Support to De-bushing Project

Harvesting of Encroacher Bush

Compendium of harvesting technologies for encroacher bush in Namibia

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The following abbreviations, definitions and explanations are applicable to the Biomass Harvesting Compendium:

- **CAPEX:** Capital expenditure
- **Chippers:** General term used for disc- (vertical rotary disc with blades); drum- (drum with blade cutters spinning horizontally and equipped with drum screen) chippers. Used to cut soft wet wood into flakes or chips. Some drum chippers can be strengthened to chip dry hard woods like some of the Namibian encroacher bush species. [Also see "Grinders", defined below]
- **CO_2:** Carbon dioxide gas (emission)
- **ϕ:** Diameter
- **FSC:** Forestry Stewardship Council, an international non-governmental organisation.
- **GCV:** Gross Calorific Value, normally measured in kcal/kg or in the SI system referred to as *Higher Heating Value [HHV]* measured in kJ/kg. Both GCV or HHV refers to the amount of thermal energy available in a dry combustible material [*1 calorie = 4.187 Joules*; *1 Joule is equal to the amount of energy required to raise the temperature of 1 cm^3 of pure water from 14.5°C to 15.5°C].*
- **GIZ:** Deutsche Gesellschaft für Internationale Zusammenarbeit/German Development Cooperation.
- **GJ/m^3:** Giga Joules per cubic meter; the term generally used to refer to Volumetric Energy Density of a combustible material [The bulk density of hard wood chips are approximately 4.5 GJ/m^3 versus power station (lignite) coal of 21 GJ/m^3].
- **Grinders:** Term generally used for larger chipping equipment. The preferred grinder type for Namibian's abrasive dry bush would be a horizontal infeed drum type grinder/chipper with adjustable anvil (or walking floor anvil) and drumscreen.
- **ha:** hectare; 100 m x 100 m = 10 000 m^2
- **hp:** horsepower [1 hp = 0.746 kW] referring to *power* in the Imperial System.
- **ISO:** International Standards Organisation
- **kWh:** The unit of energy consumption; one kW energy consumed for one hour.
- **LSU:** Large stock unit or large animal unit
- **m^3:** cubic meter
- **MAWF:** Ministry of Agriculture, Water and Forestry
- **MC:** Moisture content, generally expressed as a percentage water content of a material.
- **N$/GJ:** Cost of Thermal Energy available in a combustible material measured in NAD per Giga Joule. [The cost of thermal energy available in dry Acacia mellifera is approximately N$ 50.00/GJ versus power station (lignite) coal @ N$ 58.00/GJ, delivered to Windhoek.
- **NamPower:** The national electrical power utility of Namibia
- **OPEX:** Operational expenditure
- **PV:** Present value
- **RH:** Relative humidity
- **SME:** Small, medium enterprise
- **t = Tonne:** Metric ton or 1 000 kgf (vs Ton, referred to as a short ton or 2000 lbf)
- **Tub Grinder:** Vertical infeed grinders with a cylindrical tub equipped with cutters rotating around its vertical axis. Generally used to grind larger root systems and can take a reasonable amount of rocks, stones and sand.

CHAPTER 1: INTRODUCTION TO THE COMPENDIUM

1.1 BACKGROUND TO THE ASSIGNMENT

Bush encroachment is severely hampering the red meat industry of Namibia and it is also negatively affecting biodiversity and the recharging tempos of certain aquifers. More than 26 million hectares of Namibian rangelands and savannah has been degraded by encroacher bush.

There is a considerable market demand for biomass in the world and the use of waste wood or unwanted woody biomass has become a sought after commodity, mainly because of its low to positive impact on the environment when used as a heat source. The removal of encroaching bush from the Namibian rangelands would not only be regarded as an attempt to restore the savannah and its biodiversity, it would also be advantages to the subsurface water resources of affected areas. It is therefore important that methods to economically harvest biomass from encroaching bush need to be highlighted and documented. The purpose of this assignment is thus to compile a *Compendium* or abbreviated reference document for farmers, companies and groups looking to invest in their de-bushing capacities.

The Consultants' primary aim is therefore to pay special attention to **harvesting methods** of encroacher bush at tempos which could economically produce clean and chipped biomass yielding from a few tonnes per day up to 100 and more tonnes per day from a single "harvesting train" of equipment.

Figure 1: Savannah near Dordabis (July 2015) (Courtesy Gys Joubert)

1.2 METHODOLOGY USED

The Compendium was compiled by the Consultant after working through large volumes of work previously done by experts in the field of Namibian encroacher bush.

Several working sites were visited to come up with, in the Consultants' view, the best activity chain of harvesting actions required to harvest Namibian encroacher bush. Emphasis was therefore placed on the following activities:

i. Felling of trees and bush
ii. Stacking and gathering (for sun drying of the felled bush)

iii. Feeding the chipper or grinder operation in the field
iv. Chipping or grinding while blowing or loading the chips into a shuttle trailer
v. Shuttling and infield transporting of the chips to the transferring point on the farm/harvesting terrain
vi. Transferring the chips onto the public road transporting vehicle
vii. Transporting to the point of use.

The Compendium is concluded by supplying a list of biomass harvesting and chipping equipment suppliers in Namibia, South Africa and abroad. (See Annexure A).

1.3 RANKING ORDER OF ENCROACHER BUSH SPECIES

Table 1 below gives a good indication of the dominant invader and encroacher bush species to be found in Namibia, in ranking order of density surveys on a national basis.

TABLE 1: RANKING ORDER (ON A NATIONAL DENSITY BASIS) OF THE SIX MAIN ENCROACHER BUSH SPECIES IN NAMIBIA (2004)

Ranking	Scientific Name	Popular English Name	Afrikaans Name	Extend [%]
1.	Acacia mellifera	Black-thorn Acacia	Swarthaak/Hakkiesbos	45%
2.	Colophospermum mopane	Mopane	Baster Mopane	20%
3.	Dichrostachys cinerea	Sickle-bush	Sekelbos/Papierwiel	14%
4.	Acacia reficiens	Red-thorn	Rooihaak	9%
5.	Terminalia sericea	Silver Cluster-leaf	Vaalbos/Geelhout	8%
6.	Terminalia prunioides	Purple-pot Terminalia	Deurmekaarbos	4%

Source: de Klerk, J.N; Bush Encroachment in Namibia (2004)

1.4 HOW TO USE THIS GUIDE

It is suggested by most of the authors and researchers that each bush species and savannah type should be studied first before it is just cleared. Dichrostachys cinerea (Sickle-bush) especially should not be slashed for example, because it would stimulate further growth and thickening.
It would therefore be best for each de-bushing contractor/operator to seek expert advice prior to implementing a de-bushing programme.

A de-bushing programme will consist of the following components:

- Survey the area and determine the best (most appropriate and economical) method of de-bushing with a clear understanding of the impact on the environment.
- Determine the best post-harvest value adding application for the harvested biomass as a method to cover or reduce the cost of de-bushing.
- Determine the best aftercare method to prevent regrowth in an attempt to “permanently” restore the savannah.

This Compendium will endeavour to supply the reader with practical methods to do encroacher bush harvesting and how to convert bush into biomass chips – currently the fastest growing biomass product in Namibia. It is however important to note that special care should be taken at sickle-bush encroached areas not to create a larger problem, since sickle-bush is stimulated by mechanical harvesting techniques.

CHAPTER 2: ABBREVIATED MARKET OVERVIEW OF WOODY BIOMASS IN NAMIBIA

2.1 THE CURRENT LARGER USERS OF WOODY BIOMASS

The current and future woody biomass users of Namibian encroacher bush can be listed as in Table 2.

TABLE 2: BIOMASS USERS IN NAMIBIA (CURRENT AND FUTURE)

Item	Application	Current estimated size of the industry [t.p.a.]	Future (2025) estimated size of the industry [t.p.a]	Preferred format of biomass in-feed
1.	Firewood for heating & cooking	>1 000 000	>1 200 000	Logs (dry and fumigated for exports)
2.	Charcoal industry (Lumpy charcoal as final product)	50 000 to 60 000	± 100 000	Dry logs
3.	Charcoal industry (Briquettes)	± 10 000	± 150 000	Charcoal fines and Biochar (small pieces of char)
4.	Cement industry	>70 000	>120 000	Chipped/grinded
5.	Wood fired boilers for agri-industrial, thermal & power generating purposes	>7 000	>300 000	Chipped/grinded
6.	Torrified wood Coal	unknown	unknown	Chipped/grinded
7.	Poles and building material	>4 000	>5 000	poles/logs
8.	As animal feed supplement	>3 000	>6 000	Growth points chipped
9.	Biochar, compost & related	>1 000	>10 000	Chipped & fines
10.	Activated carbon from biomass	Nil	>30 000	Biochar and small pieces of char

2.2 MOST LIKELY FUTURE USES OF BIOMASS

From Table 2 it can be seen that:

(a) Most of the biomass applications prefer woody biomass in “chipped” or grinded format. In fact, it is envisaged that a large portion of the charcoal industry would also eventually move to a manufacturing style of charcoal of which the thermal energy produced by this exothermic process will be harnessed for other downstream uses.

(b) The future biomass-to-energy (wood fired boilers generating high pressure steam for agri-industrial and power generating use) shows the largest anticipated growth, followed by the energy intensive cement industry.

2.3 EXPECTED FUTURE MARKET REQUIREMENTS

The following qualities of biomass will become more and more important to future woody biomass suppliers:

- Only encroacher bush species of wood would be allowed onto the market. The biomass industry would become more and more self-regulating by enforcing minimum standards to be adhered to by future participating members. Organisations like the *Forestry Stewardship Council [FSC]* will be called upon to assist in this effort to ensure the protection of the protected tree species of Namibia parallel to increased in-house efforts by the biomass industry for harvesters to adhere to a set of environmental guidelines.

- Adherence to the above environmental guidelines would eventually become compulsory for the participants to stay part of this industry and to be able to export.

- *Biomass chips will also have to adhere to the following physical properties:*
  (i) A sizing or screening envelope (Chips will need to pass through a certain screen size without too much oversize or undersize).
  (ii) Purity: No or little sand or other foreign materials.
  (iii) A *Gross Calorific Value [GCV]* measured in Mega Joules per kilogram [MJ/kg] or Giga Joules per tonne [GJ/t] or kilocalories per kilogram [kcal/kg]. (The higher the calorific value, the higher the monitory value of the biomass).
  (iv) A moisture content. (Biomass will need to be dry; <12% moisture, in order not to consume additional thermal energy to dry the biomass in the boiler or kiln).

2.4 MARKET VALUES

The charcoal industry is currently paying N$ 1 500/tonne and more for lumpy charcoal adhering to the FSC requirements. Approximately 13% or N$ 100/t is allowed in the above price for transport of approximately 100 km to the charcoal packhouse from the suppliers' farms. This would translate to roughly N$ 280/t for wood logs at a 20% charcoal yield.

A farmgate price of approximately N$ 700/t for dry wood chips are currently achievable in Namibia – a norm set by the cement industry.

