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Controlling Invasive Species in a Riparian Forest Conservation Area:

Management Concept and Feasibility Study for Prosopis Control in the Namibian Part of the /Ai-/Ais-Richtersveld Transfrontier Park

Bachelor Thesis

Forest Sciences

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Table of contents

Abbreviations

ARTP	/Ai-/Ais-Richtersveld Transfrontier Park
CBNRM	Community Based Natural Resource Management
DAS	De-bushing Advisory Service
DEA	Department of Environmental Affairs (of South Africa)
DRFN	Desert Research Foundation Namibia
FA	Financial Assessment
FAO	Food and Agriculture Organization of the United Nations
FRR	Financial Rate of Return
GCN	Gondwana Collection Namibia
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GIZ-TFCA project	GIZ project 'Transboundary use and protection of natural resources in the SADC region'
JMB	Joint Management Board
MAWF	Minsitry of Agriculture, Water and Forestry of the Republic of Namibia
MET	Ministry of Environment and Tourism of the Republic of Namibia
MME	Ministry of Mines and Energy of the Republic of Namibia
NACSO	Namibian Association of CBNRM Support Organisations
NAD	Namibia Dollar
NAU	Namibia Agricultural Union
NPV	Net Present Value
NWR	Namibia Wildlife Resorts
pcs	Pieces
pd	Person days (8 hours)
QGIS	Quantum GIS
SA	Stakeholder Analysis
SADC	South African Development Community
SANParks	South African National Parks
SD	Standard deviation
SME	Small and Medium Enterprises
TFCA	Transfrontier Conservation Area
US AID	United States Agency for International Development
USD	US Dollar
WfW	Working for Water

List of Figures

List of Tables

1. Justification

Invasive species are amongst the main threats to biodiversity worldwide (Clout and Williams 2009: v). A species is generally considered invasive if it establishes and spreads aggressively in an area other than its origin. Thereby, it intrudes or overwhelms species that are native to the respective area. The possible impacts are manifold in extent and nature, ranging from minor influences to severe effects and from difficult to grasp changes in ecosystems to easily quantifiable damage in human economies (Maynard and Nowell 2009: 2). The latter case is somewhat ironic as human activity is the underlying root cause for the rise of alien invaders. With regard to plants, it was mainly for agricultural and amenity / ornamental purposes that mankind, making use of oxcarts, ships and aircrafts, helped numerous plant species to cross natural barriers and to invade new habitats (cf. Britton 2004: 1). In the bigger picture, the dynamics of controlling invasive plants are fairly simple: while invasive plant control is still relatively feasible in early stages, the necessary resource input rises dramatically with an increasing area under infestation (Parkes and Panetta 2009: 52). The main challenge in this context is the reproductive ability of terrestrial plants. The fight against partly underground vegetative buds on the one hand and large quantities of durable seeds on the other hand is oftentimes difficult to win (cf. Holt 2009: 127f).

Initiated by a request from the management of the Ai-Ais Richtersveld Transfrontier Park (ARTP), the study takes up the challenge of invasive Prosopis plants in the riparian forests of the park, with the objectives:

1. Assess the number, distribution and volumes of Prosopis plants in the study area
2. Identify stakeholders for an effective Prosopis control concept
3. Search for options for Prosopis management with both, control of the population and utilization with benefits for local livelihoods
4. Design a concept for Prosopis control and evaluate it in financial, socio-economic and ecological terms

The following section gives an overview about invasive plants in Namibia, about Prosopis spp. as a particularly challenging invader, and finally about the Prosopis infestation in Ai-Ais Richtersveld Transfrontier Park (ARTP) in southern Namibia.

1.1. Invasive plants in Namibia

Overall, the ecological and economic threat posed by terrestrial invasive plants in Namibia can be considered relatively modest (Bethune et al. 2004: 16ff). In 2004, 224 alien plant species were recorded in Namibia of which 57 were considered invasive (Bethune et al. 2004: 18). Attributes of Namibia that influence the low invasivity are primarily the low human population density and low immigration. This results in relatively low transformation pressure on landscapes, which otherwise often becomes an entry point for invaders. Additionally, the stressful environment of Namibia such as the harsh climate in general but also challenging habitats like floodplains and deserts hamper the spread of alien plants. From an institutional point of view, Namibia is signatory to a number of international conventions that aim at invasive species control (Joubert 2008: 367). Nonetheless, the Namibian government today pays modest attention to the danger of biological invasion. This is mainly for the reason that other problems, such as deforestation and bush-encroachment, are far more severe and that the need for development and improved food security still prevails over the urge to eradicate alien plants - although these problems are sometimes interlinked (Joubert 2008: 368).

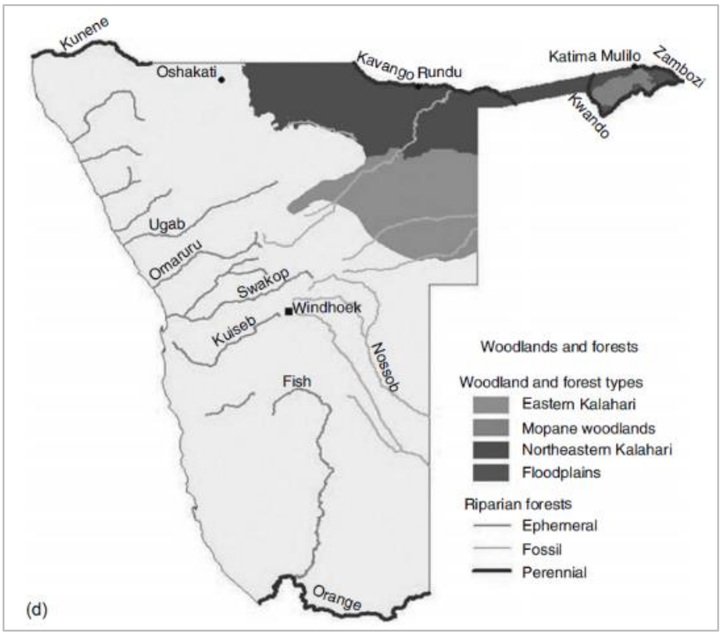


Figure 1: Namibia's forest ecosystems (Joubert 2008: 381)

Following Joubert (2008: 392), the threat occurring from invasive plants differs in Namibia's three main forest habitats (*Figure 1*).

The forests and woodlands of the northeast show a low invasibility. Despite the relatively high rainfall and the high densities of settlements, they appear to be largely unaffected by invaders. Joubert accounts this to the stressfulness of the respective environments including a low availability of nutrients, very high browsing pressure (e.g. from Elephants) as well as regular bushfires. In sum, the low level of infestation observed in these areas does to date not cause significant negative economic or ecological impacts (Joubert 2008: 391).

T situation differs in Namibia's riparian forests along perennial rivers. The higher invasibility results from the better supply of nutrients as well as the constant water supply. However, the still low propagule pressure and the high browsing pressure generally impede the establishment of invasive plants (Joubert 2008: 394f.). While data is scarce, impacts on the respective ecosystems have been observed but can be considered minor. The Orange River in southern Namibia represents an exception. As it flows through highly transformed agricultural areas in South Africa, propagule pressure is considerably higher here. Of special concern is the serious infestation with Prosopis along its banks (Joubert 2008: 396f).

The riparian forests along ephemeral rivers of Namibia are worst affected by invasive plants. Like the perennial rivers, they provide a higher availability of nutrients and water than the forests and woodlands of the northeast. As they are tangent to numerous towns and cut through commercial farmland, propagule pressure is very high. Consequently, the ephemeral rivers show the highest infestation levels of the three habitats and the most significant impact: Indigenous species are displaced, the functioning of ecosystems is disturbed and the hydrology affected. Again, Prosopis is considered the most dangerous invader in this context with the Nossob River in eastern Namibia being the hotspot of infestation (Joubert 2008: 397f).

Throughout the portrayed habitats, the capacity of Namibia to manage invasive plants is relatively low (Joubert 2008: 401). The large but sparsely populated country disposes of limited resources and as a consequence the enforcement of environmental legislation in general is rather weak (Joubert 2008: 367, 401f). Other issues such as furthering development to improve food security outweigh invasive control on the political agenda. Consequently, responsible authorities such as the Namibian Ministry of Environment and Tourism (MET) have not yet entered into larger scale programmes concerning invasive control. Joubert sees Namibia to be at a crossroad: Until now, the danger posed by invasive plants in the country is still manageable. However, this may change with further economic development and increasing propagule pressure. He therefore suggests to intensify efforts in invasive plant control. According to him, this could be supported by strengthening the cooperation with South Africa, a regional ‘powerhouse’ in the issue, as well as by attracting partners for research about and management of invasive plants (Joubert 2008: 401f).

1.2. Prosopis as an invasive plant in Namibia

Plants of the genus Prosopis are not indigenous to Namibia. At least 6 species (*P. glandulosa, P. juliflora*, *P. velutina*, *P. pubescens* and *P. chilensis*) were introduced to Southern Africa from 1880 onwards, originating from Northern, Central and Southern America (De Klerk 2004: 36; Smit 2002: 90f; Pasiecznik 2001: 11). In Namibia, *P. glandulosa*, also known as Honey Mesquite and originating from southern North America, appears to be the most common of the several species. However, the genus nowadays forms a hybridized complex without clear identity (De Klerk 2004: 36; Smit 2002: 91).

Prosopis was introduced to Southern Africa for its manifold usefulness: The pods are suitable as animal feed or even for human consumption. The wood can be used as timber or fuelwood. Moreover, the trees provide shade, can cope with a variety of (poor) soils, ameliorate such soils due to their ability to fix atmospheric nitrogen, are highly drought resistant and grow rapidly (De Klerk 2004: 36; Smit 2002: 88f, 95). In sum, Prosopis was and still is an excellent additional resource for livestock farming in the harsh environment of southwestern Africa. Therefore, its planting was subsidized by the Namibian government in the early 20th century (Smit 2002: 100).

Notwithstanding its usefulness, Prosopis is today considered the most dangerous invasive plant in Namibia (Joubert 2008: 387). This is mainly for the above mentioned growth attributes. Additionally, an average tree of the genus Prosopis produces up to one million seeds per year. They are dispersed by animals or water and can remain viable for up to 10 years. A highly adaptive root system and the lack of natural enemies in the foreign environment further increase the invasiveness (De Klerk 2004: 36; Smit 2002: 99). In some cases, selective logging of larger indigenous trees decreases competition for Prosopis. In 2004, a study on behalf of the Namibian Ministry of Environment and Tourism (MET) found that 100.000 ha of land were infested with Prosopis. Dense stands exist especially in the ephemeral rivers of southern Namibia, especially in the *Auob*, *Nossob*, *Fish* and *Swakop* rivers but also in numerous others (De Klerk 2004: 35). Research in Namibia's neighbouring country South Africa showed that the area infested with Prosopis doubled roughly every 5 years (Smit 2002: 99). The invasive character of the genus poses a considerable threat to the indigenous plant and animal biodiversity of the riparian ecosystems in which it mainly occurs (Joubert 2008: 398f; Bethune et al. 2004: 37f). Moreover, especially in ephemeral riverbeds, it is suspected to significantly impact on alluvial aquifers and to hence reduce downstream water supply with all its complex effects (Strohbach et al. 2015b: 83; Bethune et al. 2004: 38).

To date, coordinated efforts to control Prosopis in Namibia are sparse. Rather recently, the Namibian Government, mainly through the Ministry of Agriculture, Water and Forestry (MAWF), has begun to de-bush commercial farm land and to develop value chains for market-oriented de-bushing. About 30 million ha of rangeland in Namibia are encroached by mainly indigenous encroacher bush as a result of inappropriately applied grazing regimes. This causes an estimated loss in meat production of N$ 2.7 billion annually (USD 206 million). Against this background, the infestation with Prosopis seems to be economically less severe (Smit 2002: 214; Decosa 2016: viii). Nonetheless, Prosopis bears the interesting opportunity to combine employment creation through labour-based de-bushing with the additional benefit of opposing an invasive species (cf. De Klerk 2004: 240).

Employment creation in the context of natural resources in Namibia is often based on the concept of Community Based Natural Resource Management (CBNRM). After Namibia's independence in 1990, the country entered into a new approach of managing its natural resources: Communal areas could form recognized organizations like *conservancies* or *community forests* which entitled them to manage their own natural resources and to benefit from them economically, e.g. in terms of employment creation (NACSO 2015: 5). Today, the CBNRM-approach is well established in Namibia and as a matter of course, local communities are usually included in whatever effort is made to manage natural resources.

In sum, the invasive plant Prosopis in Namibia is both, curse and blessing or simply: a 'conflict tree' (Joubert 2008: 399). On the one hand, it is tremendously useful, especially for livestock farmers in the arid landscapes in southern Namibia. On the other hand, it has become an aggressive invader threatening indigenous biodiversity and water resources. As with bush-encroachment in Namibia in general, it is hence essential to develop sound approaches for controlling Prosopis in order to regain the upper hand over the invader - preferably in the spirit of CBNRM.

1.3. Prosopis in /Ai-/Ais-Richtersveld Transfrontier Park

/Ai-/Ais-Richtersveld Transfrontier Park (ARTP) is located along the border between Namibia and South Africa as depicted in *Figure 2*.

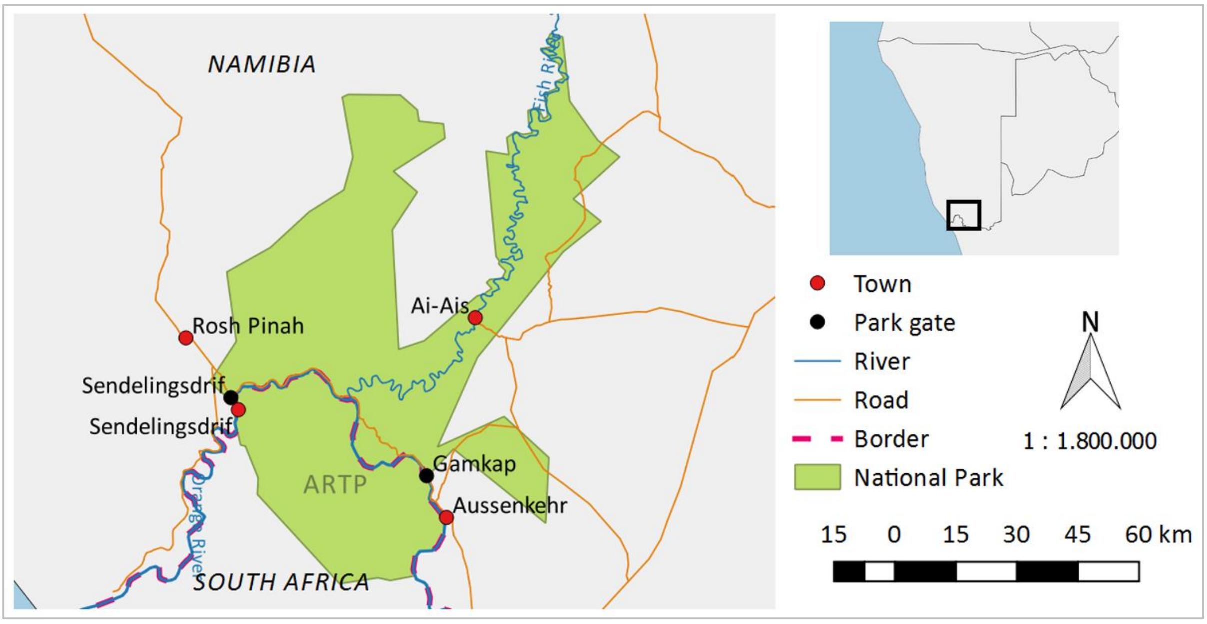


Figure 2: Map of ARTP (own illustration based on Open Street Maps)

The so called *Transfrontier Conservation Area* (TFCA) was formally established in 2003 and is comprising */Ai-/Ais Hot Springs Game Park* on the Namibian side and *Richtersveld National Park* in South Africa. The area measures 5.920 km^2 and is hyper arid, receiving 50-100mm rain per year with maximum temperatures of 40°C and an average temperature of 18°C (MET 2013: 8). Also due to the extreme climate, the park is home to the richest succulent flora worldwide and is thus recognized as an UNESCO World Heritage Site. Except the Orange River, which forms the border between Namibia and South Africa, all drainage lines in the Park are ephemeral (SADC undated: 1). The South African part of the TFCA, *Richtersveld Park*, belongs to local communities of the Nama ethnic group who commissioned the management of the park to *South African National Parks* (SANParks). SANParks is the agency entrusted to manage South Africa's national parks. The Namibian part of ARTP, */Ai/Ais Hot Springs Game Park,* is managed by MET. A *Joint Management Board* (JMB) was established through an international treaty between Namibia and South Africa signed in 2013. As main challenges, the JMB is facing ongoing mining activities along the Orange River, the management of livestock grazing, illegal fishing and poaching within the park, water management issues and the management of alien invasive plants (SADC undated: 2). The Namibian park management plan for ARTP consequently declares the eradication of invasive species a priority. Prosopis is explicitly mentioned as one of the most invasive plants in the park. Envisaged control activities in this context are the identification and mapping of invasive species, the development of management guidelines, the management and where practical eradication of the plants, and the continuous monitoring of the threats posed by them (MET 2013: 19). So far, none of these activities have been implemented by MET. In contrast, SANParks is already pursuing Prosopis control measures in Richtersveld Park for a couple of years. To this end, SANParks cooperates with the Working for Water (WfW) Programme, a government funded programme administered through the South African Department (i.e. Ministry) of Environmental Affairs. WfW is nationwide aiming at invasive plant reduction through training and employment creation for people from marginalized groups of society (DEA 2017: 1). SANParks is concerned that invasive plant control along the Orange River is only effective if both parties cooperate in a joint effort and therefore requested MET to start implementing the envisaged Prosopis control activities (*Int.* Whittington).

1.4. Study area

In the Namibian part of ARTP, Prosopis occurs primarily along the main drainage systems. These are the ephemeral Fish River and the perennial Orange River. The study area for the technical part of this study are the banks of the Orange River in the Namibian part of ARTP. The area is located between the eastern park entry gate (*Gamkap Gate*) and the western gate (*Sendelingsdrif Gate*). The stretch measures roughly 80km. The area is largely easily accessible via the C13 national road which runs parallel to the river. Additionally, the area approximately 10km upstream from Gamkap gate was examined as invasive plant control along a river must always consider the situation upstream. Areas that were not investigated are a stretch of 20km which is not accessible from the main road and a stretch in which there are mining activities. Follow-up phases of this study should consider these areas.

2. Methods

2.1. Literature Review & Expert Interviews

In general, all information on which this study is based was obtained through literature review or expert interviews. Literature is referred to in the text and listed under *6 Literature*. The same holds for expert interviews, which are listed under *7 Interview Partners*. References to expert interviews are marked with an italic *Int*. The interviews were closely linked to the stakeholder analysis as described in the following paragraph. This is for the reason that most of the stakeholders are experts at the same time. Whenever possible, interviews were held in direct, personal communication as semi structured interviews. If this was not possible, the interviews were conducted via telephone or email. The frameworks for the semi structured interviews varied highly with regard to the respective field of knowledge and thus, were individually prepared before each interview.

2.2. Stakeholder Analysis

The stakeholder analysis (SA) follows Grimble's (1998) *Stakeholder methodologies in natural resource management* as an analytical framework. According to Grimble, SA serves for multiple purposes: It improves the design of a potential project, it is essential to avoid non-cooperation or opposition from key stakeholders, and it helps to better address the distributional, social and political impacts of a potential project. In essence, it is a tool for gaining a holistic understanding of the investigated *system* (Grimble 1998: 1). Besides the *system* in a narrow sense, which in this case is ARTP and its surroundings, the SA was also used to gather an understanding of marketing opportunities for products that could be created from Prosopis harvesting. Grimble emphasizes that there is no blueprint on how to conduct SA but that creativity and flexibility are required from the researcher. Nonetheless, he suggests several stages which were applied in this study.

First of all, the project's objectives were identified. This is essential to set the direction for the following consultation of stakeholders (Grimble 1998: 4). To clarify the objectives, several interviews with Richard Fryer, MET Chief Warden Karas Parks, were held. Mr. Fryer is responsible for the management of ARTP (Namibian part) and initiated the study. With known objectives, a gradually improving understanding of the system was developed. This required the identification of as many stakeholders as possible by purposive sampling (Grimble 1998: 4f). MET Senior Warden Wayne Handley who managed the Namibian part of ARTP for the last decade served as a knowledgeable starting point. Parallel, the stakeholders' interests, characteristics and circumstances were captured through informal, semi-structured interviews (cf. Grimble 1998: 6). Attention was also given to patterns of interaction between stakeholders. This includes their interaction with each other but also with the targeted system and serves to identify potential conflicts (cf. Grimble 1998: 7f.). Finally, stakeholders were classified and ranked corresponding to their importance for the (cf. Grimble 1998: 5f).

2.3. Financial Assessment

As a toolkit for the financial assessment (FA) of the project, this study uses the FAO Forestry Paper 106 by Gregersen and Contreras (1992) *Economic assessment of forestry project impacts*. The primary aim of the guidelines is to create knowledge for decision makers to decide about (potential) projects. A project in this sense is understood as an intervention for shaping development, either initiated through a government or a non-governmental organisation. To this end, projects consist of *inputs* which they form into *output*s through a set of activities (Gregersen and Contreras 1992: 6). In the definition of Gregersen and Contreras (1992), financial assessment means to analyse the actual flow of money, goods and services between the actors directly involved in a project.

The primary aim of financial assessment is to determine the financial feasibility of a project from the point of view of a certain involved stakeholder, in this case MET (Gregersen and Contreras 1992: 11). If costs and benefits of a project are not sufficiently attractive for involved stakeholders, they will not participate in the project. Usually, the value of aggregate benefits must exceed aggregate costs. If the financial acceptability is not given, subsidies or other incentives must be provided in order to attract stakeholders.

Secondly, the budget and financial sustainability implications of the project deserve attention. The project with all its initial as well as operating costs must constantly remain within the budget limitations. Time spans between inputs and outputs must be noted and future costs must be anticipated. If the budget is not sufficient, either the scale of the project or the budget itself must be adapted. A crucial point in this context is the ability of the implementing agency to continuously support the project once external funding expires. Experience has shown that this is one of the most common pitfalls in project design (Gregersen and Contreras 1992: 10, 25f).

