roman Catholic Mission School in Aranos for 30 years. He farms with goats, sheep, and cattle and also manages the Cambridge Roman Catholic Mission School. Prosopis was planted in rows on his farm about 30 to 35 years ago, before he acquired the farm.

Father Desa acknowledges benefiting from Prosopis for shade and firewood. He uses Prosopis wood as firewood for cooking in the school hostel, which saves him about N$100.00 per day that he would have been spending on electricity. He also indicated that sometimes community members request permission to pick pods from the farm to go sell; they sell the pods for N$10.00 to N$12.00 per 50 kg bag.

Although he is benefiting from Prosopis, he has a negative perception about it and wants it removed from his farm. He said Prosopis can take over in the farm and reduce the grazing land. Therefore, one has to remove it as early as possible. He is already removing it from his farm himself with help from the school kids. He has his own approach to managing Prosopis; he cuts it and uproots it from the ground using big powerful machines, such as tractors, to ensure that the plant does not grow back. He burns it after cutting and continuously monitors to ensure that the plant does not grow again.

for anything have a negative opinion towards it. Most probably some feel that since they do not use *Prosopis* for any purpose and therefore they do not derive any benefit from it, they do not favour it. However the possible reason why some respondents do not use *Prosopis* for any purpose at all is because of its negative effects alluded to in the preceding section.

It was observed that during the interviews, more females had a positive opinion towards *Prosopis,* while males were indifferent towards *Prosopis. One* possible explanation for this could be that females have fewer options or opportunities when it comes to employment compared to males. According to the Participatory Poverty Assessment that was conducted in Omaheke and Hardap Regions in 2005, it clearly states that 73% of males in these regions are employed and only 56% of females are employed. This is further supported by Smit (2005) who stated that collection of *Prosopis* pods and firewood is mostly done by unemployed people, often woman and children on a local basis and their income is consequently limited to three months per year. In the Auob and Nossob basins most of the jobs are done manually (labour) and require manpower and therefore they are mostly fit for males.

Junias Endjala and Martin Sibongo are the Chief Forestry Technician and Senior Forestry Technician, respectively, in the Ministry of Agriculture, Water and Forestry (MAWF), Directorate of Forestry in Mariental. They are estimated to be 30 to 40 years of age, and Mr. Endjala has been in the area for 3 month only while Mr. Sibongo has been working in the area for 2 years. Their main task is to spearhead forestry activities in the region, promote tree planting and involve the community in the establishment of woodlots and also maintain law enforcement.

As part of their official work they are approached by farmers regarding Prosopis. One farmer from Aranos approached them to ask for permission to cut Prosopis and make charcoal. They normally issue a permit for someone to harvest Prosopis to avoid the harvesting of indigenous species. According to Mr. Sibongo, the town council (Mariental) does not want Prosopis along the Fish River to be removed. They said Prosopis are a big problem, as they grow fast and can tolerate harsh conditions. They further stated that, Prosopis out competes indigenous plants and the trees are regarded as a weed. Mr Endjala stated that Prosopis are spreading at an alarming rate and he believes that livestock are playing a major role in spreading Prosopis.

Mr Sibongo said, in Hardap region people mainly depend on livestock production, which is at risk of increasing Prosopis, which in turn, will decrease rangeland for animals. They further stated that commercial farmers in Mariental do not like Prosopis, however informal residents like Prosopis as they derive more benefits from the trees such as firewood and pods. Mr Endjala said, at the moment there are no management implementation measures regarding Prosopis. He further stated that they encourage farmers to grow more indigenous trees.

Sana Gomases is a 35 year old woman who was born and raised in the Gochas informal settlement. Her only source of income is generated from selling Prosopis pods. She and her two kids collect about five to six 50kg bags of pods every day which they then sell to the farmers in the area. They usually sell to the commercial farmers though in a few cases they also sell to the communal farmers. Sometimes some commercial farmers make appointments and she collects a specific amount of bags for them. However, she mostly sells along the road with her two kids everyday in anticipation that one or two people will come along and buy the pods from her. Each bag costs about N$12 on average. She claims that the only way she feeds her family and sends her kids to school is through selling the pods. Sana feels that Prosopis pods are their only option and if it is not for them, she does not know how else they will live. She makes an income of about N$336 per month.

Sana is one of the many informal residents whose livelihood is partly or entirely dependent on selling Prosopis pods. Sana alleges that Prosopis is her life and it should be left alone; she further claims that if the government ever decides to remove Prosopis from their area, then they should be given a social grant every month or be provided with jobs. Otherwise, without Prosopis, they will not be able to survive.

Conclusions and Recommendations

Prosopis as an alien invasive species is posing negative impacts to the environment, such as reduction in grazing land and groundwater and blocking of river flow. If *Prosopis* continues to increase rapidly, its projected density will stand at 3549 trees/ha in the Auob Basin and 12911 trees/ha in the Nossob Basin in ten years` time. This will further worsen the situation.

Although *Prosopis* seems to be posing negative impacts, it has a great economic potential which is not being fully exploited. Currently, N$ 67 122 is generated (over the three months of harvesting) from the sale of pods in the Auob and Nossob basins. If fully exploited, the current density of *Prosopis* (4612 trees/ha and 1191 trees/ha) can generate an income of approximately N$1 844 640/annum in the Auob Basin and N$476 612/annum in the Nossob Basin from the sale of pods. Thus at present only 1.64% of the potential income from the sale of pods is earned in the Auob Basin and a mere 0.02% is earned in the Nossob Basin. Moreover, a goodly income from timber and charcoal could also be generated. If *Prosopis* is fully exploited it can contribute to employment opportunities for many of the poorer people in the Auob and Nossob basins, especially bearing in mind the low employment rates.

Considering the negative and positive impacts of *Prosopis*, it is recommended that the control and management measures of *Prosopis* could focus on reducing the spread rather than complete eradication. This would reduce the *Prosopis* density and the negative effects, while allowing continual use and derivation of benefits by stakeholders.

Furthermore, this study recommends that all stakeholders, from government to residents of informal settlements, cooperate in the following:

- Develop and implement policies and legislation on alien invasive species to guide control measures for *Prosopis* and other alien invasive species.
- Review existing policies to allow service providers to make decisions that are befitting the areas they work in, considering that uniform policies cannot cater for the diverse regions of Namibia.
- Devise appropriate management and control measures and share with all stakeholders so that they are aware of ways on how handle *Prosopis.*
- Initiate income generating activities using *Prosopis* products in order to exploit the potential income from *Prosopis*.
- Implement hands-on training and capacity building of stakeholders in the basin on how to derive products from *Prosopis.*
- Identify priority areas for intervention regarding *Prosopis* management and control.
- Investigate development of potential markets for *Prosopis* products.
- Put into effect regular monitoring of control measures implemented by stakeholders.

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Author's address

Gobabeb Research and Training Centre
P O Box 953
Walvis Bay, Namibia

E-mail: ruusag@gobabebtrc.org

About the authors

The Summer Land Care Programme (SLCP) of December 2011-February 2012 was a chance for ten Namibian students to gain experience in critical thinking and research processes based on land use, care, and management. This cycle of students came from a variety of schools, programmes and backgrounds. The students represent the University of Namibia (UNAM), UNAM-Ogongo, and Polytechnic of Namibia and have a variety of specializations including Animal Behaviour, Environmental Science, Economics, Ecology and Geography, and Ecology and Geology.

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