2.5 THE THERMAL PROPERTIES OF BIOMASS CHIPS COMPARED TO COAL

The international market value of biomass chips is loosely coupled to the price of energy available from low grade or lignite coal and the same would apply in Namibia.

Table 3 below gives a good indication of the competitive edge which biomass from Namibian encroacher bush could hold when compared to low grade or lignite coal:

TABLE 3: ENERGY COST COMPARISON BETWEEN DRY NAMIBIAN ENCROACHER BUSH AND COAL (DELIVERED WINDHOEK)

Fuel Properties	Wood	Coal (Lignite)	Coal (Anthracite)
Typical Gross Calorific Value [GJ/t]	16 (low average)	26	30
Average bulk price (Wood in chipped format & Coal for boiler use) [N$/t]	800 (high average)	1 500	1 800
Energy cost [N$/GJ]	$\frac{800}{16}$ = 50.00	$\frac{1500}{26}$ = 57.69	$\frac{1800}{30}$ = 60.00
Ash Content	2 - 7 %	20 - 25%	16 - 18 %
Carbon status	Neutral (no Carbon Tax applicable)	Penalising/Punitive	Penalising/Punitive

Over and above the fact that the Namibian encroacher bush biomass can theoretically produce thermal energy more economically than coal, it should also be pointed out that it has a much lower ash content than fossil coal. Wood ash, with its useable content of potassium (± 3%), should be seen as an environment friendly soil improver.

When wood ash is sequestrated or returned to agricultural soils and grasslands the carbon status of wood fired boilers can be improved to “Carbon Negative” – a sought after status for any agri-industry operating in the international market. No carbon tax is levied against wood-fired applications in countries where this tax is applicable.

See Fig. 2 for a photo display of various shapes and sizes of different types of wood chips and wood fibre.

Figure 2: Wood chips and fibre

CHAPTER 3: OVERVIEW OF HARVESTING TECHNOLOGIES

This chapter contains a list of the current de-bushing and tree felling methods used in Namibia, divided into six groups.

3.1 GROUP ONE: MANUAL & SEMI-MECHANISED

Small scale labour intensive (manual) conventional biomass harvesting methods:

- Axe, panga, pruning and pruning shears, hand saws
- Trolley with power driven saw type cutters or bit type circular cutters
- Tractor drawn slasher (PTO driven)
- Multi-circular saw PTO driven (Limited application)
- Hand held chain saws (Limited application, mainly because of the bush shape and high abrasive de-bushing conditions in Namibia).

3.2 GROUP TWO: CONVENTIONAL MEDIUM TO LARGE SCALE MECHANISED OPERATIONS

Large scale mechanised equipment mainly employed for quick de-bushing, without harvesting the biomass:

- Bush roller mounted on frontend loader (Also used as aftercare)
- Mulching machines mounted to excavators, wheel or track driven
- Bulldozer/grader/tractor with blade (High risk of soil disturbance, but is often used because of its quick and visible results)
- Chain between two tractors or dozers

3.3 GROUP THREE: CHEMICAL

Root, foliar and stem-absorbent herbicides and glyphosates, without harvesting the biomass:

- Chemical spraying by hand pump
- Chemical granules applied by hand
- Chemical aerial spraying by aircraft
- Chemical granules drop by aircraft

It is generally felt that the above chemical methods would be gladly phased out by farmers, if a better alternative can be found. This Compendium aims to demonstrate that harvested biomass has a market value which could cover the harvesting costs and which could restore grazing areas in a more sustainable way than chemical methods.

3.4 GROUP FOUR: BIOLOGICAL CONTROL

A biological de-bushing method, without harvesting the biomass:

- The use of browsers
- Browsers interaction with fire
- Fungi-related natural die-off
- Natural enemies
- Bacterial applications to accelerate the rotting process of felled biomass, tree stumps and root systems (Requiring a humid climate and generally more than one application)

3.5 GROUP FIVE: HIGHLY MECHANISED

A highly mechanised method of bush clearing/thinning with the primary aim to harvest the biomass:

- Skidsteer harvester equipped with horizontal rotary cutter or circular sawblade
- Three wheel loader equipment with buncher and hydraulic cutter
- Hydraulic grab and or buncher with blade cutter
- Hydraulic grab and tree puller/bush lifter (for soft, wet sandy soils and riverbed clearing)
- Bush combined harvester and grinder plant on tracks with shuttle bucket

3.6 GROUP SIX: OTHER METHODS

A fire orientated method of bush clearing, without harvesting the biomass:

- Flame throwers
- Controlled veld fires
- Fire-herbivory interaction

3.7 EARLY FINDINGS

From the above listed methods, the following findings can be made from a biomass harvesting perspective:

(i) When clean biomass needs to be harvested for downstream use in the marketplace, an emphasis would be placed on Groups One & Five above.

(ii) For the sake of this assignment, Group Two can also be looked at, since large volumes of a mulch type covering can be obtained using these equipment. Especially for after care and the control of bush regrowth, these equipment could be applied. See Chapter 6, paragraph 6.6 for further notes on *aftercare*.

(iii) Some farmers are approaching the bush as a resource to enhance their income from biomass and would therefore leave portions of the land to regrow for harvesting again in the future. (Refer to paragraphs 6.7 and 6.8).

(iv) This Compendium could supply valuable alternatives to chemical de-bushing and will demonstrate that more environment friendly mechanical methods of bush harvesting is available.

(v) Field surveys by the Consultant have shown that encroacher bush harvesting and infield processing into clean usable chips is still in its infancy, but ready to grow into an agricultural discipline in its own right.

CHAPTER 4: EQUIPMENT SETS (OR TRAINS) TO MATCH MAIN MARKET REQUIREMENTS

4.1 INTRODUCTION

From Chapter 2, Table 2 it is clear that biomass (wood) chips would most likely become the most popular form in which biomass would be traded in future in Namibia. This chapter will endeavour to put *equipment-sets* together with the best chance of becoming a biomass harvesting unit to produce wood chips as a final product. The equipment sets or trains will also be selected to suit a wide spectrum of harvesting operations – from small, low capital cost, labour intensive units to highly mechanised and capital intensive high output units.

4.2 DESCRIBING A BIOMASS HARVESTING TRAIN FOR BEST PRACTICE WOOD CHIP PRODUCTION

4.2.1 What is a biomass harvesting train?

The Compendium focuses on harvesting methodologies and technologies available to the young Namibian biomass industry. The focus is therefore on harvesting methods and equipment which could not only cut and clear the encroacher bush areas, but also to add value to the felled trees and bushes. And to chip or grind the bush into an easy to transport marketable product. For the above harvesting process a "train" of tools and equipment is required as listed below in its seven main actions:

(i) Bush and tree felling tools and equipment (from manual to mechanised options)

(ii) Stacking by hand or by machine for the bush to dry in stacks or windrows without picking up dirt

(iii) Feeding of the infield chippers or grinders, manually or mechanically

(iv) Chipping and grinding equipment

(v) Shuttling apparatus to convey the chips from the harvesting field to the point of transfer

(vi) Transferring the chips onto on-road trailers

(vii) Transporting the chips in high volumes to the point of use

The next few paragraphs will describe each of the above components of the biomass activity chain in more detail.

4.2.2 Tree/bush felling

Trees/bush can be cut or felled using a host of apparatus. The bush-pick is widely used in Namibia for labour based manual tree felling operations. (See Fig. 3). Mechanised tree felling can start with a small trolley (Fig. 4) equipped with a belt-driven circular saw, moving up to a large excavator equipped with a grab or buncher and hydraulic cutter/shearer with the ability to fell trees at a tempo of up to four hectares of medium density (± 15 t/ha wet) acacia mellifera in an eight hour shift. See Figures 5 to 10.

Figure 3: Manual bush pick used here for sickle bush clearing (courtesy Roads Authority of Namibia)

Figure 4: Trolley saws in action – horizontal saw tree feller (top) & Logger (bottom)
(Courtesy Inventec, Otjiwarongo)

Figure 5: The "boscut" felling machine with hydraulic motor driven horizontal saw blade
(Courtesy Peter Weder, Groot Aub)

Figure 6: Gehl skidsteer with Turbo saw
(Courtesy Callie Steenkamp, Kalkfeld)

Figure 7: Repaired blades with new cutter for turbo saw
(courtesy Forklift & Allied, Windhoek)

Figure 8: Bosvark felling saw and articulated tractor
(Courtesy Georg Fredrich, Witvlei)

Figure 9: Small hydraulic buncher cutter used at the cheetah conservation fund, Otjiwarongo

Figure 10: Hydraulic grab and cutter fitted to an excavator (left). Cutting a bunch of Acacia mallifera (courtesy Woodco, Okahandja)

4.2.3 Stacking in windrows to dry

Cut trees should ideally be stacked on top of one another in an orderly fashion and with the least amount of ground and soil contamination, to dry. The dry climate of Namibia with a relative humidity [RH] that can drop to below 20% during the winter months is ideal for drying out the felled trees and bushes to moisture contents as low as 14% H_2O.

It is furthermore believed that certain tree species – the acacia mellifera in particular – are crushed and grinded better (using less energy and causing less blockages through a horizontal infeed drum grinder) when dry. Dry and harder wood species are often easier crushed or grinded by means of an impact action (like an impact mill drum grinder with horizontal and controlled infeed) or in some cases, by a tub grinder with top loading gravity in-feed.

Felled bushes and or trees are stacked in windrows to allow for the air/sun-drying thereof. See Figures 11, 12 & 13. The bush ideally needs to lower its moisture content from approximately 38% (average) when felled to < 15% H_2O before grinding.

Figure 11: Stacking (WoodCo)

Figure 12: Acacia Mallifera cut to the ground

Figure 13: Stacked windrows (WoodCo)

4.2.4 Feeding the chipping/grinding operation

The logs and branches are fed into the chipper/grinder manually or mechanically. A machine similar to the Bell three wheel logger (See Fig. 14 left) is often used for this purpose.

Smaller chippers are generally fed by hand, but by the time production of chips starts to exceed 20 to 30 m^3 per shift, mechanical feeders are required. A mechanical feeder grabs the trees from the stacked windrows with a hydraulically operated buncher or grab and feed the bush, stumps first, onto the walking floor of the grinder and into the infeed roller(s).

Figure 14: Grab (left) & shears (right) attached to Bell logger
(Courtesy Africa Biomass, Worcester)

Figure 15: Bell logger
(Courtesy WoodCo)

4.2.5 The chipping/grinding operation

This is the most difficult and costly part of the infield operations and is often the part where most of the down time occurs. The selection of the chipper or grinder is critical and must suit the throughput requirements and the type of tree/bush to be harvested.

Small gravity feed wet wood chippers are generally fed by hand and the wood is cut with blades bolted to a high inertia drum which also acts as a flywheel and pneumatic blower to blow the chips out and into a correctly positioned container.

Larger feeders are generally equipped with a horizontal infeed system with hydraulically operated reversible rollers to control the infeed tempo to the grinder. The final product can be blown out, or on the larger machines an out-loading conveyor is installed.