To clarify the above, three practical steps as suggested by Gregersen and Contreras were undertaken. In the first step, inputs and outputs of the project were identified and quantified. Once direct inputs and outputs were identified, implications related to their location were given attention. Inputs and outputs are usually not marketable directly at the project site which especially holds for the remote location of ARTP. Availability, handling, transport and marketing were reflected upon. All identified inputs and outputs were captured in *physical flow tables* (cf. Gregersen and Contreras 1992: 21).

The second step valued the identified inputs and outputs**.** To this end, current market prices for every input and output were captured. This led to *unit value tables* according monetary values in NAD and

USD[1] to inputs and outputs (cf. Gregersen and Contreras 1992: 23). The third step combined step 1 and step 2. Adding monetary values to physical flow tables allowed to generate cash flow tables for the project (cf. Gregersen and Contreras 1992: 24). The Net Present Value (NPV) as common measure capturing total discounted costs over total discounted benefits of a project was not computed as the lifespan of a project phase is relatively short and does not require discounting.

2.4. Forest Inventory

To generate in- and output data required for the FA, a small scale forest inventory was conducted. Prosopis density in the study area was assessed in order to determine the necessary inputs for removing Prosopis from the area. Additionally, harvestable biomass was estimated in order to determine the outputs that can be created from removing Prosopis. In the following, the applied inventory approach will be explained in general. Subsequently, the section touches on the methodology to estimate Prosopis density and Prosopis biomass.

2.4.1. Sampling design

The principal methodological challenges in forest inventory are the questions of how to select representative samples from a population and how to derive sound estimates from the collected data (Köhl et al. 2006: 78). Appropriate sample selection is achieved through choosing an appropriate sampling design, of which there are two overarching groups: sampling designs *with* auxiliary information and sampling designs *without* auxiliary information. The former relies solely on statistical principles in order to identify samples. The latter makes use of different kinds of auxiliary information to pre-structure the sampling frame in more homogenous groups, from which the samples are chosen (cf. Köhl et al. 2006: 81).

For this study, a sampling design close to *stratified sampling* was chosen. Stratified sampling splits up the population into several units (*strata*) by making use of auxiliary information. The aim is to create strata within which the variation of the examined attributes is very low. In other words, each stratum should be as homogenous as possible with regard to the examined attributes (Köhl et al. 2006: 105).

Stratified sampling was chosen due to the immense heterogeneity of the study area, which can be seen in *Figure 3*: Subunit of the stratum *dense riparian thickets*. As the satellite image shows, the riverbed of the Orange River resembles a jigsaw of small habitats. For instance, there are permanently flooded areas, occasionally flooded areas, small islands, dense riparian thickets, riverbanks without

[1] NAD were converted to USD based on the mean exchange rate from April 2017 to June 2017 as per *OANDA* (www.oanda.com)

much vegetation, and also steep hills just next to the river. Compared to a relatively homogenous forest, for which forest inventory methods were usually developed, the conditions in the study area are quite unfavourable. Therefore, the identification of different strata is a welcome means of creating at least some extent of homogeneity.

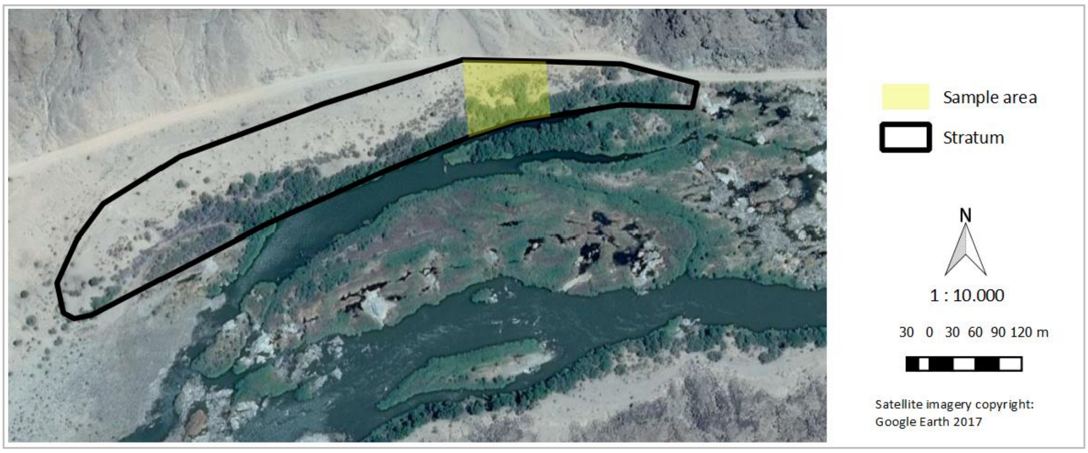


Figure 3: Subunit of the stratum *dense riparian thickets*

Based on both satellite imagery as auxiliary information, paired with first field observations, different strata were preliminary delineated within the study area. The stratum of the above mentioned dense riparian thickets was identified as the hotspot of Prosopis infestation. Prosopis is also found in other strata like the islands within the river or the occasionally flooded banks. For time and resource limitations, only the most important stratum, i.e. the dense riparian thickets, could be investigated. This serves as a good starting point while the investigation of the other strata is certainly required in follow-up phases to arrive at more robust statements about the overall infestation with Prosopis in the study area.

The stratum dense riparian thickets was demarcated using the freeware Quantum GIS (QGIS) in combination with publicly available satellite imagery from Google Maps and Bing Maps. *Figure 3***:** Subunit of the stratum *dense riparian thickets* shows an excerpt or subunit of the stratum. It comprises the dense riparian thicket next to the stream channel as well as the sandy strip between the thicket and the point close to the ascending hills where there is no more considerable woody vegetation. Once the subunits of the stratum were demarcated, 14 sample areas were distributed randomly within these subunits. The number of sample areas was chosen according to availability of time and resources.

With randomly distributed sample areas within only one stratum, mean values and standard deviation are computed as in simple random sampling (cf. Köhl et al. 2006: 83, 108):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad SD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$\bar{x}$: Mean
x_i : Recorded value sample i
n : Number of samples
SD: Standard deviation

2.4.2. Estimation of Prosopis density and Prosopis biomass

For the identified samples, the density of Prosopis (and hence of *inputs* of the project) and the biomass of Prosopis (and thus of *outputs*) was assessed. In each sample area all Prosopis trees were marked with GPS. Basal stem diameters of each tree were taken in diameter classes spanning 5 cm as depicted in *Table 1*. Plants with a basal diameter smaller than 7.5 cm were not recorded. For practical reasons, basal stem diameters were taken approx. 5 cm above the soil level making use of a tree calliper for rather circular stems and a diameter measuring tape for irregularly shaped stems.

Table 1: Definition of diameter classes

Diameter range [cm]	Diameter class [cm]
7.5 - 12.4	10
12.5 - 17.4	15
17.5 - 22.4	20
22.5 - 27.4	25
27.5 - 32.4	30

Diameter range [cm]	Diameter class
32.5 - 37.4	35
37.5 - 42.4	40
42.5 - 47.4	45
47.5 - 52.4	50
52.5 - 57.4	55

Diameter range [cm]	Diameter class
57.5 - 62.4	60
62.5 - 67.4	65
67.5 - 72.4	70
72.5 - 77.4	75

Estimation of Prosopis density

As mentioned in *1.3*, SANParks and WfW are actively pursuing Prosopis control in the South African part of ARTP. The applied form of organisation and the control method are described in detail in *3.4.1*. WfW uses a tool to estimate labour inputs for alien plant eradication. It was developed by Heinrich Neethling from DEA and made available for this study and for the project in general (*Int.* Neethling).

The Neethling-tool's estimation is primarily based on the density of the respective invasive species. In the case of a *sprouting tree*, as which Prosopis is classified due to its ability to coppice from stumps, density means canopy coverage. WfW assesses canopy coverage with transect counts. For this study, another approach was followed: During the forest inventory, the crown radius r of 110 Prosopis trees from different size classes was recorded. Based on this data the following regression analysis allocates an average crown radius to every diameter class d_i as displayed in *Table 2*.

$$\bar{r}_i = 0{,}1425 * d_i + 0{,}0754 \qquad (N = 110, R^2 = 0{,}80)$$

Table 2: Crown radius linked to diameter class

Diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
Crown radius [m]	1,50	2,21	2,93	3,64	4,35	5,06	5,78	6,49	7,20	7,91	8,63	9,34	10,05	10,76

Finally, the derived average crown radius was allocated to every single recorded tree in QGIS. The ratio of *aggregated crown area within the sample area* per *sample area* resembles Prosopis density.

Besides density, the Neethling-tool additionally takes into account the growing type of the plant (*size class*), the envisaged treatment method, and whether the clearing is planned in a landscape or riparian zone. It finally computes average person days per hectare for the clearing of the respective invasive plant. All estimations are given for a standardized clearing team as described in the tool.

For a riparian zone, the tool's estimation includes chopping Prosopis to manageable pieces and moving away all biomass 30m from the river. WfW interventions are government funded and do not include revenues from marketing Prosopis products (*Int.* De Beer). For the purpose of this study, the Prosopis biomass has to be commercialized to generate revenues for the financing of the hired labour input. The processing of Prosopis into marketable products like e.g. firewood is considered as an additional activity, which is estimated on the base of the harvestable biomass. The required labour for e.g. cutting in sections, splitting and packaging was derived from literature and expert interviews. De Wet (2015: 12) suggests a ratio of *harvesting labour* to *processing labour* between 0.25 and 0.4 for de-bushing in general. Strohbach and Ntesa (2016: 28) find a ratio of 0.25 not sufficient for semi-mechanized Prosopis control. Given the fact that the estimation of the Neethling-tool already accounts for chopping the wood down to manageable pieces and moving it away from the riparian zone, a ratio of 0.4 was adopted.

Estimation of biomass

While Prosopis density was mainly measured to determine inputs into the project, Prosopis biomass is estimated to determine outputs. The following definitions of biomass are used:

Table 3: Definition of biomass classes

Term	Definition
$m_t \quad [kg]$	**Dry above-ground biomass**: all living biomass above the soil including stem, stump, branches, bark, seeds, and foliage as per definition of the FAO (FAO: 9).
$m_b \quad [kg]$	**Dry bulky biomass / barbecue wood**: mass of parts of stem and branches with a diameter bigger than 50mm as used in Strohbach et al 2015 (there: 'harvestable biomass').
$m_f \quad [kg]$	**Dry fine biomass / fuelwood**: parts of the branches and twigs with a diameter between 50mm and 10mm.

The assessment of biomass usually follows a two-phase procedure. First, a relatively small sample of trees, bushes or shrubs is destructively taken, dried and weighed. Based on the collected data, a regression analysis is held. This leads to a model linking simple to measure independent variables like e.g. basal diameter or tree height to the dependent variable biomass. Once such a model is developed, the biomass of a population or a certain area can be estimated after the respective independent variables have been recorded (Köhl et al. 2006: 57).

For resource limitations, the first Phase could not be conducted in this study. Instead of that, Prosopis biomass estimations derived by other authors were used. The implications of this are discussed in *4 Discussion*.

A model to predict dry bulky biomass m_b was developed based on unpublished data linked to a study by Strohbach et al. (2015a). For this study, $\boldsymbol{m_b}$ and $\boldsymbol{d}$ of 17 Prosopis trees in the Fish River at Gibeon, Namibia, were recorded. The best derived regression model is:

$$\log \boldsymbol{m_b} = 0{,}0357 * \boldsymbol{d} + 0{,}212 \qquad R^2 = 0{,}89$$

As a model to predict $\boldsymbol{m_t}$, the regression analysis by Felker et al (1983) was used. For this study, $\boldsymbol{m_t}$ and $\boldsymbol{d}$ of 1352 Prosopis trees from numerous Prosopis subspecies were recorded. The derived regression model is as follows (Felker et al 1983a: 190):

$$\log \boldsymbol{m_t} = 2{,}1905 * \log \boldsymbol{d} - 0{,}9811 \qquad R^2 = 0{,}83$$

To roughly estimate $\boldsymbol{m_f}$, the difference between $\boldsymbol{m_t}$ and $\boldsymbol{m_b}$ was corrected downwards by 15% of $\boldsymbol{m_t}$. This amount approximately accounts for the Biomass of leaves and pods of Prosopis and hence is subtracted (cf. Sharifi et al 1982: 763).

$$\boldsymbol{m_f} = (m_t * 0{,}85) - m_b$$

With the above formulas, for every diameter class the average values of biomass for one tree were calculated (*Table 4*: Biomass per diameter classes).

Table 4: Biomass per diameter classes

Diameter class	$\boldsymbol{m_t}$ $[\boldsymbol{kg}]$	$\boldsymbol{m_b}$ $[\boldsymbol{kg}]$	$\boldsymbol{m_f}$ $[\boldsymbol{kg}]$
10	16	3	11
15	39	4	30
20	74	6	57
25	121	9	94
30	180	13	139
35	252	20	194
40	337	31	256
45	437	46	325
50	550	70	398
55	678	105	471
60	820	158	539
65	977	239	592
70	1150	360	617
75	1337	543	594

The biomass of each diameter class was calculated as product of plant numbers in this diameter class with average biomass of diameter class. For each sample area, the biomasses of all diameter classes were summed up, which yielded total biomass per sample area. Total biomass per sample area divided by the size of the respective sample area gave biomass densities per ha. Also, the whole biomass of the subunit of the stratum *dense riparian thickets* in the location was approximated based on the biomass densities and the size of the subunit.

3. Results

3.1. Stakeholder Analysis

3.1.1. Objective of the Prosopis Control Project

At the beginning of the SA, objectives of the project were defined as follows (*Int.* Fryer, Leineweber):

a) **Reduce Prosopis infestation** in the Namibian part of ARTP.
b) **Create employment opportunities** for local communities (beneficiaries) through applying a labour-intensive method of Prosopis control.
c) **Leave power of decision with MET**, i.e. do not apply an organizational form that establishes a co-management between MET and local communities.
d) **Keep costs for MET low** in the face of the recent budget limitations.
e) **Keep impacts on the indigenous flora and fauna at a minimum**.

3.1.2. Stakeholders

An understanding of the system was developed by recording stakeholders, their interest, characteristics and circumstances. The stakeholder analysis did not investigate the potential target group / beneficiaries of the project, i.e. the local communities that are supposed to benefit from the created income opportunities. This is because a currently ongoing joint study by MET and the GIZ-TFCA project conducts such an assessment in a very profound manner (*Int.* Leineweber). The local communities are therefore just briefly mentioned as stakeholder (9) without further specification. *Table 5* displays the identified stakeholders. It briefly describes each stakeholder and its interest in Prosopis control. It also ranks stakeholder according to their importance and influence for the project. Importance describes how much the successful integration of the respective stakeholder determines the overall success of the project. Influence describes the extent to which a stakeholder can influence the outcome of the project.

Table 5: Stakeholders of the project

Institution	Name and Function	Typology	Description	Interest in Prosopis control	Importance (very low to very high)	Influence (very low to very high)
(1) Ministry of Environment and Tourism, Directorate Wildlife and National Parks	Richard Fryer, Chief Warden Karas Parks Wayne Handley, Senior Warden Oranjemund (former Rosh Pinah) Boly Shetukana, Warden Rosh Pinah	National	main project proponent; responsible for the management of the Namibian part of ARTP	control (eradicate) Prosopis through community involvement	very high	very high

Institution	Name and Function	Typology	Description	Interest in Prosopis control	Importance (very low to very high)	Influence (very low to very high)
(2) Ministry of Agriculture, Water and Forestry, Directorate Forestry	Joseph Hailwa, Director Forestry Jonas Mwiikinghi, Senior Forestry Technician	National	Responsible for the administration of harvesting forestry resources including issuing of harvesting permits	Generally interested in controlling invasive species	medium	high
(3) Ministry of Mines and Energy, Oranjemund Office	Jeffrey Tengee	National	Overseeing mining activities in and around ARTP	no particular interest	very low	high
(4) South African National Parks	Brent Whittington, Park Manager ARTP (South African part)	National (South Africa)	Government agency responsible for the management of the South African part of ARTP	Joint interest in cooperating with MET to implement Prosopis control measures along both sides of the Orange River	high	moderate
(5) Working for Water	D'Reull De Beer, Project Manager ARTP (South African part)	National (South Africa)	Government funded programme implementing Prosopis control measures in the South African part of ARTP		high	very high
(6) GIZ project 'Transboundary use and protection of natural resources in the SADC region'	Martin Leineweber	International	Project of international cooperation between SADC and Germany; supporting community participation in ARTP and providing funding for project	create participation opportunities for local communities through Prosopis control	moderate	very high
(7) GIZ 'Support to De-Bushing Project'	Johannes Laufs Frank Gschwender	International	Project of international cooperation between Namibia and Germany; developing approaches for de-bushing commercial farmland from (mainly indigenous) encroacher bush	generate knowledge about practical implications of Prosopis control	moderate	high
(8) Orasecom		International	Interntional body established by Botswana, Lesotho, Namibia and South Africa for jointly managing the Orange Senqu Basin which includes the Fish and the Orange River; developed a concept for	Possible source of fundung for Prosopis control	low	low

Institution	Name and Function	Typology	Description	Interest in Prosopis control	Importance (very low to very high)	Influence (very low to very high)
			Prosopis control in ARTP in 2012			
(9) Local communities	to be established	Local on-site	Local communities in the larger vicinity of ARTP other than migrant workers in Aussenkehr and Rosh Pinah	employment creation	very high	high
(10) Roshskor, Rosh Pinah	Ronny Slabbert	Local on-site	Managing the town of Rosh Pinah on behalf of the mining companies *Glencor* and *Vedanta Resources*	no particular interest; contact to Rosh Pinah community; potential marketing channel for fine firewood	medium	high
(11) Aussenkehr Farm (Nature Reserve)	Eben Naude	Local on-site	Farm / Nature Reserve neighbouring ARTP upstream the Orange river	interested in keeping some Prosopis trees for animal feed production	moderate	high
(12) Namibia Biomass Industry Group	Colin Lindeque	National	NGO with the purpose to promote the Nambian biomass sector	developing new value chains for biomass production	moderate	moderate
(13) Namibia University of Science and Technology, Agriculture and Natural Resources Sciences	Dr. Ben Strohbach	National	Department of University involved in former studies on Prosopis control at Gibeon	interested in generating and sharing knowledge about Prosopis control	low	low
(14) Namibian Charcoal Association	Peter Potgieter	National	NGO with the purpose to promote the Nambian charcoal producing sector	no particular	low	very low
(15) Farmers	AP Steyn Jurgens Twyman	Local off-site	Farmers producing animal feed from bush		very low	moderate
(16) Aussenkehr vineyards	e.g. Norbert Liebich (Transworld Cargo)	Local off-site	Private businesses developing vineyards on Aussenkehr farm in the vicinity of Aussenkehr town	interested in large quantities of wood chips as fertilizer	low	low
(17) Namibia Wildlife Resorts	Simon Haimbola, Ai-Ais Anna Kubula, Hobas	Local off-site	Namibian parastatal, operating tourism facilities in Namibia's protected areas under MET	possibly interested in buying Prosopis firewood	moderate	low
(18) Gondwana Collection Namibia	Charles Cock	Local off-site	Namibian hospitality company, operating a couple of lodges in the vicinity of ARTP	Involved in community-based Prosopis control in Keetmanshoop; possibly interested in buying Prosopis firewood	very low	moderate
(19) Prosopis wood dealers	Sakkie Engelbrecht	Local off-site	Private businesses	interested in buying large	low	high

Institution	Name and Function	Typology	Description	Interest in Prosopis control	Importance (very low to very high)	Influence (very low to very high)
			dealing with prosopis firewood commercially	amounts of Prosopis firewood		

3.1.3. Stakeholder Interaction

This section briefly touches on the proposed interaction of MET with such stakeholders that are either of high importance for the project or that have high influence on the project. (2) MAWF can affect the operation of the project as it is responsible for issuing permits for de-bushing activities. As described in *3.4.3* MET should enter into consultation with the responsible Department of Forestry in order to clarify possible restrictions in advance. (3) The MME office in Oranjemund is commissioned to oversee mining activities in ARTP. Should the Prosopis control operations target areas that belong to prospective mining licences, consultation with MME is required to get permission to do so. (4 & 5) Cooperation with SANParks park management of ARTP and WfW in ARTP should become a constant component of the project as invasive control along a river can only be effective if both parties cooperate. Moreover, SANParks and especially WfW possess extensive experience on all aspects of Prosopis control and expressed their willingness to cooperate with MET in this regard. (6) The influence of the GIZ-TFCA project is very high as it provides the kick-off funding for the project. Accordingly, the good partnership between MET and GIZ should be continued. (7) The Support to De-Bushing project between MAWF and GIZ could contribute substantially to the project as it generates knowledge such as guidelines on de-bushing operations or templates for contracting SMEs (see *3.4.3*). (9) Local communities are the beneficiaries of the project. It is quintessential to establish a good working relationship with their integration directly determines the project's success. Hence, their influence on the project is very high. (10) Roshskor's influence on the project is high as it manages Rosh Pinah, one of the markets for Prosopis products. Cooperation between MET and Roshskor is already established and should be intensified in future. (11) The same holds for the management of Aussenkehr. However, there is also conflict potential as the Management of Aussenkehr indicated their willingness to keep mature Prosopis trees for animal feed production. For MET it will be important to seek cooperation in order to mitigate the negative effects of this. (19) Finally it will be very important to establish good relationships with Prosopis wood dealers to guarantee marketing success (see *3.4.4*).

3.2. Methods of Prosopis Control

3.2.1. Chemical

Chemical control methods can be divided by their mode of application as well as in their mode of action. Application is either aerial or manual. The former is highly unselective and is thus only justifiable if large areas with high densities of the targeted plants are to be cleared (De Klerk 2004: 134) and other woody plants are also accepted to be eradicated, e.g. for farm and grassland preparation. Because this is not the situation in the project, aerial application is not further considered. Manual application is far more selective and applicable in heterogeneous environments. It is usually labour intensive (cf. De Klerk 2004: 140).