A heavy duty screen forms part of the drum mechanism of a chipper/grinder to allow the grinding operation to continue until the wood fibres have reduced sufficiently to pass through the drum screen.

Figure 16: Chipper blades

Figure 17: Grinder cutters

Figure 18: Grinder cutters assembled
(courtesy WP Chippers, Worcester)

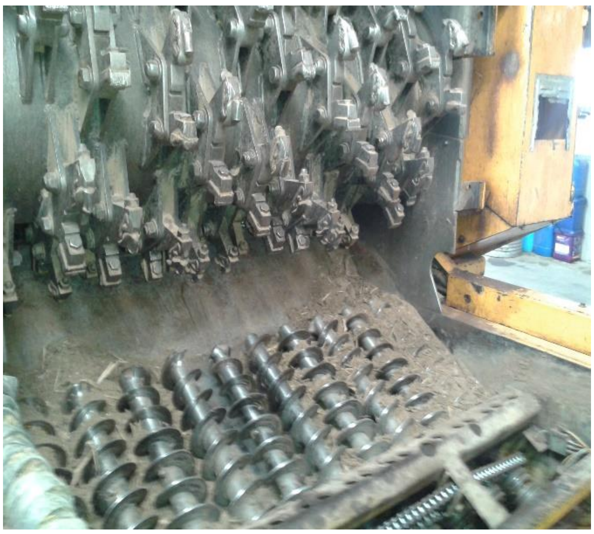

Figure 19: Grinder drum getting serviced

Figure 20: Close-up of grinder teeth
(Courtesy TreeCycle, Langebaan)

Figure 21: Small PTO driven chipper (left) Intake hopper and feeder rollers of chipper (right)
(courtesy of Georg Fredrich, Witvlei)

Figure 22: Large grinder infeed channel
(courtesy TriCycle, Langebaan)

Figure 23: Drum screen with open gate and discharge conveyor (left)
(courtesy TryCycle, Langebaan)

4.2.6 Shuttling

Once chipped, the woody load needs to be shuttled from the chipping operation to the point of transfer. Wood chips have a bulk density of between 240 to 300 kg/m^3 and therefore need large trailer type containers to convey this product. It's generally found that it is more advantages to do infield chipping and shuttle the chips, than to cart the logs and the trees out to a central chipping station.

Figure 24: Shuttle trailers
(courtesy WP Chippers, Worcester)

4.2.7 Transferring

Once the chips are near the point of transfer, it is accumulated and transferred onto 100 to 110 m^3 on-road trailers. This point is called a transfer station.

Wood making and chipping operations close to the point of use (< 25 km) can be loaded into off/on-road shuttle cars to eliminate double handling and only a change of tractor type (from off-road to on-road) takes place at the transfer station.

Commercial operations would most likely make use of large (110 m^3) trailers that can be pulled behind the grinder using a dolly-wheel-connecting-assembly. See *Illustration 1*, Chapter 5. This trailer is collected at the grinder by a shuttling tractor when full and taken to the transfer station, where an on-road horse hooks the trailer and drives off to the point of use on public roads.

Figure 25: A commercial rechipping and transferring operation in action [Note large 110 m^3 road trailer in the background to the left]
(courtesy WoodCo)

4.2.8 Transporting

The final product (chips) is transported on public roads to the point of use. High volume (up to 110 m^3) three axle walking floor trailers are used for this purpose because of the low bulk density (240 - 300 kg/m^3) of the dry wood chips (See Figure 26).

Figure 26: 2 x 110 m^3 biomass transport trucks at Ohorongo Cement

4.3 WET CHIPPING VS. DRY CHIPPING OR GRINDING

Some of the operations are considering to rather do wet chipping of bush at the point of harvesting and then to transfer the wet chips to a central point where the chips are dried mechanically and further processed into a dry correctly sized biofuel.

It is however expected that most biofuel processing operations in Namibia would try to utilise the dry climate to dry off the felled bush to a moisture content of < 15% prior to grinding (chipping). In fact, some of the hardwood species like Acacia mellifera (Black-thorn/Swarthaak) and Colophospermum mopane, is crushed and milled (grinded to a wood fibre) with less energy, blockages and mechanical difficulties when dry.

It is important to note that during the rainy season, when relative humidity of the air is high (>50% RH), it would not be possible to dry wood naturally to the <12% moisture content levels required by the cement industry. In the case of wood fired boilers, the moisture content is less critical and combustion of the biomass can still take place at moisture levels of >20% or even higher. Internal thermal energy of the boiler would however be used to drive off the moisture in the wood with a subsequent drop in usable energy.

4.4 TOP FIVE BEST PRACTICE WOOD CHIP HARVESTING TRAINS TO DATE

Table 4 contains more detail of the key five harvesting trains selected from the 10 different configurations shown, for the production of dry wood chips in Namibia at this stage. It was decided not to include the highly mechanised combined harvester type harvesters, Item 10, Table 4 (similar to the equipment used by *Energy for Future [EFF]* at Ohorongo Cement) because less capital and lower-technology-level-options are seen to be more appropriate for the harsh Namibian conditions and smaller individual biomass harvesting contractors.

Table 5 illustrates the top five typical harvesting train components available for each action step of the process.

Chapter 5 will look into the financial viability of the top five harvesting operations, starting with small scale manual cases and moving up to fully mechanised commercial ventures.

4.5 SPECIAL NOTES ON SELECTING HARVESTING MACHINES

4.5.1 Tyres

The high wear (See tyre wear shown in Fig. 27) on tyres of harvesting trains should not be underestimated. Unless relative good (stump free) infield roads can be made to the point of harvesting, forestry-type tyres are recommended. Foam filled and solid rubber tyres are also used for these harsh off-road conditions, but are often not found as cost effective as the special compound forestry-type tyres. Special tyre chains can also be used to protect the tyres.

Large operations use steel tracks on its tree felling and self-propelled grinding machines. The tracks of the grinder follows in the same tracks (ground imprints) as the excavator made when it felled the trees six to eight weeks earlier. The shuttle trailer (often pulled directly behind the grinder) also follows the above tracks. Refer to *Illustration 1*, Chapter 5.

4.5.2 Abrasiveness issues

Namibian encroacher bush types are classed as 'hard wood' and this fact must be clearly stated when ordering chipping or grinding equipment. Blade type chippers need to be sharpened in-sito (blade edge passing with special sharpening tool) every three to four hours, even when wet chipping is done in Namibia.

The negative effect of sand and termite nests in the wood on chipper wear parts are severe and need to be managed as best as possible, hence the reason for neatly stacking bush on top of one another and out of the soil prior to chipping.

4.5.3 Machine fires

Care should be taken to clean machines of dry wood chips and wood dust in engine compartments at least twice a production day to prevent machine fires. Machine (and veld) fires are seen as one of the highest risks of this industry. It is standard to fit fire extinguishers to every tree felling and chipping machine.

Figure 27: Note pieces of wood after machine compartment was cleaned out

4.5.4 Air cleaners and radiators

Because of the amount of airborne dust, special care should be taken to prevent clogging up of air intake areas, with special reference to air filters and radiators. Air intake filters are often extended to a much higher position as the grinder in an attempt to be in a cleaner (less dusty) zone.

4.5.4 Clean air

Wood dust and dust in general is not only a problem to machines but also to humans. Care should be taken that operators wear dust filters over their mouths and noses.

See the amount of soil and dry wood fibre dust created during a mid-winter grinding operation near Omaruru (Fig. 29).

Figure 28: Machine cleaning in action
(courtesy Callie Steenkamp)

Figure 29: Exceptional dust during grinding
(courtesy TreeCycle, langebaan)

4.5.6 Geophysical conditions and its impact on manoeuvrability

The harvesting equipment described in this compendium can be adapted to work in sandy, rocky and clay soils. The skid steer felling machines, as well as most of the chippers/grinders can be equipped with rubber or steel tracks to overcome most of the challenges sandy or wet clay soils can cause.

The shuttle trailers need to be pulled with four wheel drive tractors from the infield chipper to the transfer station to overcome sandy or wet clay manoeuvring conditions.

Harvesting operations could expect serious delays during the rainy season, not only for felled bush to dry, but also because of more difficult manoeuvring conditions.

TABLE 4: TEN TREE FELLING AND CHIPPING METHODOLOGIES WITH RELATED EQUIPMENT SUPPLIERS[1]

Item	Description of typical Harvesting Method	Tree Felling Equipment Suppliers		Chipping Equipment Suppliers		Claimed chipping tempo measured/day using 1 chipper & optimum crew [t chips/day]	Estimated clearing tempo per 8h day [Ha/day][	Environ-Mental impact
1.	Bush pick, tree felling hand saw, manual gathering and feeding of small hand drawn wet wood chipper BP [2]	Bush picks, hand saws, pruning shears available from Agra and hardware outlets for agri-equipment		Small 20 hp Pezzolato wet wood chipper from: Otjiwarongo Motors & Tractors	Small 20 hp TomCat hand fed chipper available from: Burgers Equipment, Otjiwarongo	3 - 5 or 16 m^3/d	0.5 to 0.6	Low
2.	Horizontal and vertical saw, hand trolley mounted, manual gathering and hand fed chipper [BP][2]	Small horizontal/vertical blade cutting trolley with 13 ph. Honda engine. Inventec, Otjiwarongo		PTO driven Pezzolato from: Otjiwarongo Motors & Tractors	35 hp TomCat from: Burgers Equipment, Otjiwarongo	7 - 9 or 28 m^3/d	0.8 to 1.2	Low
3.	Tractor drawn PTO-driven slasher, for small bushes and follow-up after care (Cut material left on land – no further processing). More for aftercare of certain species	Otjiwarongo Motors Tractors Agents for the Massey Ferguson and related equipment	Plaisance Equipment, Windhoek & Razorback Bushclearing, Centurion, SA	Not practical for harvesting chips. Mulch is left on the ground.		N/A	2 to 5	Low
4.	Light duty excavator (skid steer) with turbo saw, manual gathering and feeding into PTO driven grinder [BP][2]	Forklift & Allied Equipment, Windhoek Agents for the Gehl skid steer	Burgers, Otjiwarongo Agent for the LiuGong range of felling equipment	Rovic Leers, Cape Town Agent for the Pezzolato wet wood chippers or Otjiwarongo Motors & Tractors	Burgers Equipment, Otjiwarongo Agent for TomCat chippers, made in Worcester, SA	12 - 14 or > 50 m^3/d	2.0 to 3	Medium (tracks)
5.	Medium duty excavator on tracks with turbo, saw and tree clamp/stacker plus self-propelled medium duty grinder. OR: Three wheel loader fitted with grab and hydraulic cutter [BP][2]	Bell three wheel loaders/ cutters. Bell Equipment, Airport City, Cape Town & TreeCycle, Langebaan for Trevi Benne shearers	Burgers, Otjiwarongo Agent for the LiuGong range of felling and related equipment	Bandit Beast Grinders by Shaughn Frost, Langebaan, South Africa	Burgers Otjiwarongo Agents for TomCat drum chippers and the smaller Bandit range	20 - 30 or > 80 m^3/d	2.5 to 4	Medium (tracks)
6.	Heavy duty excavator on tracks with hydraulic cutter blade and tree clamp/stacker tree loader plus heavy duty self-propelled heavy duty grinder [BP][2]	Burgers Otjiwarongo LiuGong Agents & TreeCycle, Langebaan, SA for Trevi Benne tree felling shearers	WoodCo, Windhoek Agents for the Wood-cracker (Westtech) felling tools and hydraulic shearers		Morbark Grinders Winn, Michigan, USA	30 - 50 or 120 m^3/d	3 to 4.5	Medium (tracks)
7.	Bush roller attached to front end roller for crushing bush onto ground. Cut material left on land - no processing into chips	Ombengo Energy Windhoek	Plaisance Equipment Rozorback Bushclearing Centurion, SA	Could be used as an harvesting operation with manual collection of biomass		N/A	4 to 10	Low to Medium
8.	Bulldozing and ground clearing [Once pushed over trees are gathered and tub grinded or equivalent grinding which can endure some sand]	Nico Pretoruis Plant Hire, Windhoek	Burma Plant Hire, Windhoek	Vermeer Equipment Suppliers, Brett Park, Johannesburg, SA	Morbark Tub grinders, Winn Michigan, USA	Chipping not primary function 20 - 30	5 to 8	High
9.	Heavy duty hydraulic tree lifter (Sandy areas and river basins) and tub-grinder application	Westtech bush/tree clearing equipment, WoodCo, Windhoek	Trevi Benne Hydraulic shearers, TreeCycle, Langebaan, South Africa	Vermeer Equipment Suppliers, Brett Park, Johannesburg, SA	Morbark Tub grinders, Winn Michigan, USA	2 - 8	2 to 4	Low in sandy rivers
10.	Heavy duty self-propelled tree feller, grinder combined harvester	All in one Combined Harvesters supplied by AHWI, Germany	All in one Combined Harvester from Bandit Remus, Michigan, USA	All in one Combined Harvesters from AHWI, Germany	All in one Combined Harvester from Bandit, Remus, Michigan, USA	20 - 40	3 to 6	Medium