With regard to the mode of action, chemical control agents can either be applied to the roots of the plant, to its leaves or to the stem. Root absorbent control agents are dispersed close to the stem of the targeted plants, penetrate the soil after it rained and get absorbed by the roots of the plant. While this method is far more selective than aerial application, neighbouring plants are still affected as their root systems usually spread widely (De Klerk 2004: 139). For this reason, and for the reason that it hardly rains in the study area, root absorbent control agents are not considered a viable option in this context. The same holds for foliar absorbent control agents, which are sprayed onto the leaves of the target plants. This is generally quite effective and selective (De Klerk 2004: 139f). It is however not desired in the setting of the project because the riparian thickets are too dense to selectively target Prosopis leaves, the Prosopis trees are in many cases too big to reach the leaves from the ground, and the run-off is considered too high (*Int.* De Beer). The only remaining method of application of chemical control agents is hence stem application. Thereby, the targeted plant is cut down close to the surface. Thereafter, a chemical control agent is applied directly to the wounded stem with a brush. This is highly selective and labour intensive (De Klerk 2004: 140). Although it sounds simple, the correct application requires training as it must be ensured that the control agent reaches the cambium layer of the plant from where it is translocated into the roots (Smit 2002: 217). Wounding the stem with an axe after it has been cut can significantly increase the effectiveness of the application (*Int.* Handley). The main disadvantage of stem treatment is its expensiveness due to the cost of the chemicals (Smit 2002: 218). The active ingredients of suitable chemicals are mainly *Picloram* and *Triclopyr* (De Klerk 2004: 138). Available literature on de-bushing in Namibia attributes to the chemicals modest environmental and health risks and low toxicity to animals. Additionally, their short half-times are mentioned (De Klerk 2004: 142; Smit 2002: 218). It can however not be ruled out that these views are biased due to the interest in de-bushing.

A chemical control agent commonly used is *Garlon 480 EC* (Triclopyr). It must be diluted with diesel oil before application. It was found effective in a trial at Sendelingsdrif in the study area (*Int.* Handley) and it was also used for clearing Prosopis at Ai-Ais on behalf of NWR (*Int.* Cock). Another product is *Kaput 100 Gel* (Picloram, Triclopyr) which is water-based and ready to use. WfW is using this product successfully for its Prosopis control measures in the South African part of ARTP. It is already mixed and therefore easier to handle in the field. Moreover, the fact that it is water-based reduces environmental risks in comparison to diesel soluble products (*Int.* De Beer).

For the application of herbicides a registration at the Ministry of Agriculture, Water and Forestry is required (*Int*. Louw). Active ingredients of herbicides that are currently prescribed for targeting Prosopis are *Teburhioron*, *Bromacil*, *Triclopyr* and *Clopyralid* (*Int.* Izaaks).

3.2.2. Mechanical

Mechanical control methods can be divided by their degree of mechanization, ranging from large-scale highly-mechanized operations to small-scale manual operations. The application of highly mechanized methods is mainly intended for clearing large areas from woody plants on bush-encroached commercial farmland. Heavy machinery such as bulldozers and excavators with harvester felling heads are used (De Wet 2015: 5). The machines are capital intensive and high densities as well as large amounts of harvestable biomass are required in order to operate the equipment feasibly (*Int.* Liebich). The environmental impact can be considered high because severe soil disturbance occurs. Regrowth of targeted species from the seedbank is likely as competing plants are also removed or affected (De Klerk 2004: 158). In ARTP, highly mechanized Prosopis clearing methods are not considered viable. Prosopis in ARTP grows in dense riparian thickets with indigenous vegetation. This sensitive environment would be dramatically disturbed by heavy machinery. Moreover, the terrain is difficult and employment opportunities for local community members would be moderate, especially in relation to the immense capital costs.

Manual and semi-mechanised control methods show the far larger potential for the project. Manual de-bushing makes use of axes, handsaws, pruning shears and the like for cutting and felling shrubs and trees. It is extremely labour intensive, requires very little initial investment, and can be carried out with hardly any technical skills. Its main disadvantage is the very low productivity and the hard working conditions (Decosa 2016: 31). Semi-mechanised solutions make use of chainsaws, bush cutters and the like. This increases productivity remarkably, is less hard and thus increases the attractiveness of the work. It is however far more capital intensive than manual de-bushing and requires a certain amount of training for handling and maintaining the equipment (Decosa 2016: 32f), to prevent the high risk of serious work accidents. Semi-mechanised control methods are preferred and successfully used by all experts interviewed for this study and are therefore considered the most suitable approach (*Int*. De Beer, Cock, Haelbich, Engelbrecht, Witbooi, Brassine). Its biggest advantage with regard to the situation in the study area is its selectiveness. It allows to only target Prosopis plants even in a thicket of indigenous vegetation without causing extensive damage to other plants.

The effective cutting of Prosopis is difficult. The plant shows an immense ability to regrow from coppicing buds. Therefore, cutting below ground level, i.e. below the coppicing buds, is recommended. Nonetheless, cutting itself is usually not sufficient to kill the plant. The remaining stumps must be burned to kill all sleeping buds, or must be treated with herbicide (De Klerk 2004: 157). Burning in this context means to stack the cut-off branch material (too small for fire wood) around the stump, leave it there to dry, and then burn it and the stump with it. This is highly effective, relatively cheap and therefore applied in commercial Prosopis harvesting operations in Namibia, e.g. in the Nossob area (*Int.* Haelbich, Cock). However, it is not deemed viable in ARTP for burning would cause damage to other plants in the riparian thickets. The combination of felling and herbicide treatment on the other hand is considered highly viable for the project.

If a small-scale mechanical clearing approach is chosen, it is theoretically recommended not to immediately clear the infested area completely but to gradually intensify the clearing, i.e. to clear Prosopis in portions. Especially in areas where the Prosopis density has been very high, soils are exhausted after an infestation and the indigenous vegetation will re-establish hesitantly (Smit 2002: 222). Strohbach et al. (2015a: 85) therefore recommend to first thin Prosopis thickets and to replant indigenous trees while continuously harvesting Prosopis pods and suppressing Prosopis regrowth. Once the planted indigenous species have established, the remaining Prosopis can be removed. While this gradual approach is certainly best practice, it is also very resource intensive.

With regard to timing, Smit (2002) suggests to apply mechanical control methods in the winter months when most Prosopis subspecies shed their foliage and thickets are easier to penetrate (cf. Smit 2002: 294). However, this might increase the survival rate as reserves would then already be transferred to the roots which makes regrowth more likely (cf. De Klerk 2004: 157).

Mechanical Prosopis control in a wider sense also includes the harvesting of pods. This is deemed quintessential in order to avoid further spread (Smit 2002: 222). Once the pods are ripe, they fall off and can be collected from the ground. Pods can either be destroyed or used as animal feed (see *3.3.4*).

As indicated above, manual mechanical control methods alone are not sufficient. They should therefore be combined with burning the stumps or with the application of herbicides. While the former is hardly viable in ARTP, the latter is already applied by WfW in the South African part of the park. It will be discussed in the following paragraph.

3.2.3. Semi-mechanised & Chemical

WfW deploys teams from local communities to eradicate Prosopis in the South African part of ARTP. These teams usually consist of 10 to 12 workers, including a contractor, one or two chainsaw operators, one or two herbicide applicators, and several general workers which are partly trained in first aid, work place risk assessment and the like (*Int.* De Beer).

The control method applied by WfW is to cut down Prosopis trees as close to the ground as possible. It was found successful to remove sand around the stem where possible and to cut below the lowest growth node in order to avoid regrowth. Larger trees are felled with chainsaws while smaller shrubs are lopped with pruning shears. Immediately after cutting, herbicide is applied with a brush to the stump. Currently, the ready-to-use water based *Kaput 100 Gel* is used. Foliar application was not found suitable as the run-off was too high and would negatively affect the sensitive riparian environment. The cut material is moved away 30m from the riparian area and from sensitive vegetation. Where it is possible, i.e. where it poses no danger to the indigenous vegetation, the material is burnt. Some of the wood is removed and used as fire wood, but not commercially. All initially cleared areas receive a follow-up treatment every six months. Regrowth and seedling are removed with pruning shears and herbicide is applied with brushes again. Follow-up treatments will ideally be conducted for about 3 years. After that, Prosopis is usually under control and follow-up treatments are reduced to a monitoring activity once a year (*Int*. De Beer).

The South African example shows that so called *aftercare*, i.e. suppressing Prosopis regrowth after initial clearing, is a lengthy and resource intensive process. However, such aftercare is absolutely essential in the context of de-bushing and with regard to Prosopis in particular due to its strong coppicing ability and the extensive seed bank (cf. De Klerk 2004: 135; Strohbach et al. 2015a: 79; *Int*. De Beer).

The example also shows that Prosopis infestations in a sensitive riparian zone are manageable by applying a combination of mechanical and chemical methods. While the application of herbicides is doubtlessly expensive, it is indispensable as it became evident in a very recent community-based Prosopis control project at Gibeon in southern Namibia. Gibeon is located close to the Fish River which is also densely infested with Prosopis. In a donor funded project, a mechanical clearing method was carried out by workers recruited from the community. For donor policies, herbicide was not applied. This resulted in extensive regrowth of about 80% of the removed plants. No considerable ecological long term benefits will remain at best. In a worst-case scenario, the long term outcome could even be worse than the initial situation (Strohbach and Ntesa 2016: 16, 30ff).

3.2.4. Biological

As biological control agents for Prosopis, the beetles *Algarobius prosopis* and *Neltumius arizonensis* have been introduced to southern Africa in 1987 and 1993 (De Klerk 2004: 148). The larvae of both species feed on ripe Prosopis seeds and prevent them from germinating. The pod itself is largely unaffected, maintains its nutritional value and its usefulness as animal feed. While the beetles do have the potential to significantly reduce the seed bank, most of the pods are ingested by livestock or game before the larvae can feed on the seeds. In practice, this reduces the short term effectiveness of the biological control agents (De Klerk 2004: 150). Nonetheless, and especially as almost all stands of Prospois in Namibia are infested with the beetles, their presence certainly diminishes the overall invasive potential of Prosopis. The control method is relatively environmentally friendly as the beetles are host-specific, self-perpetuating and cost effective, and is therefore largely considered a welcome support in the effort to control Prosopis (cf. Smit 2002: 220). However, cases in which the beetles feed on indigenous plants if Prosopis is not available have been reported (*Int.* De Beer). The beetles are present throughout ARTP.

Another method of biological control is regrowth-management with browsers such as goats and sheep or several game species (Decosa 2016: 37). It is however mainly discussed in the context of clearing large areas of bush-encroached farmland where goats and sheep can be deployed in a controlled manner. In ARTP it is rather the game species like Kudu and Zebra that probably will contribute to suppress Prosopis regrowth. In contrast to livestock, they cannot be deployed in a controlled manner.

3.2.5. Fire

To get a complete picture, it should be mentioned that a traditionally well-established method of bush-control in Namibia is controlled burning Thereby, bush-encroached areas or forests are converted to rangelands. However, it is absolutely unselective, kills numerous animals like birds, insects and mammals, and provides little employment opportunity. It is therefore not applicable in ARTP as the primary purpose of the National Park is to protect the indigenous flora and fauna (cf. Decosa 2016: 30).

3.2.6. Recommendation: Semi-mechanised & Chemical

In sum, it is recommended to apply a semi-mechanised approach to Prosopis control as this strikes a desirable balance between productivity and labour-intensiveness. Moreover, investment needs are modest and environmental damage is low. To avoid regrowth, subsequent chemical treatment is absolutely essential.

3.3. Marketing Opportunities for Prosopis Products

3.3.1. Firewood

With an estimated market volume of 600.000 to 1.000.000 tonnes per annum, firewood is the most prominent woody plant product traded in Namibia (De Wet 2015: 3). At least one half of the Namibian households depend on fuel wood for heating as well as for cooking (Decosa 2015: 4). This notwithstanding, the market is highly informal and the channels in which firewood is traded vary greatly (*Int*. Lindeque). While in rural areas fuel wood is used for daily cooking, in urban centres the use is rather for barbeques (braai) as special and rather luxury event. In urban centres, where the demand for such high-quality firewood is highest, it is traded through supermarkets and petrol stations. Here, the retail prices are as high as 3.000 N$ per tonne. Many households in the rather informal settlements use firewood for daily cooking, and informal markets for lower quality firewood are well present. In contrast to rural areas, where firewood collection is free of charge, for the urban poor the access to this important resource is linked to substantial costs (Decosa 2015: 4f.). Nevertheless, energy from firewood is not jet substituted with the more expensive energy forms like liquefied petroleum gas (LPG) or electricity. From a marketing point of view, the value addition through selling in urban centres yields per tonne (of premium braai firewood) prices comparable or even higher than those for charcoal (Decosa 2015: 4; Strohbach et al.: 84).

Although the nationwide demand is huge, in rural areas firewood has only little commercial value due to the free-of-charge open access. Substantial markets for premium firewood are (only) in the urban centres, so marketing of firewood in remote areas is connected with high transportation cost and is challenging. For instance, the Prosopis control project at Gibeon failed mainly due to marketing challenges. On the one hand it was difficult to achieve a sufficient and constant supply to satisfy commercial bulk dealers and on the other hand the demand of local small scale dealers was too low to sustain the project (*Int*. Strohbach). Thus, it is quintessential to establish an individual network of distributors or buyers - especially against the background of the high informality of the markets (*Int*. Lindeque). Moreover, Prosopis firewood has to compete with firewood from indigenous hardwood. While the calorific value of Prosopis wood is high and its burning quality is excellent, indigenous hardwood (e.g. Acacia spp.) is even slightly better. Therefore, and also from cultural habit, many Namibians prefer the latter. However, the indigenous species usually grow very slowly, large areas are already depleted, and consequently heir supply will decline. Invasive Prosopis firewood can therefore be marketed as environmentally friendly alternative with comparable quality (*Int*. Strohbach).

In the vicinity of ARTP it makes sense to differentiate the product firewood into two quality classes, namely higher quality *barbeque/braai wood* (see *2.4.2*, diameters above 50mm) and lower quality *fuelwood* (diameters below 50mm) (*Int*. Handley; cf. Strohbach et al 2015a: 84). Buyers for barbeque wood could be the retail markets in the towns close to the park, i.e. Aussenkehr, Rosh Pinah, and Oranjemund. Another buyer of barbeque wood is the tourism sector. Two larger tourism companies in the vicinity are the parastatal Namibia Wildlife Resorts (NWR) with Lodges and campsites at Ai-Ais as well as Hobas at the Fish River Canyon and the Gondwana Collection Namibia (GCN) also with Lodges and campsites around the Fish River Canyon. In the past, both companies entered into a joint venture for Prosopis clearing and firewood production at Ai-Ais. While NWR provided the biomass on its premises, GCN was running the operation. Hence, both are generally interested in buying Prosopis firewood which was explicitly expressed by GCN in the course of this study (*Int*. Cock). Today, NWR is obtaining firewood from a dealer commissioned by the NWR head office in Windhoek. Average quantities could not be specified by local NWR staff (*Int*. Haimbola, Kubula). GCN is still involved in a Prosopis clearing project with Keetmanshoop town council (see 3.4.1) from where it is obtaining 30-40 tonnes of Prosopis firewood per annum. Its total demand of firewood for the facilities in the vicinity of ARTP is roughly 150t per annum. The firewood is mainly used for barbeque and hot water boilers (*Int*. Cock). Besides NWR and GCN, there are numerous smaller tourism enterprises close to ARTP who could be interested in purchasing Prosopis firewood. Another potential buyer for larger quantities of barbeque wood are bulk dealers. One of them who specialises in Prosopis wood showed interest to buy up to two truckloads of 30 tonnes per month (*Int*. Engelbrecht).

Fuelwood, i.e. wood with diameters lower than 50mm, is not demanded by the above mentioned consumers but can be marketed in the informal urban settlements close to ARTP (cf. Strohbach et al: 84). These would mainly be the townships of Rosh Pinah and Aussenkehr. In Tutungeni, the township of Rosh Pinah counting 3000 inhabitants, only 30% of the households are connected to the power grid (*Int.* Slabbert). Hence, many of the households depend on fuelwood for heating and cooking. Moreover, even if electrical power is available, fuelwood is oftentimes preferred as source of energy for traditional reasons. The immense demand is contrasted by the extreme scarcity of firewood in the hyper arid environment of the area. As a consequence, dwellers are regularly observed collecting fuelwood in the only place where woody plants grow in considerable amounts, the riparian zone of ARTP (*Int*. Handely, De Beer, Naude). Slabbert, town manager of Rosh Pinah, occasionally fells trees in town by employing casual workers from the informal settlements. The finer fuelwood is then sold in Tutungeni in bundles of 8kg for N$ 10 per bundle. The resulting per tonne price is roughly half the local retail price of *barbeque wood*. This helps to supply the township with more affordable fuelwood while it covers some of the expenses for tree felling. However, the availed quantities do not satisfy the demand as the primary aim of the operations is urban tree management and not fuelwood production (*Int*. Slabbert).

In sum, marketing opportunities for Prosopis firewood do exist in the vicinity of ARTP. Notwithstanding this, seizing these opportunities in a feasible and sustainable way will require remarkable effort. Organizational implications are discussed in *3.4.4*. *Table 6* provides an overview of the above mentioned marketing opportunities for Prosopis wood.

Table 6: Marketing opportunities for Prosopis wood around ARTP

Potential buyer	Conditions
Barbeque wood	
Namibia Wildlife Resorts	Buying at 2250 N$/t (delivered; 8kg bags) Selling at 5600 N$/t (8kg bags) Amount: unknown Note: currently not using Prosopis wood
Gondwana Collection Namibia	Buying at 800 N$/t (picking up; 20t bulk truckload) Amount: up to 100t a year
Bulk dealers (Engelbrecht)	Buying at 600-700 N$/t (picking up; 30t truckload in 15kg bags) Amount: up to 2 truckloads a month
Local retail markets	Selling at 2150 - 2500 N$/t (20 - 40 kg bags) Buying price unknown Note: currently not using Prosopis wood
Fuelwood	
Tutungeni informal settlement	Buying at 1250 N$/t (delivered; 8kg bundles) Amount: unknown but presumably high

3.3.2. Wood Chips

Wood chips primary use in Namibia is as source of thermal energy. Chipping the wood bears the main advantage that almost every woody part of the plant is used. Nevertheless, chipping wood is energy intensive and the price for producing wood chips depends heavily on the scale of the produced volume. The current demand in Namibia is mainly for commercial scale cement production and is estimated to be bigger than 80.000 t per annum. The operations are mainly based in the central north and harvest encroacher bush on commercial or communal farms making use of highly mechanised solutions like large wood chippers. Due to the harsh conditions of the Namibian environment, technical challenges persist and the demand of the market cannot be satisfied. Investment costs are high and relative employment opportunities low. Moreover, feasible transport distances for wood chips are short due to the low weight (low energy content compared to competing fossil fuels like coal) of the product (Decosa 2015: 10f, 13). In relation to the project, large scale wood chips production for thermal use was not considered feasible. This is mainly for the fact that a constant supply for any potential buyer, e.g. the mining operations in the area, could probably not be achieved due to the varying densities of Prosopis in ARTP (see *3.5*) which would result in an unstable harvesting output. Additionally, the involved investment needs as fixed costs would render the project unfeasible due to the limited total amount of Prosopis biomass available in ARTP.

Wood chips can also be used to ameliorate soils in irrigation schemes (Strohbach et al: 84). There are several grape plantations at Aussenkehr just next to ARTP. An interview was held with Norbert Liebich who is running one of the plantations, a wood chipper operation in the central north and a logistics company. The plantations demand wood chips as a substitute for the currently used straw which is largely imported from South Africa at N$ 500 per cubic metre. The corresponding price for wood chips is roughly N$ 2.000 per tonne approximated with a density of 0.25t/m^3 (De Wet 2015: 8). However, prices of straw are likely to adapt if competition from woodchips occurs. In a potential scenario of operation, a large chipper is moved from the central north to ARTP occasionally. To render such an effort feasible, a minimum amount of 300 tonnes of Prosopis biomass needs to be readily stockpiled for processing when the chipper arrives. Harvesting could be done in a labour-intensive approach. The chipper operation would then pay roughly N$ 250 per tonne of raw Prosopis biomass to the harvesters (*Int*. Liebich, Lindeque). The realized price per tonne of harvested biomass is very low compared to other solutions and the organizational effort is remarkable. Also, the total quantities of Prosopis biomass available in ARTP are probably too low to regularly satisfy the demand of a large scale chipping operation. In sum, operations of that kind are not considered feasible in the context of the project. However, it could potentially be a viable option on Aussenkehr farm itself where the Prosopis density is presumed to be higher than in ARTP (*Int*. Naude).

Another potential scenario worth investigating could be producing wood chips for the grape plantations in a smaller scale. Therefore, a combination of labour intensive harvesting and chipping with a small scale hand-fed chipper appears to be attractive. Again, almost every wooden part of the plants can be used increasing the amount of useable biomass. Investment needs are far lower than for a large scale chipper but would already exceed the initial project budget (see *0*; cf. De Wet 2015: 16f). As main disadvantage, the need for technical knowledge, i.e. for operating and maintaining the chipper increases considerably compared to e.g. solely producing firewood. For this reason and for the budget limitation, the approach is not considered feasible in an early piloting project phase and not investigated in detail. It could however be a viable option for the future.

The same holds for the production of compressed briquettes of wood chips. A value chain for a product called *bushbloks* is already developed in Namibia (e.g. by the Cheetah Conservation Fund). Through compression, transport costs could be reduced significantly. However, technical difficulties persist and marketing opportunities are not sufficiently clarified. Hence, the required additional investment for the project is not justifiable at the time of writing (cf. Decosa 2015: 6f).