[1] For a more detailed list of equipment suppliers, refer to Annexure A.

[2] Items marked "[BP]" are regarded as best practice equipment from a harvesting perspective. Equipment designed for bush harvesting (When clean biomass can be collected and processed for further downstream use).

TABLE 5: TOP FIVE TYPICAL[3] WOODCHIP PRODUCTION TRAINS/OPTIONS FOR NAMIBIA BASED ON A BEST PRACTICES APPROACH AND RANKED FROM SMALL TO LARGE

Item	Felling	Stacking	Chipping /Grinding	Shuttling	Transferring	Average estimated monthly throughput per optimum Crew [Dry tonnes per month]
1.	Bush pick (Axe-pick combination) + handsaw + large pruning shears [3 x Operators]	No real stacking takes place, Branches are cut by the pruning shear to fit the chipper [2 x Operators]	Smaller branches are fed into a small 20 ph. wet branches chipper mounted onto a trolley – chips are collected in bulk bags on a trailer. Can chip up to 100 mm ⌀ logs; up to 16 m^3/day chip production [Using stacking crew]	Bulk bags on trailer are drawn by a small tractor to the transfer station [0.5 x Operators]	Bulk bags are loaded with hi-up crane (or similar) on a long distance truck to a depot for drying and further processing [0.5 x Operators]	± 80
2.	Trolley saw set (2 x horizontal + vertical) + large pruning shears [4 x Operators]	As above [2 x Operators]	As above, using 35 ph. wet wood chipper PTO driven. Can chip up to 125 mm ⌀ logs; up to 28 m^3/day chip production [2 x Operators]	As above [0.5 x Operators]	As above [0.5 x Operators]	± 140
3.	Skid steer multi-purpose light duty excavator with hydraulic motor drive cutter blade/'turbo' saw [1 x Operators]	As above [3 x Operators]	2 x PTO-driven (55 ph. tractor) chippers/ grinders into bulk tipper bin trailer. Can chip up to 200 mm ⌀ logs; up to 22 m^3/day per chipper [0.5 Tractor driver + stacking crew]	Same tractor pull bulk bin to transfer station [0.5 Tractor driver]	Bulk bins tip into bunker with lorry feeder conveyor [1 x Supervisor/Handyman]	± 220
4.	Multi-purpose medium duty excavator with hydraulic blade cutter & tree grab stacker [1 x Operator]	Cut trees/bushes are stacked by the multi-purpose exactor immediately after cutting [Same crew as per felling operation]	Dried trees bushes are loaded into the PTO driven drum grinder (200 ph.) which pneumatically blow chips into roll-on-roll-off bulk bins on off-road trailer using Bell logger or similar to feed chipper. Can chip up to 200 mm ⌀ logs; >120 m^3/day [2 x Operators]	Same or additional tractor pulls bulk bins to transfer station [1 x Operator]	Roll-on-roll-off bulk bins are transferred onto long distance horse and trailer [No additional crew]	± 600
5.	Multi-purpose heavy duty excavator with hydraulic cutter & tree grab stacker [1 x Operator]	As above [Same crew as per felling operation]	As above, using high torque self-propelled heavy duty grinder. Grinder conveys chips into 110 m^3 bin on/off road trailer chassis. Can chip 200 mm ⌀ logs if required; >160 m^3/day [2 Bell logger operators + 1 grinder operator]	Propose built long distance tractor pulls on/off road trailer to transfer station for signing out [1 x Operator]	Same shuttle system move onwards to remote offloading point without any double handling [No additional crew]	>800

[3] Some variations to the production trains are discussed in Chapter 5 using specific models of equipment as proposed by the suppliers and a single chipper per train.

CHAPTER 5: COMPARISON ANALYSIS OF TOP RANKED MECHANICAL HARVESTING METHODS

5.1 BEST PRACTICE BIOMASS HARVESTING TRAINS TO PRODUCE DRY CHIPS/FIBRE

Biomass harvesting trains as described before would be regarded as best practice machines when each of the individual actions adheres to the following criteria:

- Easy to operate, clean and maintain.
- Reliable and well tested under the harsh, dry and dusty Namibian conditions.
- Does not disturb the soil too much when operating (Low environmental impact).
- Can select the encroacher trees amongst other protected tree species.
- Each component of the harvesting train can be employed to maintain a steady pre-selected throughput measured in tonnes per hour or cubic meters per hour, in order to be used economically.

This chapter will focus on mechanical harvesting trains from small scale (SME) to larger commercial operations. Each train will be equipment with one chipper only.

5.2 FIVE CASE STUDIES (FROM SMALL SEMI-MECHANISED TO HIGHLY MECHANISED TRAINS)

5.2.1 OPTION ONE: Small scale mostly manual – Chipping @ 16 m^3/day or 800 t.p.a.

This operation consists of manual felling, stacking and feeding actions. Only the chipping operation consists of a chipper with hydraulic infeed. It can theoretically do wet logs up to a diameter of 150 mm, but for Namibian conditions its advised to limit the chipper to logs of <100 mm ⏀. The chipper can, when continuously hand fed with biomass, produce 16 m^3 of chips per 8 hour day. This represents a total tonnage of between 3.5 and 4.5 tonnes of chips per day depending on the bush species and moisture content. The capital cost of the above chipper is approximately N$ 230 000 (VAT excluded) delivered to Burgers, Otjiwarongo by the TomCat chipper factory from Worcester, SA.

Chips are blown by the chipper into 1 m^3 bulk bags positioned on a trailer next to the chipper. The trailer is manoeuvred by a small lightweight 25 hp tractor which is also used to move the chipper from time to time to remain close to the felled trees and off cut stacks.

The bulk bags are hoisted up at the transfer station to above the waiting on-road bulk trailer and by opening the bottom discharge end of the bulk bag, unloads its contents.

The following production figures can be achieved with the harvesting train as illustrated in Table 6.1:

- Total biomass chip production: 80 tonnes per month
- The total capital cost of the above harvesting train is approximately: N$ 500 000 (VAT excluded)
- Production cost of chips only (without taking the selling of logs into account): N$ 930/t.

A smaller and cheaper chipper can also be used, but a corresponding lower throughput would keep the cost of small scale chip making near N$ 930/t.

5.2.2 OPTION TWO: Light duty semi mechanised – Chipping @ 28 m^3/day or 1 400 t.p.a.

Two horizontal trolley saw cutters and one vertical saw cutter trolley by Inventec is proposed for the above felling and logging operation. Stacking, trimming and chipper feeding is done by hand.

A Tomcat 150 AFE Chipper or equivalent, with the following specifications are recommended for this operation:

- 150 mm ɸ maximum infeed capacity.
- 35 hp Perkins diesel Engine with 7" heavy duty over-centre clutch.
- Double hydraulic infeed rollers (reversible).
- Variable infeed speed system to control chip size.
- Mounted on off-road trailer with spare wheel.
- Capital cost delivered to Burgers, Otjiwarongo: N$ 280 000 (VAT excluded).

[The TomCat range of chippers are manufactured in Worcester, South Africa. TomCat SA is also the Agents in Africa for the smaller Bandit Chipper range and have appointed Burgers' Equipment in Otjiwarongo to cater for the Namibian market. The Pezzolato chipper Agency in Namibia is held by Otjiwarongo Motors and Tractors].

Shuttling and transfer is done by means of 1 m^3 bulk bags positioned on a tractor drawn purposely built trailer.

The following production figures can be achieved:

- Total biomass chip production: 140 tonnes per month
- Total capital cost for this harvesting train: N$ 1 300 000 (VAT excluded)
- Breakeven production costs of chips only: N$ 910/t.

See Table 6.2 for further detail.

5.2.3 OPTION THREE: Medium duty fully mechanised – Chipping @ 120 m^3/day or 6 000 t.p.a.

Felling and stacking is done by one medium duty (9 - 12 t) excavator available from Liebherr, LiuGong, BobCat or similar. The track type excavator is equipped with a C250 Woodcracker or a WT005 Trevi Benne, complete with rotator, baseplate and connected to the hydraulics of the excavator. See Annexure A for the complete list of the applicable suppliers.

Once felled and dried off, the bush is collected with a Bell logger equipped with grab and forestry tyres and fed into a commercial drum chipper valued at approximately N$ 2.2 million, VAT excluded. Roll-on-roll-off bins of 25 m^3 capacity each is used to shuttle the chips from the chipper to the transfer station pulled by off-road tractors, From the transfer station public road transport is done by on-road tractors. See Table 6.3 for further detail.

OPTION ONE: SMALL SCALE MOSTLY MANUAL – CHIPPING @ 16 m^3/day or 800 t.p.a.