3.3.3. Charcoal

The volume of the Namibian charcoal market is 100.000 tonnes per annum (De Wet 2015: 3). This output requires an input of 400.000 to 600.000 tonnes of wood which is slightly less than the amount traded in the Namibian firewood market. About 99% of the produced charcoal is exported which makes Namibia the 6th largest charcoal exporter worldwide. Due to immense demand from overseas and exhaust of many natural savannahs in other export countries, the market is estimated to quadruple until 2025 (Decosa 2015: 9). The Namibian charcoal producing sector is highly formalized in comparison to the firewood sector. About 240 producers are employing 6000 people and in many cases supply the few factories doing grading and retail packaging for the export markets (Decosa 2015: 8f).

The hotspot of charcoal production is Namibia's central north. Here, different woody species are harvested, including encroacher bush. A few producers have specialized in making charcoal from Prosopis. These are located in the heavily infested Nossob and Auob areas in eastern Namibia. Usually, they enter into agreements with landowners to harvest Prosopis and to keep the biomass as reward. Prosopis is then felled in a manual or semi-mechanized approach and left for drying. Subsequently, it is processed mainly in metal kilns, sifted and packed. The investment needs are relatively low (Decosa 2015: 9). With regard to dimensions, only such wood with diameters bigger than 50 mm is processed (*Int*. Haelbich). Approximately 4 to 6 tons of wood yield one tonne of charcoal (*Int*. Potgieter). Current charcoal prices are N$ 1.500 per ton for bulk charcoal to N$ 2.500 per tonne for sifted and packed charcoal (*Int*. Haelbich, Lindeque). This is in between lower end firewood bulk prices of N$ 800 per ton and higher end firewood retail prices of N$ 3.000 (cf. Decosa 2015: 4; *Int*. Engelbrecht, Cock). Having in mind the high input of wood for charcoal production, the added value resulting from processing firewood to charcoal might not always justify the additional investment. The specific local situation, i.e. mainly the marketing opportunities for firewood - charcoal is anyways mostly exported to export markets - should therefore be considered carefully. In the case of ARTP where a firewood bulk price of N$ 700 per tonne appears to be realizable, a charcoal bulk price of N$ 1.500 per ton, requiring an input of 4 to 6 tons of firewood, appears not to be very attractive (cf. Strohbach et al: 84). Additionally, charcoal is always be processed on the harvesting site for reasons of logistics and feasibility (*Int*. Haelbich, Lindeque). This would require setting up charcoal kilns just behind the stretch of riparian vegetation in ARTP which is not considered desirable by MET park management (*Int*. Fryer). The above mentioned reasons, paired with the higher investment needs and the additional skills required renders charcoal production unattractive in the context of the project. It is therefore not investigated in greater detail.

3.3.4. Animal Feed

The Namibian market of bush based animal feed is estimated at 3000 tons per annum. It is highly fluctuating depending on the current drought situation and the informal character of the business transaction (Decosa 2015: 15).

For animal feed, bush is usually harvested in a semi-mechanised way. It is then chipped or milled as fine as possible and mixed with other ingredients like binding agents and mineral supplements. In some cases, the mixture is pelletized (DAS 2016: 1). With regard to Prosopis, it is mainly the nutritious pods that are of value as animal feed. They are one of the main reasons why the plant was originally imported to southern Africa and are still appreciated among livestock farmers especially in times of drought. A tree can produce up to 140kg pods per year which fall to the ground when they are ripe (Smit 2002: 226). Once on the ground, the pods can easily be collected. Pods analysed in South Africa contained about 50% carbohydrates and 15% proteins (Pasiecznik 2001: 86). They can either be fed in one piece or milled and mixed with other livestock feed. Also leaves and fine twigs of Prosopis can be added to the mixture. In order to control the further spread of Prosopis, it is essential to thoroughly mill the pods. By doing this, the seeds must be crushed which can usually only be achieved with roller mills. The often used hammer mills do usually not crush the seeds although many think so. This mistake probably supported the invasion of Prosopis in Namibia (*Int*. Gessert; Smit 2002: 224). In a survey conducted in the Auob and Nossob regions an average price of N$ 320 per ton of Prosopis pods based on prices for bags of 50 kg could be identified (Auala et al 2014: 102). The study also found that pods are also consumed by informal residents in the area (Auala et al 2014: 101). Other than that, trendy superfoods and sophisticated products like coffee substitute can be produced from the pods (*Int.* Gessert; Pasiecznik 2001: 90).

Besides the pods, finer twigs of Prosopis are also suitable as animal feed. In the course of the study, Mr Steyn, a farmer based south of Keetmanshoop (Aikanes) and about 250 km from ARTP was interviewed. He uses a chipper to chop Prosopis twigs and branches that do not have hard core wood yet as well as the leaves. Afterwards, he mills the chips with a hammer mill, ads crushed Prosopis pods, pods from other species, crushed maize and molasses as binding agent. Because of Prosopis' drought-resistance and its early sprouting after the dry winter, the mixture supports his animals through the current drought. Mr Steyn only produces feed for own use (*Int*. Steyn).

While such a solution is suitable on a small scale, the largest Namibian animal feed supplier *feedmaster* does not use Prosopis for its products. On the one hand, any product of Prosopis is difficult to obtain in a standardized quality for its irregular growth. On the other hand, many customers would refuse to buy a product that could potentially be contaminated with Prosopis and further spread the invader (*Int*. Du Plessis).

The two examples illustrate the difficult marketing situation for Prosopis as animal feed in the context of the project. It seems irresponsible to directly market Prosopis pods from the project without being certain that the seeds are properly crushed by a suitable mill. Anything else could further increase the spread of the invader. However, the types of mills and chippers that are currently used in Namibia tp process animal feed are too big an investment in the primary project phase. The existence of smaller scale and more feasible alternatives should be investigated. The alternative of selling unprocessed twigs and pods to an animal feed producer who has the necessary equipment in place is also not considered feasible for the long transport distances in relation to the low weight of the products.

Moreover, the local market is limited. There is not much commercial livestock farming in the vicinity of ARTP and hence not many potential buyers. For instance, the strip north of Rosh Pinah up to Aus received the last considerable rain in January 2011. This caused most farmers to give up their farming activities in the meantime (*Int*. Gessert). The same generally holds for commercial farms between Aussenkehr and Keetmanshoop (*Int.* Cock). Aussenkehr farm itself uses their own Prosopis pods without processing them and would therefore most likely not be willing to buy processed and certainly more expensive animal feed from the project.

In sum, the production of animal feed from Prosopis is generally possible but comes with a number of investments and difficulties in the setting of the project. It is therefore recommended to not consider it an option in the beginning of the project.

3.3.5. Timber

The market for timber in Namibia is relatively small with at least 4000 tons traded per annum. Timber is mainly used as fencing poles and building material (De Wet 2015: 3). Fencing poles are used throughout the country on commercial as well as communal farms. The demand is high which makes Namibia a net importer of poles. However, making fencing poles from bush is challenging for the crooked growth forms. On the other hand, no particular skills and investment are required (Decosa 2015: 16f). In the study area, most of the Prosopis indeed shows growth forms not suitable as fencing poles. Nonetheless, fencing poles could be made as a by-product of firewood production, i.e. whenever a suitable stem or branch is identified while making firewood, it could be kept as fencing pole. For the scarcity of suitable growth forms, the production and marketing of fencing posts in and around ARTP was not investigated in detail.

As building material, Prosopis is in Namibia is essentially used as outdoor decking. Its dark core wood has a high density of 920 kg per m^3 and extremely low shrinkage values of around 5%. Due to the crooked growth form, planks as long as 3m are hardly available (Smit 2002: 227). The Windhoek based *Prosopis Timber and Decking* is currently the only company in Namibia focussing on Prosopis timber. With semi-mechanised felling, a truck-mounted winch and a small scale sawmill, it mainly produces decking from Prosopis. The addition of value is remarkable with a cubic meter of Prosopis decking selling at N$ 13.500. The wood is increasingly demanded for its robustness and its environmentally friendly image (*Int*. Brassine). The owner of the company identified the Prosopis trees found in ARTP as not suitable for timber production based on a number of pictures taken in the study area.

A small scale opportunity arising from harvesting Prosopis in ARTP could be arts and crafting. Prosopis is particularly suitable for wood carving. Products could be sold at tourist destinations which is practiced throughout Namibia (Decosa 2015: 30). This could provide an additional income for community members not directly involved in the harvesting of Prosopis (*Int*. Leineweber). Moreover, it would release the high pressure on the native timber species which are unsustainably used for carvings.

3.3.6. Recommendation: Firewood

In sum, it is recommended to focus on marketing firewood in its two distinctions *fuelwood* and *barbeque wood*. Almost any other product requires capital investment that exceeds the project's preliminary budget or comes with other negative implications. Moreover, firewood is the easiest-to-produce Prosopis product and thus a good option to start with. The analysis has shown that a market for firewood exists. However, seizing the market's opportunity will not be an easy task as other projects have proven.

3.4. Organizational Concept

3.4.1. Organizational Examples

The proper management of de-bushing activities is their crucial point as emphasized in numerous expert interviews conducted for this study. Only proper management allows to meet the main challenges of sufficient productivity and sufficient quality of the delivered work which includes keeping environmental risks at an acceptable level (e.g. *Int*. Laufs, Strohbach, De Beer; Decosa 2016: 45). The central organizational question in de-bushing is about the degree of outsourcing. The one extreme, namely no outsourcing, is to employ managers and workers for Prosopis control directly at MET. In the other extreme, i.e. maximum outsourcing, every single task of Prosopis control from site assessment to planning and implementation is subcontracted. The desirable solution lies between these extrema: all governmental institutions so far involved in de-bushing apply an approach in which strict supervision by the respective institution is combined with creating a business opportunity for Small and Medium Enterprises (SMEs) (cf. Decosa 2016: 49). This results in a relatively high quality of work due to strict supervision and relatively high productivity due to the business element. In the following, some de-bushing and Prosopis control projects that already exist are briefly described. They are operated by the Namibian Ministry of Agriculture, Water and Forestry (MAWF), the Working for Water-programme (WfW) attached to the Department of Environmental Affairs (DEA) of South Africa, a private sector SME, and a donor-supported community in southern Namibia.

Ministry of Agriculture, Water and Forestry

The MAWF is allocated an annual budget to de-bush government farms. In 2016, a budget N$ 20 million allowed to clear 6.200ha of bush-encroached rangeland. MAWF subcontracts SMEs for units of maximum 50 ha per contract. The contracts are prepared by MAWF after site assessment. In manual or semi-mechanized approaches, teams of usually 10 workers take 3-5 months to clear one unit. MAWF pays N$ 2.000 to 4.000 for the clearing of one hectare depending on vegetation type and density. The harvested wood is not marketed due to the organizational effort: as government property the wood had to be auctioned. Contracts for de-bushing are tendered in newspapers and allocated according to certain set of standards. Subsequently, an initial site briefing is held. After 50% of the work has been delivered, an inspections follows and a first payment is made. The same follows when the task is completed. MAWF is aware of tensions between contractors and workers in some cases due to poor working conditions and remuneration (*Int*. Mwiikinghi). Besides MAWF, Roads Authority and NamPower are de-bushing around their infrastructure projects with comparable approaches (Decosa 2016: 51). None of the three agencies is focussing on Prosopis control.

Working for Water

WfW in ARTP is also allocated an annual budget from the South African government to achieve its purpose which is alien plant eradication through community empowerment as a means of poverty relief. For managing Prosopis control in the area of ARTP, WfW currently employs in full-time one project manager, one admin assistance and one field assistance. The park management staff of ARTP is not primarily involved in Prosopis control. This underlines that considerable additional capacities are created only for Prosopis control. The personnel conducts site assessments to estimate Prosopis density and other conditions like accessibility. Units of varying sizes are subsequently tendered and subcontracted to local SMEs for Prosopis control. After initial clearing, a final inspection is conducted. The applied clearing method is described in *3.2.3*. None of the Prosopis products derived from the removal are marketed. Currently, WfW in ARTP subcontracts 8 SMEs. In total, 104 people are working on a stretch of roughly 120km along the Orange River. Workers and contractors are recruited locally and identified via an unemployment list from the local town councils. Before contractors and workers are deployed, they receive thorough training including chainsaw operation and maintenance, herbicide application, first aid training, workplace risk assessment, peer education, personal finance, entrepreneurship, computer skills, block planning, and Prosopis density estimation. WfW as well as the SANParks management for ARTP expressed their willingness to cooperate with the Namibian park management in issues relating to training. Regarding equipment, tools for Prosopis clearing, camping gear and transport allowances are provided by WfW. In sum, the approach is resource intensive but yields good results in ARTP and in the nationwide WfW-programme in general (*Int*. De Beer).

Private Sector

An organizational example from the private sector is found at the town of Keetmanshoop, roughly 300 km from ARTP. Here, a SME is removing Prosopis in the area around the town's sewage-treatment facility on behalf of the town council. The SME is allowed to keep the produced firewood as payment. The firewood is in turn sold to the Gondwana Collection Namibia (GCN), a private hospitality business with facilities between Keetmanshoop and ARTP. GCN provides the equipment necessary for the semi-mechanized Prosopis control and picks up the bulk firewood with its own truck. The SME is run by a contractor from Keetmanshoop who currently employs 4 workers from the local community on a piece-rate (*Int*. Witbooi, Cock).

Donor-funded community project at Gibeon

While the above mentioned projects are well established, another recent Prosopis control project failed. The donor-funded project was supported by the United States Agency for International Development (US AID) through the Desert Research Foundation Namibia (DRFN). Its primary aim was to clear Prosopis in the Fish River at Gibeon through community involvement and to produce firewood for income generation. Thirty community members from Gibeon were involved in the project divided in teams of 10 workers (Strohbach and Ntesa 2016: 22). The workers were directly employed by the community. All involved personnel received training on how to technically remove Prosopis and on basic business management skills (Strohbach and Ntesa 2016: 22f). The project failed for the following reasons: The production lines were inefficient and the maintenance of equipment was insufficient. Wages were time-based and not linked to output which dramatically reduced productivity. Challenges in marketing resulted from a lack of transport for produced firewood and the inability to satisfy bulk dealers. Insufficient business management skills persisted because the training given was not adapted to the skill-level of the participants. Finally, corruption and nepotism by the project committee members discouraged workers (Strohbach and Ntesa 2016: 27ff). From an ecological point of view, no herbicide was applied and the Prosopis infestation is now potentially worse than before the project. In sum, the project lacked the above mentioned core elements, i.e. strict control by an overseeing authority paired with creating a business opportunity.

3.4.2. Recommendation: SME-approach

As described in the introduction to this paragraph, the organizational concept of a project in Prosopis control is essential and can determine its failure or success. This is also illustrated by the above examples. Experience has shown that the involvement of SMEs as contractors yielded better results than directly employing labourers at the respective institution. Thereby, responsibility is transferred to the contractors by creating a business opportunity which vitally increases productivity. Moreover, new SMEs are created and gain theoretical and practical skills which makes them a viable asset for the local economy and future de-bushing projects (cf. Decosa 2016: 80). The SME-approach was strongly advocated by several of the interviewed experts (*Int*. DeBeer, Laufs, Gschwender, Leineweber). It is therefore recommended as the potentially most suitable concept for Prosopis clearing in ARTP.

In brief, the organizational contours of SME-involvement are: MET park management assesses sites to be cleared in ARTP and tenders these units to SMEs. SMEs deploy teams of approximately 10 people working together in their allocated unit. The teams apply a semi-mechanized method of Prosopis removal and camp in ARTP on site until their unit is cleared. MET supports the operation with inputs like e.g. equipment, raw materials or transport as agreed upon before conclusion of the contract. With regard to scale, it is strongly recommended to not contract more than two SMEs in the initial project phase. *Table 7* gives shows the composition of WfW-teams working on Prosopis control as suggested by the Neethling-tool.

Table 7: Composition of WfW's Prosopis control teams.

Initial Clearing	1 x Contractor 1 x Chainsaw Operator 1 x Herbicide Applicator 1 x Safety Worker 1 x 1st Aid Worker 2 x Peer Educators 5 x General Workers	**Follow-up Clearing (Aftercare)**	1 x Contractor 7 x Herbicide Applicator 1 x Safety Worker 1 x 1st Aid Worker 2 x Peer Educators

The following abstracts discuss in more detail the steps required to prepare and operate a Prosopis control project with SME-involvement. A comprehensive guideline on de-bushing operations with SME-involvement was recently developed by Decosa (2016) in the context of the Support to De-Bushing project between the Ministry of Agriculture, Water and Forestry and the GIZ.

3.4.3. Preparation

Capacity development

First of all, capacities both at potential SMEs as well as at MET park management for ARTP must be build. A survey on behalf of ARTP park management and GIZ is currently identifying potential beneficiaries of the project (see *3.1.2*). Any SME-personnel should be recruited from this group of beneficiaries. The survey will also help to clarify whether required capacities and structures do already exist within the pool of beneficiaries.

If no such structures exist, potential contractors and workers must be selected and trained (cf. Decosa 2016: 80f). This is quite challenging as the project in Gibeon has shown. Training must be adequate and comprehensive. It is therefore strongly recommended to seek advice and cooperation with institutions that have already gained experience. Such are WfW as well as Roads Authority and NamPower (cf. Decosa 2016: 59f). WfW possesses in depth knowledge about the specific conditions and requirements in ARTP and of suitable training methods. Moreover, WfW suggested willingness to assist in the development of a Prosopis control project in the Namibian part of ARTP. Other institutions facilitating the required kind of training in Namibia are *SME Compete* and the *Institute for Management and Leadership Training* (IMLT) (Strohbach and Ntesa 2016: 33). The latter two were involved in the Gibeon project.

Table 8 provides an overview of skills that workers, their supervisors, and contractors should acquire. MET park management personnel will have to identify, assess and characterize the sites for tendering to SMEs. It will also conduct inspections. It therefore needs to command a number of skills that the SMEs must also acquire. These skills are underlined in the table. MET park management personnel should participate in training if it does not command the required skills yet.

Table 8: Required skills for Prosopis control by SMEs (cf. Decosa 2016: 59; Int. De Beer)

Workers	**Supervisors**	**Contractors**
de-bushing techniques	*all skills of workers*	*all skills of workers and supervisors*
aftercare techniques	environmental protection	forestry / de-bushing / labour laws and regulations
use of equipment for semi-mechanised de-bushing	know-how transfer to workers	basic business principles
maintenance of equipment	motivation of workers	financial management
requirements of biomass-use and processing	monitoring and control	personnel management
environmental rules of de-bushing and camping		contractual management including tendering
species identification		Prosopis density estimation
first aid training		Prosopis biomass yield estimation
workplace risk assessment		
rights and responsibilities		

Contract development

In order to simplify the tendering process, standardized contracts are required. MAWF and WfW have such contracts for their de-bushing projects (*Int*. Mwiikinghi, De Beer). Consultation of these institutions is therefore recommended. A general template for government supported de-bushing projects is currently developed by MAWF and the GIZ Support to De-Bushing project (*Int*. Laufs). It can potentially be used by MET but certainly needs to be adapted. Issues requiring special attention are the legal status of workers and adequate remuneration. This is because the transferral of responsibility to contractors has been observed to cause conflicts between workers and contractors (*Int*. Mwiikinghi). For instance, contractors keep workers in precarious employment relationships and vice versa workers are unreliable (Decosa 2016: 56f). As a result, the Namibian charcoal industry is working on a collective agreement guaranteeing minimum standards (Decosa 2016: 57). Once finished, the agreement could serve as viable guideline for Prosopis control.

Acquisition of Equipment

The project must provide equipment for Prosopis control to some extent in order to lower the investment hurdle for potential SMEs. On the other hand, such provisions also pose a considerable challenge as they insidiously undermine the business character of the project and hence its productivity. For instance, if a chainsaw is provided by the project and not owned by the contractor, he will most likely reduce the effort to maintain the machine.

As example, WfW provides its subcontracted SMEs with some of the inputs required for Prosopis removal. The degree differs according to how financially strong the respective SME is. Some of the provisions are subtracted from the payments. The provided equipment comprises tools, protective gear and camping equipment. The provision of protective equipment is of special importance as many contractors and workers involved in de-bushing in Namibia refuse to spend money on this (Decosa 2016: 63f). Also herbicide is always provided by WfW to ensure sufficient application (*Int.* De Beer).

For the project, the initial investment in equipment for Prosopis removal was described as the primary purpose of the GIZ support to the project and is welcomed by MET park management (*Int*. Leineweber, Fryer). A list of equipment is provided in the financial assessment (*0*).

Forestry permit

Bush harvesting projects are strictly regulated in Namibia. The two central legal requirements are forestry permits as stipulated by the Forest Act (2001) and its Regulations (2015) and environmental clearance certificates as per the Environmental Management Act (2007) and its regulations (2012) (MAWF and MET 2016: 8). Any commercial bush harvesting project exceeding 15 ha per annum must obtain a harvesting permit, a transport permit, and a marketing permit from the Department of Forestry of MAWF. The lengthy process of obtaining an environmental clearance certificate from MET has been simplified for de-bushing operations. It is not necessary for projects up to 150 ha per annum. Projects of 150 - 5.000 ha per annum can obtain environmental clearance based on a simplified generic environmental management plan (MAWF and MET 2016: 10f). In sum, the mentioned requirements could mean considerable procedural effort for the project. However, MAWF hinted at the possibility to waive the conditions for a Prosopis removal project operated by MET. This would require MET to consult the Director of Forestry at MAWF (*Int.* Louw).

Another legal issue that arose in the context of the study is the general prohibition to remove bushes from riparian zones in order to avoid erosion as laid down in section 22 of the Forestry Act (2001) (cf. Strohbach et al. 2015a: 79). This prohibition was mistaken by many interviewed experts to also apply to the removal of Prosopis. However, Prosopis is in fact exempted from the regulation and may be removed in riparian areas (*Int*. Louw; MAWF and MET 2016: 15).

3.4.4. Operation

The tasks in the actual operation of the project are split up between MET and the subcontracted SME. *Figure 4* gives an overview about the process. The left column shows responsibilities of MET, the right column shows responsibilities of subcontracted SMEs.