TABLE 6.1: BREAKEVEN OPTION ONE

Description of plant & activity 800 t.p.a. or 80 t.p.m. chips plus 30 t.p.m. logs	Capital Cost	Instalment p.m.	Staff	Fuel	Maint.	Tyres	Sharpening	Insurance	Other (Cont.)	CAPEX + OPEX [N$ pm]	Cost/t of chips @ farmgate
Felling • 4 x Set of bush picks • 2 x Hand saws 2 x Pruning shears + protective clothing	5				0.5						
Stacking and Feeding: • Manual	-										
Chipping • 1 x 20 hp TomCat 125 AFE hydraulic infeed chipper with blower for wet logs up to 125 mm ɸ and 16 m^3/day on trailer	230			3.5	2.0	1.5	2.0	0.4			
Shuttling • 24 x Bulk bags (starter stock) • 2 x Light weight off road trailers for 4 bags cycle @ N$ 40 000 each • 1 x Light weight 25 hp tractor @ N$ 120 000	200			1.5	1.0	1.5	-	0.4			62 000 x12 800 t.p.a.
Transfer • Airhost, compressor, I-beam and crawl to load trucks by discharging bulk bags	65				0.5			0.2			
Staff											
• 1 x Supervisor/chipper operator @ N$ 7 000 pm • 4 x Tree fellers @ R3 600 pm each • 4 x Stackers, trimmers, chipper feeders @ R2 000 pm each • 1 x Tractor driver/chipper operator @ N$ 4 000 pm each			7.0 14.4 8 4								
TOTALS N$ x 1 000 (VAT excluded)	**500.0**	**10.9**	**33.4**	**5.0**	**4.0**	**3.0**	**2.0**	**1.0**	**2.7**	**62.0**	**N$ 930/t**

Note: The income from log sales was not taken into account.

OPTION TWO: LIGHT DUTY SEMI MECHANISED – CHIPPING @ 28 m^3/day or 1 400 t.p.a.

TABLE 6.2: BREAKEVEN OPTION TWO

Description of plant & activity 1 400 t.p.a. or 140 t.p.m. chips plus 150 t.p.m. logs	Capital Cost	Instalment p.m.	Staff	Fuel	Maint.	Tyres	Sharpening	Insurance	Other (Cont.)	CAPEX + OPEX [N$ pm]	Cost/t of chips @ farmgate
Felling • 2 x Hand operated 13 hp Inventec trolley saws @ N$ 25 000 each • 1 x Vertical saw trolley (13 hp) @ N$ 20 000 • Spare saw blades, pruning shears and protective clothing	100			2.0	1.0	0.5	2.0	0.2			
Stacking, pruning, chipper feeding Manual	-										
Chipping • 1 x 35 hp TomCat 150 AFE or Pezzolato PZ 150 PTO driven hydraulic infeed chipper with blower discharge for wet or dry logs to 150 mm ⌀ @ 28 m^3/day on trailer @ N$ 280 000 • 1 x 40 hp Tractor @ N$ 330 000 to pull chipper	600			4.0	2.5	1.5	4.0	1.2			106 000 x 12 1 400
Shuttling • 100 Bulk bags (starter stock) @ N$ 500 each (second hand) • 2 x Trailers for 8 bulk bags per cycle @ N$ 50 000 each • 1 x 40 hp Tractor @ N$ 330 000	480			3.5	2.5	1.5	-	1.0			
Transfer • Airhosts, compressor I-beam and crawls to load trucks by discharging bulk bags	120				0.5			0.4			
Staff											
• 1 x Supervisor/Handyman/Chipper operator @ N$ 15 000 pm • 2 x Bulk bag trailer/tractor operators @ N$ 4 000 pm • 4 x Stack/pruners/feeders @ N$ 2 000 pm each • 3 x Trolley saw operators @ N$ 4 000 pm each			15 8 8 12								
TOTALS N$ x 1 000 (VAT excluded)	**1 300**	**28.3**	**43.0**	**9.5**	**6.5**	**3.5**	**6.0**	**2.8**	**6.4**	**106.0**	**N$ 910/t**

Note: The income from log sales was not taken into account.

OPTION THREE: MEDIUM DUTY FULLY MECHANISED –CHIPPING @ 120^3m/day or 6 000 t.p.a.

TABLE 6.3: BREAKEVEN OPTION THREE

Description of plant & activity 6 000 t.p.a or 600 t.p.m. chips	Capital Cost	Instalment p.m.	Staff	Fuel	Maint.	Tyres	Sharpening	Insurance	Other (Cont.)	CAPEX + OPEX [N$ pm]	Cost/t of chips @ farmgate
Felling • 1 x Medium duty excavator (LiuGong 906 D, BobCat or Liebherr equivalent) on tracks with grab and hydraulic shearing blade with buncher @ N$ 775 000 + N$ 295 000 Protective clothing and infield workshop facilities @ N$ 130 000	1 200			7.0	3.0	2.0	1.0	4.0			
Stacking & Feeding • 1 x Three wheel Bell logger with bunching grab and forestry tyres	790			5.0	2.5	1.5		1.2			
Chipping/Grinding • 1 x Drum chipper for logs up to 250 mm Ø with own 200 hp diesel engine drive on trailer. Throughput > 120 m^3/day @ N$ 2 200 000 • 1 x 55 hp Tractor to pull chipper @ N$ 400 000	2 600			12.0	6.0	5.0	8.0	3.8			
Shuttling • 12 x Roll-on-off bulk bins of 25 m^3 @ 120 000 each = N$ 1 440 000 • 4 x Off road trailers @ 280 000 each = N$ 1 120 000 • 4 x Tractor 55 hp @ N$ 400 000 each = 1 600 000	4 160			10.0	4.0	8.0	-	7.0			400 000 x 12 6000
Transfer • Bulk bins onto public road (Marshalling yard)	250							0.6			
Staff											
• 1 x Supervisor and Mechanic/Welder @ N$ 30 000 pm			30								
• 1 x Felling operator @ N$ 7 000 pm			7								
• 1 x Feeding operator @ N$ 7 000 pm			7								
• 1 x Grinder operator @ N$ 8 000 pm			8								
• 4 x Tractor operators @ N$ 6 000 pm each			24								
• 8 x Machine cleaners/helpers @ N$ 2 000 pm each			16								
TOTALS N$ x 1 000 (VAT excluded)	**9 000**	**196.0**	**92.0**	**34.0**	**15.5**	**16.5**	**9.0**	**16.6**	**20.4**	**400.0**	**N$ 800/t**

Items like LDVs, fencing around the marshalling yard, ablutions, office space etc., have not been taken into account.

5.2.4 OPTION FOUR: Commercial scale fully mechanised – Chipping @ 160 m^3/day or 8 000 t.p.a.

Table 6.4 illustrates an abbreviated breakeven of a 160 m^3/day @ N$ 13.5 million capital outlay commercial operation, using high lift trailers to shuttle the chips from the Pezzolato chipper to the transfer station. The breakeven farmgate price for chips is calculated as N$ 765/t.

5.2.5 OPTION FIVE: Large commercial scale – Chipping @ 400m^3/day or 20 000 t.p.a.

- **The problem statement:** A large biofuel user is requiring 20 000 t.p.a. (equivalent to 400 m^3/day for 10 months of the year) of wood chips from an encroacher bush harvesting area some 100 km away from the point of use. Determine the breakeven cost of dry wood biomass fibre delivered to the user.

- **Production train layout:** See *Illustration 1* for a planview of the production site layout. Note that the chipper/grinder plant is following in the tracks left by the excavator some six to eight weeks earlier, to minimise soil disturbance, while "paving the way" for the large three axel (tyre) shuttle trailer. The trailer can be used both off-road as well as on public roads and is thus saving double handling at the transfer station. An off-road tractor collects the shuttle trailer at the grinder and after removing the off-road dolly-wheel-assembly, the trailer is hooked behind a horse for its overland public road journey to the user. It should be noted that this arrangement has not yet been tested in Namibia and could have the following challenges:

  (i) The removable dolly wheel assembly would be heavy to manoeuvre on site.
  (ii) The same engine driving the grinder, discharge conveyer belt and forward motion of the machine, also needs to drive the chip flinger and pull the 110 m^3 shuttle trailer – an exercise which could require more than the current 540 hp on offer for uphill scenarios. Illustration 2 provides an alternative layout to overcome this challenge but would require additional handling at the transfer station.

- **Breakeven and bankability:** From Table 6.5 it can be ascertained that dry wood chips can be delivered at a tempo of approximately 20 000 tonnes per annum or 2 000 tonnes per month to a user at a total production cost of N$ 780/t over a distance of 100 km from the harvesting site. Part of the breakeven costs includes for an N$ 100 000 p.m. management fee for the equipment owner and main contracting party. Contracts of this magnitude will not happen before the following items have been agreed to between the biofuel buyer and producer beforehand:

  - A long term (five years, renewable for a further five years) biofuel supply agreement has been signed, complete with biofuel quality specifications.
  - The above agreement (contract) would be needed by the biofuel producer to obtain financing from a banking institution.
  - An environmental impact assessment [EIA] that the biofuel can be harvested over the agreed time period at the required tempo without harm to the environment.
  - A feasibility study with breakeven or cash flow analysis would be required by the bank.
  - Proof that the quantities of raw biomass would be available from the producer's supply base for the duration of the contract.

OPTION FOUR: COMMERCIAL SCALE FULLY MECHANISED – CHIPPING @ 160 m^3/day or 8 000 t.p.a.

TABLE 6.4: BREAKEVEN OPTION FOUR

Description of plant & activity 8 000 t.p.a. or 800 t.p.m. chips	Capital Cost	Instalment p.m.	Staff	Fuel	Maint.	Tyres/ Tracks	Sharpening	Insurance	Other (Cont.)	CAPEX + OPEX [N$ pm]	Cost/t of chips @ farmgate
Felling • 1 x 10 t excavator on tracks with grab and hydraulic shearing blade + spare blade Protective clothing	1 500			7.0	2.5	1.5	1.0	2.0			
Stacking & Feeding • Stacking with above machine • Feeding with 2 x light duty three wheel loader with bunching grab @ N$ 700 000 each	1 400			9.0	5.0	3.0	-	2.4			
Chipping • Self-propelled 250 hp horizontal Pezzolato grinder on tracks (heavy duty). Through-put > 160 m^3/day	4 500			14.0	8.0	1,5	10.0	7.6			
Shuttling • 8 x Purposely build high volume (25 m^3) high lift trailers with on/off road capability @ N$ 400 000 each = N$ 3 200 000 • 4 x Off-road shuttle tractors @ N$ 650 000 each = N$ 2 600 000	5 800			12.0	6.0	10.0	-	9.0			<u>510 000 x 12</u> 8 000
Transfer • High lift trailers side tip chips into 100 m^3 on-road trucking systems • Allow for marshalling yard and emergency spares	300										
Staff • 1 x Supervisor and Mechanic/Welder @ N$ 30 000 pm • 1 x Felling operator @ N$ 7 000 pm • 2 x Feeding operators @ N$ 7 000 pm each • 4 x Shuttle drivers @ N$ 6 000 pm each • 6 x Machine cleaners/helpers N$2 000 pm each = N$ 12 000 pm			30 7 14 24 12								
TOTALS N$ x 1 000 (VAT excluded)	**13 500**	**294.0**	**87.0**	**42.0**	**21.5**	**16.0**	**11.0**	**21.0**	**17.5**	**510.0**	**N$ 765/t**

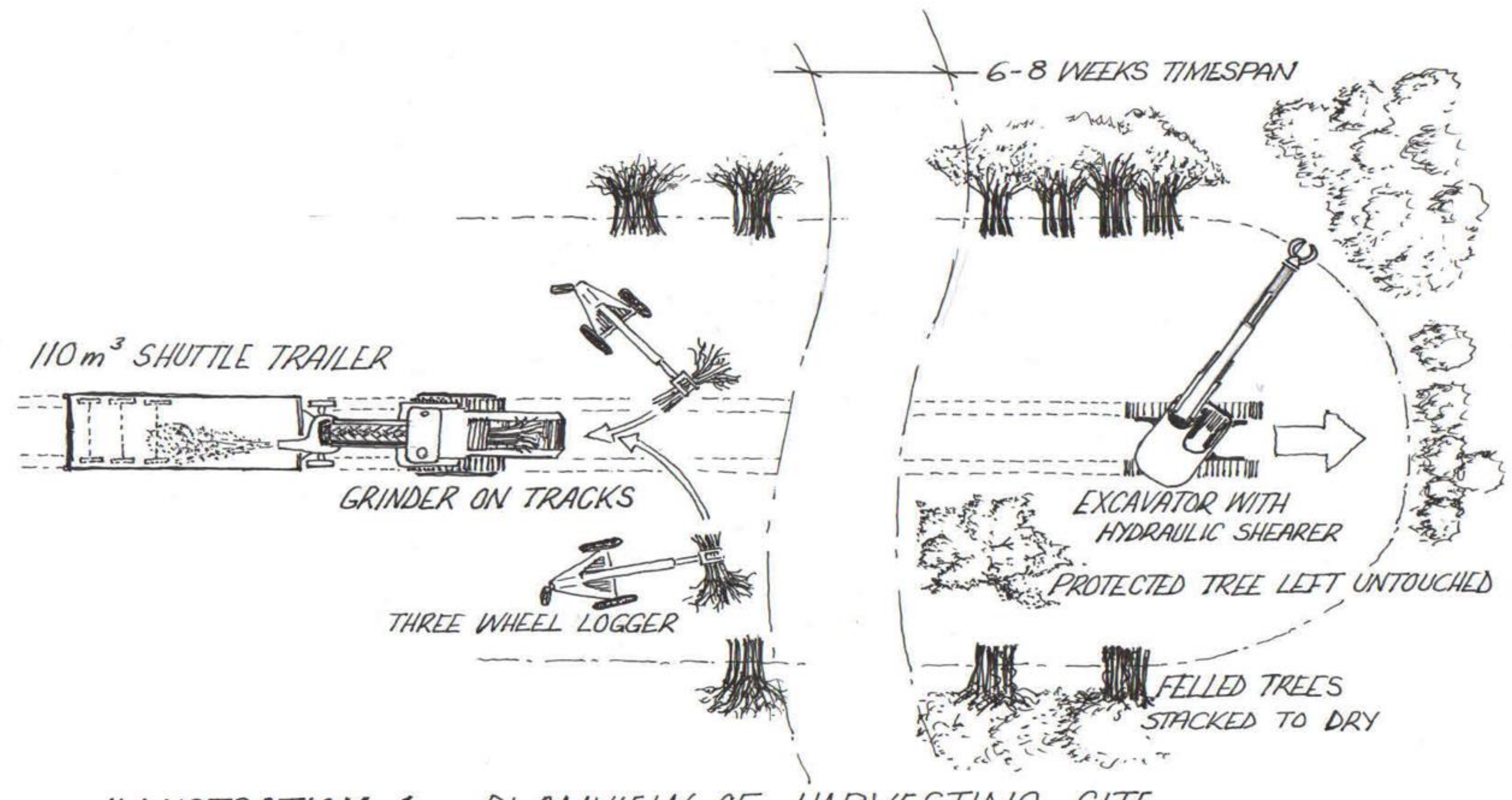

ILLUSTRATION 1 : PLANVIEW OF HARVESTING SITE

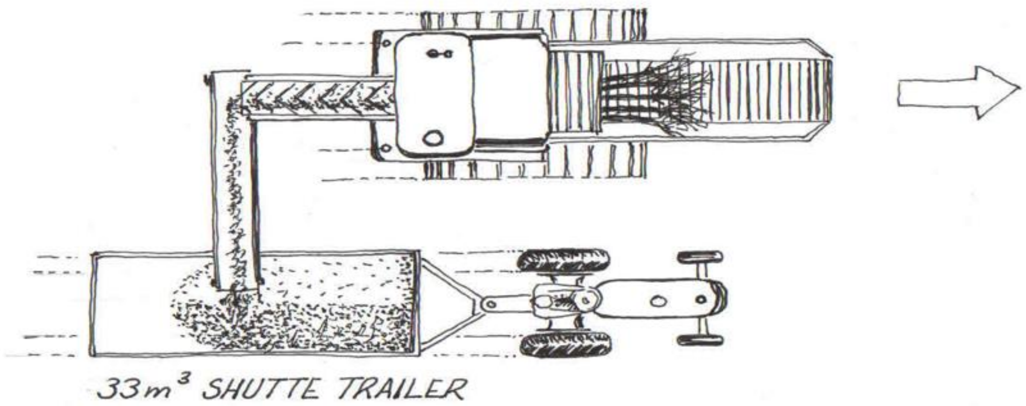

ILLUSTRATION 2 : GRINDER WITH SIDE DISCHARGE

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OPTION FIVE: LARGE COMMERCIAL SCALE – CHIPPING @ 400 m^3/day or 20 000 t.p.a.[4]

TABLE 6.5: BREAKEVEN OPTION FIVE

Description of plant & activity (See Illustration 1) 20 000 t.p.a. or 2 000 t.p.m. chips	Capital Cost	Instalment p.m.	Staff	Fuel	Maint.	Tyres/ tracks	Sharp- ening	Insu- rance	Other (Cont.)	CAPEX + OPEX [N$ pm]	Breakeven cost/t of dry chips delivered to user
Felling and stacking equipment:											
• 1 x 12 t Excavators with ± 200 kW diesel engine on tracks @ N$ 1 100 000	1 100			16	4	3	1	1.5			
• 2 x Hydraulic grab and shearing attachments with rotator and baseplate @ N$ 350 000 each (one spare)	700				1	-	1	1			
• 1 x Mechanic dedicated and trained for this operation @ N$ 40 000 pm			40								
• 2 x Operators @ N$ 6 000 pm each, including grease and cleaning own machine (one Operator on standby)			12								
Feeding											
• 2 x Three wheel Bell 225 loggers with *Super Severe* tyres by General capable of 300 m^3/day each @ N$ 840 000 each	1 680			30	5	5	-	2			
• 2 x operators/greasers/cleaners @ N$ 6 000 pm each			12								
Chipping/Grinding:											
• 1 x Bandit 2680 track Beast of 540 hp capable of 400 m^3/day fiber production	8 810[5]			60	30	4	15	13			
• 1 x Operation manager and chipper operator @ N$ 20 000			20								1 300 000 x 12 / 20 000
• 1 x Chipper cleaner/greaser @ N$ 3 000 pm			3								
Shuttling:											
• 2 x Dong Feng 60 kW (DF 804) off-road tractors to position shuttle trailers @ N$ 280 000	560			20	2	2	-	1			
• 8 x 110 m^3 high volume shuttle trailers @ N$ 650 000	5 200				16	10	-	7			
• 1 x Dolly wheel assembly @ N$ 220 000	220										
• 2 x Shuttle tractor operators @ N$ 6 000 pm each			12								
Transferring:											
• Container type offices, ablutions, marshalling yard, protective clothing, etc.	780										
Transport:											
• 2 x Transport double diff horses @ N$ 1 300 000 each	2 600			96	9	8	-	6			
• 3 x Lorry drivers and standby operators @ N$ 7 000 each			21								
Backup spares and workshop:											
• Wear parts, filters, tyres, stores, workshop					-	-	-	-			
• Additional mechanic/welder	1 350		20								
Management fee:			100								
Totals N$ x 1 000 (VAT excluded)	**23 000**	**500**	**240**	**222**	**67**	**32**	**17**	**31.5**	**190.5**	**1 300**	**N$ 780/t (Delivered)**

[4] 20 000 t.p.a. ÷ 10 operational months = 2 000 t.p.m; @ 250 kg/m^3 translate to [illegible] = 8 000 m^3/month or 400 m^3/day [1 day = 8 hours].

[5] A Bandit 2680 Track Beast with 540 hp Cat engine and second chipping-option drum delivered to Namibia from the USA @ US$ 688 000 and 12.8 N$/USD would cost N$ 8.81 million, VAT excluded, capable of producing >400 m^3/day of dry chips when correctly fed by two Bell loggers.

5.3 COST ANALYSES – SUMMARY

See Tables 7 & 8 for a summary of the various breakeven case studies done to date.

TABLE 7: TYPICAL BIOMASS (DRY CHIPS) TOTAL COSTS[6] PER ACTIVITY OF THE OVERALL HARVESTING TRAIN DELIVERED OVER A DISTANCE OF 100 km (AUG 2015)

Item	Harvesting action	Typical cost breakeven per action (rounded off)		
		Small scale operations <2 200 t.p.a. [N$/t]	Commercial scale operations [N$/t]	Remarks
(i)	Felling	170	140	**Commercially:** By turbo saw or hydraulic cutter fitted to an excavator to fell the bush **Small scale:** By hand or trolley saw
(ii)	Stacking (and drying)	20	Included in (i)	Assume sun drying takes place in the field
(iii)	Feeding the chipping operation	90	70	**Commercially:** By three wheel logger or equivalent **Small scale:** By hand, often trimmed to fit the chipper
(iv)	Chipping/Grinding	310	360	Dry chipping/grinding takes place
(v)	Shuttling ± 5 km	90	60	Chips are transported with off-road trailers from the point of harvesting to the transfer station
(vi)	Transferring	30	10	Chips are transferred onto a public road system
(vii)	Transporting to the point of use (100 km) with empty return load	150	140	A 100 km delivery distance is taken into account
TOTAL PRODUCTION COST DELIVERED OVER 100 km (VAT EXCLUDED)		**860**	**780**	

- Production cost to farmgate = All costs up to (vi) above
  = N$ 710/t for small scale operations
  = N$ 640/t for commercial operations

[6] Total production costs = CAPEC + OPEX excluding VAT or any mark-up.