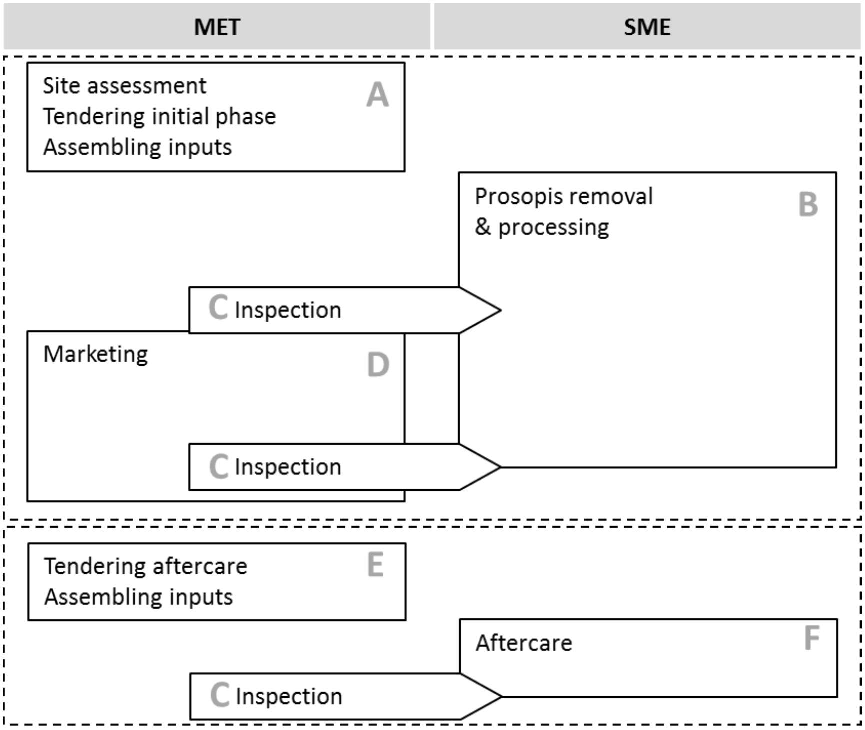


Figure 4: Flow chart of the operational phase of Prosopis control

A. Site assessment, tendering initial phase, assembling inputs

Site assessment includes the demarcation (e.g. with GPS) of the site, the estimation of Prosopis density on site and the assessment of general conditions of the site like environmental vulnerability and accessibility. In order to prepare and value a contract, the collected data must be evaluated and required inputs like labour, raw materials etc. must be estimated. While tendering is in process, the inputs that are provided by MET must be ordered and / or assembled for them to be readily available once the work on site starts (cf. Decosa 2016: 78f).

B. Clearing & processing

The planning of the actual Prosopis clearing operation is done by the contractor. This includes determining the required inputs, time planning and signing of workers. In cooperation with MET, the availability of inputs as well as transport if required have to be arranged (cf. Decosa 2016: 78f).

The camp should be placed as far away from the sensitive riparian vegetation as possible but strategically so as to reduce walking distances to the clearing sites. MET and the SME must agree which walking distances are reasonable and when the camp has to be shifted. Other important issues to clarify in advance are mobile toilet facilities, waste collection, and the provision of basic needs like water and firewood. The working times are to be agreed upon within the team (cf. Decosa 2016: 89).

Once the camp is set up, the Prosopis removal can begin. The steps of de-bushing are (1) debranching, (2) felling, (3) immediate application of herbicide, (4) crosscutting, (5) moving the wood from the riparian zone, (6) processing and packing (cf. Decosa 2016: 77f). The freshly cut wood must at least be given a drying time of two months. It will lose up to 20% of its initial weight while drying (Strohbach et al.: 78). Whenever possible, Prosopis pods should be raked and burned in insensitive spots.

C. Inspection

Strict supervision by MET is very important. It is recommended to conduct more frequent inspections in the early phase of the project and with new SMEs. Once a certain standard is established, the inspections can be reduced to one inspection after 50% of the contract is fulfilled and a final inspection (*Int*. Mwiikinghi). Special attention should be given to correct species identification, complete removal of Prosopis, and correct application of herbicide (*Int.* De Beer). The inspections can serve as basis for authorising payments to the contractors. It is important that payments are always made on a piece-rate, e.g. per cleared area, and not on a time-rate. All public institutions in Namibia as well as WfW in South Africa pay on a piece-rate which is essential to guarantee productivity (cf. Decosa 2016: 68).

D. Marketing

Marketing is certainly one of the biggest challenges within the project and should not be underestimated. None of the established projects by WfW or MAWF do market products that arise from de-bushing or Prosopis clearing. The recent Gibeon project failed partly due to challenges in marketing. Hence, experience of good practice is very limited.

It is suggested that MET should responsible for marketing although this considerably increases the workload. Leaving the marketing to the contracted SMEs would dramatically increase environmental risk as indigenous trees would most likely also be felled to increase the amount of biomass. Procedural obligations for government agencies like MET publicly selling government property (the wood) could be complicated and need to be clarified in advance (*Int.* Mwiikinghi).

The Gibeon project showed that a central challenge in marketing is reliable transport for the products. In Gibeon, no vehicle was available, the products could not be transported to markets and hence no revenue was generated. For the project, two possibilities of transport exist. Fuelwood could be collected with MET pick-ups on their routine patrols through the park. The patrols connect the two park gates and are regularly extended to the MET office in Rosh Pinah passing the harvesting site. The payload of the pick-ups allows for the transportation of low density fuelwood. At the park gate or preferably at the MET office in town, the fuelwood could be sold to locals by MET staff. This solution is attractive as it makes use of internal costs that exist already, i.e. the patrolling pick-up truck (*Int.* Leineweber). The scenario for barbeque wood is different. Due to its higher density it could significantly increase wear on MET pick-ups and should therefore be transported differently. The potential buyers mentioned in *3.3.1* would provide own transport. To this end, the wood needs to be stored in an easily accessible spot. Such spots could again be the park gates or the MET office at Rosh Pinah. The wood could be collected from the harvesting sites in the park with a rented truck (20t) which is available in Rosh Pinah including driver and fuel. Loading and unloading would be part of the SMEs task towards the end of a contract. The wood could further dry up at the place of storage.

E. Aftercare

Aftercare follows initial clearing in rotations of 6 months. It should at least be conducted for two years and ideally for three years (*Int.* De Beer). Site assessment and tendering by MET will be easier than for initial clearing as most of the required data has already been collected. The actual operation requires less inputs in terms of labour and equipment. Aftercare is mainly carried out with pruning shears to cut off shoots and brushes to apply herbicide. No chainsaw is needed and no considerable output is to be expected.

3.5. Forest Inventory

The forest inventory investigated 14 sample areas. Their distribution is depicted in *Figure 5*: Distribution of sample areas within ARTP. As higher Prosopis densities were observed upstream, i.e. close to Aussenkehr, most of the sample areas are concentrated here. The stretch between sample areas 5 and 12 could not be investigated for accessibility reasons. The same holds for the stretch between sample areas 8 and 7, where there are ongoing mining activities. Sample areas 1 and 2 are outside the park and just in front of the eastern Gamkap park entrance gate. They belong to Aussenkehr farm. They are included in the study as upstream Prosopis removal in a buffer zone of 10km would be desirable.

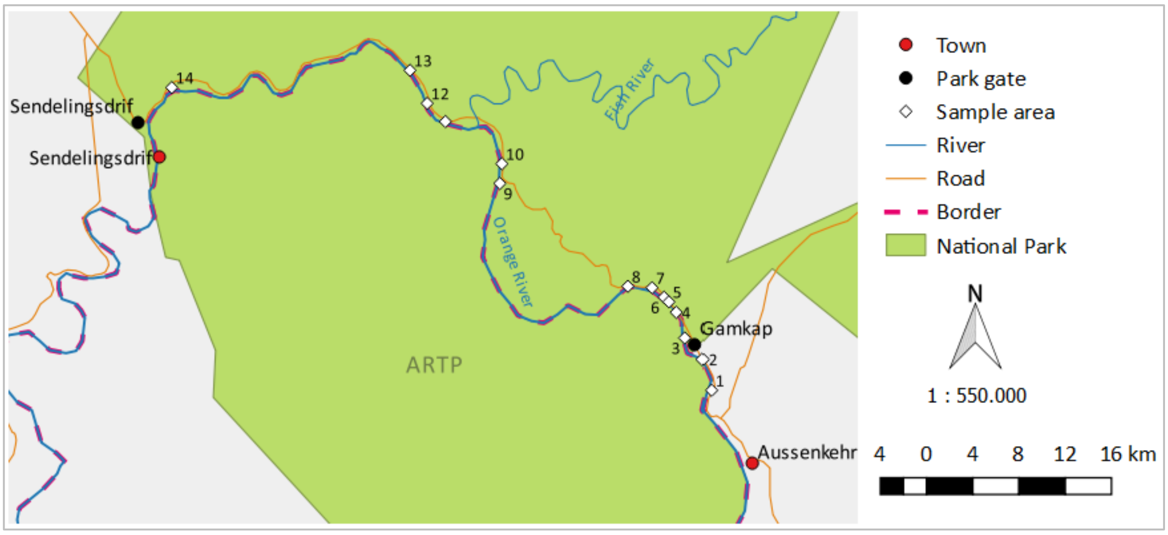
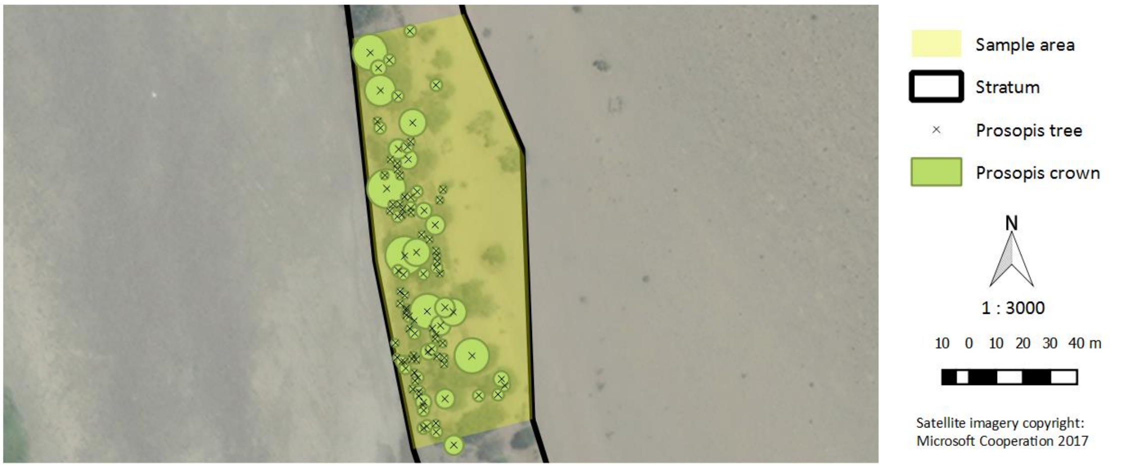


Figure 5: Distribution of sample areas within ARTP

For each sample area, Prosopis density and Prosopis biomass were calculated according to the methods described in *2.4*. The values were also extrapolated to the whole area of the stratum *dense riparian thickets* at the respective location as demarcated in GIS based on satellite imagery. These demarcated subunits of the stratum amount to 17 km alongside the river. This accounts for roughly 20% of the total distance (80km) from sample area 1 to the western park gate close to sample area 7. In the following, 3 sample areas are portrayed. *Annex A* contains the same information about the other sample areas.

Sample area 3 is the first sample downstream from Gamkap gate. It is depicted in *Figure 6*: Sample area 3. The sample area measures 0.8 ha and the subunit of the stratum *dense riparian thickets* stretches to an area of 9.89 ha in this location. The sample area shows a high density of Prosopis with 23.4 % canopy coverage. The distribution of diameter classes shows high numbers of trees with low diameters and only a few bigger trees. With regard to biomass, this results in a high share of fuelwood (m_f) and far less barbeque wood (m_b). Due to the relatively high density and the large area of the subunit of the stratum, the amounts of biomass within the stratum (rightmost column in the table) are noteworthy.

Sample area 3



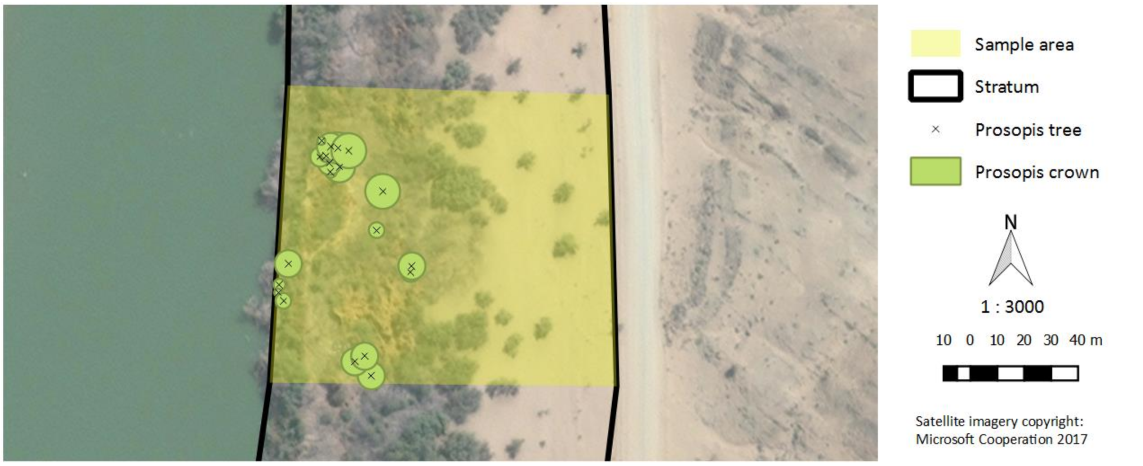
sample area [ha]	0.80	**m_t [t]**	6.71	**m_t [t/ha]**	8.40	**m_t strat [t]**	83.10
stratum area [ha]	9.89	**m_b [t]**	0.70	**m_b [t/ha]**	0.88	**m_b strat [t]**	8.71
density [%]	23.4	**m_f [t]**	5.00	**m_f [t/ha]**	6.26	**m_f strat [t]**	61.93

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	45	32	5	7	0	3	1	3	2	0	0	0	0	0

Figure 6: Sample area 3

Sample area 10 is located further downstream and just north of the abandoned farm Bo Plaats. It shows a lower Prosopis density than sample area 3 and especially smaller Prosopis trees are less frequent here. Consequently, the amount of harvestable biomass is also much lower. The indigenous riparian vegetation seems to be more intact here and slows down the Prosopis invasion in the area. The picture shows considerable indigenous vegetation surrounding Prosopis trees.

Sample area 10



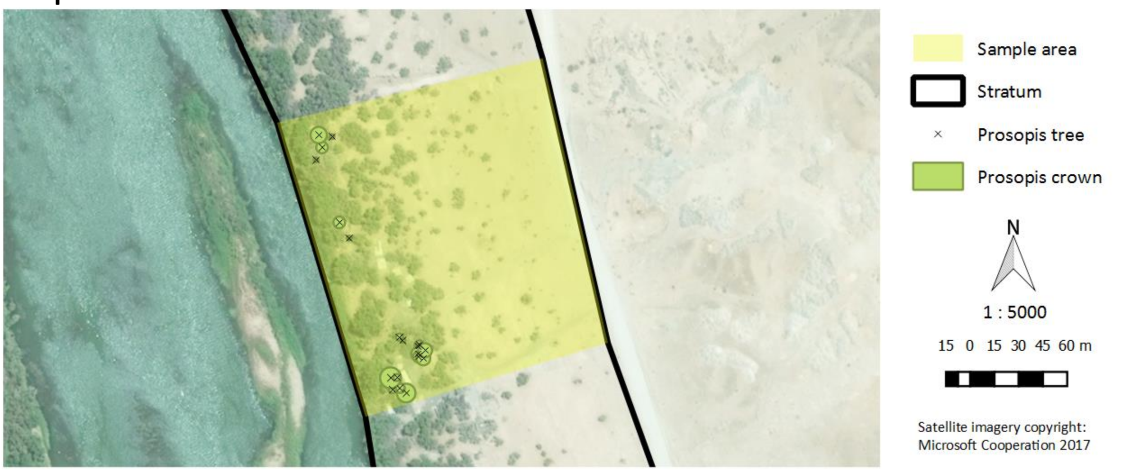
sample area [ha]	1.36	**m_t [t]**	3.78	**m_t [t/ha]**	2.78	**m_t strat [t]**	29.71
stratum area [ha]	10.68	**m_b [t]**	0.33	**m_b [t/ha]**	2.63	**m_b strat [t]**	2.63
density [%]	6.0	**m_f [t]**	2.88	**m_f [t/ha]**	2.12	**m_f strat [t]**	22.62

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	2	3	2	2	1	6	2	2	0	0	0	0	0	0

Figure 7: Sample area 10

Sample area 12 is located even further downstream and after the confluence of Fish and Orange River. The map shows that most of the vegetation in this location is indigenous. Prosopis covers only 2 % of the area. As a result, the amount of harvestable biomass per ha is rather low. Especially the bulky biomass m_b is hardly available with only 70 kg per ha. The subunit of the stratum is exceptionally long in this place.

Sample area 12



sample area [ha]	3.01	**m_t [t]**	2.27	**m_t [t/ha]**	0.76	**m_t strat [t]**	32.05
stratum area [ha]	42.41	**m_b [t]**	0.20	**m_b [t/ha]**	0.07	**m_b strat [t]**	2.82
density [%]	2.0	**m_f [t]**	1.73	**m_f [t/ha]**	0.58	**m_f strat [t]**	24.41

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	5	3	2	3	3	1	1	1	0	0	0	0	0	0

Figure 8: Sample area 12

Table 9 provides an overview of all sample areas. The sample areas are sorted according to their distance downstream from Gamkap gate. The table shows an overall trend of declining Prosopis density the further downstream the sample area is located. Amounts of biomass per ha decline accordingly. In general, the variability between the sample areas is very high. For instance, densities range from no Prosopis in sample area 11 to 23.4 % Prosopis canopy coverage over sample area 3. Also total biomass per area ranges from no biomass in sample area 11 to 9.73 tonnes per hectare in sample area 1. It is noteworthy that biomass does not perfectly correlate with density it is also influenced by the respective stem diameter distribution. The high variety in obtained values is also reflected in the standard deviations (bottom line) which are in the same magnitude as their respective means values.

Table 9: Overview results forest inventory

Sample area no	**Area**	**Stratum area**	**Density**	**m_t**			**m_b**			**m_f**		
	[ha]	[ha]	[%]	[t]	[t/ha]	[t] in stratum	[t]	[t/ha]	[t] in stratum	[t]	[t/ha]	[t] in stratum
1	1,30	17,35	19,6	12,60	9,73	168,76	1,38	1,07	18,52	9,32	7,20	124,93
2	0,67	7,16	22,8	5,71	8,49	60,77	0,59	0,88	6,32	4,26	6,33	45,33
3	0,80	9,89	23,4	6,71	8,40	83,10	0,70	0,88	8,71	5,00	6,26	61,93
4	0,59	2,78	8,2	1,59	2,67	7,43	0,16	0,26	0,73	1,19	2,01	5,59
5	1,92	5,13	3,9	2,21	1,15	5,91	0,20	0,10	0,54	1,68	0,87	4,49
6	0,68	6,81	18,6	5,30	7,77	52,94	1,08	1,58	10,76	3,43	5,03	34,24
7	1,35	4,25	3,5	1,22	0,91	3,87	0,14	0,10	0,44	0,90	0,67	2,84
8	0,91	8,47	6,7	2,07	2,26	19,16	0,24	0,27	2,26	1,51	1,66	14,02
9	1,67	51,97	2,9	1,51	0,90	47,01	0,16	0,09	4,84	1,13	0,68	35,12
10	1,36	10,68	6,0	3,78	2,78	29,71	0,33	0,25	2,63	2,88	2,12	22,62
11	5,20	29,12	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
12	3,01	42,41	2,0	2,27	0,76	32,05	0,20	0,07	2,82	1,73	0,58	24,41
13	4,98	81,36	0,3	0,43	0,09	6,97	0,04	0,01	0,60	0,33	0,07	5,32
14	5,69	25,12	0,9	1,87	0,33	8,27	0,42	0,07	1,87	1,17	0,21	5,16
Mean	**2,15**	**21,61**	**8,49**	-	**3,30**	-	-	**0,40**	-	-	**2,41**	-
SD	**1,82**	**22,86**	**8,67**	-	**3,60**	-	-	**0,49**	-	-	**2,61**	-

3.6. Financial Assessment

MET does not have an independent budget for the project. It will contribute through diverting capacities of park management in ARTP towards the project. This comprises manpower and material (*Int*. Fryer). The only independent budget that exists for the project is contributed by the GIZ-TFCA project. As things stand, the sum of N$ 300.000 is available as *kick-off funding*. It was suggested to use these funds for preparatory expenses or initial investments and not for running costs in the operation of the project (*Int*. Leineweber).

3.6.1. Preparation

The principal steps of the preparatory project phase causing expenses are capacity development and acquisition of equipment. While the nature and content of capacity development is described in *3.4.3*, its financial implications were not analysed in this study. This is because capacity development must be well adjusted to the target group. However, the actual target group, i.e. the beneficiaries of the project, is yet to be established by an ongoing study on behalf of MET and the GIZ-TFCA project. Moreover, the market for capacity development services in Namibia is limited. For instance, no commercial chainsaw training opportunity exists. Therefore, and for the small initial scale of the project, it is strongly recommended to enter into cooperation with institutions mentioned in *3.4.1* to find individual training solutions once the profile of the beneficiaries - and the needs of MET - are clear. As a very rough approximation, consulting costs for one week of capacity development are N$ 50.000 (USD 3.800) (Decosa 2016: Annex 8).

The initial investment into equipment for Prosopis removal is the primary aim of the GIZ support to the project (see *3.4.3*). Such equipment comprises tools, protective gear and camping equipment. *Table 10* gives an estimation of required basic equipment for one Prosopis removal team composed as suggested in the Neethling-tool. The values were obtained from summing up single items in each category. A full list of these items is provided in *Annex B*.

Table 10: Initial expenses for equipment of one Prosopis control team

Item	**Price**	
	NAD	USD
Equipment		
Chainsaw (2x)	24.000	1.828
Tools other	18.000	1.371
Protective equipment	16.000	1.219
Camping gear	65.000	4.953
Subtotal	*123.000*	*9.373*

Although the standard team includes only one chainsaw operator, it is recommended to have a replacement chainsaw in place if one breaks down and needs maintenance or repairs. Experience in other projects has shown that if such a replacement is not available, breakdowns can considerably impact on project progress (cf. Strohbach and Ntesa: 28). Given the budget available for kick-off funding, the expenditure of equipment for one Prosopis removal team is remarkable. Therefore, reducing team sizes could be a viable possibility to reduce capital investment needs while it would certainly slow down the Prosopis removal.

3.6.2. Operation

Physical flow

Table 11 gives an overview over the physical flow of inputs and outputs, i.e. items without valuation, during the operational phase of the project. The table is based on the assumption that the above mentioned equipment is available. It lists inputs and outputs subdivided in several categories. Inputs that should be provided by MET and covered by MET internal expenses are mentioned in italic. Crosses indicate actual additional inputs required for the operation of the project as well as outputs of the project. The covered time period is 24 months which resembles the minimum timeframe for aftercare.

Table 11: Physical flow table operational project phase

Item	**Unit**	**Months**				
		0	6	12	18	24
INPUTS						
Preparatory fieldwork						
Site assessment		*by MET in advance*				
Tendering		*by MET in advance*				
Assembling inputs		*by MET in advance*				
Prosopis removal						
Transport		*provided by MET*				
Supervision		*by MET*				
Labour	pd[1]	x				
Herbicide	kg	x				
Fuel (Chainsaw)	l	x				
Chain Oil	l	x				
Chain	pcs	x				
Processing						
Labour	pd	x				
Bags & Wire	pcs	x				
Transport barbeque wood (m_b)						
Labour	pd	x				
Truck Rental	pcs	x				
Marketing						
Marketing fuelwood (m_f)		*by MET*				
Marketing barbeque wood (mb)			*by MET*			
Aftercare						
Site assessment			*by MET in advance*			
Tendering			*by MET in advance*			
Assembling inputs			*by MET in advance*			
Transport			*provided by MET*			
Labour	pd		x	x	x	x
Herbicide	kg		x	x	x	x
OUTPUTS						
Prosopis products						
Barbeque wood (mb)			x			
Fuelwood (mf)		x				

[1]: Person day (8 hours)

The forest inventory (*3.5*) showed a wide variety in Prosopis densities in the different sample areas. It also revealed the trend of declining densities the further downstream the sample is located. In order to account for this trend, physical flows have been computed for three different density scenarios: the *average density* scenario is based on mean values of all sample areas, the *high density* scenario is based on mean values of the three sample areas with highest densities, and the *low density* scenario is based on mean values of the three sample areas with lowest densities (sample area 11 where no Prosopis was recorded). *Table 12*, *Table 13,* and *Table 14* show the physical flows of the three scenarios. They do so for 1 ha (left) and 30 ha (right). The latter area resembles the size of potential contracts.

Table 12: Physical flow table AVERAGE density (density = 8.5%; mb/ha = 0.40t; mf/ha = 2.41t)

Item	Unit	Months					Months				
		0	6	12	18	24	0	6	12	18	24
INPUTS		**1 ha**					**30 ha**				
Prosopis removal											
Labour	pd	2,84					85,26				
Herbicide	kg	1,03					30,93				
Fuel	l	20,46					613,87				
Chain Oil	l	0,85					25,58				
Chain	pcs	0,09					2,81				
Processing											
Labour	pd	1,14					34,10				
Bags & Wire	pcs	140,50					4215,00				
Transport barbeque wood (m_b)											
Labour	pd	0,10					3,00				
Truck Rental	pcs	0,02					0,60				
Aftercare											
Labour	pd		0,49	0,49	0,49	0,49		14,76	14,76	14,76	14,76
Herbicide	kg		0,18	0,18	0,18	0,18		5,35	5,35	5,35	5,35
OUTPUTS											
Barbeque wood (m_b)	t		0,40					12,00			
Fuelwood (m_f)	t	2,41					72,30				

Table 13: Physical flow table HIGH density (density = 21.95%; mb/ha = 0.94t; mf/ha = 6.60t)

Item	Unit	Months					Months				
		0	6	12	18	24	0	6	12	18	24
INPUTS		**1 ha**					**30 ha**				
Prosopis removal											
Labour	pd	5,71					171,27				
Herbicide	kg	2,81					84,33				
Fuel	l	41,10					1233,14				
Chain Oil	l	1,71					51,38				
Chain	pcs	0,25					7,54				
Processing											
Labour	pd	2,28					68,51				
Bags & Wire	pcs	377,00					11310,00				
Transport barbeque wood (m_b)											
Labour	pd	0,24					7,05				
Truck Rental	pcs	0,05					1,41				
Aftercare											
Labour	pd		0,99	0,99	0,99	0,99		29,58	29,58	29,58	29,58
Herbicide	kg		0,49	0,49	0,49	0,49		14,56	14,56	14,56	14,56
OUTPUTS											
Barbeque wood (m_b)	t		0,94					28,20			
Fuelwood (m_f)	t	6,60					198,00				

Table 14: Physical flow table LOW density (density = 1.09%; mb/ha = 0.05t; mf/ha = 0.28t)

Item	Unit	Months					Months				
		0	6	12	18	24	0	6	12	18	24
INPUTS		**1 ha**					**30 ha**				
Prosopis removal											
Labour	pd	0,39					11,76				
Herbicide	kg	0,12					3,63				
Fuel	l	2,82					84,67				
Chain Oil	l	0,12					3,53				
Chain	pcs	0,01					0,33				
Processing											
Labour	pd	0,16					4,70				
Bags & Wire	pcs	16,50					495,00				
Transport barbeque wood (m_b)											
Labour	pd	0,01					0,38				
Truck Rental	pcs	0,00					0,08				
Aftercare											
Labour	pd		0,07	0,07	0,07	0,07		2,04	2,04	2,04	2,04
Herbicide	kg		0,02	0,02	0,02	0,02		0,63	0,63	0,63	0,63
OUTPUTS											
Barbeque wood (m_b)	t		0,05					1,50			
Fuelwood (m_f)	t	0,28					8,40				

Unit values

Monetary unit values are required to link physical flows with cash flows. *Table 15* shows monetary values for the above listed inputs and outputs of the operational project phase. It also gives references for each value.

Table 15: Unit value table operational project phase

Item	Unit	Price	Unit	Price	*Reference*
Inputs					
Labour	NAD/pd	100,00	USD/pd	7,62	*Decosa 2016: 62, 88*
Herbicide	NAD/kg	200,00	USD/kg	15,24	*Int. De Beer; Novon South Africa*
Fuel	NAD/l	15,00	USD/l	1,14	*Int. Cock, Witbooi*
Chain Oil	NAD/l	75,00	USD/l	5,72	*Int. Cock, Witbooi*
Chain	NAD/pc	350,00	USD/pc	26,67	*CYMOT Namibia*
Bags & Wire	NAD/pc	2,40	USD/pc	0,18	*Beisswanger et al. 2015: 109*
Truck Rental	NAD/pc	5800,00	USD/pc	441,96	*Rosh Pinah Bricks and Sand*
Outputs					
Barbeque wood (m_b)	NAD/t	700,00	USD/t	53,34	*see section 3.3.1*
Fuelwood (m_f)	NAD/t	1250,00	USD/t	95,25	*see section 3.3.1*

Cash flow

By combining physical flows and unit values, cash flows for the operational project phase are calculated. *Table 16*, *Table 17*, and *Table 18* display cash flows in USD for each of the three density scenarios. Cash flows are divided in revenues and cost. As above, the data is given for 1 ha and 30 ha. *Annex B* contains cash flow tables with NAD as currency.

Table 16: Cash flow table AVERAGE density

Item	**Unit**	**Months**						**Months**					
		0	6	12	18	24	**0 - 24**	0	6	12	18	24	**0 - 24**
Revenues (receipts)		**1 ha**						**30 ha**					
1. Sale of mb	USD	0,00	21,34	0,00	0,00	0,00	**21,34**	0,00	640,08	0,00	0,00	0,00	**640,08**
2. Sale of mf	USD	128,55	0,00	0,00	0,00	0,00	**128,55**	3856,48	0,00	0,00	0,00	0,00	**3856,48**
Subtotal	USD	*128,55*	*21,34*	*0,00*	*0,00*	*0,00*	**149,89**	*3856,48*	*640,08*	*0,00*	*0,00*	*0,00*	**4496,56**
Cost (expenditures)													
3. Labour	USD	31,08	3,75	3,75	3,75	3,75	**46,08**	932,41	112,47	112,47	112,47	112,47	**1382,30**
4. Herbicide	USD	15,71	2,72	2,72	2,72	2,72	**26,59**	471,37	81,60	81,60	81,60	81,60	**797,79**
5. Fuel	USD	23,39	0,00	0,00	0,00	0,00	**23,39**	701,66	0,00	0,00	0,00	0,00	**701,66**
6. Chain Oil	USD	4,87	0,00	0,00	0,00	0,00	**4,87**	146,18	0,00	0,00	0,00	0,00	**146,18**
7. Chain	USD	2,50	0,00	0,00	0,00	0,00	**2,50**	74,94	0,00	0,00	0,00	0,00	**74,94**
8. Bags & Wire	USD	25,69	0,00	0,00	0,00	0,00	**25,69**	770,84	0,00	0,00	0,00	0,00	**770,84**
9. Truck Rental	USD	8,84	0,00	0,00	0,00	0,00	**8,84**	265,18	0,00	0,00	0,00	0,00	**265,18**
Subtotal	USD	*112,09*	*6,47*	*6,47*	*6,47*	*6,47*	**137,96**	*3362,58*	*194,07*	*194,07*	*194,07*	*194,07*	**4138,88**
Net revenue	USD	***16,46***	***14,87***	***-6,47***	***-6,47***	***-6,47***	**11,92**	***493,90***	***446,01***	***-194,07***	***-194,07***	***-194,07***	**357,69**

Table 17: Cash flow table HIGH density

Item	**Unit**	**Months**						**Months**					
		0	6	12	18	24	**0 - 24**	0	6	12	18	24	**0 - 24**
Revenues (receipts)		**1 ha**						**30 ha**					
1. Sale of mb	USD	0,00	50,14	0,00	0,00	0,00	**50,14**	0,00	1504,19	0,00	0,00	0,00	**1504,19**
2. Sale of mf	USD	352,04	0,00	0,00	0,00	0,00	**352,04**	10561,32	0,00	0,00	0,00	0,00	**10561,32**
Subtotal	USD	*352,04*	*50,14*	*0,00*	*0,00*	*0,00*	**402,18**	*10561,32*	*1504,19*	*0,00*	*0,00*	*0,00*	**12065,51**
Cost (expenditures)													
3. Labour	USD	62,69	7,51	7,51	7,51	7,51	**92,75**	1880,83	225,40	225,40	225,40	225,40	**2782,43**
4. Herbicide	USD	42,84	7,40	7,40	7,40	7,40	**72,43**	1285,19	221,96	221,96	221,96	221,96	**2173,05**
5. Fuel	USD	46,98	0,00	0,00	0,00	0,00	**46,98**	1409,48	0,00	0,00	0,00	0,00	**1409,48**
6. Chain Oil	USD	9,79	0,00	0,00	0,00	0,00	**9,79**	293,64	0,00	0,00	0,00	0,00	**293,64**
7. Chain	USD	6,70	0,00	0,00	0,00	0,00	**6,70**	201,09	0,00	0,00	0,00	0,00	**201,09**
8. Bags & Wire	USD	68,95	0,00	0,00	0,00	0,00	**68,95**	2068,37	0,00	0,00	0,00	0,00	**2068,37**
9. Truck Rental	USD	20,77	0,00	0,00	0,00	0,00	**20,77**	623,16	0,00	0,00	0,00	0,00	**623,16**
Subtotal	USD	*258,73*	*14,91*	*14,91*	*14,91*	*14,91*	**318,37**	*7761,77*	*447,36*	*447,36*	*447,36*	*447,36*	**9551,23**
Net revenue	USD	***93,32***	***35,23***	***-14,91***	***-14,91***	***-14,91***	**83,81**	***2799,55***	***1056,82***	***-447,36***	***-447,36***	***-447,36***	**2514,28**

Table 18: Cash flow table LOW density

Item	**Unit**	**Months**						**Months**					
		0	6	12	18	24	**0 - 24**	0	6	12	18	24	**0 - 24**
Revenues (receipts)		**1 ha**						**30 ha**					
1. Sale of mb	USD	0,00	2,67	0,00	0,00	0,00	**2,67**	0,00	80,01	0,00	0,00	0,00	**80,01**
2. Sale of mf	USD	14,94	0,00	0,00	0,00	0,00	**14,94**	448,06	0,00	0,00	0,00	0,00	**448,06**
Subtotal	USD	*14,94*	*2,67*	*0,00*	*0,00*	*0,00*	**17,60**	*448,06*	*80,01*	*0,00*	*0,00*	*0,00*	**528,07**
Cost (expenditures)													
3. Labour	USD	4,28	0,52	0,52	0,52	0,52	**6,35**	128,31	15,54	15,54	15,54	15,54	**190,49**
4. Herbicide	USD	1,84	0,32	0,32	0,32	0,32	**3,12**	55,32	9,60	9,60	9,60	9,60	**93,71**
5. Fuel	USD	3,23	0,00	0,00	0,00	0,00	**3,23**	96,78	0,00	0,00	0,00	0,00	**96,78**
6. Chain Oil	USD	0,67	0,00	0,00	0,00	0,00	**0,67**	20,16	0,00	0,00	0,00	0,00	**20,16**
7. Chain	USD	0,29	0,00	0,00	0,00	0,00	**0,29**	8,80	0,00	0,00	0,00	0,00	**8,80**
8. Bags & Wire	USD	3,02	0,00	0,00	0,00	0,00	**3,02**	90,53	0,00	0,00	0,00	0,00	**90,53**
9. Truck Rental	USD	1,10	0,00	0,00	0,00	0,00	**1,10**	33,15	0,00	0,00	0,00	0,00	**33,15**
Subtotal	USD	*14,44*	*0,84*	*0,84*	*0,84*	*0,84*	**17,79**	*433,05*	*25,14*	*25,14*	*25,14*	*25,14*	**533,62**
Net revenue	USD	***0,50***	***1,83***	***-0,84***	***-0,84***	***-0,84***	**-0,19**	***15,01***	***54,87***	***-25,14***	***-25,14***	***-25,14***	**-5,55**

The tables show that the operational project phase is profitable in the average density scenario and in the high density scenario. In contrast, it is in slight deficit in the low density scenario. The first year shows positive net revenues because biomass is marketed. Not surprisingly, time periods with aftercare only cause negative net revenues. This is one of the main reasons why aftercare is oftentimes neglected.

4. Discussion

4.1. Stakeholder Analysis

The study showed that stakeholder analysis is of relevance for the project for several reasons. First of all, the study area Orange River as a physical system cuts through social, economic, political and administrative systems (cf. Grimble 1998: 2). This generally complicates management approaches. In social terms for instance, it touches both, the traditional livelihoods of the Nama ethnic group in Richtersveld Park as well as the more or less informal settlements of the migrant workers in Aussenkehr and Rosh Pinah (*Int.* Slabbert). Also, Prosopis as a resource in ARTP is perceived differently from different local stakeholders. MET's primary aim is to eradicate the invasive alien. In contrast, the management of Aussenkehr Farm, which is located just upstream ARTP, considers the trees a valuable source of animal feed (*Int.* Naude). Different property and access rights to areas in ARTP complicate the situation (cf. Grimble 1998: 3). Some of the infested areas in ARTP are located in *Exclusive Prospecting Licenses*, i.e. mining licences. As the mined resource along the Orange River are diamonds, security zones with access restrictions exist around some of the operations (*Int.* Tengee). With regard to tourism, Prosopis control efforts by MET could be contrary to the interest of other stakeholders (cf. Grimble 1998: 3): One of ARTP's primary purposes is to enhance tourism in the region (SADC undated: 2). Prosopis control measures could negatively influence tourist's impression of the park and hence worsen marketing opportunities for the tourism sector in the region. Finally, SA is of special importance whenever marginalized and under-represented members of society are affected by a project (cf. Grimble 1998: 4). Such stakeholders are the primary target group of this project and hence assessing their interests, needs, and capacities would have been a very important aspect of the SA. Yet, this was not undertaken because MET and the GIZ-TFCA project commissioned an independent survey to identify potential beneficiaries of the project. The results of this survey must eventually be matched with this feasibility study and underlying assumptions must be critically reviewed. In sum, the stakeholder analysis lacks this very typical aspect and rather focused on gaining an understanding of the system, i.e. the setting in and around ARTP and the Namibian biomass sector and markets in general.

4.2. Methods of Prosopis Control

The study showed that knowledge about the actual methods of Prosopis control is sufficiently available. Best practices like for instance semi-mechanized Prosopis removal paired with chemical treatment are well established in the South African Working for Water programme and have proven their viability. However, it was observed that such methods differ from knowledge and technology that is currently developed and applied in the Namibian biomass sector. The biomass industry mainly focuses on removing indigenous encroacher bush from commercial farmland. The primary aim here is to restore as much rangeland as possible and to harvest as much biomass as possible in order to make the operations profitable. While ecological considerations are certainly made in this context, biodiversity conservation is not a high priority. This also holds for Prosopis harvesting operations in the often quoted ephemeral river systems in eastern Namibia, namely the Auob and the Nossob Rivers. Here, the dense and widespread stands of Prosopis could almost be mistaken for a short-rotation plantation and the biomass yields are high. Workers here are usually paid on a per-tonnage rate and hence it must be assumed that indigenous trees are harvested as well.

The setting for Prosopis control in a protected area like ARTP is different. In such a context, Prosopis is not only removed to generate revenue but also and foremost to protect the indigenous ecosystem from the aggressive invader. Hence, any measures must strike a careful balance between removing the alien in a cost-effective way and preserving the natural environment. Consequently, the de-bushing industries' most important instrument to increase productivity, namely remuneration on a per-tonnage rate, is disqualified in this setting. Too great would be the danger that Prosopis removal teams equipped with chainsaws mistake an Acacia for a Prosopis tree. The implication of this: strict supervision is absolutely essential. Nothing else can guarantee that a SME which is paid per cleared hectare removes every single Prosopis tree scattered in the dense riparian thickets. Good practice about this is rare as the scenario is somewhere in between the sheer biomass harvesting of the Namibian de-bushing industry and the completely subsidized WfW-programme which only removes Prosopis but does not market its products.

4.3. Marketing Opportunities

The study assessed marketing opportunities for Prosopis products in the vicinity of ARTP. It found that the easiest solution, i.e. producing firewood, is also the most desirable one. Theoretically, the market situation looks quite promising and considerable income can be generated. Nonetheless, reality might tell a different story as observed in the project at Gibeon. The challenge is complex. On the one hand, the suggested organizational concept does not provide strong incentives for successful marketing. SMEs are not paid for the wood they produce and sell but for the area they clear from Prosopis for the above mentioned reasons. It will therefore be the responsibility of the local MET park management staff to organize sales - an activity which is in turn not linked to any monetary incentive. Also, and of special importance in the remote location of ARTP, the pool of potential buyers is limited. Only time and effort will show whether the suggested sales opportunities can be realized. In sum, the management challenge linked to marketing could become one of the project's potential pitfalls.

4.4. Forest Inventory

The forest inventory posed noteworthy methodological challenges. To estimate Prosopis biomass, models based on data by Strohbach et al. (2015a) and Felker (1983) were used. Such allometric equations are usually not readily transferable to populations in other environmental conditions. The model by Strohbach et al. was developed in the ephemeral Fish River which eventually flows into the Orange River. Although not identical, the environmental conditions are at least comparable to those in the study area and also the complex of Prosopis subspecies should be similar. Unfortunately, Strohbach et al. only recorded biomass with a diameter exceeding 50 mm as dependent variable. Consequently, another model had to be used to estimate biomass finer than 50 mm diameter. However, almost all available allometric studies on Prosopis were not deemed appropriate for they either used different independent and dependent variables, for they were derived in very different environmental conditions, or because they examined other subspecies of Prosopis (e.g. Cienciala et al. 2013, Maghembe et al. 1983, Muturi et al. 2012, Whisenant and Burzlaff 1978). Eventually, a model developed by Felker (1983) appeared to be the most suitable one. Developed in the United States, it can be attributed some extent of universal validity as it is based on extensive data (N = 1352) covering 27 accessions and at least 14 subspecies of Prosopis in different moisture regimes (Felker 1983: 187, 192). However, to avoid any uncertainty about the validity of biomass estimations, an allometric model would need to be developed on site in ARTP to do justice to the specific environmental conditions.

With regard to sampling, the immense heterogeneity of Prosopis distribution in ARTP became a challenge. Originally, the approach of stratified sampling was chosen to keep variety within the samples as low as possible. Yet, the results of the inventory show a different picture as Prosopis density varies considerably in the different sample areas. At least, a trend of declining density the further downstream a sample area is located could be noted. The observed heterogeneity makes it difficult to extrapolate from the samples to the whole population as it increases the standard error (cf. Kramer and Akça 2008: 49f).To overcome these difficulties, the number of sample areas would need to be increased. This was not possible due to resource limitations. For the same constraints, only the stratum *dense riparian thickets* was investigated and some areas of ARTP were excluded from analysis for accessibility reasons. Consequently, the samples are not distributed evenly along the course of the Orange River but clumped in areas with higher Prosopis densities. This certainly results in skewed mean values that do not represent the entire population.

In sum, the observations of the forest inventory should be expanded and the obtained results must be validated. If no further studies can be conducted, this should at least be undertaken accompanying an initial project phase.