TABLE 8: SUMMARY OF FIVE BIOMASS CHIPMAKING SCENARIOS APPLICABLE TO NAMIBIA – LEVELIZED COST OF PRODUCTION AT FARMGATE

Item	Description of operation [m^3/day]	Throughput (chips only) [t.p.a.]	Capital required [N$ million]	Total Cost p.a. [N$]	Total production breakeven cost of biomass chips at farmgate [N$/t]
6.1	Small scale, mostly manual [16 m^3/day]	800	0.5	744 000	930
6.2	Light duty, semi mechanised [28 m^3/day]	1 400	1.3	1 272 000	910
6.3	Medium duty, full mechanised [120 m^3/day]	6 000	9.0	4 800 000	800
6.4	Heavy duty, fully mechanised [160 m^3/day]	8 000	13.5	6 120 000	770
6.5	Fully commercial dry grinder operation [400 m^3/day]	20 000	20.4	13 680 000	680
LEVELIZED AVERAGE PRODUCTION COSTS (VAT excluded) AT FARMGATE					**N$ 720/t**

The figures of Item 6.5 were derived from Table 6.5, excluding the overland transport costs to obtain the production cost at farmgate of this 400 m^3/day operation.

- Proposed farmgate price (mixture of small, medium and commercial scale operations) = 720 plus 15% mark-up
  = 720 x 1.15
  = N$ 830/t

- Therefore, the corresponding energy cost for biomass with a HHV @ 16.5 GJ/t $= \frac{830}{16.5}$
  = N$ 50.30/GJ

- The above value of biomass energy compares favourably with that of fossil coal @ N$ 57/GJ to N$ 60/GJ

CHAPTER 6: ENVIRONMENTAL ISSUES SUMMARISED

6.1 A GROWING RESISTANCE AGAINST CHEMICAL METHODS

Farmers and environmentalists are increasingly becoming aware of the devastating negative effect on the savannah biodiversity when chemical de-bushing methods are used. Although the process is relatively quick and cheap, it invariably kills off far more than the trees targeted.

This Compendium aims to provide an *alternative* to farmers and land care contractors. The Consultants believe that most of the best practice mechanical means, as described in this document would provide a cost effective way to do bush harvesting. Not only is the best practice mechanical means giving the harvester a way to convert bush into sellable wood chips, it also has low impact on the environment when executed correctly. Unlike chemical de-bushing where the farmer is left with virtually unharvestable trees and bushes and a massive hot-fire hazard, mechanically harvested bush is sold off to cover the costs of the clearing operation, often at a small profit.

6.2 DEFORESTATION OF PROTECTED SPECIES

Because wood chips can be made of small bushes as well as the side branches and twigs of trees, there is no need to target the larger trees only.

It must be stressed that it is illegal to cut any tree in Namibia with a trunk diameter of larger than 200 mm (or a circumference > 628 mm).

Best practice mechanical harvesting methods are geared to do selective de-bushing and because of the fact that chip production can be done with lower fuel consumption on < 200 mm diameter trees, there should be no need to target the larger trees.

It goes without saying that none of the protected species should be allowed to be harvested – a task which a well-regulated biomass industry should make its own to regulate. Some producers of charcoal are guilty of targeting larger and even protected tree species to obtain larger logs for better yields of lumpy charcoal.

6.3 BEST PRACTICE THERMAL PROCESSES AND FUTURE CHARCOAL MAKING

Best practice thermal processes, like wood fired boilers, hot gas pyrolysers and wood gasification, uses wood chips as infeed and produces either a clean wood ash or biochar as out-feed. Wood ash and biochar are sought after soil conditioners and soil health enhancers.

By using for example wood chips on a continuous infeed into a hot gas pyrolyser, the hot gas can be used to dry wood for other purposes, while producing biochar or activated carbon or charcoal. The point is, that the thermal properties of the woody biofuel is then also used in a controlled fashion with nearly clear (mostly CO_2 and water vapour) emissions, while producing valuable clean carbon derivatives. An added advantage to the above process is that the whole bush can be utilised for the required infeed, emphasising the fact that the future of biomass harvesting is slowly moving towards 'chips' or a woody fibre processed at the point of harvesting and away from large logs. In other words, future charcoal production will swing to the manufacturing of briquettes from smaller biochar pieces and charcoal fines, rather than the infield kiln process where predominantly larger branches and logs are used to produce lumpy charcoal. Lumpy charcoal is favoured by the charcoal buyers and packers. Larger and more advanced, higher yielding, centrally located retort type kilns, which recycle the syngas for additional thermal energy can be seen as the next generation of sustainable charcoal making.

6.4 SOIL DISTURBANCE

Bush clearing with for example bulldozers and large graders are not regarded as savannah restorers in the true sense of word. Biomass is often dozed onto a pile and burned without any form of utilisation.

Some of the large track propelled excavators and bush grinding machines are often regarded as harsh machines on the soil, but most environmentalists agree that smaller tyre equipped machines are worse.

The larger commercial biomass harvesting trains can be planned to have the grinder tracks driving on exactly the same tracks left by the tree felling excavator.

Figure 30: Soil disturbance with grader de-bushing

6.5 DEVELOPING A TRUSTWORTHY BRAND FOR NAMIBIAN BIOMASS PRODUCTS

For the biomass from encroacher bush industry to grow, it will eventually have to adhere to international environmental guidelines given by the FSC, IS0 14 000 and ISO 22 000. The essence of these guidelines can be summarised as follows:

- Target only the listed encroaching bush and tree species smaller than 200 mm diameter.
- Do not generate visible emissions (smoke).
- Do not generate concentrations of toxic residues (tars).
- Disturbance of the biodiversity should be kept at a minimum.
- Harness the thermal energy coming from the process as much as possible.
- Replace the minerals taken from the soil in the form of biomass by returning clean ash and biochar into the ecosystem (as part of the sustainability process).
- Restore the grasslands and indigenous trees with active replanting methodologies (part of the sustainability cycle).
- Follow-up and aftercare is required of the cleared areas in a seasonal cycle to maintain a natural rhythm in the savannah restoration process.

By doing the above as a collective – as a unified biomass harvesting and savannah restoration industry – will give a good name and a sough after 'brand' to Namibian biomass products. This would lead to continued exports, growth and subsequent prosperity for the participants.

6.6 AFTERCARE AND REGROWTH MANAGEMENT

There are two schools of thought on this topic. Some farmers interviewed felt that biomass harvesting should become a second crop to the farming business which must allow the harvested bush to regrow for harvesting again after 10 to 12 years.

Others feel strongly that the grasslands must be restored and that regular follow-up and removal of regrowth should be managed.

Special care should be taken with sickle-bush which is stimulated when mechanically disturbed. Rapid regrowth from the disturbed root system of the sickle-bush will follow and densification will occur. One of the aftercare proposals made by the bush roller manufacturer (Ombengu Energy, Windhoek) is to do rapid roller passes over the young and sprouting sickle-bush to break off and crush its twigs to ground level during early autumn. Grass regrowth during the rest of autumn is allowed, while the crushed twigs are allowed to dry off. By late winter/early spring when the grass and twigs are all dry, this biomass is burned in a controlled fire, killing off most of the sickle-bush root systems. The same process is repeated the next year for the remainder of the sickle-bush which was not killed off by the first attempt. See Fig. 31 for the Bush roller in action.

Figure 31: The bush roller in action
(courtesy Ombengu Energy, Windhoek)

6.7 PROTECTING THE BIOMASS RECOURSE

Care should be taken to ensure the continued protection of the indigenous shrubs, bushes and trees. The volume of unwanted encroacher biomass available is however so immense that even at tempos of 1 000 tonnes per day to feed say 5 x 10 MW_e wood fired power stations, the current resource would last more than 300 years[7] assuming no regrowth and access to only say 50% of the 26 million hectares of infested areas.

[7] At 1 000 tonnes per day or approximately 360 000 tonne p.a. of biomass burned for the generation of 50 MW_e, and at 9 tonnes usable dry biomass per hectare from 50% of the 26 million hectare infested, the practical lifespan of the resource can be calculated as $\frac{26\,000\,000 \times 9 \times 50\%}{360\,000}$ = 325 years.

It is however suggested that the best way to protect the resource would be to give biomass an agricultural value, while at the same time provide the necessary specifications for the biomass product to adhere to. Suppliers of biofuel would in other words stand to lose their fuel supply agreement to its client (e.g. Ohorongo Cement, NamPower, O & L Energy, etc.) if any protected tree material is found in the wood chip supply.

6.8 LOOKING AT HARVESTING THE RESOURCE IN A SUSTAINABLE WAY

Over and above the sustainability guidelines suggested earlier, it is important to note that the following items form part of long term sustainability:

- **Good governance:** The industry should be well managed and controlled.
- The **environment** should gain in the process, implying a best practice approach to restore the grasslands and indigenous trees and the natural biodiversity.
- The most appropriate and **best practice technologies** and methodologies should be followed with the least amount of soil disturbance, noise and emissions.
- The **socioeconomic wellbeing** of the workers should be attended to by endeavouring to introduce permanent work flow, safe working conditions and skills development.
- The full value chain should be **profitable** and economical to commercial as well as SME operations.

Once biomass has reached the status of an agricultural commodity at a benchmark value of say N$ 700/t for clean, dry chips at the farmgate, this new industry will show steady growth and good internal control for all role-players to comply to the 'rules of the game'.

Figure 32: Restored savannah middle of winter (courtesy Gys Joubert, Dordabis)

CHAPTER 7: FINDINGS AND CONCLUSIONS

7.1 FINDINGS

The following findings can be documented:

- A full range of biomass harvesting equipment is available in Namibia, from low cost to capital intensive, highly productive plant and equipment.
- Agencies, workshops and spares back-up facilities exists for some of the above equipment and would certainly improve as the biomass industry grows.
- The risks of mechanical harvesting equipment fires and the winter savannah catching fire are high and requires dedicated attention.
- Other risks include:
  - High wear on cutter tools due to the extreme abrasiveness of the imbedded silica, dust and termite nests in the dry encroacher bush
  - High tyre failures experienced in the harvested areas
  - The profitability of the operation is volume driven.

- Ohorongo Cement is a leading roleplayer in the field and is requiring more than 70 000 tonnes per annum of dry chipped biomass delivered to its plant north of Otavi at a price of approximately N$ 700 - N$ 800 per tonne.
- Pre-Feasibility Studies conducted by various Consulting Engineering companies (2014) indicate that when the retail price of electricity in Namibia starts to exceed N$ 1.60/kWh, generating power from encroaching bush biomass could become viable. Approximately 40 000 tonnes p.a. of dry wood chips would be required per 5.0 MW_e of electricity generated through a wood fired high pressure (60 bar) boiler and steam turbine system.
- One of the risks of upscaling biomass harvesting to the volumes required for energy generation was, until recently, that plant and equipment was not designed and was not reliable enough for such large quantities – a fear which has been resolved over the past few years by harvesting productivity levels achieved by companies like WoodCo and WP Chippers in Namibia and South Africa respectively.
- NamPower has progressed well over the past two years to implement a biomass-to-energy division as part of its long term renewable energy division, which could benefit the biomass harvesting and eventually the livestock farming communities of Namibia immensely.

7.2 CONCLUSIONS

Biomass harvesting can be done in a sustainable manner in Namibia with specific reference to:

- Profitability (especially at commercial scale).
- The creation of jobs through labour based operations, followed by in-service training.
- Appropriate technology is available, although back-up services for the harvesting equipment are still below required levels for larger scale operations.
- Self-regulation and good governance of protected species need to be improved.
- At the current farmgate price for biomass of approximately N$800/t, this industry will grow.
- Best practise mechanical plant can do harvesting in an environmentally friendly and cost effective manner, while restoring the grazing capacity and biodiversity of the savannah.