4.5. Financial Analysis

If only the operational phase is considered, the project appears to be feasible in the short term and if certain conditions are met. As first condition, the GIZ-TFCA project must provide kick-off funding in order to cover initial investment needs for equipment. Second, MET must dedicate significant contributions towards the project. In the assessed concept, MET supports the Prosopis control operation through organizational and material inputs that are diverted from ARTP park management. This resembles the approach of WfW, where three full-time positions manage the alien species removal programme. To keep the additional workload for MET at an acceptable level, it is recommended to start the initial project phase in a fairly small scale. This can be achieved by subcontracting only a small number of SMEs. An additional measure is to reduce the size of the Prosopis removal teams. This would slow down the whole process and moreover reduce the need for initial capital investment, i.e. fixed costs. The financial analysis came to the conclusion that variable costs during the operational phase could in an average scenario be covered by revenues generated from the marketing of the products. Furthermore, it predicts clearly positive net revenues in higher density scenarios and only slightly negative net revenues in low density scenarios. However, this alone does not mean that the project is financially sustainable in the long term. The kick-off funding provides tools and gear that are indispensable for the operation of the project. Over time, this equipment will wear and repairs or replacements will be necessary. Sustainability of the project would only be given if the income generated in the operational phase could cover the depreciation of the equipment. This is most likely not the case. The cash flow table for the average density scenario predicts a net income of about USD 12 per hectare. Very roughly estimated, the riparian thickets in the Namibian part of ARTP cover an area of 800 ha.[2] If the total area was cleared from Prosopis at average density, the total income would account for the initial investment required for one standard Prosopis clearing team as described above. However, as also described above, the obtained average values of Prosopis density are most likely skewed and in reality average density is lower. While financial sustainability is hence hardly given in the average scenario, higher Prosopis density would yield higher incomes and financial sustainability could be achieved. Beginning to remove Prosopis in the upstream high density areas and continuing further downstream with steadily decreasing densities would therefore only be sustainable in the short term. In sum, the cash flow tables look promising. However, they alone do not adequately describe financial sustainability implications of the project. In the long run, Prosopis densities appear to be too low in ARTP to sustain the capital costs of Prosopis control. Additional subsidies are required.

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[2] The distance from Gamkap gate to Sendelingsdrif measured along the Orange River is 80 km. The depth of the stratum dense riparian thickets is roughly 100 m.

5. Conclusion

The project breaks new ground as it tries to bridge the gap between conventional biomass harvesting operations as seen in the de-bushing industry in Namibia and selective invasive Plant removal in the sensitive environment of a protected area as undertaken by the South African role model *Working for Water*. The fundamental question of this study is about the financial feasibility of such a scenario. Is it possible to feasibly combine the creation of income opportunities for local communities in biomass harvesting with the fight against one of Namibia's most aggressive invasive plants? To answer this question, the study gathered information in several aspects of the envisaged project.

A stakeholder analysis showed that the setting is generally suitable for the undertaking. No serious conflicts of interest between involved parties were identified. On the contrary, numerous possibilities for joint action could be seized. This especially holds for the desirable cooperation between the *Ministry of Environment and Tourism*, *South Africa National Parks*, *Working for Water*, and the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ).

The stakeholder analysis in a wider sense also revealed that marketing opportunities for Prosopis products are manifold at large. Also in the remote location of ARTP, marketing opportunities for some Prosopis products - mainly firewood - exist. However, putting them into practice might become a major challenge. With regard to technical implications around the actual act of Prosopis removal, the study could draw from ample knowledge laid down in literature or being shared by experts in the field. The same generally holds for the best practice organizational concept which was identified as the SME-approach. It yielded acceptable results in several other scenarios of biomass harvesting in Namibia and South Africa.

This notwithstanding, the forest inventory conducted showed that a significant difference in comparison to conventional biomass harvesting operations lies in the low densities of the resource, i.e. Prosopis trees in ARTP. From an ecological point of view, low densities of the invader are of course welcome. Seen from the business perspective, densities would generally need to be higher for a feasible and financially sustainable Prosopis control operation.

The financial assessment worked out that the average Prosopis densities found in ARTP could be just enough to cover the short term variable costs of Prosopis removal with revenues created from the sale of biomass - if the Ministry of Environment and Tourism commits to thoroughly support the project by availing considerable capacities for it. The financial assessment also showed that Prosopis densities in ARTP are most likely too low to guarantee the long term financial sustainability of the project once the equipment obtained with the available kick-off funding must be replaced. In sum, additional financial support is deemed necessary.

In the bigger picture, the ongoing Prosopis invasion in Namibia will be difficult to control without a large scale government programme providing the required support as it is the case in South Africa. Labour-intensive Prosopis control involving local communities will otherwise not be sustainable in the long term. This is because the opportunities of income generation are insufficient in areas with low Prosopis density or in areas that are difficult to access. For instance, removing Prosopis biomass in a cost effective way from the virtually inaccessible Fish River Canyon which lies between the often mentioned Gibeon project and /Ai-/Ais-Richtersveld Transfrontier Park is almost impossible. However, if Prosopis is not removed exhaustively, cleared areas will continuously be reinvaded. In his assessment of the status quo of invasive plants in Namibia, Joubert (2008) sees the country at a crossroads: either act now against the invaders or miss the chance. With regard to the already widespread Prosopis, large scale concerted action is urgently needed in the foreseeable future.

6. Literature

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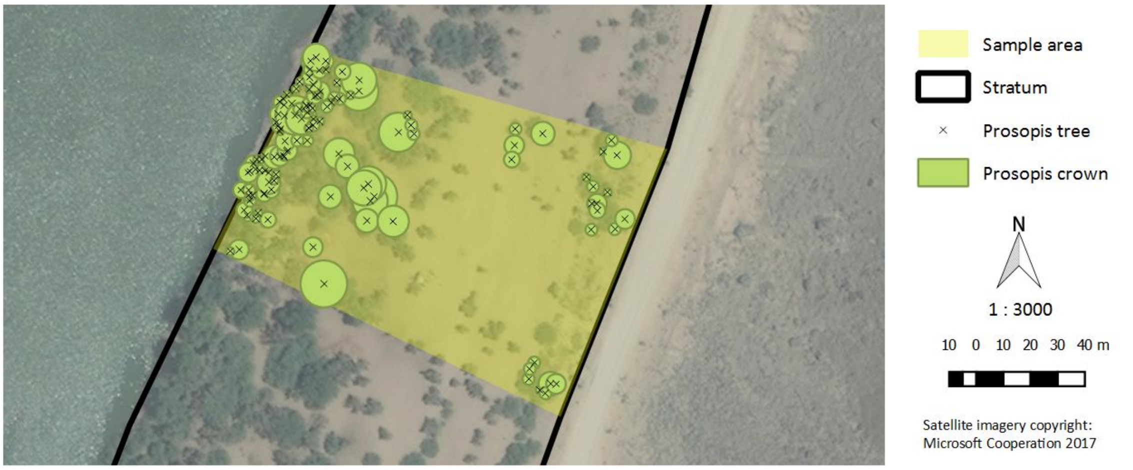
7. Interview Partners

Name	Institution
Brassine	Prosopis Timber and Decking, Brakwater, Windhoek
Cock	Gondwana Collection Namibia
De Beer	Working for Water, /Ai-/Ais Richtersveld Transfrontier Park
Du Plessis	Feedmaster
Engelbrecht	Prosopis dealer
Fryer	Ministry of Environment and Tourism, Chief Warden Karas Parks
Gessert	Huib Plateau Park
Gschwender	GIZ Support to De-Bushing Project
Haelbich	RED Nossob
Haimbola	Namibia Wildlife Resorts, Ai-Ais
Handley	Ministry of Environment and Tourism, Senior Warden Oranjemund
Izaaks	Minsitry of Agriculture, Water and Forestry
Kubula	Namibia Wildlife Resorts Hobas
Laufs	GIZ Support to De-Bushing Project
Leineweber	GIZ Transboundary use and protection of natural resources in the SADC region
Liebich	Transworld Cargo
Lindeque	Namibia Biomass Industry Group
Louw	Ministry of Africulture, Water and Forestry
Mwiikinghi	Ministry of Africulture, Water and Forestry
Naude	Aussenkehr Farm
Neethling	Department of Environmental Affairs
Potgieter	Namibia
Slabbert	RoshSkor
Steyn	Aikanes Farm
Strohbach	Namibia University of Science and Technology
Tengee	Ministry of Mines and Energy
Twyman	FARM
Whittington	South African National Parks, /Ai-/Ais Richtersveld Transfrontier Park
Witbooi	Keetmanshoop

Annex

A. Forest Inventory

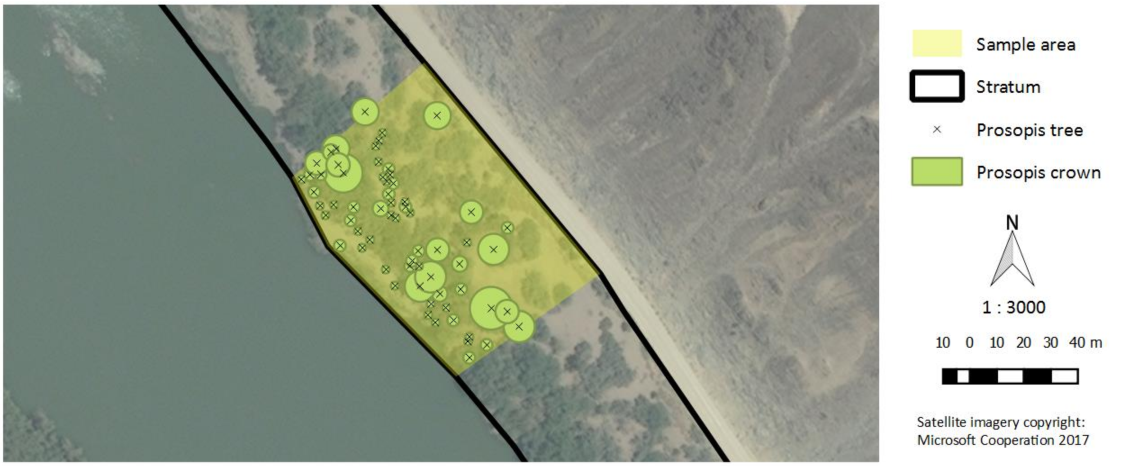
Sample area 1



sample area [ha]	1.30	**m_t [t]**	12.60	**m_t [t/ha]**	9.73	**m_t strat [t]**	168.76
stratum area [ha]	187.35	**m_b [t]**	1.38	**m_b [t/ha]**	1.07	**m_b strat [t]**	18.52
density [%]	19.6	**m_f [t]**	9.32	**m_f [t/ha]**	7.2	**m_f strat [t]**	124.93

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	41	28	18	14	7	2	3	4	3	0	2	0	0	0

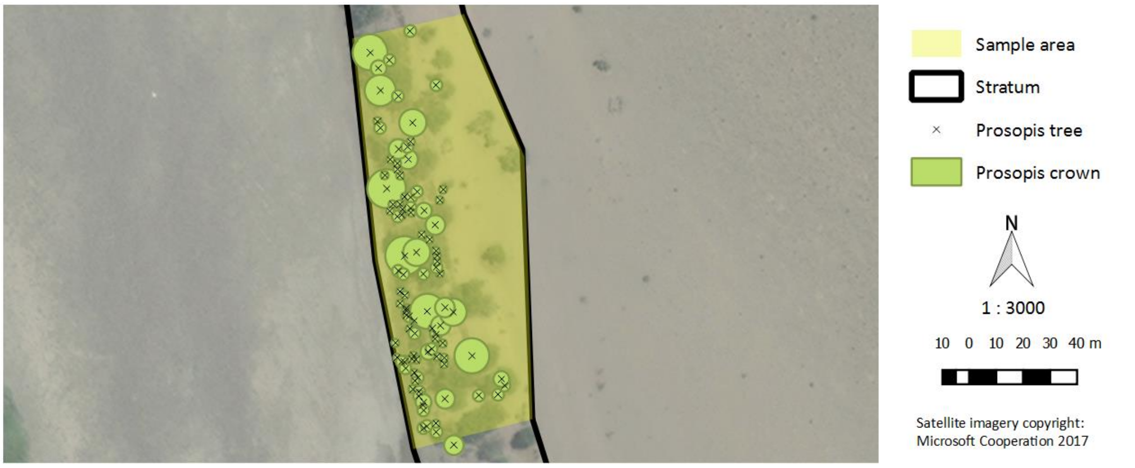
Sample area 2



sample area [ha]	0.67	**m_t [t]**	5.71	**m_t [t/ha]**	8.49	**m_t strat [t]**	60.77
stratum area [ha]	7.16	**m_b [t]**	0.59	**m_b [t/ha]**	0.88	**m_b strat [t]**	6.32
density [%]	22.8	**m_f [t]**	4.26	**m_f [t/ha]**	6.33	**m_f strat [t]**	45.33

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	29	18	4	0	5	3	4	0	1	1	0	0	0	0

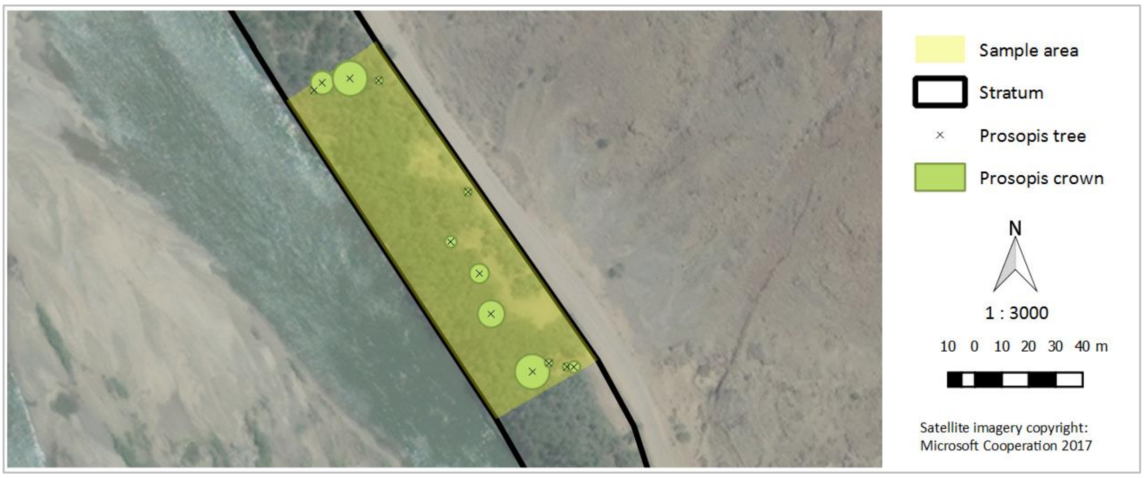
Sample area 3



sample area [ha]	0.80	**m_t [t]**	6.71	**m_t [t/ha]**	8.40	**m_t strat [t]**	83.10
stratum area [ha]	9.89	**m_b [t]**	0.70	**m_b [t/ha]**	0.88	**m_b strat [t]**	8.71
density [%]	23.4	**m_f [t]**	5.00	**m_f [t/ha]**	6.26	**m_f strat [t]**	61.93

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	45	32	5	7	0	3	1	3	2	0	0	0	0	0

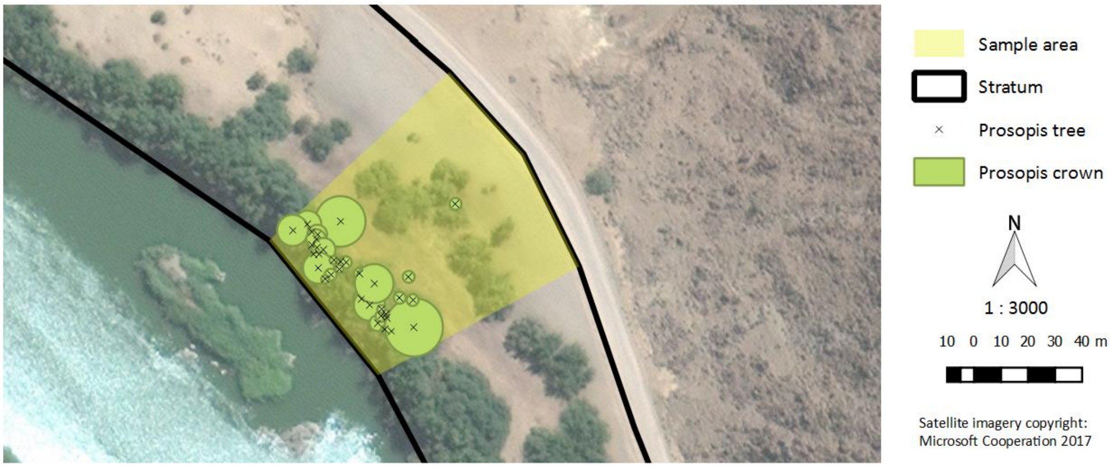
Sample area 4



sample area [ha]	0.59	**m_t [t]**	1.59	**m_t [t/ha]**	2.67	**m_t strat [t]**	7.43
stratum area [ha]	2.78	**m_b [t]**	0.16	**m_b [t/ha]**	0.26	**m_b strat [t]**	0.73
density [%]	8.2	**m_f [t]**	1.19	**m_f [t/ha]**	2.01	**m_f strat [t]**	5.59

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	5	2	0	1	1	1	0	2	0	0	0	0	0	0

Sample area 5



sample area [ha]	0.68	**m_t [t]**	5.30	**m_t [t/ha]**	7.77	**m_t strat [t]**	52.94
stratum area [ha]	6.81	**m_b [t]**	1.08	**m_b [t/ha]**	1.58	**m_b strat [t]**	10.76
density [%]	18.6	**m_f [t]**	3.43	**m_f [t/ha]**	5.03	**m_f strat [t]**	34.24

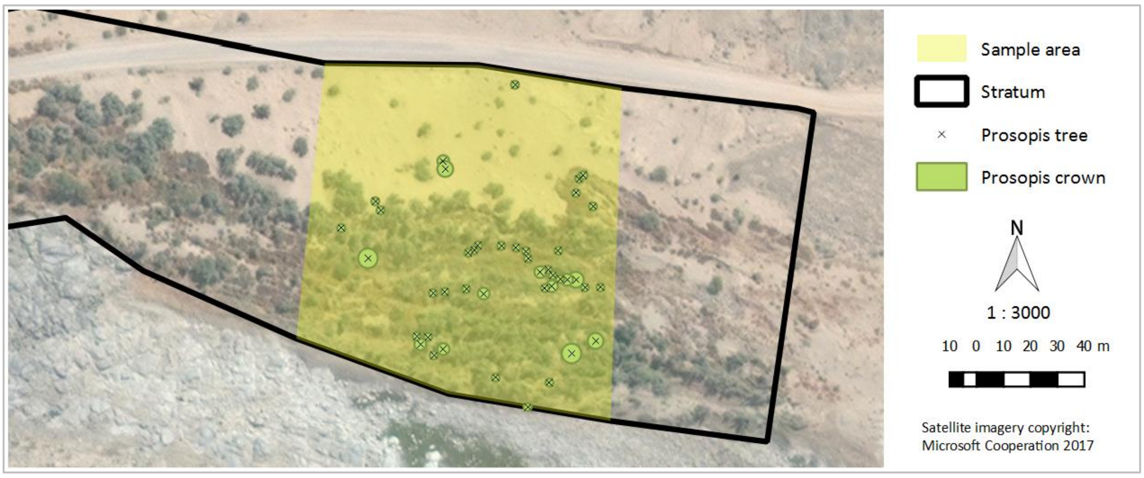
diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	13	8	3	2	1	1	3	0	1	0	0	1	0	1

Sample area 6

sample area [ha]	1.92	**m_t [t]**	2.21	**m_t [t/ha]**	1.15	**m_t strat [t]**	5.91
stratum area [ha]	5.13	**m_b [t]**	0.20	**m_b [t/ha]**	0.10	**m_b strat [t]**	0.54
density [%]	3.9	**m_f [t]**	1.68	**m_f [t/ha]**	0.87	**m_f strat [t]**	4.49

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	11	6	2	5	2	1	0	1	0	0	0	0	0	0

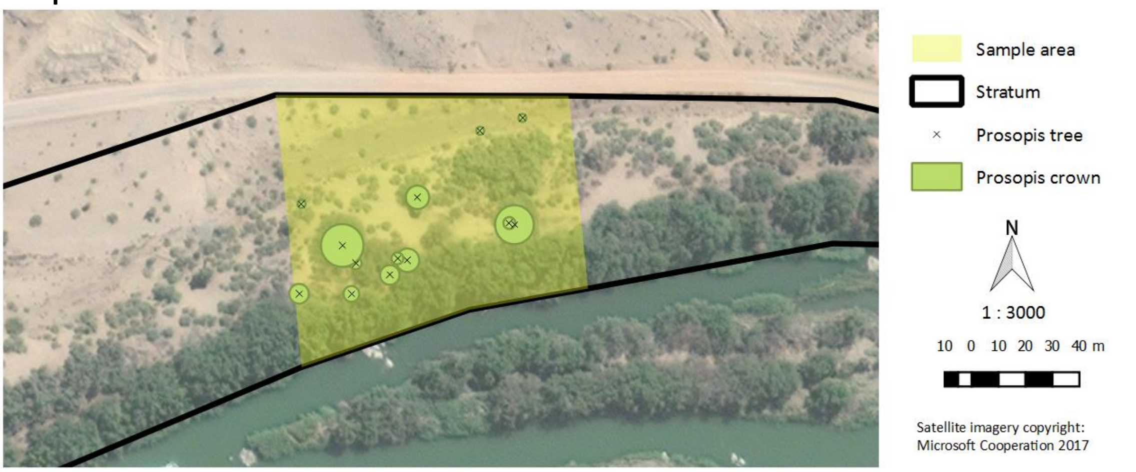
Sample area 7



sample area [ha]	1.35	**m_t [t]**	1.22	**m_t [t/ha]**	0.91	**m_t strat [t]**	3.87
stratum area [ha]	4.25	**m_b [t]**	0.14	**m_b [t/ha]**	0.10	**m_b strat [t]**	0.44
density [%]	3.5	**m_f [t]**	0.90	**m_f [t/ha]**	0.67	**m_f strat [t]**	2.84

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	30	7	3	2	0	0	0	0	0	0	0	0	0	0

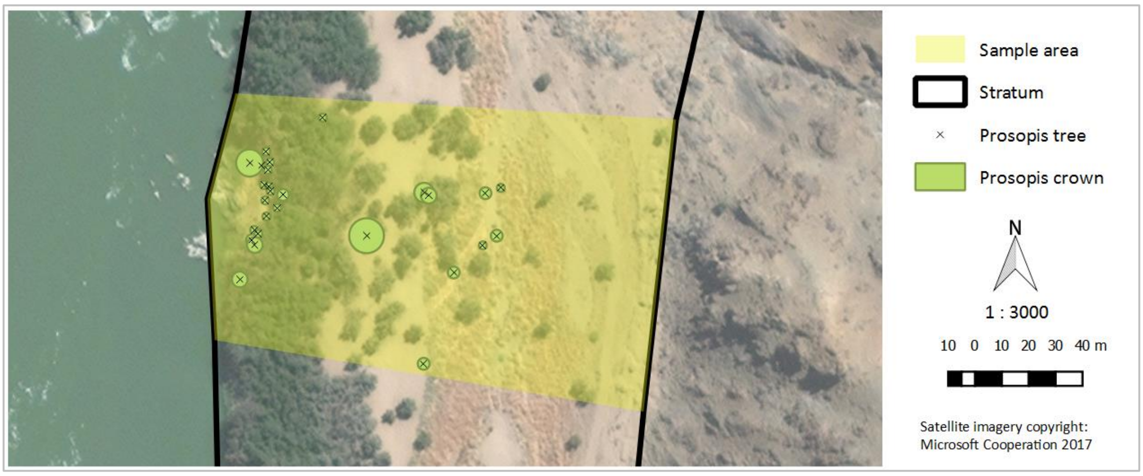
Sample area 8



sample area [ha]	0.91	**m_t [t]**	2.07	**m_t [t/ha]**	2.26	**m_t strat [t]**	19.16
stratum area [ha]	8.47	**m_b [t]**	0.24	**m_b [t/ha]**	0.27	**m_b strat [t]**	2.26
density [%]	6.7	**m_f [t]**	1.51	**m_f [t/ha]**	1.66	**m_f strat [t]**	14.02

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	3	3	1	2	2	0	0	0	1	1	0	0	0	0

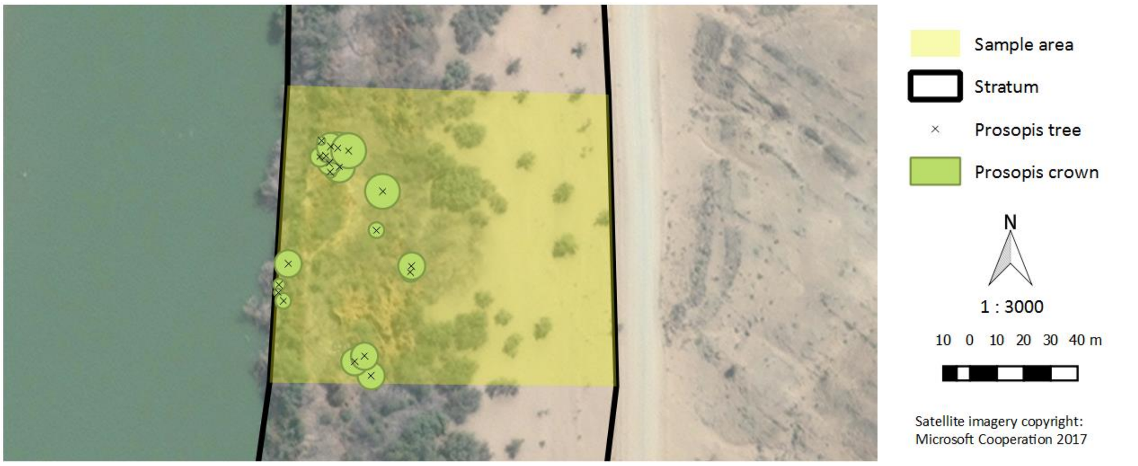
Sample area 9



sample area [ha]	1.67	**m_t [t]**	1.51	**m_t [t/ha]**	0.90	**m_t strat [t]**	47.01
stratum area [ha]	51.97	**m_b [t]**	0.16	**m_b [t/ha]**	0.09	**m_b strat [t]**	4.84
density [%]	2.9	**m_f [t]**	1.13	**m_f [t/ha]**	0.68	**m_f strat [t]**	35.12

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	15	6	3	1	0	1	0	1	0	0	0	0	0	0

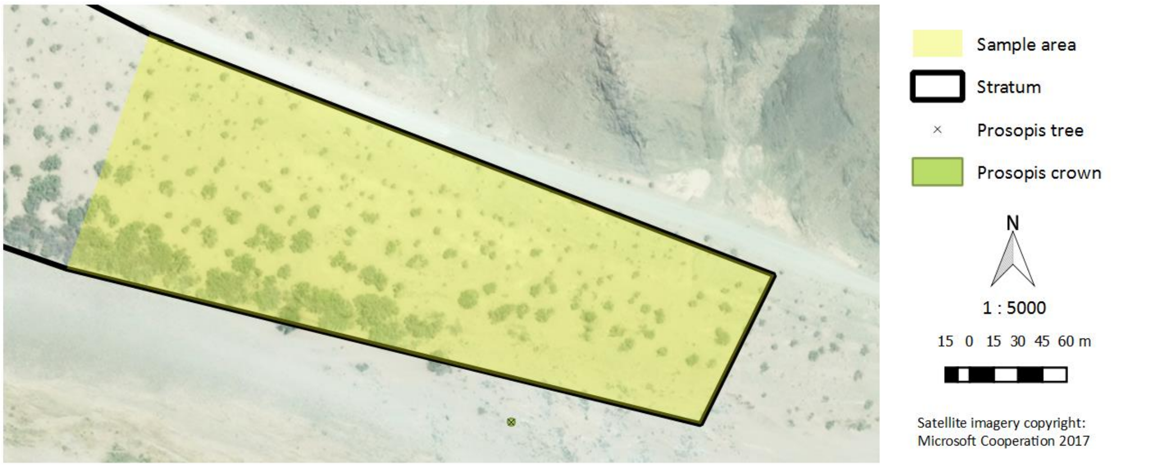
Sample area 10



sample area [ha]	1.36	**m_t [t]**	3.78	**m_t [t/ha]**	2.78	**m_t strat [t]**	29.71
stratum area [ha]	10.68	**m_b [t]**	0.33	**m_b [t/ha]**	2.63	**m_b strat [t]**	2.63
density [%]	6.0	**m_f [t]**	2.88	**m_f [t/ha]**	2.12	**m_f strat [t]**	22.62

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	2	3	2	2	1	6	2	2	0	0	0	0	0	0

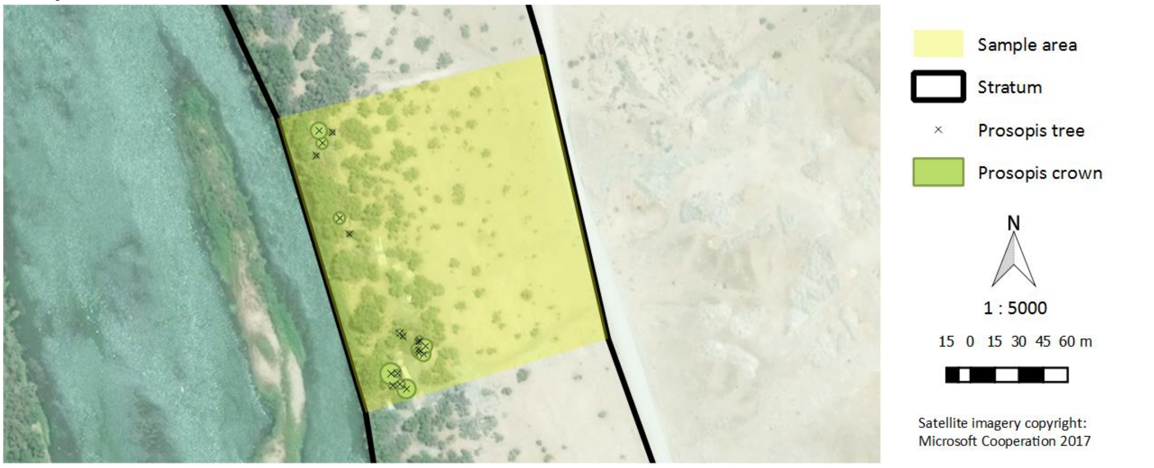
Sample area 11



sample area [ha]	5.20	**m_t [t]**	0.00	**m_t [t/ha]**	0.00	**m_t strat [t]**	0.00
stratum area [ha]	29.12	**m_b [t]**	0.00	**m_b [t/ha]**	0.00	**m_b strat [t]**	0.00
density [%]	0.0	**m_f [t]**	0.00	**m_f [t/ha]**	0.00	**m_f strat [t]**	0.00

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	0	0	0	0	0	0	0	0	0	0	0	0	0	0

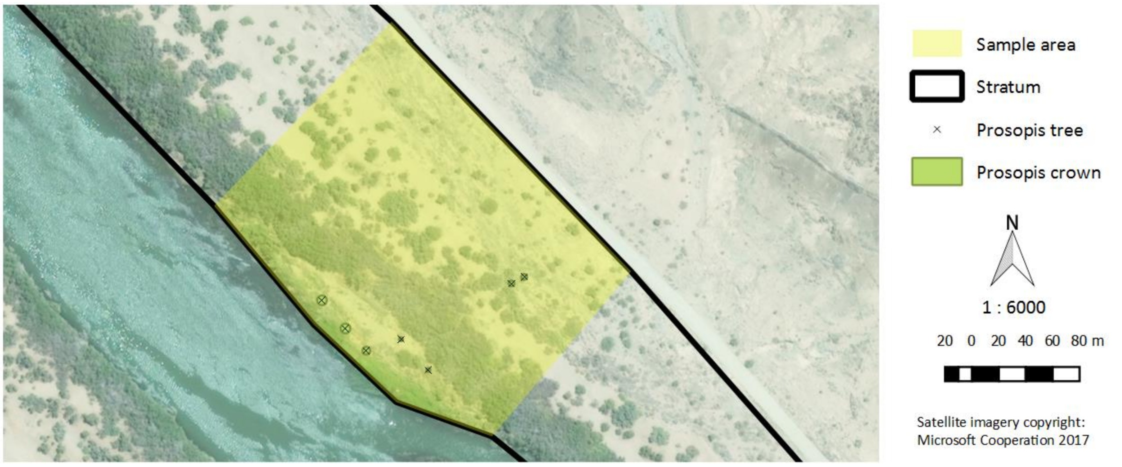
Sample area 12



sample area [ha]	3.01	**m_t [t]**	2.27	**m_t [t/ha]**	0.76	**m_t strat [t]**	32.05
stratum area [ha]	42.41	**m_b [t]**	0.20	**m_b [t/ha]**	0.07	**m_b strat [t]**	2.82
density [%]	2.0	**m_f [t]**	1.73	**m_f [t/ha]**	0.58	**m_f strat [t]**	24.41

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	5	3	2	3	3	1	1	1	0	0	0	0	0	0

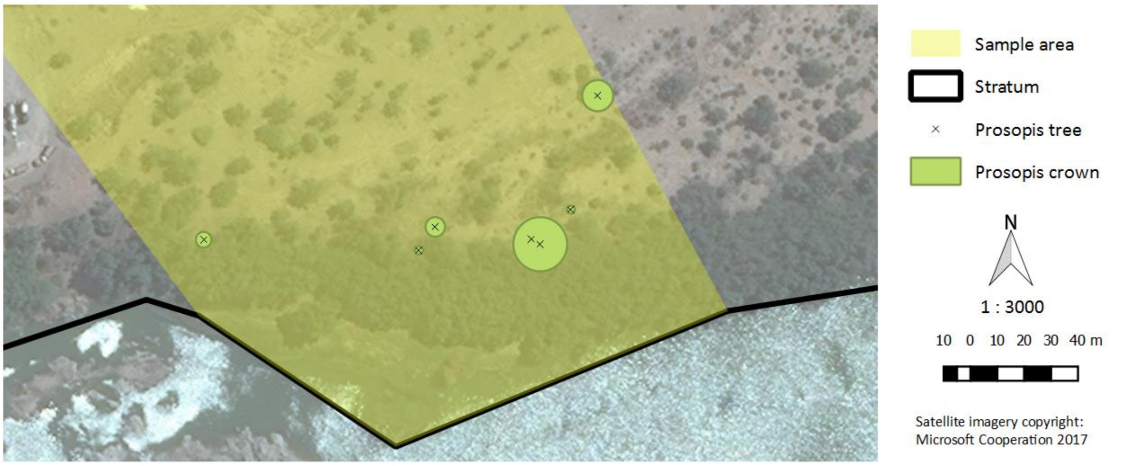
Sample area 13



sample area [ha]	4.98	**m_t [t]**	0.43	**m_t [t/ha]**	0.09	**m_t strat [t]**	6.97
stratum area [ha]	81.36	**m_b [t]**	0.04	**m_b [t/ha]**	0.01	**m_b strat [t]**	0.60
density [%]	0.3	**m_f [t]**	0.33	**m_f [t/ha]**	0.07	**m_f strat [t]**	5.32

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	2	2	1	2	0	0	0	0	0	0	0	0	0	0

Sample area 14



sample area [ha]	5.69	**m_t [t]**	1.87	**m_t [t/ha]**	0.33	**m_t strat [t]**	8.27
stratum area [ha]	25.12	**m_b [t]**	0.42	**m_b [t/ha]**	0.07	**m_b strat [t]**	1.87
density [%]	0.9	**m_f [t]**	1.17	**m_f [t/ha]**	0.21	**m_f strat [t]**	5.16

diameter class [cm]	10	15	20	25	30	35	40	45	50	55	60	65	70	75
number of trees	2	1	1	2	0	0	1	0	0	0	0	0	1	0

B. Financial Assessment

List of Equipment for one Prosopis control team

Item	Price per piece [NAD]	Quantity	Price total [NAD]	incl. 20% shipping
Chainsaw				
Chainsaw	8500	2	17000	
Maintenance tools	1500	2	3000	
Chain	300	5	1500	
Subtotal			*20000*	*24000*
Tools				
Bowsaw	140	2	280	
Blade	40	5	200	
Pruning saw	110	2	220	
Pruning shears heavy duty	640	8	5120	
Panga	100	2	200	
Slasher	330	2	660	
Axe 1.5 kg	500	3	1500	
Axe 0.9 kg	200	3	600	
Spade	180	3	540	
Brush	40	10	400	
Rakes	130	2	260	
Wheelbarrow	1000	2	2000	
Scale	70	2	140	
Toolbox	600	3	1800	
Jerry can 25l	270	4	1080	
Subtotal			*15000*	*18000*
Protective Equipment				
Overall	300	12	3600	
Safety boots	400	12	4800	
Sunhat	40	12	480	
Helmet	40	12	480	
Gloves	40	12	480	
Dust mask 5x	70	12	840	
Dust goggle	20	12	240	
Chainsaw trousers	1500	1	1500	
Earmuffs	50	12	600	
Subtotal			*13020*	*15624*
Camping gear				
Stretcher	1500	12	18000	
Mattress	800	12	9600	
Tent 3x3	4100	5	20500	
Water can 25l	270	10	2700	
Other	3000	1	3000	
Subtotal			*53800*	*64560*
Total				***122184***

Cash flow tables NAD

Cash flow table AVERAGE density

Item	Unit	Months						Months					
		0	6	12	18	24	**0 - 24**	0	6	12	18	24	**0 - 24**
Revenues (receipts)		**1 ha**						**30 ha**					
1. Sale of mb	NAD	0,00	280,00	0,00	0,00	0,00	**280,00**	0,00	8400,00	0,00	0,00	0,00	**8400,00**
2. Sale of mf	NAD	1687,00	0,00	0,00	0,00	0,00	**1687,00**	50610,00	0,00	0,00	0,00	0,00	**50610,00**
Subtotal	NAD	*1687,00*	*280,00*	*0,00*	*0,00*	*0,00*	**1967,00**	*50610,00*	*8400,00*	*0,00*	*0,00*	*0,00*	**59010,00**
Cost (expenditures)													
3. Labour	NAD	407,88	49,20	49,20	49,20	49,20	**604,68**	12236,40	1476,00	1476,00	1476,00	1476,00	**18140,40**
4. Herbicide	NAD	206,20	35,70	35,70	35,70	35,70	**348,99**	6186,00	1070,90	1070,90	1070,90	1070,90	**10469,62**
5. Fuel	NAD	306,94	0,00	0,00	0,00	0,00	**306,94**	9208,08	0,00	0,00	0,00	0,00	**9208,08**
6. Chain Oil	NAD	63,95	0,00	0,00	0,00	0,00	**63,95**	1918,35	0,00	0,00	0,00	0,00	**1918,35**
7. Chain	NAD	32,78	0,00	0,00	0,00	0,00	**32,78**	983,50	0,00	0,00	0,00	0,00	**983,50**
8. Bags & Wire	NAD	337,20	0,00	0,00	0,00	0,00	**337,20**	10116,00	0,00	0,00	0,00	0,00	**10116,00**
9. Truck Rental	NAD	116,00	0,00	0,00	0,00	0,00	**116,00**	3480,00	0,00	0,00	0,00	0,00	**3480,00**
Subtotal	NAD	*1470,94*	*84,90*	*84,90*	*84,90*	*84,90*	**1810,53**	*44128,33*	*2546,90*	*2546,90*	*2546,90*	*2546,90*	**54315,95**
Net revenue	NAD	***216,06***	***195,10***	***-84,90***	***-84,90***	***-84,90***	156,47	***6481,67***	***5853,10***	***-2546,90***	***-2546,90***	***-2546,90***	4694,05

Cash flow table HIGH density

Item	Unit	Months						Months					
		0	6	12	18	24	**0 - 24**	0	6	12	18	24	**0 - 24**
Revenues (receipts)		**1 ha**						**30 ha**					
1. Sale of mb	NAD	0,00	658,00	0,00	0,00	0,00	**658,00**	0,00	19740,00	0,00	0,00	0,00	**19740,00**
2. Sale of mf	NAD	4620,00	0,00	0,00	0,00	0,00	**4620,00**	138600,00	0,00	0,00	0,00	0,00	**138600,00**
Subtotal	NAD	*4620,00*	*658,00*	*0,00*	*0,00*	*0,00*	**5278,00**	*138600,00*	*19740,00*	*0,00*	*0,00*	*0,00*	**158340,00**
Cost (expenditures)													
3. Labour	NAD	822,76	98,60	98,60	98,60	98,60	**1217,16**	24682,80	2958,00	2958,00	2958,00	2958,00	**36514,80**
4. Herbicide	NAD	562,20	97,10	97,10	97,10	97,10	**950,59**	16866,00	2912,92	2912,92	2912,92	2912,92	**28517,69**
5. Fuel	NAD	616,57	0,00	0,00	0,00	0,00	**616,57**	18497,16	0,00	0,00	0,00	0,00	**18497,16**
6. Chain Oil	NAD	128,45	0,00	0,00	0,00	0,00	**128,45**	3853,58	0,00	0,00	0,00	0,00	**3853,58**
7. Chain	NAD	87,97	0,00	0,00	0,00	0,00	**87,97**	2639,00	0,00	0,00	0,00	0,00	**2639,00**
8. Bags & Wire	NAD	904,80	0,00	0,00	0,00	0,00	**904,80**	27144,00	0,00	0,00	0,00	0,00	**27144,00**
9. Truck Rental	NAD	272,60	0,00	0,00	0,00	0,00	**272,60**	8178,00	0,00	0,00	0,00	0,00	**8178,00**
Subtotal	NAD	*3395,35*	*195,70*	*195,70*	*195,70*	*195,70*	**4178,14**	*101860,54*	*5870,92*	*5870,92*	*5870,92*	*5870,92*	**125344,23**
Net revenue	NAD	***1224,65***	***462,30***	***-195,70***	***-195,70***	***-195,70***	1099,86	***36739,47***	***13869,08***	***-5870,92***	***-5870,92***	***-5870,92***	32995,77

Cash flow table LOW density

Item	Unit	Months						Months					
		0	6	12	18	24	**0 - 24**	0	6	12	18	24	**0 - 24**
Revenues (receipts)		**1 ha**						**30 ha**					
1. Sale of mb	NAD	0,00	35,00	0,00	0,00	0,00	**35,00**	0,00	1050,00	0,00	0,00	0,00	**1050,00**
2. Sale of mf	NAD	196,00	0,00	0,00	0,00	0,00	**196,00**	5880,00	0,00	0,00	0,00	0,00	**5880,00**
Subtotal	NAD	*196,00*	*35,00*	*0,00*	*0,00*	*0,00*	**231,00**	*5880,00*	*1050,00*	*0,00*	*0,00*	*0,00*	**6930,00**
Cost (expenditures)													
3. Labour	NAD	56,13	6,80	6,80	6,80	6,80	**83,33**	1683,90	204,00	204,00	204,00	204,00	**2499,90**
4. Herbicide	NAD	24,20	4,20	4,20	4,20	4,20	**40,99**	726,00	125,94	125,94	125,94	125,94	**1229,76**
5. Fuel	NAD	42,34	0,00	0,00	0,00	0,00	**42,34**	1270,08	0,00	0,00	0,00	0,00	**1270,08**
6. Chain Oil	NAD	8,82	0,00	0,00	0,00	0,00	**8,82**	264,60	0,00	0,00	0,00	0,00	**264,60**
7. Chain	NAD	3,85	0,00	0,00	0,00	0,00	**3,85**	115,50	0,00	0,00	0,00	0,00	**115,50**
8. Bags & Wire	NAD	39,60	0,00	0,00	0,00	0,00	**39,60**	1188,00	0,00	0,00	0,00	0,00	**1188,00**
9. Truck Rental	NAD	14,50	0,00	0,00	0,00	0,00	**14,50**	435,00	0,00	0,00	0,00	0,00	**435,00**
Subtotal	NAD	*189,44*	*11,00*	*11,00*	*11,00*	*11,00*	**233,43**	*5683,08*	*329,94*	*329,94*	*329,94*	*329,94*	**7002,84**
Net revenue	NAD	***6,56***	***24,00***	***-11,00***	***-11,00***	***-11,00***	**-2,43**	***196,92***	***720,06***	***-329,94***	***-329,94***	***-329,94***	**-72,84**