CHAPTER 8: RECOMMENDATIONS TO THE PROSPECTIVE BIOMASS PRODUCER

If the anticipated growth in biofuel demand in Namibia continues to grow at its current rate, a great future for biomass harvesters will become a reality, while at the same time helping to restore the much needed productivity of the grazing lands of the areas scientifically cleared. It is therefore proposed that prospective biomass producers pay attention to the following recommendations.

- Start with a bankable business plan consisting of:
  - A detailed equipment selection plan after researching all options
  - A long term biofuel off-take agreement from a reputable buyer/user. Ensure full understanding of the specifications, terms and conditions
  - A comprehensive breakeven analysis (Allow for the harsher Namibian conditions; fuel consumption, wear on cutters, tyres, training)
  - A guaranteed biomass supply base for the duration of the contract period
  - A full understanding of the value chain and its risks from start to end

- Visit harvesting sites and equipment suppliers to familiarise yourself with this developing industry and all the complexities of the chain of harvesting actions required.

- Check the local technical back-up levels on spares, in-house knowledge and experience, with special attention to the chipping/grinding operation.

- Do not under estimate the abrasiveness (mainly caused by imbedded silica) and general difficulties of handling the Namibian bush and high volumes of low bulk density chipped material.

- Compile a formal *Request for Proposals*, complete with throughput figures, technical and back-up specifications, general and specific conditions of contract and invite a minimum of three suppliers per key harvesting component to tender.

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ANNEXURE A

A.1: HARVESTING OF ENCROACHER BUSH
A.2: LIST OF BIOMASS EQUIPMENT AGENCIES APPLICABLE

August 2015

ANNEXURE A

A.1 FELLING EQUIPMENT

Item	Description of Machine	Price [N$] (VAT Exc.)	Supplier Details	Backup available in Namibia
1.	• Inventec tree cutting trolley. Hand operated two wheel trolley with belt driven circular saw	25 000	Inventec Agricultural & Industrial Designs 16 West Street, Otjiwarongo +264 67 307 489 Mr Johan Theron +264 81 124 1916 info@iventecnam.com www.inventecnam.com	Inventec has in-house design, manufacturing and repair facilities
2.	• Inventec log cutter. Hand operated two wheel trolley with belt driven vertical circular saw	20 000	Inventec Agricultural & Industrial Designs 16 West Street, Otjiwarongo +264 67 307 489 Mr Johan Theron +264 81 124 1916 info@iventecnam.com www.inventecnam.com	Inventec has in-house design, manufacturing and repair facilities
3.	• Ghel skid steer loader Model R260, 50 kW, with Yanmar 3.3 liter turbo diesel engine and hydrostatic drive • Fitted with Turbo saw SB 3000 with hydraulic oil cooler and swing boom	930 000 260 000	Forklift & Allied Equipment CC [FL & A] 10 - 12 Rendsburg Street, Lafrenz Industrial Area, Windhoek +264 61 262 390 Mr Klaus Papendieck klaus@fae.co.na www.forkliftnamiba.com	FL & A has in-house as well as field service repair and maintenance facilities
4.	• LiuGong 906 D, 5.9t excavator with 39 kW Yanmar 3.05 liter diesel engine. Can be fitted with turbo saw or hydraulic cutter • Turbo saw SB300 with hydraulic oil cooler FL & A	660 000	Burgers Equipment & Spares [BE & S] C/o Rikumbi & Bahnhoff Street, Otjiwarongo +264 67 307 487 3785 Mr Marius Cronje +264 81 149 0713 manager.otji@burgersafrica.com www.burgersafrica.com	BE & S has in-house service, repair and maintenance capability
5.	• Woodcraker felling tools. A range of hydraulic tree felling shears with clamping devices are available, from clamp diameters of 900 mm up to 1 600 mm	200 000 up to 450 000	WoodCo/Transworld Cargo Von Braun Street, Windhoek +264 61 371 100 Mr Heiko Meyer +264 81 249 7876 hrm@iway.na www.woodco.biz Mr Norbert Liebich +264 61 37 1101 n.liebich@transworldcargo.net	Advisory to new equipment and spares orders
6.	• Woodline Trevi Benne felling tools. A range of hydraulic tree felling shears with clamping devices are available from clamp diameters of 850 mm up to 1 800 mm	180 000 up to 400 000	TreeCycle (Pty) Ltd 49 Park Drive, Langebaan, Western Cape, SA +27 22 772 0307 Mr Shaughn Frost +27 82 338 8951 shaughn@treecycle.co.za www.treecycle.co.za	Advisory to new equipment and spares orders

NOTE: *Excavators can also be obtained from the following agencies:*

BobCat, SA: Johan Claassen, Stikland, Cape Town Tel: +27 21 945 1423, jclaasen@bobcatsa.co.za

- **BobCat, Namibia:** 14 Rensburg Street, Lafrenz Industrial, Windhoek Tel: +264 61 333 000
- **Caterpillar:** Barloworld Equipment, 166 Mandume Ndenufayo Ave, Windhoek Tel +264 61 280 4811, www.barloworld.co..na
- **Komatsu:** Lafrenz Industrial, 43 Nordland Street, Windhoek Tel: +264 61 26 1281
- **Liebherr:** Mr Fanie Bosman, Windhoek +264 81 148 9947

A.2 CHIPPING & GRINDING EQUIPMENT

Item	Description of Machine	Supplier Details	Backup available in Namibia
1.	**TomCat Chippers:** A full range of chippers are manufactured in Worcester, SA • 5.5 hp to 35 hp gravity feed applications • 25 hp to 50 hp hydraulic feed, drum applications	**Factory:** Tomcat Chippers 26 Samual Walter Street, Worcester, SA Sales: Mr Frans Greyling +27 72 292 1821 frans@tomcatchippers.co.za **Owner:** Mr Hugo van der Merwe +27 83 442 7693 www.tomcatchippers.co.za **Namibian Agent:** Burgers Equipment & Spares C/o Rikumbi & Bahnhoff Street, Otjiwarongo +264 67 307 487 3785 Mr Marius Cronje +264 81 149 0713 manager.otji@burgersafrica.com www.burgersafrica.com	Factory in Worcester South Africa BE & S has in-house spares supply and advisory service capability
2.	**Bandit Chippers:** From 48 hp to 213 hp drum-style chippers with hydraulic infeed (Note: Disc-type chippers not recommended for Namibian hard wood encroacher bush)	**Factory**: Bandit Industries Inc. Remus, Michigan, USA www.banditchippers.com **Namibian Agent:** Burgers Equipment & Spares [BE & S] C/o Rikumbi & Bahnhoff Street, Otjiwarongo +264 67 307 487 3785 Mr Marius Cronje +264 81 149 0713 manager.otji@burgersafrica.com www.burgersafrica.com **SA Agent:** Bandit Chippers Africa 26 Samual Walter Street, Worcester, SA +27 23 342 1594 Mr Hugo van der Merwe +27 83 442 7693 hugo@banditchippers.co.za www.banditchippers.co.za	BE & S has in-house spares supply and advisory service capability
3.	**Pezzolato Chippers:** Drum chippers (PTH Series) from 100 hp to 590 hp self-propelled and self-feeding machines	**Factory:** Pezzolato, Envie, Italy **Namibian Agent** Otjiwarongo Motors & Tractors [OM & T] Banhoff Street, Otjiwarongo Massey Ferguson Dealer Mr Thorsten Kopp +264 67 303 041 www.tractors-namibia.com **SA Agent:** Rovic Leers Saxenburg Road, Blackheath, Cape Town +27 21 907 1700 Mr Marius Ras Pr. Eng. +27 82 453 4808 marius@rovicleers.co.za www.rovicleers.co.za	OM & T has workshop and service capability Rovic Leers has a large workshop and service capability near Cape Town, SA

4.	**Bandit Beast Grinders:** • Model 1680: 160 hp -275 hp Towable or track driven • Model 2680: 365 hp - 540 hp Towable or track driven • Model 3680: 400 hp - 800 hp Towable or track driven • Model 4680: 875 hp - 1200 hp Towable or track driven	**Factory:** Bandit Industries Inc. Remus, Michigan, USA www.banditchippers.com **Africa Agent:** TreeCycle (Pty) Ltd 49 Park Drive, Langebaan, Western Cape, SA +27 22 772 0307 Mr Shaughn Frost +27 82 338 8951 shaughn@treecycle.co.za www.treecycle.co.za	Shaughn Frost, with the assistance of Africa Biomass Company, Worcester, can assist with spares, maintenance & operator training
5.	**Ritlee Chippers and Morbark Tub Grinders:**	**Africa Agent:** AfrEquip (Pty) Ltd 18 A shortts Retreat Rd, Pietermaritzburg, KwaZulu Natal, ,SA +27 33 386 5034 Mr Marc Custers marcc@afrequip.co.za www.afrequip.co.za	
6.	**Vermeer**	**USA Factory:** Vermeer Corporation – Agriculture 120 Vermeer Road East Pella, Iowa, USA www.vermeer.com **SA Agent** Vermeer Equipment Suppliers (Pty) Ltd 11 Jersey Drive Long Meadow Business Park East Johannesburg, SA +27 11 608 0893 www.vermeer.co.za	
7.	**Heizohack** Hydraulic infeed drum chipper from 30 ph. to 300 hp	**UK Factory:** Fuelwood Ltd Claywood, Warwick Warwickshire, United Kingdom +1926 484 673 sales@fuelwood.co.uk www.fuelwood.co.uk	
8.	**TEREX Hybrid Chippers** The hybrid Terex drum chipper is suitable for trunk wood as well as untreated rootstocks. • Model: THC 465 Log chipper 462 hp or 653 hp • Model THC 465 Root chipper 462 hp or 653 hp	**USA Factory:** Terrex Environmental Equipment 1250 Commerce Drive Farwell, Michigan +1 800 953 5532 www.terex.com/enviromental-equipment **Africa Agent:** James Kamau Mfangano Solutions +27 82 747 1920 +27 11 440 2072 James@mfangano.co.za www.mfagano.co.za	James Kamau can also offer ***TS Industry*** mobile chipper-shredders

HARVESTING OF ENCROACHER BUSH

Biomass harvesting can be done in a sustainable manner in Namibia. It can be profitable, especially at commercial scale, while restoring the grazing capacity and biodiversity of the savannah.

This study is aimed at farmers, companies and groups with an interest to invest in de-bushing activities. It takes a closer look at methods to economically harvest biomass, from manual and semi-mechanised to large scale operations. Depending on the harvesting method, clean and chipped biomass can be produced economically yielding from a few tonnes up to a hundred and more tonnes per day.

Today, the appropriate technology is available to convert bush into sellable wood chips. When executed correctly, environmental friendly harvesting is possible. The authors call for a unified biomass harvesting and savannah restoration industry.